A case study of teaching interdisciplinary collaboration for engineering students

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INTRODUCTION

In the current era, engineers are increasingly confronted with the growing complexity of challenges that require knowledge and competencies from a wide range of professional disciplines. In parallel, the growing specialization and professionalization of many disciplines has generated a separation between the numerous branches of knowledge. This specialization amplifies the boundaries between and within many disciplines and makes it difficult to integrate perspectives and knowledge of other fields. In spite of this paradox, the necessity of interdisciplinary collaboration is generally recognized in most disciplines. But implementing this collaborative practice entails a challenging organization of a complex relationship between several disciplines. To work effectively in an interdisciplinary team, engineers need to be capable of integrating knowledge of two or more disciplines. Through dynamic interaction between disciplines they would be able to cope with complexity and develop new knowledge.

As a consequence, there is an increasing interest in interdisciplinary teaching with the creation of meaningful connections between disciplines. Interdisciplinary approaches have become an emerging trend in higher education but with diverse intensification of the collaboration between the team members [1]. Among the three forms of collaboration, - multidisciplinary, interdisciplinary or transdisciplinary, - frequently discussed in literature, we are focusing on the one last mentioned. In interdisciplinary collaboration, engineering students work on the basis of several disciplines that provide them with holistic understanding. They became better prepared for the labor market with the ability of interdisciplinary thinking including higher capacity of exploring, analyzing and understanding complex phenomena [2]. Moreover, interdisciplinary working experience stimulates students' creativity and enhances their capacity to innovate by the combination of different disciplinary knowledge and methods [3].

In spite of these numerous positive learning outcomes the application of interdisciplinary teamwork is usually not without any difficulties. It demands the engagement of the entire person in the learning process involving cognitive, relational, social and emotional aspects [4]. For instance, to put together

interdisciplinary students in a project team, it is not sufficient to teach them how to collaborate efficiently. Teaching only the traditional teamwork skills is not enough for a successful interdisciplinary collaboration [5]. We need to apply a new teaching approach to support the development of collaborative skills. These skills are essential to prepare engineering students to be able to produce quality interdisciplinary work in their future professional lives to resolve complex problems. This means that they need to change disciplinary perspectives and to develop not only domain-specific knowledge and general skills but boundary-crossing skills [6].
The aim of this paper is to explore the main difficulties of this teaching practice from a case study of interdisciplinary collaboration between engineering students specialized in multiple engineering fields and students specialized in communication. As an introductory explanation we will present the course design and overview. Next, we will focus on the main aspects and difficulties of interdisciplinary collaboration and their role in the collaborative learning. Finally, this paper will discuss results and future perspectives.

1 COLLABORATIVE LEARNING PRACTICE

1.1 Course design and overview

The main objective of this 12 week long “Applied Marketing Innovation” course is to develop engineering students’ ability to work in an interdisciplinary collaboration. This course places special emphasis on the development of their collaborative skills from cognitive, relational, psychological aspects. For that reason engineering students specialized in various engineering fields are teamed up with students specialized in communication. In each team six students (2 engineering students and 4 communication students) work together on a real life assignment for an external company. Students are all in the later stages of their specialization (6^{th}-8^{th} semesters) with a strong disciplinary knowledge and identity. Despite the advanced stage in their studies, they have had team working experience only with other engineering students in the same specialization. In this regard, this course is fundamentally different from their previous experiences.
The structure of the course is divided into two phases. The first period of the course (week 1-6) is a mainly divergent phase [7] when engineering students devote their time to learning the theory of marketing innovation strategies and the basic practice of communication. This work is supported by course manuals, exercises, case studies, meetings (with groups of final year classes), lecturers and by the tutor. The second period (week 7-12) is mainly a convergent phase when students work in an interdisciplinary team to generate a new and innovative solution for a real problem. For this, they use their disciplinary knowledge (for exemple to develop a technical solution of a new multimedia service) and integrate new knowledge from the marketing or communication field (to find a new way to use this service). In the transition period between the two phases, the industrial company, which is the client of the students’ teams, presents their problems and their requests to find an appropriate solution. During this planning session students organise and preplan their work together. At the end of the course, the client company is involved in the oral exams and in the assessment of learning outcomes.
The expected learning outcomes of the course enable students to deal with complex problems: comprehensively understanding, critically analyzing, conceptualizing, synthetizing/implementing knowledge and getting a solution to it [8]. In this course, students are expected to develop an interdisciplinary thinking that entails their “capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement – such as explaining a phenomenon, solving a problem, or creating a product – in ways that

would have been impossible or unlikely through single disciplinary means" [9, pp. 219]. They should be able to demonstrate their interdisciplinary thinking and explain the collaboration processes they have gone through together during the course. At the end of the course, they should be able to persuade their real client (the external company) about their resolution as the best solution to their problem.
The course is not assessed using traditional assessment methods only. We considered both formative and summative assessment in a progressive process during this collaborative interdisciplinary project. Formative assessment was used by tutorial teachers for monitoring the students' progress on a regular basis during the learning period. Summative assessment was practiced at the end of the project by the client on the basis of the project outcome.

1.2 Collaborative teamwork

For the first time, engineering students frequently consider interdisciplinary teamwork as a foreign practice. This working method differs widely form their usual project teamwork where they work together in their own technical domain. Consequently, their initial reluctance to work together with students from a completely different discipline is not surprising. To overcome this reluctance, we organize a meeting with higher class engineering students to speak about their former experiences of interdisciplinary teamwork and to give their own accounts. This meeting generally results in a positive, stimulating and motivating effect. Effective collaborative practice is based on personal engagement on voluntary basis [10] so it is important to strengthen student's motivation to be involved in interdisciplinary teamwork.
We define interdisciplinary collaboration as a dynamic interpersonal process that implies a complex relationship between several disciplines [11]. Therefore, the interpersonal relationship between students is an important element of our teaching strategy. In a good relationship, students are motivated and enthusiastic about working together. Operating in a good working atmosphere help them to create interpersonal cohesion and facilitate team interactions. Collaborative practice is enhanced when team relationships are good by establishment of mutual trust and engagement between the team members [12]. These should be founded in an early stage of a new working team. For this reason, we bring together students during the transitional period of the course to participate in informal team building activities for initiating and nurturing team relationships [13]. These team building activities give the possibility for students to get to know each other outside of academic context. This opportunity is really important for them because they are not only in different institutions but also geographically dispersed. Getting to know their team members before the beginning of the project teamwork facilitates them to work together more effectively.
In a collaborative process the success of one team member is determined by the success of the team. This positive interdependence is considered as a basic element of collaborative learning practice [14]. In the framework of this course, we apply an interdisciplinary teaching strategy focusing on problem-solving [15]. For this reason, we try to develop positive goal interdependence between our students. When positive goal interdependence occurs, the project team is united around the common goal, which contributes to establish a common ground.
However, to succeed in common goals, good team coordination is required. Students are at liberty to manage team coordination by the members. The coordination of individual roles to meet common goals can result in diverse conflicts. A conflict in itself is not necessarily bad in collaborative teamwork and may provide the development of conflict management skills. Therefore teachers do not interfere in case of conflicts, only at team members' request in the event of a deadlock.

1.3 Collaborative environment

As we mentioned before, students are geographically dispersed, making it difficult to work together regularly in a physical collaborative environment. In this context, we try "to combine distance and presence which makes learning environment more robust" [16, pp. 6]. We have only a small amount of presence-based team work at the beginning and the end of the project just before the oral exams but it may help them to solve some of the problems (for example conceptual misunderstanding at the launch of the project). The flexibility of the virtual collaborative environment allows the students to create specific working schedules for each team to optimize their time. In a physical environment it would be really complicated to find a common working schedule for the entire class with students from different institutions.
Working in a virtual collaborative environment has a broad influence on students' interpersonal interactions. Firstly, "virtual collaborative learning is effective if group members engage in rich interaction" [16, pp. 13]. To foster interpersonal interactions between students we hold a regular tutorial for each team. Tutors provide an external regulator function to make sure that regular interactions occur but they should mainly act as facilitators to the learning process not as controllers [17]. Their role is not to help students in task resolution but to structure and to regulate the collaborative learning process. Secondly, today's virtual collaborative environment provides a very large range of applications that facilitate activities of communication and interpersonal interactions [18]. This is an important opportunity for students as well for teachers because these collaborative technologies can considerably improve the effectiveness of collaborative learning practices. Engineering and communication students are accustomed to using this kind of application and they know exactly what they need for working effectively. Thus, we give them the freedom to make a choice between numerous applications to construct their own virtual collaborative environment.

2 INTERDISCIPLINARY COLLABORATION

Nowadays, there is a clear tendency to promote interdisciplinary learning practice in the higher education institutions' curriculum [19]. Nevertheless, "curricula that aim to develop interdisciplinary thinking on a broad scale are likely to experience more difficulties than curricula that aim to develop interdisciplinary thinking on a narrow scale" [6, pp. 366]. Engineering students are not really used to working across different disciplines. This makes it difficult to adopt easily an interdisciplinary way of thinking. Students may have problems with differences between disciplines in terms of epistemology, working and teaching methods, professional language, etc. As a result, we limited our interdisciplinary course to the collaboration between two really different disciplines.
We identified several obstacles that have an influence on the interdisciplinary collaboration teaching and learning practice. We classified these obstacles according to of their cognitive, relational, psychological basis.

2.1 Cognitive aspect

At the beginning of the interdisciplinary teamwork good understanding of the problem is essential. However, misunderstanding of the problem is a common problem especially for engineering students. They are prone to focusing on the technical aspects of the project without really considering other viewpoints. Fortunately, this problem is more often than not altered in a collaborative learning process by team members from non-technical disciplines. Otherwise this situation may result in conflict and students' demotivation, requiring tutor intervention.

Usually, there are high differences in skills and knowledge between the interdisciplinary team members. In this situation, the development of shared knowledge is essential for working together effectively [20]. In the phase of common knowledge construction each member of the team should identify what knowledge and skills is needed to solve the project problem. Identification and integration of individual knowledge and skills in the common knowledge is not always easy. If this situation arises we propose informal or formal (in case of major difficulties with the participation of the tutor as moderator) negotiation between the team members.
Converging their individual mental model with a team mental model causes significant difficulties for several students. This problem occurs for various reasons as the failure of communication, the psychological characteristics of an individual, cultural differences and lack of common ground between team members, etc. The detection of this difficulty is rather problematic in a collaborative learning context where the coordination of the team activities is entirely in the hands of the team members. In this case, a team building intervention can have a positive impact to identifying and overcoming this problem.

2.2 Relational aspect

In collaborative teamwork, the interpersonal relationship between team members is a decisive element for the efficiency and effectiveness of their work [12]. Nonetheless, to create a good interpersonal relationship between students who do not know each other and have little familiarity is not an easy challenge. Engineering and communication students present numerous divergences in their way of thinking, in their working methods, in their communication or collaboration skills. So, we have a really heterogeneous team composition that can influence negatively the collaborative teamwork [21]. In this context, the creation of a common ground has noticeably a positive effect to interpersonal relationship. That represents team members' shared understanding, values, objectives, norms, vocabulary, etc.
However, the establishment of common ground needs some time for a team which is coming together for the first time. The time period of the interdisciplinary project is largely limited to one semester. We must admit that this time limit is an important constraint for students. They do not have enough time to fully establish common ground in their team and to create a high collective identification [22].
Working in a virtual collaborative environment makes the development of interpersonal relationship more complicated. When students work virtually, separated by distance or time, communication tools can resolve several team organizational problems. But for conflict resolution, operating in a virtual environment is not the best condition [23]. In a conflict situation, the physical presence of team members can facilitate negotiation. It would be useful if students could have regular face-to-face work in parallel with virtual work to strengthen their relationship and to come to an agreement more easily in case of conflict.
A good interpersonal relationship in a collaborative teamwork is based on mutual trust and engagement [12]. As students are from different higher education institutions, they have diverse interests in the project's accomplishment. More particularly, for communication students this course has more importance in their curriculum than for engineering students. Consequently, they do not have the same level of commitment to collaborative teamwork. This difference between students with high and low level of engagement in the same team is a source of relational problems.

2.3 Psychological aspect

Psychological factors influence significantly the outcome of interdisciplinary team collaboration [24]. Between several factors of influence, we point out the importance

of students' willingness to collaborate [25]. For this course, the lack of willingness to collaborate remains a basic problem when the interdisciplinary project is announced. Without any preliminary experience, students have no or little faith in the benefits associated with this kind of collaboration. However, after the meeting of final year students there is a spectacular change: they became enthusiastic and motivated to collaborate. This first-hand account gives them positive professional expectations about interdisciplinary collaboration.

For the development of interdisciplinary thinking, students' personal characteristics play an important role. In particular, their openness, curiosity and respect are necessary to have a positive attitude towards other disciplines [6]. At the launch of the project, there is a really wide variance between students in their attitudes. But this attitudinal discrepancy does not persist for a long term. During the course period usually there is a team convergence towards positives attitudes that enable students to change disciplinary perspectives that foster collaboration.

3 CONCLUSION AND PERSPECTIVES

In an increasingly complex world, the necessity of interdisciplinary collaboration is definitively established in most of disciplines. To construct a complex system, the contribution of a single discipline is not sufficient. So, there is a growing interest in collaboration between disciplines. For engineering students the development of interdisciplinary collaboration skills became essential to prepare their future professional career. They are required to work effectively across disciplinary boundaries and create a link between these disciplines.

This interdisciplinary learning experience helps them effectively to acquire collaborative skills and to develop interdisciplinary thinking. Students have to overcome differences between disciplines that enable them to deal with complexity. Their ability to integrate knowledge of other disciplines deliberately develops their capacity to produce new and innovative solutions to a problem. During this experience, they work in a virtual collaborative environment that gives them the opportunity to organize their interdisciplinary team activities and to choose the most convenient collaborative tools to create their own virtual workplace.

Obviously, it is not an easy challenge and students have several difficulties in working in collaboration with other disciplines. Through this teaching experience, we perceived cognitive, relational and psychological obstacles in engineering students' learning practice. We hope that they will be taken into consideration in the future development of specific interdisciplinary courses for engineering students.

After the end of this interdisciplinary course, we organize an informal meeting for engineering students to discuss their experiences and feelings. Usually we have very positive feedback with constructive ideas and suggestions for future improvements. Final year students suggested not limiting this learning experience to only one single semester but extending it to the following semesters. Considering this suggestion, we develop a new interdisciplinary course during the two following semesters for the improvement of innovative and entrepreneurship collaborative competences.

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