THE CHALLENGE OF TEACHING MULTIDISCIPLINARY SUSTAINABLE DEVELOPMENT CAPSTONE PROJECT

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ABSTRACT

The Sustainable Development Capstone Project is a multidisciplinary, fourth-year undergraduate project course. The course has two components: an individual project that accounts for 20% of the final grade and a group project that accounts for 80% of the final grade. For the individual project, students prepare educational material (one-hour lecture, case study or practicum) from the standpoint of sustainable development for a course that they have already taken in their program. For the group project, students work in multidisciplinary teams on a preliminary design for a sustainable community building with related services.

The individual project and group project both aim to integrate sustainable development into engineering programs and demonstrate that all engineers should be concerned with sustainable development no matter what their field of engineering. In addition to incorporating technical concepts learned during the bachelor's program and integrating sustainable development, the group project introduces students to multidisciplinary teamwork and integrated process design, a practice that is increasingly common in the design of green buildings. A foundation of sustainable development, integrated process design may be difficult to apply but can ensure a project's success, as the constraints and goals of all disciplines involved are considered from the beginning of the project. Through course activities and support, teachers encourage students to work together and avoid working in silo despite the multidisciplinary dimension of the project and the different technical languages of team members. Teachers supervise the students' design process, organize activities involving professionals from different fields to provide students with technical support, and guide students in addressing all aspects of sustainable development. Teachers must frequently remind students that sustainable development is not limited to the environment and that social aspects must be considered. Students must also realize that the proposed preliminary design is for a community, whose needs and desires must be considered even if this sometimes leads to compromises on energy efficiency. The challenge for teachers is to integrate sustainable development into the course in terms of both technical aspects and implementation.

KEYWORDS

Sustainable development, capstone project, multidisciplinary project

INTRODUCTION

The creation of the course Sustainable Development Capstone Project (ING4901) is the result of a desire to change how things are done and to demonstrate that all engineers are affected by sustainable development no matter what field of engineering they work in. The course ING4901 is a fourth-year undergraduate project course offered to students from all engineering specialties, which is almost unheard of at École Polytechnique de Montréal (Polytechnique). The course has been offered since the 2008 winter term and has been given four times. Students work in multidisciplinary teams on the design of a sustainable development project in a context very similar to a real engineering working environment. In addition to integrating the concepts learned in the bachelor's program, students must provide engineering solutions to a real-life, complex project from the standpoint of sustainable development, which requires taking into account and balancing environmental, economic and social components—the latter being often overlooked in engineering practice. The course objectives for ING4901 are in keeping with those of CDIO™, which aim to develop skills through project-based learning and to expose students to complex problems that are more representative of reality to help them meet the needs of the industry.

The many challenges surrounding ING4901 involve logistics, technical support for students, and the integration of sustainable development. To provide background for the reader, an outline of the course context along with its goals and support activities will be presented, followed by a presentation of the main topic: the integration of sustainable development in all of its aspects, from technical dimensions to implementation.

CONTEXT

In 2005, Polytechnique completely reorganized all of its undergraduate engineering programs.[1] One of the major changes to all programs was the addition of a project course to each year so that students could integrate technical learning and apply oral and written communication skills developed in complementary studies. During this process to overhaul the engineering programs, each department suggested the improvements needed to address the desired competencies and to meet the requirements of the Canadian Engineering Accreditation Board (CEAB). To propose such changes, the Civil Engineering Department compared the competencies achieved in each program course with the desired competencies outlined in *Civil Engineering Body of Knowledge for the 21st Century* (American Society of Civil Engineers).[2] This exercise highlighted certain gaps in terms of environmental management and sustainable development.

The creation of ING4901 allowed the university not only to fulfill its goal to offer project courses but also to include aspects of environmental management and sustainable development in undergraduate courses and address a number of CEAB graduate attributes, such as design, teamwork and multidisciplinarity, and the impact of engineering on society and the environment.[3] Thanks to the concept of ING4901, Ms. Louise Millette, Associate Professor and Director of the Department of Civil, Geological and Mining Engineering, was able to obtain a five-year grant from the Desjardins Foundation.

The course ING4901 is an elective course offered to students from all disciplines in their final undergraduate year, and it may be chosen in lieu of the project course required during the last year of their program. The multidisciplinary aspect of the course allows students to work in an environment that is close to reality and allows teachers to introduce students to an integrated process design, which is increasingly used in the design of sustainable buildings. This process requires involving all project stakeholders from the beginning so that the design is initiated on a sound basis and takes into account the constraints and goals of all disciplines involved.[4] With this process, projects may start slowly, but problems are avoided later in the design.

Multidisciplinary work has many pedagogical advantages; however, implementing multidisciplinarity in an institution like Polytechnique is complex. The bachelor's degree includes 120 credits, 108 of which are for compulsory courses. There is a nominal course choice grid for each undergraduate term, but students are not obligated, or not always able, to follow it. Students are promoted in their disciplines by subject and not on a yearly basis. This flexibility generates timetable conflicts within programs and becomes a real puzzle when trying to schedule a multidisciplinary course. Timetable conflicts are thus inevitable for ING4901, even with the full cooperation of the registrar. Course teachers must deal with this reality and plan compulsory activities for times when there are fewer scheduling conflicts.

COURSE DESCRIPTION

The course ING4901 is divided into two parts: an individual project that represents 20% of the final grade and a group project that represents 80% of the final grade. The course goals are to:

1) Define and understand the role of the engineer in terms of sustainable development.
2) Increase knowledge of sustainable development and the ability to apply this knowledge through real case studies.
3) Identify, evaluate and implement best practices in terms of eco-design and sustainable development.
4) Develop a holistic view of technical problems (social, economic and environmental).
5) Delineate the challenges of sustainable development for a project.

For their individual projects, students must choose a course that they have already completed and prepare educational material for the course by re-examining the subject from a sustainable development viewpoint in collaboration with the teacher of the chosen course. Collaboration with the teacher involves a one-hour meeting at the start of the project to define the orientations for the individual project and the type of material that will be developed (one-hour oral presentation, practicum, or case studies). Subsequently, the teacher can give occasional support to the student as required. The educational material can then be used by the teacher if he or she wishes to include sustainable development concepts and viewpoints in the course. The goal is to assist all teachers in adding the sustainable development dimension to engineering courses. Individual projects are evaluated by the ING4901 teachers. First, students submit a detailed plan of their individual reports to the teacher. The teachers perform a formative assessment of each plan to allow students to improve their individual reports. Students submit a final written report half-way through the term. The following components are evaluated:

1) Relationship of the individual project with the chosen course and the field of engineering.
2) Integration of sustainable development.
3) Explanation of the individual project (context for assignments and case studies, accompanying text for the oral presentation).

4) Structure and visual quality of the material developed.

For the group project, students work in multidisciplinary teams on a real engineering design project from a sustainable development standpoint. The first two times the course was given, the students worked on the design of a sustainable, multi-use community building in an urban setting with the collaboration of a non-profit support organization: Montreal Urban Community Sustainment (MUCS). The third and fourth times, the students worked on the design of a sustainable, multi-use building set in an eco-village. This project encompassed the supply and treatment of drinking water, wastewater treatment, local energy production and the impact of transportation stemming from the geographic location of the eco-village. Since the beginning, all projects have involved client participation.

The first time the course was offered, only five students enrolled. About twenty-five students on average took the course in the following terms. The teams (five to six students per team) are chosen by teachers and balanced based on discipline, specialty and academic achievement. The literature shows that the academic success of a team is related not only to the skills of each individual but also to motivation, team dynamics, personal factors and the compatibility of team members' personalities.[5] Several authors suggest methods for forming teams based on students' personalities, strengths and weaknesses to ensure teams are as balanced and functional as possible.[5] [6] [7] While the methods proposed in the literature are interesting, they were not selected for ING4901. One of the goals for the group project is to develop teamwork skills regardless of team composition. To help students improve their team skills, a team-building activity is organized mid-term with a professional from the Polytechnique who specializes in interpersonal skills and teamwork (IST). Instead of trying to avoid team conflict by selecting members based on their personalities and ambitions, teachers and the IST specialist give students tools to improve teamwork regardless of the context. In their future engineering careers, students will inevitably have to work on teams in sometimes difficult circumstances; this is why ING4901 and several other project courses and capstone projects use IST tools.

The course is popular mostly with civil, mechanical and chemical engineering students. Students from electrical, industrial, materials and geological engineering have also participated, but in smaller numbers. Two teachers, a mechanical engineer and a civil engineer, prepare the course and supervise and evaluate the students. As a complement to technical support, activities with professionals are also scheduled during the term:

1) Lectures: During the first six weeks of the term, professionals from various disciplines give lectures to upgrade students' technical knowledge.
2) Workshops: A workshop follows each lecture to encourage students to apply the concepts learned and to begin the design process with the support of the invited speaker.
3) Design studio: Professionals from various disciplines participate in a design studio twice throughout the term. During the activity, a professional works with the students on their project design for a period of forty minutes. After that time, the professional moves to another group so that each team eventually receives support from each visiting professional.

In the course of the term, students must hand in four written assignments in the form of technical reports. The goal of each assignment is to have the students:

1) Show an understanding of the task and goals and plan the team's work and project schedule.
2) Make and justify the design choices.

3) Design the project components and present them to an expert panel.
4) Reply in writing to the panel's questions, present the project to a wide public audience, and answer the question, "If you had to do the project again, what would you do differently from a technical standpoint and in terms of teamwork and crisis management?"

SUSTAINABLE DEVELOPMENT INTEGRATION

Regardless of the type of project and the disciplines involved, the integration of sustainable development is essential and should be a reflex. Sustainable development is becoming more and popular, and the field of education is no exception to this trend. In recent years, educational programs have incorporated sustainable development in different ways. Some engineering programs include the basics of sustainable development in first-year program courses; Rowan University,[8] Colorado State University,[9] and Virginia Tech [10] are some examples. At Rowan University, not only are sustainable development basics taught in the courses of the first year program, but sustainable development is also integrated in multidisciplinary projects offered to students in their sophomore, junior and senior years.[8] In addition to courses in the first-year program, sustainable development is often integrated into project courses.[8] [11] Many of these are geared towards green technology and energy efficiency (green buildings) and address more specifically the environmental and economic aspects of sustainable development. Project courses that delve further into social aspects are often associated with international cooperation projects.[8] [12]

For ING4901, there is a willingness to include sustainable development in all of its aspects, including the social dimension, for local projects. Engineering students tend to be attracted by technological challenges, modelling, and calculations. Teachers must remind students that they are devising engineering solutions for a community, whose needs and desires must be considered, which sometimes involves compromises on energy efficiency to address social aspects, for example. Teachers point students toward the concept of "need" so that they can develop optimal solutions from the standpoint of sustainable development and not simply that of energy efficiency. To help students integrate sustainable development, to support them in the design process, and to foster cooperation among team members, a tool for integrating sustainable development was added to the course. Since the 2010 winter term (which was being given as this article was being written), students have used the sustainable development project assessment tool [13] proposed by Professor Claude Villeneuve, Chaire de recherche et d'intervention en Éco-Conseil at the Université du Québec à Chicoutimi. The purpose of this assessment tool is to evaluate a project based on the three dimensions of sustainable development along with the added component of ethics. The tool lets students perform a summary and/or exhaustive analysis of a project from a sustainable development standpoint. A graphics creation tool can also generate a visual representation of the analysis. The tool is available free of charge, as its creators wanted it to be used as much as possible. As the tool is currently being used for ING4901, the real impact of its use cannot be measured at this time. However, the elements of the tool represent avenues of thought for considering all dimensions of sustainable development and therefore guide students in their thinking process and the development of their project.

Along with the integration of environmental, social and economic aspects of sustainable development, the course teachers attach great importance to the design approach and process. Teachers encourage students to work on an integrated process design, to work as a team, and to avoid working alone. These values are part of the sustainable development process. The workshops and design studios are meant to get students to work together and improve how

different disciplines are integrated into the project while providing students with technical support from professionals. Despite these activities, teamwork is a challenge that can be exacerbated because students come from different disciplines, have not taken the same courses, and speak different technical languages. To encourage collaboration between students from different teams but from the same discipline and to allow them to share difficulties and find solutions, the workshops and second design studio were modified for the 2010 winter term.

Modification of the workshop:
Following a specific lecture, the students from this discipline come together to talk about and establish the design process with the support of the expert who gave the lecture. This approach introduces inter-team collaboration and forces students to reflect on the entire design process from the beginning of the term.

Modification of the second design studio:
For the second design studio, the students are grouped by discipline and work with an expert for approximately one hour. The modified format of the second design studio has allowed experts to work with all students from the same discipline at the same time, to send the same message to all teams, to avoid explaining the same thing over and over again, and to enhance the design process. The experts appreciated this format. The teachers will discover how well the students liked this approach once they receive the course evaluations.

The modification of the workshops and the second studio does not minimize the importance of teamwork. Following the second studio, the students must continue to develop the project with their teams to ensure project cohesion and an optimal integration of all elements.

CONCLUSION

The goal of ING4901 is to “contaminate” engineering programs with sustainable development, thereby ensuring that tomorrow’s engineers are familiar with the principles of sustainable development and have the tools to integrate these principles into their profession, regardless of their field. The individual projects fulfill this goal and therefore affect not only the students registered in ING4901 but also the teachers and students of almost all undergraduate courses. The group project also meets this goal, although on a smaller scale. Students not only incorporate technical concepts related to sustainable development into a real project but also integrate design processes from the sustainable development standpoint. It is this process that represents the biggest challenge for students, a challenge that will follow them throughout their careers.

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Biographical information

Anouk Desjardins
Anouk Desjardins has worked on the evolution and the teaching of the course Sustainable Development Capstone Project. After graduating in civil engineering from École Polytechnique de Montreal she obtained a Master's of Applied Science in 1999. Then she worked in industry as a process engineer. Since 2008 she joined École Polytechnique as a research assistant for sustainable development projects and as a lecturer.

Louise Millette
Louise Millette is, since 2002, the first (and only) woman to hold the position of Department Director at École Polytechnique de Montreal. After graduating in civil engineering at École Polytechnique, she obtained a Master's of Applied Science from UBC and then a Doctorate from École Polytechnique. An experienced environmental manager, she worked at Bell Canada for 12 years before joining École Polytechnique as Director of the Department of Civil, Geological and Mining Engineering. Very involved on the municipal scene, Dr. Millette chairs two committees of "la Conférence régionale des élus de Montréal": the Environment and Sustainable Development committee and the Urban Landscape Committee. She is a founding member and a major contributor to Montréal's First Strategic Plan for Sustainable Development.

Erik Bélanger
Erik Bélanger has worked on the development of the course Sustainable Development Capstone Project. Since then, he has contributed to the evolution and the teaching of the course. He obtained his engineering bachelor's degree in mechanical engineering from University of Sherbrooke in 1999. After graduating he worked in industry as a design engineer before completing a Master's of Applied Science Montreal at École Polytechnique de Montreal. Since 2004 he has worked at École Polytechnique as a research assistant for sustainable development projects and as a lecturer.

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