DEVELOPMENT OF COLLABORATIVE AND SOCIAL SKILLS THROUGH MULTIDISCIPLINARY DESIGN PROJECTS

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ABSTRACT
MATI Montreal is a new inter-faculty research center, which focuses on the development of methodologies, tools and knowledge for the use and integration of information and communication technologies in sciences, engineering and management educational programs. Multidisciplinary projects at MATI Montreal are designed for strategic project-based teaching aiming at the collaborative development of customized interdisciplinary courses, the systematic involvement of industrial partners to drive and co-supervise student projects, and thus allowing students to experience a complete product development process. This paper describes the instated pedagogic structure and discusses the social and collaborative skills that the students developed within such a learning framework.

Keywords: product development, multidisciplinary student teams, project-based learning, collaborative and social skills, CDIO initiative.

1 INTRODUCTION

In January 2004, École Polytechnique Montreal launched a major reform program for all its engineering curricula. The Mechanical Engineering department adopted the CDIO (Conceive-Design-Implement-Operate) approach to foster the changes needed to prepare its future engineers for the realities that the industry of the 21st century is facing [1]. One of the important CDIO standards is to encourage project-based learning where students participate in active and experiential learning through real product development situations.

École Polytechnique Montreal, one of the founding members of the MATI Montreal research centre (La Maison des technologies Roland Giguère) along with the University of Montreal and the School of Business and Management (HEC Montreal) have joined efforts to fully support this reform. The centre is dedicated to the development of knowledge, methods and tools for the efficient integration of information and communication technologies in sciences, mathematics, engineering, and management educational programs. In the case of product development activities, multidisciplinary teams also known as Integrated Product Teams (IPT) are fundamental for the success of an engineered product [2]. This Concurrent Engineering practice is typically supported by a number of advanced software solutions which support teamwork in a quest to enhance efficiency in temporally and physically distributed situations [3]. For

educational institutions, this effectively means training student engineers, designers and managers to work in IPT using tools and methodologies that enable them to transcend disciplinary and geographic boundaries. This digital environment involves advanced computer aids dedicated to specific engineering tasks and sophisticated management technologies that support the information generated across the life of a product [4]. For the Mechanical Engineering reform programme, MATI Montreal therefore provides a unique opportunity to develop, assess and validate the efficient integration of these information technology solutions within the new courses and integrated learning projects.

A brief review of key multidisciplinary student design projects across the world is presented in the next section. The paper then focuses on the multidisciplinary initiatives taken at École Polytechnique over the past 10 years and their continuing development. Finally, the benefits in terms of social and collaborative skills for the participating students are discussed in the concluding section.

2 REVIEW OF KEY MULTIDISCIPLINARY STUDENT DESIGN PROJECTS ACROSS THE WORLD

Project-based learning has been widely acknowledged as a fundamental educational experience for engineering design students [5], [6]. Based on the background work presented by Dym *et al.* [5], the authors have been reviewing current practices in academia, especially the multidisciplinary dimension of project-based learning. This study has enabled to categorize multidisciplinary design teaching approaches along two main dimensions: 1) a cross-engineering vs. a multidisciplinary framework, 2) a course-based vs. an option-based approach.

In practice, the term “multidisciplinary” for design student projects can be understood and implemented in two different ways. Indeed, the review shows that a distinction can be made between cross-engineering initiatives and complete multidisciplinary frameworks usually fulfilled by an inter-faculty or inter-university effort. Complete multidisciplinary design projects typically involve three major areas of expertise driving the development of a new product, namely Design, Engineering, and Business & Management. Of course, in theory, a multidisciplinary approach should be inclusive of the cross-engineering framework to match industrial realities, but the authors have observed that in practice multidisciplinary projects seldom include several engineering domains.

The second classification dimension related to this study is the distinction that can be made between a course-based and an option-based approach to multidisciplinary project-based learning. The course-based approach presents certain administrative advantages, i.e. students from different institutions can enrol in the same project-based course, which is accredited by their home University or Faculty. On the other hand, the option-based approach is obviously more complicated to set-up; it requires the establishment of a new option or specialization accredited by all academic partners. In engineering programmes, multidisciplinary course-based projects are understandably more common than their option-based counterparts. Nevertheless, from an educational standpoint, option-based multidisciplinary design initiatives are more complete since they typically offer a combination of pragmatic experiences and theoretical knowledge closely tied to the project needs. Figure 1 presents and classifies four multidisciplinary projects that the authors found most representative for the classification scheme discussed in the previous paragraphs.

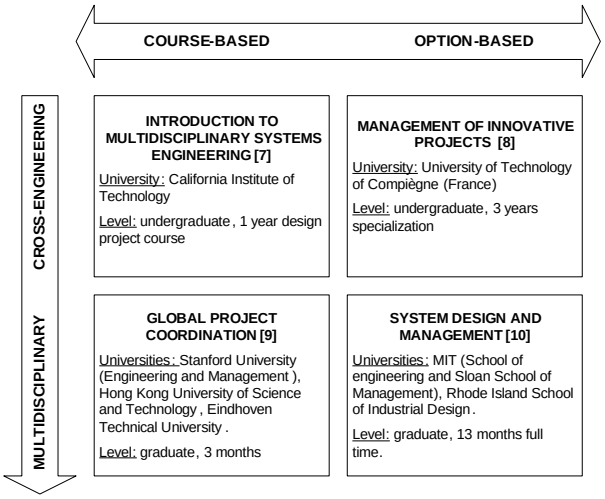

Figure 1 Examples and classification of multidisciplinary design projects

It is important to note that not a single multidisciplinary design project at the undergraduate level was found. Also most of the multidisciplinary project-based experiences, whether course-based or option-based, are held at the graduate level.

3 MULTIDISCIPLINARY STUDENT DESIGN INITIATIVES AT ÉCOLE POLYTECHNIQUE

The new Mechanical Engineering curriculum is articulated around four integrated learning projects, which constitute a cohesive chain of learning experiences [11]. A brief description of these four major design projects is provided in Table 1.

Table 1 The four integrated learning projects at École Polytechnique Montreal

	Integrated learning project description
Year 1 project	• 1 semester cornerstone project: 3 case studies and design exercises • Teams of 5 mechanical engineering students • Work focussed on communication skills, teambuilding experience, project management tools and practices • Set in a controlled design solution space in time and scope
Year 2 project	• 1 semester cornerstone project, presented in the form of a design contest • Teams of 5 mechanical engineering students • Work focussed on conceptual design and prototype building/testing • Set in a closed-ended, rule-based design solution space
Year 3 project	• 1 semester cornerstone project • Individual assignment submitted by local companies or research laboratories • The students answer a design specification document, manage budgets and project timelines
Year 4 project	• Capstone project covering 2 semesters with industrial partners • Teams of 20 students from École Polytechnique, the School of Industrial Design, and the School of Business and Management. • Open-ended product design where the solution must be achieved by using virtual prototyping systems and advanced collaborative tools. • Work focuses on Integrated Product Team management, product information management, and professional communication skills.

Even though the reform program is still in its implementation phase, the vision at École Polytechnique extends the CDIO framework, which essentially recommends cross-engineering project-based learning, through the development of multidisciplinary projects. Although multidisciplinary initiatives to product development in academic institutions have been increasing in the last few years, their success rate remains questionable [12]. A new approach has therefore been put into place, where the experience gained from a successful graduate aerospace design project, presented in the next section, has gradually helped to build a new multidisciplinary project for 4th year undergraduate students focusing on the design of innovative products, detailed in section §3.2.

3.1 The aerospace design project

Since 1999, the Virtual Environment (VE) option, initiated under the impulse of the Centre for Aerospace Manpower Activities in Quebec (CAMAQ), is directed towards familiarizing students to virtual product development technologies and methodologies. The graduate VE teaching scheme aims at representing these aerospace technological realities and developing soft skills such as project management, communication, and leadership. This option-based cross-engineering design initiative (see §2), includes a two semester aerospace design project and two integrated courses ("Integration of Design and Manufacturing" and "Project Management in Aerospace Engineering"). The teaching and supervising staff involved, blends academics from the Mechanical Engineering department and practicing engineers from the Montreal aerospace sector.

The Master's aerospace design project also known as the "CAMAQ project" [13] represents a unique experience for the training of aerospace engineers. Some fifteen students work on the redesign and manufacture of an aircraft pylon prototype to allow the retrofit of a new engine to an existing fuselage. In recent years, the participating students are highly sought after in the aerospace job market and the level of professionalism they achieve is often praised by their new employers [13].

3.2 Towards an undergraduate multidisciplinary product design option

Based on the experience gained from the aerospace design project and previous 4th year capstone projects [14], the Mechanical Engineering department has developed over the last two years a new undergraduate multidisciplinary design project. In 2006, a partnership with the School of Industrial Design allowed to set up a team of 20 undergraduate students, selected from both institutions. They were given the task to design a three wheel electric vehicle. The project was sponsored and co-supervised by an industrial partner. In 2007, HEC Montreal has become the third academic partner involved in this novel project-based learning venture. The 2007 capstone project teamed up students from all three partner institutions to develop a new urban bus concept built from composite materials and equipped with a "green" energy type motorization.

Both the aerospace design project and the multidisciplinary design project share common educational goals: immerse a team of students in an industrial context, develop social and collaborative skills, introduce state of the art collaborative product development methods and technologies, develop project management experience, and confront students with a real problem which has no given solution. Nevertheless, the aerospace design project is a graduate cross-engineering project, which essentially deals with integration issues between engineering and manufacturing, while the new multidisciplinary capstone project initiative focuses on the development of new products. In this case, 4th year students not only explore in more depth the conceptual

stages of a product development process, but also experience the dynamics of a multidisciplinary environment, while attempting to achieve realistic design solutions. Figure 2 presents the organizational teaching structure adopted to support such a complex and multidisciplinary project.

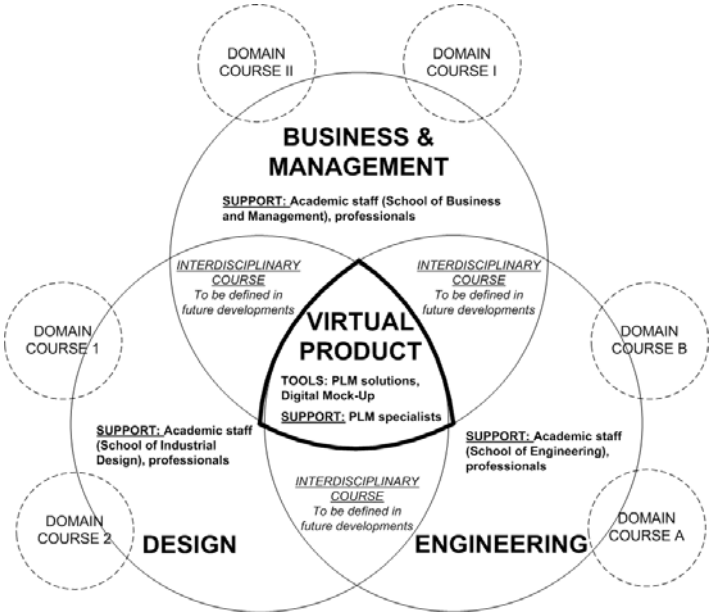

Figure 2 Organizational structure for the capstone multidisciplinary design project

The next development step for the capstone multidisciplinary initiative is planned for the 2008/2009 academic year, which will see the initiative broaden to multiple teams working on a range of different products mandated by various industrial sectors. As shown in figure 2, a number of closely related interdisciplinary courses could also be included in the framework in order to fulfill the requirements of a multidisciplinary project-based learning option or specialization, as defined in §2.

4 CONCLUSION: FOSTERING COLLABORATIVE AND SOCIAL SKILLS

It is widely accepted that traditional product development training in academia fails to provide industry with individuals possessing key collaborative and social skills required by modern working practices. Therefore, the new educational initiative described in this paper addresses in particular the social skills framework as outlined by Lauche [15]. Indeed, through the capstone multidisciplinary design project, students experience team and task coordination, collaboration, conflict resolution, client communication, dealing with uncertainty and failure, and are confronted with the need for reflection and self awareness [15].

The multidisciplinary project-based learning initiative described in this paper was not set-up overnight; it was a long and intense reflective process lead by a multidisciplinary team of dedicated teachers and professionals. The authors believe that the success observed so far can be accredited to a number of organizational factors: the theoretical teaching framework provided by the CDIO reform, the incubator environment for technology and teaching methodology integration at MATI Montreal, the close involvement of industry, and the multidisciplinary context in which the initiative has

grown. Finally, it is important to mention that the multiple capstone projects to be launched in the next academic year will take place in a new state of the art 1000 m^2 Integrated Teaching Laboratory (ITL), which will further enhance the students' project-based learning experience.

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