AC 2008-696: MEETING THE CHALLENGE OF REVIEWING ELEVEN ENGINEERING PROGRAMS

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Meeting the challenge of reviewing eleven engineering programs

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Context

For 135 years, École Polytechnique de Montréal has provided an engineering program in the province of Québec, Canada. During its long history it has, successfully, faced and overcame many challenges in several areas such as teaching, research, funding, and international collaborations. The recent process through which it has, thoroughly, remodeled its eleven engineering undergraduate programs is, however, quite unique. This remodeling, in part, reflected on the basic mathematics courses and the complementary courses (social and economical aspects of engineering, ethics, etc.). It is unique in many ways: the size of the operation; the depth of the changes implied; as well as, a decentralization process which used and imbedded an extraordinary direct involvement and responsibility of faculty members.

What was the problem? During the many decades of its existence (135 years old), École Polytechnique has reviewed and created many undergraduate and graduate programs. At the undergraduate level we are now providing, on a four-year basis, eleven curriculums to close to four thousand students: civil engineering, mechanical engineering, electrical engineering, software engineering, computer engineering, materials engineering, industrial engineering, physics engineering, chemical engineering, geological engineering and mining engineering. For more than 25 years, The educational model in all our programs has included a first common year of mandatory basic courses in mathematics, physics, chemistry, materials, etc., without a real good knowledge, by the student, of the definition and challenges of the engineering profession.

During their first year at École Polytechnique, students lacked motivation. Their success rate was not satisfying. Other universities, without such a first year of basic courses, began to be more appealing and our inscription rate dropped a little benefiting these other universities, in the province of Québec. Also, as all universities do, we received messages from industry asking us to better prepare our students for «other skills», deemed very important in the actual context of the market place; such as independence, communications and teamwork skills, managing people and tasks, and mobilizing innovation and change. (1)

It was time for a good and thorough analysis of our educational model and a consequent review of all undergraduate programs, according to a contemporary vision of the engineering profession and a corresponding philosophy of teaching engineering.

But time mattered! After many thoughts, our president mandated the Dean of studies to propose a process of review of our programs that would involve the profound changes needed. Because of the competition with other universities, and more importantly because of the long period of implementation of these changes (during the following four years of all of our undergraduate programs), the process analysis, conception and design of our eleven programs had to be done in three years! If we wanted to do a profound review of our practices, if we wanted the changes to be accepted, if we wanted these changes to last and to produce their longitudinal effects, we had to innovate in our active incorporation of the process throughout the École community. It was a tremendous challenge!

What was the process? If we wanted success, the process could not be top-down. So we decided to engage all the faculty members in a bottom-up process where, according to a series of guidelines and required constraints proposing a rigorous process, faculty members would have to do the work for their own programs with regular feed-back from their colleagues in all the other programs. This process needed the creation of «pedagogical leading teams» in each program, weekly meetings of at least 40 professors discussing outputs, and the respect of a very tight schedule, under the soft (but strong) central coordination committee. And it worked! The Professors involved were pushed and tired, but the openness of the process and the hard work and enthusiasm of the faculty overcame the fatigue and the stress of such an operation. The academic leaders and administrative leaders were more of a guide on the side than a sage on the stage.

This program review is in spirit of the recent evolution of engineering programs that began in the USA in the mid-80. Some studies of the National Research Council, the National Science Board, The American Society for Engineering and the Accreditation Board for Engineering and Technology revealed that engineering education has a tendency to produce scientists instead of design oriented engineers. This was reflected, in recent studies, and in the comments from employers about the background of new engineers (2,3). However, the engineering curriculum should maintain a solid background in mathematics and science with emphasis in design and problem-solving-based learning in an engineering context, increase the non-technical aspect, develop soft and management skills, consider the international challenge, and use new learning strategies to help engineers update their knowledge during their entire career (2). It was evident that a cultural change was necessary to switch from "sink or swim" culture to a less competitive and collaboration-based environment. In fact, we need a change of paradigm from a teacher-centered to a student-centered pedagogy (4).

Structure

The road to success for this project requires everyone's contribution and involvement. Each person's opinion and contribution must be requested and valued. What is especially important is to avoid giving people the impression that changes are imposed upon them. In the same way, certain elements must be considered as supportive to the success of the project. For example, managing the resistance to change, putting in place an effective communication system (Web site, messages to the community, etc), providing the required resources, and encouraging faculty and support staff collaboration.

Figure 1 shows the structure used to ensure all the personnel participated in the process The key actors in this structure are described below.

- The Director of studies - the project maestro, the thinker, the one who must clinch the argument when a decision must be made.

- Chief/Chairman of the Department - the Chief of the department supervises the work completed within his/her Department; the directorate allows the possibility to share information and to make concerted decisions.
- The supervision committee - this committee is composed of various directors of services, faculty, and students. The committee works on the improvement of student supervision.
- The implementation committee – this committee is under the Director of studies responsibility. It must make sure that the revision of the programs respects the constraints established in the project timeline and deliverables. It works in collaboration with the supervision committee and can find help within specialized resources.
- Pedagogical team - each program is under the responsibility of a pedagogical team where a leader is identified. It is formed of some teachers and students. This team also has ties with the Consultative Committee whose members are practicing engineers.

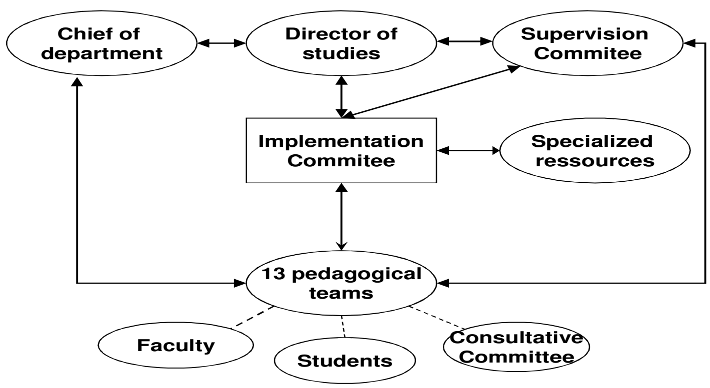


Figure 1- Organizational structure

The teaching staff and faculty are the main actors in this project. However, the implementation committee proved to be the angular stone of this structure. The committee consists of people whose competences and interests make it possible to step in quickly and adequately. This committee is headed by the assistant-director of studies, who also happens to be the director of graduate studies. The other members are: the director of academic affairs, the director of the center for teaching aid, a project management specialist, a development aid agent, two faculty members and one student.

The committee's mandate is to:

- help each program's teaching staff;
    - at each step described in the project timetable;
    - and with the constraints and specifications;
- inform the teaching staff;
- ensure the conformity of the proposals made by the teaching staff with the constraints and specifications;
- offer opinions to the teaching staff;

In order to achieve the goals of this mandate the committee realized several tasks. For example, it managed an electronic site, took part in more than one hundred meetings, organized several information or discussion sessions, and met with the teaching staff over forty times.

Process

During the 2004 winter, the implementation committee laid out a project timetable and deliverables which described the work to be done. The project deliverables define the principles on which the programs must be renewed, and describe the organization of work.

The renewal of the programs project is realized as an engineering project. Once the principal activities are identified, a timetable is set. It was agreed upon from the beginning that the first year of the renewed programs would be offered as early as the 2005 autumn semester. The challenge of the project is expressed by the extent of work to be realized in such a short period of time.

The educational project is the first document to be produced by each program. This document is the blueprint for each program's curriculum. It describes the challenges each program must face, its vision as well as the disciplinary and teaching organization for the four years of the baccalaureate. Finally it specifies each program's student exit profile, the kind of engineers to train. The educational project requires an initial analysis of the needs. Here are a few questions that needed to be answered. What are the society's expectations about the engineers that will be trained? What are the employers' expectations? What are the students' expectations? A useful benchmarking was made to compare ourselves with the curriculum of some other reputable universities.

With these two elements, the project includes:

- the list of courses which will be set up jointly with other programs;
- the list of courses which will be delegated to the departments of support;
- the sequence of the courses;
- the process of integration of the courses which will be privileged;
- strategies to include an internship in the program;
- strategies to include an international aspect in the curriculum;
- strategies to facilitate access to the graduate levels;
- the supervision process which will be set up;
- various methods of assessment which will be adopted;
- various methods of teaching and learning which will be used.

The development of the curriculum is based on the principles exposed in the framework of this educational project. The development of the program is divided into three steps: the renewing of the first year (reorganization of basic science and mathematics courses and introduction of two disciplinary courses), the reorganization of second and third year (disciplinary kernel courses including internship), and the upgrading of the fourth year (revision of the different specializations, international exchange opportunity and access to graduate studies). At the end of each step a document is required. For example, for the first year, the document must describe:

- contents and assessment modes for each course;
- preferred teaching methods for each course;
- description of the process of multiple course integration and interaction;
- specific support and supervision of the new students;
- integrated projects;
- other elements to incorporate in the first year, such as internationalization, soft skills (personal and relational), etc.

The following figure shows how the 120 credits four years curriculum of our engineering programs were distributed before and after the implementation of the new programs. The old programs started with a 30 credits common year of mathematics and science courses followed by a block of 60 credits (2 years) of engineering courses coupled with complementary studies. The structure is completely different in the new programs. The common year does not exist any more. The mathematics and science courses are distributed along the two first years and positioned where they are needed. Furthermore, the mathematics courses are contextualized as a function of the engineering discipline. There is a group project each year to integrate the new engineering knowledge and to apply the communication and written skills developed in the complementary studies. The specialization and the international studies are concentrated in the final year.

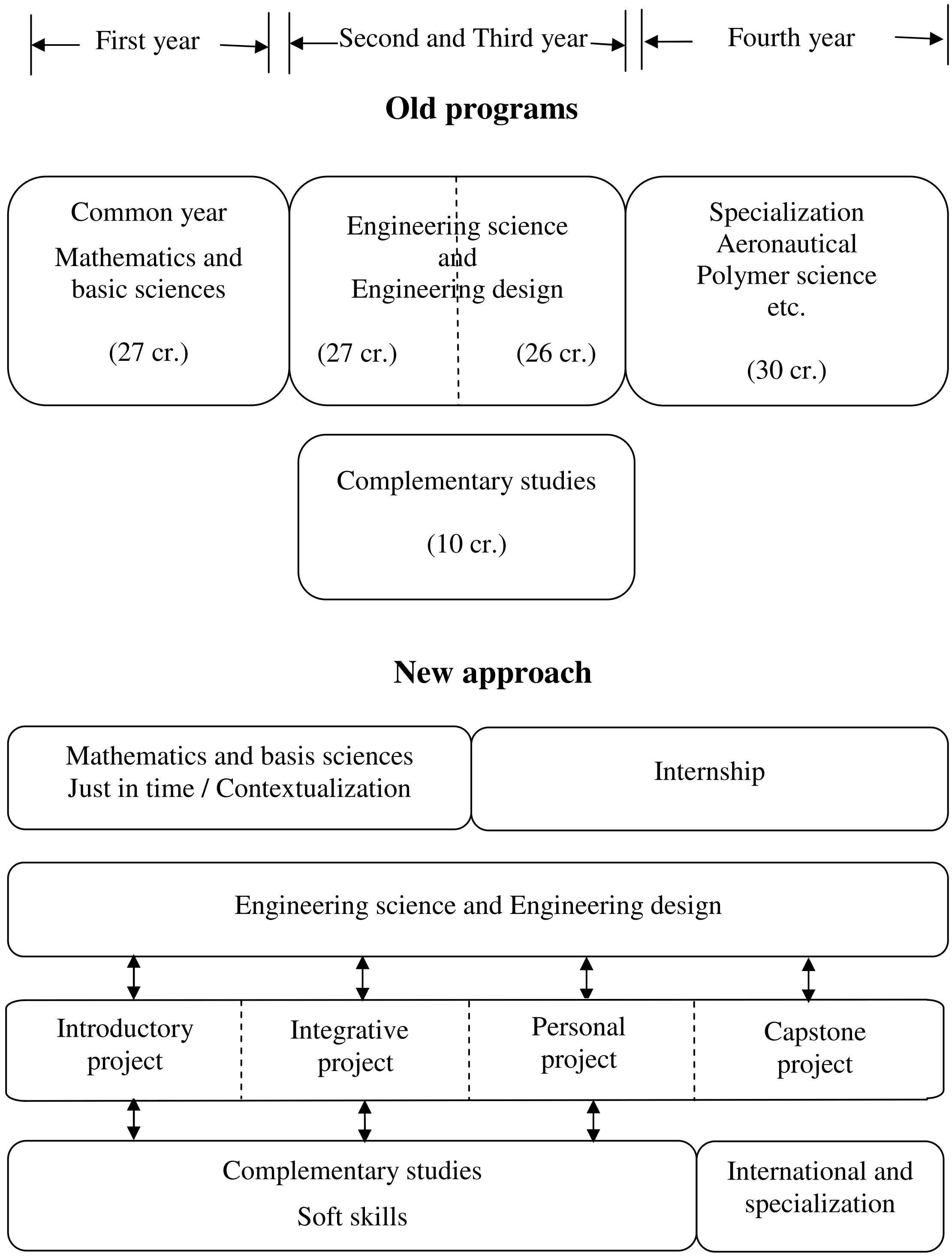


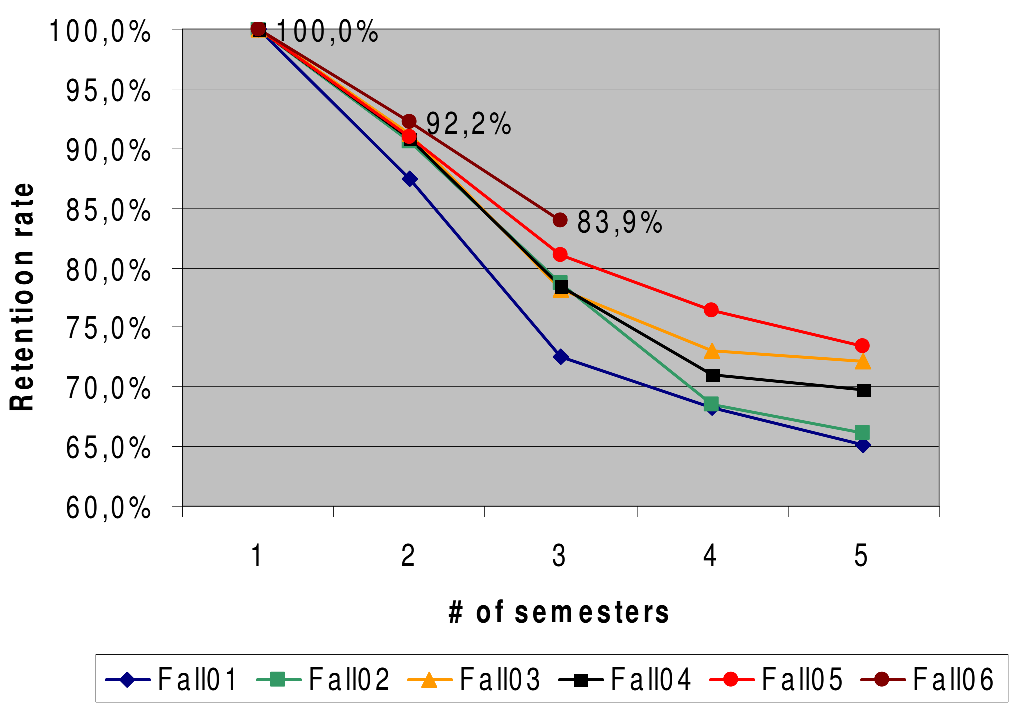
Figure 2.0: Comparison between the old and new programs

Discussion

The eleven new programs started at the same time in September 2005. In parallel we have planned to accumulate different statistics on the students and on the programs. A survey, including questions about the new programs, was also prepared to be distributed at each semester. After more than two years into the project, some preliminary results are showing some positive results.

The retention rate of our students in average has reached as low at 65% after 5 semesters. Figure 1 shows that after the first year the retention rate was always below 80%. We were able to increase that rate to 84% for the second batch of students enrolled in the new program.

Figure 3.0: Retention rate vs number of semesters



Each semester a survey, including 20 questions, was administered in the classrooms to all the students of the new programs in October for the Fall semester and in March for the Winter semester. The number of students responding to the various surveys varied between 52% and 63%. For all the questions, the students responded, on a scale of 1 to 4, by 1) I totally disagree, 2) I disagree, 3) I agree and 4) I agree totally. A 3 or a 4 is considered positive and the sum of the two is presented in the tables as the Global positive answer. The questions were related to the curriculum, the courses, the support from the institution and the students satisfaction. Some of the results are reported in this paper. One of the complaints we were getting from the students before we started modifying our curriculums is the excessive work load, especially at certain points in time, during the 4 years of their study. Therefore, we specifically ask the coordinators to look at each year of their curriculum to calculate the number of formal evaluations (exam, homework, project) and to try to limit them to 3 per week. When asked if their work load was realistic the number of positive answers (agree or totally agree) goes down at each semester for the first four semesters. Furthermore, when we compare the first group to the second one, we note a decrease in satisfaction, which is an indication of the difficulty of controlling the number of summative evaluations in the courses.

Table 1.0: Do you consider the work load in your courses as being realistic?

Work Load							
September 2005, Group				**September 2006, Group**			
Semester	**No. Students (%)**	**Global Positive answer**	**Positive answer Min./Max**	**Semester**	**No. Student s (%)**	**Global Positive answer**	**Positive answer Min./Max**
S1 October	316 (51%)	66%	52/79 (31, 19)	S1 November	419 (62%)	57%	28/74 (39, 58)
S2 April	291 (52%)	52%	33/75 (6, 4)	S2 March	312 (54%)	33%	24/56 (76, 32)
S3 November	290 (57%)	41%	20/91 (30, 23)				
S4 March	230 (39%)	33%	7/94 (68, 16)				

When preparing our list of guidelines and constraints for the program coordinators we included the comments coming from our industrial advisors. One of their main concerns about the background of our students was their lack of soft skills. Therefore, we decided to include one course on team work and one course on written and oral presentation in each curriculum. According to the surveys we can see from Table 2 that even though we had some difficulties finding the appropriate pedagogical formula for these courses, they were appreciated by the students.

Table 2.0: Do you think it is important for you, as a future engineer, to develop your soft skills?

Soft Skills							
September 2005, Group				**September 2006, Group**			
Semester	**No. Students (%)**	**Global Positive answer**	**Positive answer Min./Max**	**Semester**	**No. Students (%)**	**Global Positive answer**	**Positive answer Min./Max**
S1 October	298 (48%)	91%	89/94 (54, 72)	S1 November	424 (63%)	76%	65/89 (23, 18)
S2 April	290 (52%)	92%	83/100 (6, 16)	S2 March	310 (53%)	75%	64/100 (25, 12)
S3 November	290 (57%)	72%	57/100 (30, 2)				
S4 March	230 (39%)	76%	65/100 (31, 3)				

A number of initiatives were put together to supervise the students especially during their first year. A professor was recruited in each department to advise the students about their course selection and to help them contact the good person in the student office in case they needed help. As we can see from Table 3, the students seem to appreciate the support they were getting from the University staff.

Table 3.0: Are you satisfied with the academic support you are getting from the University?

University Support Initiatives							
September 2005, Group				**September 2006, Group**			
Semester	**No. Students (%)**	**Global Positive answer**	**Positive answer Min./Max**	**Semester**	**No. Students (%)**	**Global Positive answer**	**Positive answer Min./Max**
S1 October	260 (42%)	88%	68/93 (50, 27)	S1 November	339 (50%)	86%	79/100 (34, 24)
S2 April	235 (42%)	82%	75/100 (4, 11)	S2 March	254 (44%)	90%	79/100 (19, 17)
S3 November	234 (46%)	79%	50/100 (2, 10)				
S4 March	191 (32%)	82%	62/100 (8, 8)				

In the past, when asked about their overall satisfaction with their stay in our institution, we never got a score greater than 6 (on a scale from 1 to 10). With our renewed programs, we can see from Table 4 an overall increase in the first semester along with some decrease at the end of the second year.

Table 4.0: On a scale from 1 to 10, what is your overall degree of satisfaction in your courses?

Overall Students Satisfaction							
September 2005, Group				**September 2006, Group**			
Semester	**No. Students (%)**	**Global Positive answer**	**Positive answer Min./Max.**	**Semester**	**No. Students (%)**	**Global Positive answer**	**Positive answer Min./Max.**
S1 October	309 (50%)	7,40	4,7/8,1 (3,49)	S1 November	421 (62%)	7,65	7,4/7,9 (58, 53)
S2 April	285 (51%)	7,05	6,3/8,1 (111, 20)	S2 March	311 (53%)	7,30	6,4/7,8 (36, 49)
S3 November	287 (56%)	6,67	6,0/8,0 (80,2)				
S4 March	226 (38%)	6,42	5,6/7,8 (44, 13)				

Conclusion

In the spring of 2009 we will graduate our first students with the new curriculum entirely in place. Then, we will be able to compare the "new" with the "old" students. However, we already know, after two years of implementation, that some of the changes that were made will have to be adapted in order to attain the original objectives. For example, four major team projects in each program require new versatile laboratory and demand more supervising resources. In order to teach communication skills and team work efficiently we had to work with small groups requiring again more resources. Finally, the implementation committee played a major role in defining the timeline, the deliverables and ensuring the animation of the pedagogical teams. Since communication is a key factor in such a major change the committee had to be proactive and show a strong leadership.

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