AC 2011-870: SUSTAINABLE DEVELOPMENT CAPSTONE PROJECT:
COLLABORATION BETWEEN ARCHITECTURE AND ENGINEERING
STUDENTS

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Since 2008, Anouk Desjardins has been developing and teaching the ING4901 Sustainable Development Capstone Project course. She graduated from the cole Polytechnique de Montral (EPM) with a degree in Civil Engineering, and earned her Masters of Applied Sciences in 1999. She worked on engineering design projects for several years as a project engineer and project leader. In 2008, she joined EPM as a research associate for sustainable development projects, and as Instructor for capstone projects in Civil Engineering and sustainable development, and the Civil Engineering Freshman Project.

Louise Millette, Ecole Polytechnique de Montral

Louise Millette is, since 2002, the first (and only) woman to hold a position as Department Director at cole Polytechnique de Montral (EPM). After graduating in civil engineering at EPM, she obtained a Master’s of Applied Science from UBC and a Doctorate from EPM. An experienced environmental manager, she worked at Bell Canada for 12 years before joining EPM 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 lus de Montréal”: the Environment and Sustainable Development committee and the Urban Landscape Committee. She is a founding member and close collaborator to Montréal’s First Strategic Plan for Sustainable Development.

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Marc-Andr Plasse obtained his undergraduate degree in Architecture with honours at McGill University in 1997. After working for several architecture firms in Montréal, he established his own architectural and design firm _naturehumaine_ in 2003. Closely involved in the academic milieu, he has been lecturing at the Université de Montréal since 2007. In the fall of 2009, he began supervising Architecture students involved in the ING4901 - Sustainable Development Capstone Project course.

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Erik Blanger 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 Université de Sherbrooke in 1999. After graduating he worked in industry as a design engineer before completing a Master’s of Applied Science in civil engineering at cole Polytechnique de Montréal. Since 2004 he has worked at cole Polytechnique as a research assistant for sustainable development projects and as a lecturer.
Sustainable Development Capstone Project: Collaboration between Architecture and Engineering Students

Introduction

The Sustainable Development Capstone Project (ING4901) is a multidisciplinary, fifteen-week, six-credit project course that has been offered to engineering students in any discipline in their final undergraduate year since 2008.\(^1\) For the fall 2009 term, which marked the third time the course was given, an agreement with the School of Architecture was established. Accordingly, architecture students who had registered for final-year undergraduate workshop (ARC3012-B) were integrated into the multidisciplinary teams of engineering students. A teacher from the School of Architecture joined the teaching team to supervise the architecture students. Students in ING4901 work in multidisciplinary teams to design a real sustainable development project, which includes a sustainable building and aspects such as water and wastewater treatment, local energy production and the impact of the geographic location of the building on transportation. In addition to incorporating technical knowledge learned in the bachelor’s program, students must provide solutions to a real-life, complex project from the standpoint of sustainable development. This requires taking into account and balancing environmental, economic and social components—aspects that are often overlooked in practice.

In fall 2010, the course was offered for the fifth time, and open to architecture students for the second time. Integrating the architecture students into the course proved to be a complex but stimulating challenge. If the results of the first experience were mixed, subsequent efforts undertaken to improve the course made it a complete success. The present paper presents the course objectives, the pedagogical context, the support provided to students, the learning activities, the challenges associated with the course and the results of the two experiences involving the integration of architecture students.

Pedagogical context

ING4901 is an elective fifteen-week, six-credit (270 hours per student) course open to students in any engineering program. It may be chosen in lieu of the disciplinary capstone project required during the last year of their program. The course is also open to School of Architecture students who register for their final-year undergraduate workshop in the fall term. The multidisciplinary aspect of the course allows engineering and architecture students to work in a context that is similar to a real working environment. It also enables teachers to introduce students to integrated process design, a practice that is increasingly common in the design of sustainable buildings. Integrated process design\(^2\) involves 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 the corresponding disciplines. With this process, projects may start slowly, but problems which typically surface later in the design process are avoided.
The two times the course was given to both engineering and architecture students, the disciplines involved were the following: architecture, civil engineering, mechanical engineering, electrical engineering, chemical engineering, physics engineering and geological engineering. It was the first multidisciplinary experience for all of the students. 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.\textsuperscript{4} Several authors suggest methods for forming teams based on students’ personalities, strengths and weaknesses to ensure teams are as balanced and functional as possible.\textsuperscript{4,5,6} While the methods proposed in the literature are interesting, they were not selected for the course. One of the goals for the group project is to develop teamwork skills regardless of team composition. It was felt that tight control over the teams’ composition would not reflect the randomness of a real work situation. For the ING4901 course, the teams (each of which comprised five engineering and two architecture students) were assigned by teachers and balanced based on discipline, specialty, gender and academic achievement.\textsuperscript{3} This method of selecting team members proved satisfactory, although in each term some teams experienced more difficulties than others, especially from the perspective of workload organization. The students were nevertheless made aware of the rules at the outset of the course and knew that the circumstances to which they were being exposed were much like the ones they would encounter in the real world. In addition, to help students improve their team skills, a team-building activity was conducted mid-term with the support of a professional who specializes in interpersonal skills and teamwork (IST). The IST team is responsible for the teamwork course that is given to all first-year undergraduate students. The team is also involved in all project-oriented courses and provides students with various tools to develop their team-building and conflict management skills. 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 careers as engineers and architects, students will inevitably have to work on teams in sometimes difficult circumstances.

**Course objectives**

The objectives of the ING4901 course for engineering students are as follows:

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 particular project.

The objectives of the ARC3012-B course for architecture students are as follows:

1) Develop critical thinking, collaborative and communication skills.
2) Develop an architecture project, based on a defined problem that makes the most of innovative techniques, especially those that promote sustainable development.
3) Develop a quality architectural proposal.
4) Define and understand the role of the architect in a project and in terms of sustainable development.

**Framework**

The course is particularly popular among students in the architecture, and civil, chemical and mechanical engineering programs. Some students from the electrical engineering, physics engineering and geological engineering programs have also enrolled, but in smaller numbers. Three teachers—a civil engineer, a mechanical engineer and an architect—prepare the course, supervise and evaluate the students. As a complement to technical support, three distinct types of activities involving professionals are also scheduled during the term:

1) Lectures: During the first six weeks of the term, professionals from various engineering and architectural fields give lectures to upgrade students’ technical knowledge.
2) Workshops: Workshops follow some lectures to encourage students to apply the concepts learned and to begin the design process with the support of the speaker.
3) Design studio: Professionals from various fields participate in a design studio twice throughout the term. During the activity, a professional works with the students on their project designs 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; propose the architectural concept.
3) Design the project components, elevation drawings and architectural features and present them to an expert panel.
4) 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?”

**Integration of architecture students: Challenges and results of the first course delivery**

Architecture students were integrated into the course in the fall 2009 term, the third time the course was given. The undertaking presented considerable logistical challenges. Even though the Engineering School and the School of Architecture are both part of the same campus, their course terms do not start and end at the same time, and their school breaks
are one week apart. The first agreement with the School of Architecture was finalized shortly before the beginning of the term. The ING4901 course had already been prepared, and all the speakers had already confirmed, making it difficult to adjust the course schedule. The first class was therefore taught solely to engineering students, and a make-up class was offered to architecture students a week later. The architecture students agreed to come to class during their school break. They also completed an extra assignment at the end of the term, which wrapped up a week later.

The engineering and architecture teachers adapted the ING4901 course to integrate architecture students and to encourage collaboration among the engineering and architecture students, with a focus on integrated process design. The following decisions made when adapting the course all had the same objective: to maximize interdisciplinary collaboration and prevent students from working in isolation:

- Lectures were compulsory for everyone, regardless of discipline, so that students could learn from other disciplines.
- All students, regardless of discipline, were required to participate in the writing of the design reports. All assignments were due at the same time for both engineering and architecture students.
- Oral presentations to the expert panel were to be delivered by the entire team.
- All students, regardless of discipline, were graded according to the same marking grid.

The results of this first attempt at integrating architecture students into the course were mixed. The efforts of the teachers to promote interdisciplinary collaboration did not have the desired results. Informal discussions with students and their comments in the formative (mid-term) evaluation and official (term-end) evaluation of the course conducted by the Office of Pedagogical Support pointed to certain trends. In particular, the architecture students did not feel as if they had been effectively integrated into the course for many reasons:

- The fact that the architecture students started one week after the engineering students had a greater impact than expected. The first assignment was due early in the term, and work had already begun on it by the time the architecture students joined the course.
- The lectures at the beginning of the term took up too much time and prevented the architecture students from getting straight to work on their architectural concept.
- Architecture students are used to handing in aesthetically pleasing renderings. This was impossible in ING4901, because the architectural concept had to be decided on quickly so that students working in other disciplines, in particular those involved in the structural calculations, could proceed with the building design, and because the deadlines for both aspects were the same.
- The architecture students revised the architectural concept several times. This was a cause of stress and frustration for the students working in other disciplines, who needed to start their work over countless times, with the deadline drawing nearer and nearer.
• Architecture students are usually graded on their designs and are not, as a rule, called upon to write very many reports. As a result, they felt they were not being graded fairly. This perception was exacerbated by the use of the same marking grid for both engineering and architecture students.

• The technical oral presentation was delivered to a multidisciplinary expert panel, and the amount of feedback time for the students in the various disciplines was limited, given the number of disciplines involved. The teaching approach employed at the École d’architecture calls for a roughly forty-five-minute feedback session with professionals. This was not feasible given the way the course was structured. The architecture students would have preferred to receive more, and more frequent, feedback to help them improve their concept.

• Architecture students spent much more time on the project to meet the course objectives than did their engineering counterparts.

Positive outcomes nevertheless resulted from the experience. Students’ feedback in the mid-term formative evaluation and the official evaluation conducted by the Office of Pedagogical Support at the end of the term showed that the engineering and architecture students appreciated the multidisciplinary approach, the learning activities and most of the lectures, despite the frustrations they encountered. Changes were made in the course following a post-mortem analysis by the teachers, based on the overall experience, students’ comments and course evaluations.

**Integration of architecture students: Changes to and results of the second course delivery**

The first time the course was given to both engineering and architecture students, the teachers made decisions that did not prove optimal in terms of promoting interdisciplinary collaboration. They opted to standardize the work and the assignments to encourage collaboration. The second time the combined course was offered, teachers adopted an approach that was more representative of what students can expect in a real working environment. This meant staggered due dates, different assignment objectives and differentiated assessments. The associated logistical challenges and complexity did not change, however. The adjustments made may appear minor, but the outcome was very positive:

**Beginning of the course**

The beginning of the course was pushed back for engineering students to ensure all students enrolled in the course could attend the first class at the same time.

**Lectures**

Students were required to attend lectures only if they were related to their discipline; all other lectures were optional. This decision was made in order to free up some time at the start of the term to enable architecture students to begin developing their architectural concept earlier. Interestingly, even though attendance at all the lectures was no longer
compulsory, the architecture students still went to all of them out of interest. There were no complaints, however, because the lectures were no longer a course requirement.

Architectural feedback sessions

Two architectural feedback sessions were added: one three weeks into the course and one mid-term. Although these sessions focused solely on the architectural concept, engineering students were welcome to attend.

School breaks

No activities were planned for the architecture students during their week off. A lecture of lesser interest to them was presented to engineering students during that week. The architecture students worked on the visuals for their architectural concept while the engineering students were away on their break. (See “Evaluation” below.)

Evaluation

Engineering students were graded on their design reports (drafting of a client report, design notes (calculations), schematics and sketches), while architecture students were evaluated on their plans, details and elevation drawings. The engineering and architecture students were therefore graded according to two separate marking grids. The first time the course was given, the deadline for the second assignment (choice of design and architectural concept) was the aspect that generated the most tension. Architecture students felt they were submitting something that was incomplete because the architectural concept had to be finalized before the other disciplines could move forward. The second time the course was given, the second assignment (choice of design and architectural concept) was divided into two parts for the architecture students. The deadline for the first part was the same as that for the engineering students. The second part—the enhanced architectural concept (minor changes only) and the improved renderings—was due a week later. The architecture students worked on enhancing the architectural concept the week the engineering students were away on school break.

Change to the second design studio

The planning of the second design studio was changed to allow students in the same discipline to spend more time with the expert in their field. During the second design studio, students were grouped together according to discipline and worked with an expert in this discipline for roughly two hours. The change in the format of the second design studio made it possible for experts to work with all the students from the same discipline at the same time, to share the same messages with all the teams, to avoid explaining the same thing several times and to delve deeper into the design process. The approach was preferred by the experts and students alike and facilitated collaboration among students who were on different teams but shared the same discipline.
The change made to the second design studio does not take away from the importance of teamwork. After the second studio, students must continue to work on their project with their team to ensure project cohesion and the optimal integration of the various components.

End-of-term activity

The first time the course was given to both engineering and architecture students, students from each of the disciplines gave two oral presentations, with a two-week interval in between. The first technical presentation on the final project was given to a panel composed of five experts from different fields, and the second presentation was delivered to a wide public audience. The students presented their project to the expert panel using visual aids and a scale model of the building. The technical presentation did not give students the opportunity to really showcase their work. The scale model was all but overlooked, and there was limited time for students in each of the disciplines to interact with experts and the public. Moreover, during the public presentation, the first teams were the only ones to have an audience.

The second time the course was given to both engineering and architecture students, the technical and public presentations were combined into a new format: the students set up booths, with scale models and posters describing the project from the point of view of each discipline. A panel of three experts from different disciplines queried each of the teams. Members of the public and the client were also welcome to visit the booths and ask questions. The event was a success: the students had time to interact with the experts; the scale models were given ample attention; and each of the booths was visited by a number of people.

Course evaluation

The official course evaluation conducted by the Office of Pedagogical Support confirms the teachers’ impressions and the informal feedback received from the students. All the students took part in the official course evaluation. The same questionnaires were administered to the engineering and architecture students, but the answers were compiled separately by the Office of Pedagogical Support in order to identify any trends in the points of view of each group. The course received an outstanding evaluation from both architecture and engineering students, well above that of the previous time and well above average.

Conclusion

Integrating architecture students into the ING4901 course involved a number of complex logistical and technical challenges. The results of the first attempt at integrating the architecture students were mixed, in part because students of different disciplines work differently and are used to produce different deliverables, but also because of logistical difficulties. The concept of integrating the architecture students was nevertheless promising and worth improving. The teaching team worked to enhance the course,
despite the complexity of the undertaking, taking into account the initial experience, students’ comments and course evaluations. These efforts paid off: the second time the combined course was offered, it was a great success.

The course allows future engineers and architects to become acquainted with integrated process design, work in a multidisciplinary context, realize that sustainable development is a shared responsibility and recognize that, as future professionals, they will have a key role to play in promoting the technical aspects of sustainable development (from a social, economic and environmental standpoint) and integrated process design.

Bibliography