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Coordination of Student Teams Focused on Project Management Processes*

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Engineering learning processes are expected to develop technical and transversal competencies on students that are demanded by the engineering professional bodies. The need for the development of competencies raised an incremental interest in applying innovative approaches in Engineering Education. One of the methodologies used in this context is Project-Based Learning (PBL). At the University of Brasilia, a course degree in Production Engineering was created having as a main reference the Project-Based Learning (PBL) approach. The use of PBL implies a change of behavior of teachers who play a main role of facilitators of competencies development, and of the students, who learn in a collaborative way, working with others in teams. Students' working in team and developing a project during a semester will require effective coordination models. The objective of this paper is to propose a model of coordination among students' teams based on project management knowledge. Furthermore, a qualitative approach is applied to evaluate the application of this model during one semester. The results show that a coordination model for student teams developing projects is important to support their learning process, which is not solely dependent on students, as teachers/tutors have an important role before, during and at the end of the project. The tutor is especially important, as he/she is responsible for supporting the teams in several project management dimensions. This is an essential support for students to know how to manage the team, communicate, define goals, carry out the activities on time, plan the milestones and understand the impact of their decisions. These competencies are also part of student learning and are an important part of engineering education.

Keywords: design centric education; project based learning; project management in education; coordination of student teams

1. Introduction

Engineering is a profession or field of knowledge that uses art and critical thinking to design and develop solutions for a large number of real demands [1]. Engineers must be able to handle the challenges imposed by the design problems, which is widely considered as the central or distinguishing activity of engineering [2]. The training of engineers has evolved in recent years towards models that approximate the engineering learning to the engineering practices, particularly those with more interdisciplinarity and teamwork. These models are based on design, project and/or problem solving. Engineering education, therefore, must help engineering students develop the necessary skills to confidently and successfully handle design problems and design unique effective solutions to meet social needs [3, 4]. In order to accomplish this, students must be able to develop design projects in an effective way and the new teaching and learning approaches, like design centric, problem and project based learning, are intended to support students' development of both technical competences and transversal competences useful for engineering practice.

The new models of teaching and learning, with more customized learning requirements, include the coordination of student teams as the students develop the required competences. The coordination of students' teams in the new models based on design, projects or problem solving demand new roles for both teachers and students [5–7]. The new student roles include the need for greater autonomy, the integration of interdisciplinary content and teamwork. The new teacher roles have shifted the focus of the learning process to student activities and participating in tutorial activities with a closer relationship with students.

At the University of Brasilia (UnB), a course degree in Production Engineering was created based on seven projects, which are Project-Based Learning (PBL) oriented, raising curricular integration. Students' teams should be able to design and develop unique interdisciplinary solutions in each project. This implies a new role for the teacher, who becomes a tutor of a team, and for the students, who must learn and work with the other team members. Therefore, the coordination of students' teams is an important issue for the learning process because all students must develop competencies during the project in a sustainable way.

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Considering both, the described Engineering overall context and the UnB specific context, the project management methodology emerges as a tool to enabling students to fulfill a new role. In particular, the Project Management Body of Knowledge (PMBOK) [8], from the Project Management Institute, can be used as an input for establishing the fundamental processes for coordination of students. The objective of current paper is to present a model proposal for student team's coordination in project environments considering Project Management concepts. This model considers five knowledge area processes from the PMBOK as the most important in this context of students' teams as Integration Management; Scope Management; Time Management; Communication Management; Teamwork (from Human Resources Management). It is also based on three phases, preliminary project, intermediate project and final project, each with a specific result that contributes for the overall project result. Furthermore, there is also the objective of demonstrating the usability of this model, analyzing a particular case of coordination of student teams. This case was analyzed with a qualitative approach based on data collected during the development of the project using the following methods: document analysis (students' results and teachers' feedback), participatory analysis (based on tutors), and questionnaires with open questions.

The coordination of student teams does not depend only on students, as teachers/tutors have an important role before, during and at the end of the project. The tutor is especially important, as he/she is responsible for supporting the teams in several dimensions, for instance, in project management. This is an essential support for students to know how to manage the team, communicate, define goals, carry out the activities on time, plan the milestones and understand the impact of their decisions. This model as the underlying assumption that students should be able to make most of the coordination tasks of their own project. In this way it is expected that they will develop, with teachers/tutors support, project management competencies that are also part of student learning and are an important part of training as an engineer.

2. Design and projects

2.1 Design

According to Dym *et al.*, engineering design is a systematic, intelligent process. In this process, designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints [9]. Nowadays, design refers to the process of creating innovative solutions, and is related to products, processes or services. According to Naveiro and Borges [10], design is an activity which produces a description of something that doesn't exist and this description allows the production of the intended product. Therefore, the final result of a design process is unique and exclusive.

Design involves challenges, multiple problem representations, ambiguity, multiple solutions, and a lack of procedural and declarative rules. According to Atman et al., design is situated in real contexts, involves social processes and involves people with different perspectives from different disciplines (within and outside of engineering) working together to solve complex technological problems that address societal and consumer needs [11].

According to Naveiro and Oliveira [12] the challenges to be faced in a design process are to create an environment for collaborative intellectual work, management and control of information status, and sharing information related with appropriate content at right time. This approach requires: identifying and organizing several tasks to be executed and prepared in different stages; time management; defining the role of team members and the tools of communication among them.

The features mentioned above assure the characterization of design as a project and, consequently, their management can be based on guidelines proposed by project management.

2.2 Project based learning

Project-based learning (PBL) promotes learning through participation in projects. Projects are complex tasks that are based on challenging questions or problems. These projects involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations [13, 14]. According to Prince and Felder, 'Project-based learning begins with an assignment to carry out one or more tasks that lead to the production of a final product—a design, a model, a device or a computer simulation. The culmination of the project is normally a written and/or oral report summarizing the procedure used to produce the product and presenting the outcome' [15].

With the project, students must be able to lead, decide, manage, plan, adapt, and anticipate, as these actions are needed to solve problems. PBL enhances learning spaces where students have the opportunity to link theory and practice and develop technical and transversal competencies. Sole and Schrader stated, 'Project-based learning is a pedagogy that prepares students for the real world through an

active process that teaches critical thinking, problem solving, teamwork, negotiation skills, consensus building, technology, and responsibility for one's own learning' [16]. The literature has shown that these competencies are essential to the professional practice of engineering [17–20].

In fact, PBL provides a set of activities related to management and planning processes that only seems sensible in a group [21]. The activities require an intense and extended interaction between team members during the time of the project. According to Powell and Weenk, 'teamwork takes probably about 40 to 50% of learning activity' [22]. Teamwork highlights a continuous interaction between group members concerning the project activities, purposes, knowledge and goals.

Students working together could be a critical issue because demand much more effort than working individually. Problems happen during teamwork processes and aren't easy to solve them as conflicts between team members, motivation, communication problems, and so on. And these problems can compromise the quality of the activities that students are working on and at same time their own learning.

Tarricone and Luca [23] summarized the most important successful attributes for an effective teamwork, based on a literature review: 1) Commitment to team success and shared goals; 2) Interdependence; 3) Interpersonal Skills; 4) Open Communication and positive feedback; 5) Appropriate team composition; 6) Commitment to team processes, leadership and accountability. When students work in teams to develop a project, it's crucial to pay attention to these attributes. A successful team is when these attributes are achieved by the team. Normally, teams highly collaborative also achieve better results with the project. An unsuccessful team is evident that happen when these attributes are critical for the team. In that order, teams need more support tools and strategies to deal with the problems.

Therefore, teamwork in PBL is linked to learning process. Despite of the difficulties and problems that the students can experience during the process, teamwork activities become students more responsible and engaged in their own learning process [24], giving a different meaning to what they learn, why they learn, how they learn and, particularly, with whom they learn.

2.3 Project management

According to the PMBOK [8], a project is a temporary endeavor that is undertaken to create a product, service or unique result. Thus, a project must be developed during a predefined period of time for delivering a product with unique features. PMBOK propose a framework of management supported in five groups of processes and nine project management knowledge areas. The five groups of processes are mainly related with time and can be used as an indicative guide for project life cycle. They are: Initiating; Planning; Execution; Monitoring and Controlling; Closing. Nevertheless it is not a project life cycle proposal, i.e. it is not a definition of project phases, but can be considered for the definition of project phases for each project context. The nine project management knowledge areas present a functional classification for project management processes that are Project Management Integration; Project Scope Management; Project Time Management; Project Cost Management; Project Quality Management; Project Human Resource Management; Project Communications Management; Project Risk Management; Project Procurement Management.

There are scarce evidences of application of principles of project management in the context of project based learning. Most of the published works are related to teamwork (some examples: [25– 30]), which is a fundamental knowledge area of projects in learning environments. However, not only the dimensions related with teamwork are important in coordination of student teams and other knowledge areas of Project Management should be considered.

3. PBL at Production Engineering graduate program in University of Brasilia

The University of Brasilia Production Engineering graduate program is designed as a Project-Based Learning (PBL) curriculum. The curriculum of the program follows the national curriculum guidelines established by the National Education Council [31]. It is a full Engineering degree composed of a total of 3,600 hours of night classes, which are distributed across twelve semesters. The curriculum also offers the required disciplines, electives and free modules and provides students a range of project disciplines that must be taken through the 4th to the 10th semester of the course. The seven disciplines of Production Systems Project (PSP1 to PSP7) are centered in the PBL methodology. The aim is to consolidate the methodological aspects of PSPs with the topics covered in the courses of technical content, with a focus on the case studies brought by external partners linked to each theme of the project [32].

PSP projects are based on the following four major anchors [33]: (i) project methodology (PSP1 to PSP7), (ii) discipline of technical content, (iii) external partners linked to real problems, and (iv) other disciplines with interest in specific topics of the project, as shown in Fig. 1.

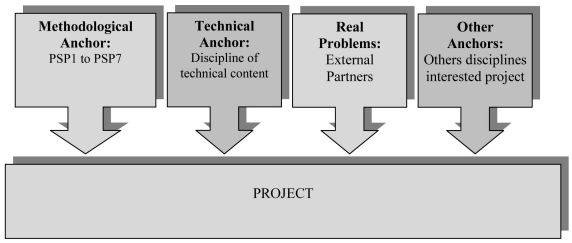

Fig. 1. General scheme of anchors for projects UnB Production Engineering Graduate Program.

The PSP1 discipline begins, in the 4th semester, with a project, related with other disciplines of the semester, which is assigned to 'project teams', each with the task of studying the relevant issues and developing responses and solutions throughout the semester. Solving a broad and open problem and developing an adequate solution requires design competencies as the integration of multidisciplinary knowledge and skills of teamwork.

The discipline PSP1, case study of this work, is the structure to implant all PSPs. The disciplines Value in Production Systems, Ergonomics and Human Behavior at Work and Project Methodology of Production System are prerequisites to PSP1. The Discipline Probability and Statistic (PS) is the technical anchor that provides the theoretical background to project development. It is expected that the case study brought by the external partner presents a real problem for students to solve. Students' projects must meet the following three basic premises: (1) use of statistical tools, (2) data analysis from large databases and (3) the project scope should be focused on the case study proposed by the external partner, in the current case the International Labour Organization (IOL). PSP1 students, 28 in total, are divided into four groups of five students and two groups of four students. Each group develops a teamwork project on a specific theme. The group formation is random resulting in heterogeneous groups with two restrictions: gender balance; at least three students who are attending the Probability and Statistic course.

Students are expected to conduct statistical analysis such as frequency of distributions and tables and are expected to generate measures of central tendency (mean, median, mode and separatrices), measures of dispersion (variance, standard deviation and coefficient of variation) and correlations between variables. In the final delivery, students are expected to conduct hypothesis testing, simple regression and ANOVA. It is noteworthy that at all stages, the groups must present data and understand what these data represent and their impact on the problem situation.

The coordination team of PSP1 contains the coordinator of the discipline, a teacher who supports the anchor discipline (PS), a teacher who supports the project management methodology, a teacher who supports the teamwork technical aspects and three tutors, each with two teams. This team aims to support teaching (applying active methods of teaching/learning) and to assist in facilitating the groups' work, help students to monitor project progress and the development of skills covered in the project. The facilitation process is accomplished in weekly meetings and at project milestones.

4. Methodology

This is an exploratory study which is applied to analyze a situation or a theme that is understudied. In that order, several concepts can be linked for a wider and better understanding of the research subject [34].

The contribution of this study involves a proposal based on a model for student team's coordination in project environments, considering Project Management concepts for coordination of students' teams as key-elements to achieve effective performances throughout the semester. Thus, the data collection pretends to identify the main problems and the several needs experienced by students at UnB and, for that reason, a qualitative approach was defined for this study [34]. This methodological approach allows a greater understanding of the meanings of the actions related to the object of study. In the current case, several methods were used to collect the data. The options were based on the idea of the interpretation of learning situations, namely the coordination of student teams in a project environment, through an inductive exploration process [35–36].

The data were collected during the development of the project and it was based on document analysis (students' results and teachers' feedback), participatory analysis (based on tutors), and questionnaires with open questions. The following three categories of data were identified: (1) results of questionnaires to analyze the team performance applied during the process; (2) milestones feedback and results of the project; (3) results of the project based on a workshop event with the objective of collecting students', teachers' and tutors' perceptions of the PSP1.

During process (1), two instruments were applied. In the first moment (fifth week PSP 1), students completed questionnaires related to team performance to gather information about team management (e.g., decision-making process, managing time, dealing with motivation and conflicts, cooperation between team members, distribution of

tasks, and solving problems and difficulties). This information allows a further understanding of the team's performance through questions such as: Are there problems within the team? Are these problems impacting the project results? Are some members of the team working less than the others? Is the team developing good strategies to accomplish the goals and the activities of the project? Closed questions were also included in the questionnaires to gain a greater understanding of some of the variables that impact the process of student self-coordination. In the second moment, a questionnaire was applied to analyze the team dynamics. The main principle was to ask all members about their performance as a team to obtain suggestions for improving the coordination of student teams. Therefore, the teams completed a self-assessment exercise that highlighted what was going on well, what was not going well and how to improve the team's performance.

At each milestone, the teams delivered a written summary, as explained in item 3. This summary covered both the project scope development and the project development process. The results were analyzed by the technical tutors (statistics, project management and teamwork), and feedback (2) was sent to team tutors and team members. The analysis of results presented in each milestone had the following two main objectives: to understand whether students acquired the technical expertise needed for the project scope development and to determine whether the students perceived the knowledge in project management as an enhancement tool in the design process or simply as another requirement of the evaluation team.

At the end of the project, a workshop was organized (3). The purpose of the workshop was to collect students' perceptions about the project and this methodology of learning. Initially, an email was sent to all students to complete an online questionnaire online. The questionnaire dimensions were as follows: project theme, developed competencies and learning situations, teamwork, teachers' and tutor's roles, evaluation model and PBL as a learning methodology. The response format was a Likert scale. An open and free space was provided for students to identify the strengths and weaknesses of the project and provide suggestions for future editions. Thirteen students (13/28) attended the final workshop and responded to the questionnaire. In this workshop, groups were created to discuss the following two issues: 1. 'Learning and Assessment Methodology'; 2. 'Project management, Planning, Scope, Team and Control'. The discussion of the two groups focused on the more and less positive aspects, solutions to solve existing problems, and suggestions for improvement. Then these results were presented and discussed in a plenary session that included teachers and tutors.

Based on the data collected, analyses were conducted to examine the frequency and response trends. These results were also crossed with the findings from content analysis, which is another tool to analyze more qualitative data. According to the goal of this study, this analysis was focused on issues related to the coordination of student teams, especially with regard to the areas of knowledge of Project Management. Thus, it is possible to verify and validate the relevance of the Project Management model proposed to students for the coordination of their work.

5. Model of project management processes for coordination of students' teams

During the project, the team is responsible for delivering partial results at different milestones. Project management processes are proposed as a means for helping students develop their project activities with the support of the tutors' orientation.

Between the two milestones, start and end, a project team undertook a continuing effort of creation that was characterized by project processes that were specific to the project. Although an expected general result was pre-established, the unique characteristics of the product, service or result to be created in each PSP and the specific characteristics of each student team resulted in uncertainties that the team of tutors managed according to a particular project management model.

The proposed Model of Project Management Processes for Coordination of Students' Teams is based on the following three stages: preliminary project, intermediate project and final project (Fig. 2). At each stage, an oral presentation and written summary are evaluated. The criteria for evaluating the oral presentation involve questions regarding the structure of the presentation (graphics formatting, compliance with standards), communication (posture, clarity of presentation, the meeting time), creativity (new ideas) and content (accuracy, technically adequate, technical basis). The written summaries are evaluated based on project scope, project planning and on-time delivery. At the end of the first phase students must deliver a preliminary project design to cover the project scope. The final product and the project scope must adhere to the basic premise of statistical data manipulation in a real problem raised by the external partner.

Learning projects such as those described in this work do not have a budget for students to manage and have few risks and no procurement management requirements. Quality aspects are fundamentally related to the learning process and results, and

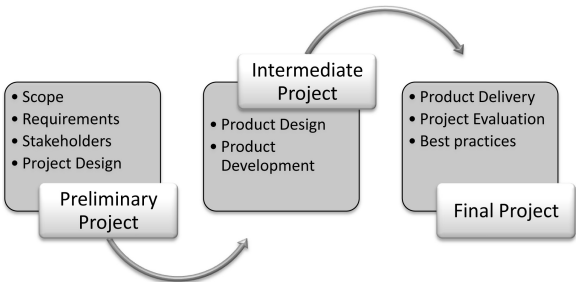

Fig. 2. Project Phases.

therefore, they are intrinsically related with all project activities, decisions and results. Considering this perspective, quality management processes were reflected in all other process results and one could say that the students' commitment and teachers' feedback and evaluation are the main guarantee for project quality. As such, the proposed methodology focuses specifically on the other five project management knowledge areas defined by the PMBOK [8]: integration, scope, time, communication and human resources (teamwork). The following figure represents the proposed relation between project phases and knowledge areas, which can be used as a framework of processes and deliveries for coordination of students' work.

In the beginning of the semester, the project is presented to the students and, in the first week, is expected that students are able to organize themselves in teams, interact with the tutor, analyze the project as a whole, identify project requirements, stakeholders' expectations and start work as a team. At the end of this initial phase, the main deliverables will be: Project Chart; Project Management Plan; Project Requirements and WBS; Project Activities and Schedule; Human Resource Plan; Communication Plan and Quality Plan.

The intermediate project aims detailing and developing the scope which was previously approved. During this phase some evidences should be taking into account, because revels some technical difficulties (related with product design) or management difficulties (related with team dynamic). At his moment, students don't organize in an intuitively way, because they start to feel the need to develop a method for internal coordination, in order to support their own needs and also the demands of stakeholders. This is essential to ensure the balance between the team and project development. Thus, in the intermediate project, the activities associated with the development and team management, the creation and distribution of the information, and the management of stakeholders' expectations, are presented with greater intensity. In this phase, the products deliverables are: Product Design (technical part development); Intermediate Product Development; Project Management Plan Updates; Project Schedule Updates; Communication Plan Update and Quality Plan Update.

The third and final phase (Final Project) begins with feedback from the tutors about part of product development presented in the previous phase. Then, students focus on product details and process assessment. The requirements deliveries in this phase are Product; Performance Report and Learned Lessons. Additionally, it's proposed a workshop, at the end of the project, with students' and teachers' participation.

6. Coordination of student teams: findings from the project management processes

The data collection was directed, fundamentally, by the necessity to understand how student teams managed to coordinate their work. In this perspective, the following knowledge areas were considered as fundamental: management integration, scope management, time management, human resource management (teamwork) and communication management. The analysis of data collection focused on these dimensions particularly considered the students' voice because they had the most information about the team. However, teachers' voices were also considered for the study. The feedback was an important process for the coordination of the teams' performance.

	Preliminary Project	Intermediate Project	Final Project
Integration Management	Project Chart Project Management Plan	Project Management Plan Updates	Learned lessons
Scope Management	Project Requirements WBS	Product Design Partial Product Development	Product delivery
Time Management	Activities Schedule	Schedule Updates	
Communication Management	Communications Plan	Communication Plan Update	Performance Report
Teamwork	Team Setup and Plan	Team development	Team Evaluation

Fig. 3. Relation between project phases and project management knowledge areas: main processes.

The following sections focus on the knowledge areas of Project Management that are considered more relevant for this study. These areas were analyzed according to the data collected during and at the end of the project.

6.1 Project management integration and management of scope

Project Management Integration is an area of knowledge that requires the definition and articulation of different groups of processes based on the process and activities involved in project management. A project's success depends on it [8]. Management of Scope basically assumes the definition, planning, verification and control of the scope. These two areas of knowledge were considered together in the data analysis because they are connected by the issues related to the scope.

Considering the groups of processes addressed in this study, the following elements were analyzed: at the planning process level, the management plan defines and records the activities needed for the definition and connects all additional plans in the main plan of project management. The monitoring and control process is essential in regulating the relationship between the development of the project and the achievement of goals. Finally, integrated control of changes provides the review of any changes that need to be included in the project and the influence of these on the other processes of the project. All of these issues are related to the scope.

The context studied shows evidence that the scope planning and control was one of the most critical aspects during the implementation of the project, and thus it affected the performance of the teams. Based on information from the workshop held at the end of the project, two main factors that are closely linked contributed to this issue. First, the vision was unclear about the project scope. According to students, the theme was not well situated, and therefore, it was difficult to understand what was being asked.

> '. . . There was no clarity regarding the definition of the objectives of the project . . .' (student 4—workshop questionnaire).

> 'Demand from the ILO made the project a bit too loose, we could choose anything. This led us to be more motivated with the theme than with the database itself. ' (student 7—workshop questionnaire)

Second the lack of information for the teams to begin working. This can be justified based on the following two assumptions: (a) lack of clarity in the planning and definition of project deliverables and (b) the content of the feedback given by tutors at each milestone.

> '(. . .) There was no clarity regarding the definition of project objectives and criteria for acceptance of different deliveries. (. . .)' (student 7—workshop questionnaire)

> 'The guidelines for what needed to be done and/or delivered at PSP1 classes were informed very short notice (. . .)' (student 6—workshop questionnaire)

> '(. . .) Weak and conflicting feedback (. . .)' (student 2—workshop questionnaire)

Analysis of these knowledge areas of Project Management identified the need for greater investment in planning the scope and demonstrated the importance of scope monitoring and control processes in the project execution phase.

6.2 Time management

This area of knowledge describes the processes that are needed to ensure that the project closes according to the deadline [8]. Thus, the planning process defines the activities and their order and estimates the resources required to accomplish the intended activities and the time needed for each activity. A schedule is an important tool for project management, as it controls deadlines and adjustments that other processes require. The control of the programming is an activity that occurs during all aspects of the project and is crucial to their success.

At the final workshop, the organizational form of the project based on a three-phase life cycle, or with three milestones, was considered as positive by the majority of the students. Both at the final workshop and on the questionnaires, this life cycle was referred to as an aspect to be maintained during future project coordination. However, both tutors and students questioned the time allotment of the phases, especially the first phase.

> 'Schedule incoherent, very idle at the beginning of the course. The project has effectively started only in the last month of school.' (student 12—workshop questionnaire)

Project Management defines the scope of the first delivery (preliminary project) as the Project Management Plan [8], which is associated with the Planning Process Group. For that delivery, the milestone position in the project schedule is correct. However, according to the PMBOK, the preparation of the Project Management Plan demands as its input a previously approved document labeled Project Charter. The Project Charter itself must include the project scope definition in a clear and complete way. Thus, the Project Management Plan can only be written after the Project Charter is approved (by the coordination team). The absence of a clearly defined milestone for delivery and approval of the Project Charter, prior to the Project Management Plan, can be perceived as an inconsistency in the schedule (as noted by the student) and result in a lack of clarity about the project development.

The student teams also revealed some difficulties in internally managing their time during the project. The questionnaires that assessed team performance verified that all teams had different dynamics and group interactions but that, at the middle of the process, the students generally considered that the group was managing time in a positive or neutral manner, without any exceptional cases. However, at the final workshop, time management was considered one of the major difficulties by four of the six groups in PSP1. Among the reasons, students indicated not only the failure to meet deadlines but also the difficulty in gathering because of the incompatibility of personal schedules and the existence of unproductive meetings. During a project, there are always factors that interfere with the initial programming. Thus, in line with the processes of monitoring and control of programming, one group suggested performing a 'redefinition of activities (schedule) according to weekly charts.' These tables must indicate short-term activities, deadlines and responsibilities and could be more easily controlled by the group than the WBS created at the beginning of the project.

6.3 Teamwork

One of the most important parts of a project is the people. The teamwork area of knowledge deals with processes related to the people involved in the project, including the planning and recruitment of human resources and the management and development of the teams [8]. In this study, the focus was on the following two dimensions: team planning (roles, responsibilities) and team management (monitoring the performance of the teams, problem solving).

In the begging of the project, teams were set by the teachers. Therefore, during the project, students had more control over team planning and management. The individual perceptions related with team performance (Fig. 4) shows that teams experienced difficulties managing teamwork. According to the students, the critical issues are the 8 and the 12. However, the G4 assess the team performance in a positive way (minimum 4.0) and the G6 assess 6 items in an intermediate level (3.0 which means often).

These difficulties are reinforced by the global view of the questionnaire which showed the same critical points, 8—Prevalence of some group members over others and 12—Motivation. These results, linked with other sources of information (group reflection and final workshop), show some evidence of a lack of student motivation. On the one hand, this could be due to the students' perceptions about the performance of coordination teams (lack of communication and organization) and from the other stakeholders, in this case, the external partner that did not demonstrate involvement and interest during the project. On the other hand, the project theme did not promote student motivation because of the gap between theory and practice, i.e., students

		G1	G2	G3	G4	G5	G6	**Mean**
1	Did the team have formal meetings?	5.0	4.2	4.4	5.0	4.5	3.0	**4.4**
2	Were the team roles played?	4.5	3.6	3.4	4.0	3.8	4.5	**4.0**
3	Were the results of individual tasks shared in the team?	5.0	4.2	4.6	4.8	3.8	4.5	**4.5**
4	Were the decisions made with agreement?	5.0	4.6	4.6	4.5	3.8	3.0	**4.2**
5	Were all members involved when a decision was to be made?	4.8	4.2	3.6	4.3	3.8	3.0	**3.9**
6	Did the team provide opportunities for everybody to talk and give suggestions?	5.0	4.4	4.4	4.8	4.0	4.5	**4.5**
7	Did the team members help each other?	4.8	4.0	3.8	4.5	4.5	4.0	**4.3**
8	Did some team members overlap the others?	2.0	3.2	2.8	4.0	3.8	4.5	**3.4**
9	Did the team easily solve the problems and the main difficulties?	4.3	3.0	4.2	4.3	3.3	3.0	**3.7**
10	Did the team members maintain the team together?	4.8	3.8	4.0	4.3	3.0	3.0	**3.8**
11	Did the team manage time well?	3.8	2.8	3.6	4.5	3.5	4.0	**3.7**
12	Was the team motivated?	2.5	2.6	3.4	4.3	3.0	3.5	**3.2**
13	Was the team working as a team?	5.0	3.4	3.8	4.5	3.75	3.0	**3.9**

Always (5) Very Often(4) Often(3) Seldom(2) Never (1)

Fig. 4. Teamwork performance questionnaire— visual monitoring based on team's elements average.

identified the scope of the problem as being far from their professional context.

> 'Communication failure between the teachers and the failures in the transmission of what was really needed in each stage of the project' (student 5—workshop questionnaire).
>
> ' . . . the project themes could be more motivating in regard to the question of the connection of the subject in the career of a Production Engineer' (student 4—workshop questionnaire).

However, the co-assessment of group dynamics revealed that students had problems with internal organization and communication. When asked about ways to improve these issues, the answers were evasive or ambiguous; they only stated that better communication, more motivation from the team members and a higher level of commitment were needed. This may happen because students did not know how to alter their performance as a team, and the tutor's role in this process of team management can help to solve this problem. In addition, students' considered teamwork as one of the most significant dimensions of the experience because it developed competencies and was important in the learning process. In particular, in the workshop questionnaire, teamwork was positively assessed, with an average of 3.6/5 for the overall student perception. The questions with a particularly positive perception (with an average of 4.3/5) were the following: I believe that the interpersonal competencies are important for my professional training during the semester and I play an active role in the group. Analyzing these data, the students showed a preference to work in teams but, at same time, teamwork did not contribute to increased motivation for the learning process. This is an issue to solve in future projects. Despite all of the difficulties, all teams accomplished the necessary requirements to complete the project.

6.4 Communication management

Managing a project requires production and information sharing. These tasks require clarity, consistency and accuracy; otherwise, the entire project may be compromised. Therefore, this area of knowledge describes the processes related to communication management, such as communication planning, information distribution, project performance reporting and management of stakeholders [8].

This study focuses on dimensions related to communications planning, project performance reporting (feedback processes) and management of stakeholders. This last issue, as previously stated, has an impact on team performance. Teachers communicated with students in the classroom, in extra meetings and through the e-learning environment Moodle. All documents considered relevant for the project were placed in Moodle, and the students were notified through forums on this platform. No formal mechanism of communication with the external partner was established, and this caused some problems in regards to student involvement, as reported by the students. All project teams used different communication tools within the teams and to communicate with the tutors, including email, texting, Moodle, and electronic repositories of information (e.g., Dropbox). However, some groups highlighted the difficulty of meeting outside the classroom to work on the project and finding the best solution to overcome this difficulty. The data collected did not include evidence related to a lack of communication tools; however, students noted failures in the clarity of the communication process. For instance, in response to the questionnaire in the final workshop on the issues 'information available in Moodle was clear, useful and adequate' and 'Moodle is an adequate tool for communication with teachers and for the delivery of documents', the average was 2.3 and 3.3, demonstrating a negative view of the formal process of communication. These perceptions were also discussed in the final workshop. For instance, students highlighted the weakness of information management between the tutors:

> 'There was conflicting information between teachers. It happened that one teacher gave some information and then another stated the opposite' (student 6—workshop questionnaire)

The difficulty of communication and integration between tutors cited by students was noted by the coordination team in the first milestone and discussed in the coordination meeting. The definition of a hierarchy in the flow of information between teams and technical tutors, with tutor teams as intermediaries, sought to solve this problem for the following steps. This episode shows the application of process monitoring and control in the execution phase of the project, with the goal of detecting deficiencies of organization in the early stages of development (the first milestone) and defining measures for its solution. However, the impact generated by the students' perception of teachers' initial lack of integration extended throughout the project. At the final workshop (project closure process), it was the most mentioned comment in the open ended portion of the questionnaire. The communication process and the responsibilities of all stakeholders are issues that stand out as requiring improvement in future projects.

7. Final remarks

This study sought to propose and analyze the coordination of teams of students in a design envir-

onment based on the five areas of knowledge proposed by PMBOK as integration management, scope management, time management, human resource management (teamwork) and communication management.

The proposed coordination model is based on a three phase project life cycle, with deliveries at the end of each phase. At these three milestones both process and scope quality control is performed. Also, at each phase, the students organize the project activities following the proposed five knowledge areas.

The analysis of the results showed articulation and interdependence between the different areas of knowledge. For example, the scope was identified as one of the most critical problems in the project, primarily due to the lack of clarity of objectives, which increased the uncertainty of the project. Students felt, especially at the beginning of the project, that they did not know what to do. This stage denoted the major problems of time management, whose consequences were reflected in the milestones. This is essentially derived from the following processes of communication between teachers / tutors; communication of teachers / tutors with students; communication between teams of students; communication within the team of students; and the communication of teachers / tutors and students with the external partner. Therefore, communication is key to ensuring efficient coordination of the project during development because it influences other processes that are associated with communication, such as time management, as noted above.

Despite the difficulties identified, it is important to emphasize that teamwork was one of the most relevant aspects for students, as it allowed the development of a set of skills that a traditional context of learning could not. PBL makes students more responsible for the actual learning process. When learning is developed in a project environment, managing the project effectively ensures learning. Students noted this assumption, stating: *'[projects] need to be taken VERY seriously. [Projects] must demand a lot from the students. Too much research. Too much study.'* In this sense, Project Management, as a field of knowledge, allows a set of concepts, mechanisms and tools that are an asset for interdisciplinary learning contexts. The results of this study indicate the dimensions in which it is possible to take action to ensure effective coordination of teams of students. However, the quality of coordination also depends on the role of the tutor, who should take an active role (with strategies based on Project Management), guide the student team, and consider the specific needs of the team throughout the project. Students perceived the lack agreement between the tutors, who transmitted aimless in the project performance. Above all, it is essential that students learn how to coordinate the team in a sustained and integrated manner, remaining aware of their actions and decisions, rather than on the basis of trial and error and bad experiences.

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