Setting up an Engineering MSc program in a network of schools

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November 15th, 2010

Abstract

Creating an Engineering MSc program from scratch in a loose network of schools, when those schools have so far run Bachelor programs only, and some of them are very small, even by Swiss standards. Doing so with no investment and a cost per credit and per student similar to that of a Bachelor program. Taking into account the market needs as well as the wide variety of Bachelor backgrounds the MSc students will possess. Meeting these challenges calls for some inventive solutions, like creating a competitive market where professors propose modules and students shop (almost) freely. The result is a system that auto-adapts to financial constraints, to variations in the number of students, to technological and scientific changes (hopefully progress), as well as to the work market.

Introduction

Switzerland is a confederation of fairly autonomous states called "cantons". Education is a cantonal affair in all but a few areas. The Swiss government exerts some leverage, however, through a partial financing of the cantonal 'High' schools (in most countries, known as universities) and through legislation. Taking the introduction of the Bologna reform as a pretext, this leverage has been applied recently to induce the cantons to streamline, optimise and even merge their 'High' schools. As a result, the Haute Ecole Spécialisée de Suisse Occidentale (HES-SO), known in English as the "University of Applied Sciences of Western Switzerland", was created by means of joining the existing 'High' schools of the 6 cantons into a network. The engineering "domain" in the HES-SO (hardly a "department" in the usual sense) is therefore responsible for making the network of 5 cantonal 'High' schools operate with some degree of coordination. This is quite a feat, since those 'High' schools are very different in size, spread all over Western Switzerland on 8 sites, and very dependent on cantonal politics.

While Bachelor curricula were by and large derived from the existing curricula leading to a title of "Ingénieur HES" (by downsizing them from 200 ECTS credits to 180), the setting up from scratch of curricula for the Master's program has been a real challenge which has called for many original solutions.

The HES-SO being a network has compounded the many conditions to be fulfilled in order to obtain Bern's (siege of the Swiss government) green light for a Master's training program. Such as: virtually no funding for investments (no additional floor space, little additional equipment) should be expected, cost per credit and per student should not exceed that of the Bachelor level, admission should be restricted to the best Bachelor graduates, no more than 20% of the Bachelor graduates should accede to a Master's degree, every distinct curriculum should attract a minimum of 30 students, only those faculty members involved in research projects of national relevance should be allowed to teach, proof that the curriculum caters to the needs of the ...arket (companies, ad.....strations, ...) must be provided, proof that the curricula do not duplicate those already offered by other 'High' schools (in particular the Federal Institutes of Technology in Zürich and Lausanne) must be provided, tight links between research and teaching must be evidenced.

Here are a few of the questions we had to answer:

- How do we keep within the budget boundaries when financing is based on a fixed amount per ECTS credit and per student, and we do not know in advance the number of students?
- How do we make sure that we attract a sufficient number of Master's students while being very selective, when the German-speaking sister-HES all together (four times the size of HES-SO) have struggled to do so?
- What additional capabilities do companies expect from a Master's degree holder (as compared to a Bachelor's)?
- Are companies willing to help some of their Bachelor graduates to go for a Master's degree and, if so, under what conditions?
- What criteria do we use to select the best candidates?
- As no single cantonal 'High' school can run a Master's training program of its own, how do we make them share the load (and the loaf...)?

- How do we get the required floor space and equipment?
- What criteria do we use to select the best professors?

After 18 months of intense planning, we started a Master's of Science in Engineering (hereafter "MSE") in September 2009 with two different specialisation areas: industrial technologies and information technologies. Over 160 students were admitted, well beyond our expectations. This year, again over 120 students have been admitted. Roughly 50% are employed by a company or a 'High' school and study part-time.

This paper will show you the road we have followed, the choices we have made and the tools we have developed to make it possible.

Staying within the budget boundaries

As the cost per student and per ECTS credit shouldn't exceed the one prevailing in the Bachelor education programs, and as teaching staff wages account for most of that cost, the average number of students per module in MSE should be close to that of a Bachelor program. Decreasing the percentage of study time spent under supervision (lectures, supervised lab work), when compared to that of a Bachelor program, makes up for a lower average number of students.

Our 90 credits MSE curricula are split into:

- theoretical modules (no lab): 30 credits
- hands-on modules (1/3 to 2/3 of supervised study takes place in a lab): 24 credits
- project module: 6 credits
- MSE theses: 30 credits

Taking into account the higher maturity and the higher-quality level of the students, the ratio of supervised study time was set at 35% for both theoretical and hands-on modules, compared to a typical 40% in the last year of a Bachelor program. Thus, meeting the cost requirements led us to the following figures:

- theoretical modules (no lab): average of 30 students per module, 35% of study time under collective supervision
- hands-on modules (with lab work): average of 15 students per module, 35% of study time under collective supervision
- project module: individual supervision 15% of work time
- MSE theses: individual supervision 10% of work time

When you expect a total of 60 students to come with a variety of over 20 'flavours' of Bachelor degrees ranging from mechanical engineering to computer science, there is no way you can reach the required averages if you stick to set curricula, unless you drastically limit the number of distinct MSE curricula (no more than 3 to 6, depending on the percentage of modules they share). Moreover, if you offer only a few distinct curricula, you'll fail to attract a sizeable part of the potential students and may not even attain the required 60 students. So, instead of 12 distinct standard curricula as initially proposed by the professors, we needed to look for flexible individual curricula, based on modules that the students could select among the given year's offer. The idea is quite simple: you initially propose a wide range of modules to the students, get their preferences, then actually teach only those modules that have obtained the highest level of preference, while limiting their number to what the financing allows (i.e. while attaining the required average numbers of students per module).

The advantages of letting the students choose quite freely, while ensuring that there will be no budget overflow are many:

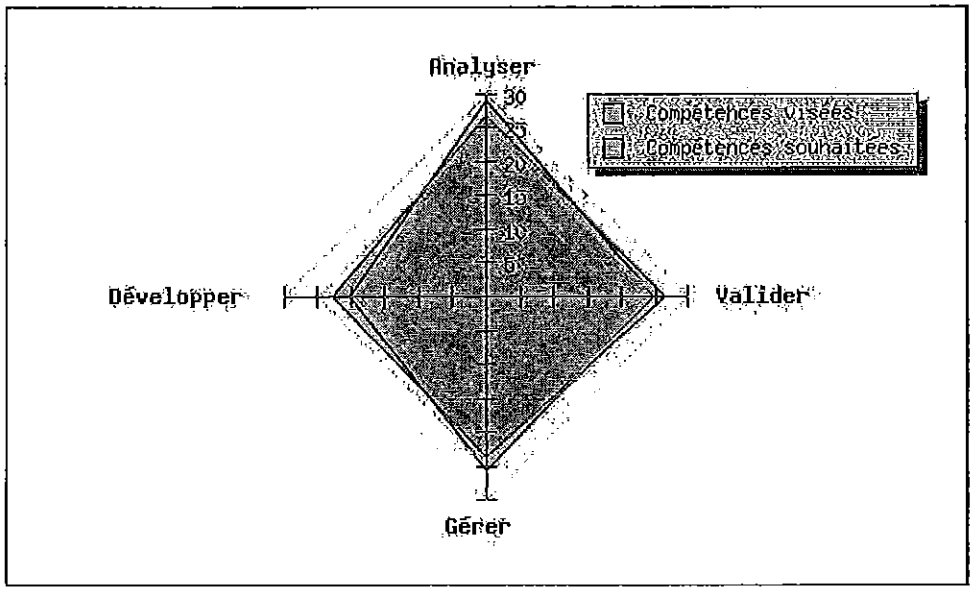
- students are made responsible for their individual curriculum
- students are highly motivated for every module they attend
- as many students are actually part-time students and work in a company, that company can assist the student in his or her choice of modules
- a variety of MSE profiles fill the varied needs of the work market
- professors have to strive to propose modules arousing a high level of interest among students and companies
- the higher the number of students, the higher the number and variety of modules that are taught in a given year
- this academic system auto-adapts to fluctuations in the number of students (both total and per specific area of interest)
- this academic system auto-adapts very fast to scientific, technological and work market evolution

There are however a few disadvantages that need to be overcome:

- the students need some help to choose a well-balanced set of modules
- individual curricula need much more complex academic planning and managing than a few standard curricula
- you need to build a time-table optimising the fulfilment of the students wishes, i.e. allowing every one of them to attend his or her best choice of modules

Overcoming the disadvantages of a free choice of modules

To help each student select a proper set of modules, every student is provided with an advisor chosen from among the professors involved in the MSE program. In addition, the student is shown the competence profile that he or she will have to achieve through his or her choice of modules, and can compare that profile with the average profile fulfilling the wishes of a significant number of companies. To that end, each module specifies the percentage of study time that should be spent acquiring each one of four major project-oriented competences. A spider-web chart is computed by our academic planning software for every student's individual set of modules.



An example of such a chart shows, in pink, the ideal profile identified by means of a survey and, in blue, the profile that this particular student is aiming at through his choice of modules. These aren't overall profiles, only the profiles of **additional competences** the student should acquire **by means of his MSE training.** Obviously, his overall profile must take into account the competences he acquired by means of his Bachelor training and his professional experience.

The necessity of having a well-designed information system to help in planning and managing individual modular curricula is obvious. GAPS, for « Gaps is an Academic Planning System », is our home-made solution, tailored to fulfil such needs as:

- recording the specifications of all modules
- choosing and displaying the modules that will be initially proposed in a given year, then those that are finally selected to be taught (based on students' preferences)
- allowing every student to attach his or her level of preference to each one of the modules initially proposed, than to those finally selected
- entering the professors' time constraints (all professors have other activities than teaching in MSE)
- recording every student's individual curriculum (attended modules), grades, competence profile and other personal data
- putting together all of the above data to be fed to the time-table software
- displaying overall as well as individual time-tables and modifying them
- entering student and professor evaluations of modules (as part of a quality assurance system)

Students, professors and management staff have, of course, different access-rights to the GAPS website, but most of the information is available for all of them to read.
Building a time-table fulfilling, to a large extent, the wishes of the students is a tough optimisation problem that cannot be solved without appropriate software help. SACHEM, for « Système d'Aide à la Conception d'Horaires pour l'Enseignement Modulaire », is our home-made software help. With it, we built this year time-tables for 177 students (62% of them studying part-time), achieving an average level of preference of 4.57 for full-time students and 4.27 for part-time students (students enter preference levels from 5, maximum, to 0, minimum, for every module in this year's final selection). Actually, the time-table SACHEM delivered had an average level for part-time students of about 4.4. It came down to 4.27 because of the changes requested by the students, mostly to make their time-tables more compact and to reduce their travel time.

Attracting students requires knowing the market needs
Unlike Bachelors coming (rather falling) out the Federal Institutes of Technology, Bachelors trained in our Universities of Applied Sciences are fully employable as design engineers. There is no real need for them to go for a Master's degree. Some incentive is required to do so. Obviously, the expectation of better wages and better employment opportunities are powerful incentives. But are the companies willing to pay higher wages to an MSE holder? For which types of jobs? How many MSE holders do they expect to hire in the next two years? Most of all: what are the additional capabilities the companies expect from an MSE holder (when compared with a Bachelor graduate)?

Between the end of 2008 and the beginning of 2009, we made a survey by interviewing managers in 70 companies among our AR&D (Applied Research and Development) partners, mostly medium- and small-sized companies, and got some interesting answers:

- our Bachelor graduates are trained well enough for design engineering jobs
- what the companies expect of an MSE holder are additional management skills, leadership and multi-disciplinary knowledge
- better wages will be offered only for jobs with higher responsibilities, such as that of a project manager
- 3 companies out of 4 are willing to help some of the Bachelor graduates in their staff to undertake part-time MSE studies by letting them take one day off per week (i.e. reducing their work time and wages to 80% of a full-time job)
- there are a total of 114 Bachelor graduates in their staffs that would deserve being given that opportunity
- these companies expect to hire a total of 243 MSE holders in the next two years

These answers led us to the following conclusions:

- MSE competence profiles must be tuned to fit project manager jobs
- acquiring a specific technical profile is not all that important, whereas acquiring soft skills is
- only the best Bachelors should be considered for admission in our MSE program
- the number of part-time students might be even higher than that of full-time students (as things have turned out, that is the case)
- to attract part-time students we need to work out time-tables compatible with their jobs
- to attract part-time students we should make it possible for them to get the required 60 ECTS credits in 2 years (60 credits = 1 year full-time), before starting their thesis work
- part-time students can do their thesis work full-time since the subject will be provided by their employers
- attending lectures one day per week is not sufficient to allow part-time students to get 60 credits in 2 years, therefore teaching hours should be extended beyond the usual 8 a.m. to 5 p.m. working hours
- part-time and full-time students should, of course, attend the same lectures

Two of this year time-tables for full-time and part-time students are shown hereafter. The example full-time student has chosen a set of modules that requires attending lectures in 4 different cities, Lausanne, Yverdon-les-Bains, Fribourg and Geneva (this year's average is 3.05). Three of those modules are taught in a time slot starting after 5 p.m. The example part-time student has chosen a set of modules that requires attending lectures in 3 different cities (this year's average is 2.57). He has chosen to take one day a week off work during the first semester, and one and a half days off per week during the second semester.
Publishing both results of our survey, our strong resolve to abide by them and the means for doing so, went a long way in attracting 160 students the very first year (2009), 55% of them holding a job and studying part-time. Drop-outs reduced that count to 120 by the end of that first academic year. At present, 50 of them are working on

their thesis and the remaining 70 are part-time students attending their second academic year. In 2010, another 120 students were admitted and 105 of them are presently on-board. During the next few years, we expect about 100 new students every year, half of them part-time.

S1

Lundi	Mardi	Mercredi	Jeudi	Vendredi
MEDI Dumas Jean-François 08:30 - 10:55 G03 Yverdon-les-Bains				INTE Zürcher Olivier 08:45 - 14:25 B30 D00.09 Fribourg
CSMOT Besson Christophe 11:10 - 13:35 B01b B57c Yverdon-les-Bains	T-Multiphy Alberty Jose-Manuel 11:15 - 13:40 Provence3 Lausanne		F-AppSta Voirin Pascale Zuber Jacques 11:15 - 13:40 Provence4 Lausanne	
ECOB Ciberlet Stéphane 14:30 - 16:55 G03 Yverdon-les-Bains	F-Energy Niederhäuser Elena-Lavinia Sari Osmann 15:00 - 17:25 Provence3 Lausanne			
	F-PartDif Blanc Philippe Leuenberger Christoph 17:30 - 19:55 Provence5 Lausanne	C-ORM Riess Raymond 17:30 - 19:55 Provence3 Lausanne		

S2

Lundi	Mardi	Mercredi	Jeudi	Vendredi
		PA-I	C-IonChem Hilz Marc 08:45 - 11:10 Provence3 Lausanne	
C-CorpCom-A Finaben Laurence Guenette Alain-Max 11:15 - 13:40 Provence3 Lausanne	EBE Sari Osmann 11:10 - 13:35 U32 S129 Yverdon-les-Bains			
	SEH Affolter Jean-François 14:30 - 16:55 B01b B57c Yverdon-les-Bains		T-ManTech Schulz Jean-Michel 15:00 - 17:25 Provence4 Lausanne	ECO De Mestral Francois Richard Jacques 14:40 - 17:05 LebMec Mec2-C106 Genève
			C-Entrep Borgeaud Yves Uwamungu Bernard 17:30 - 19:55 Provence3 Lausanne	

S1

Lundi	Mardi	Mercredi	Jeudi	Vendredi
		T-EmbNeal Joye Philippe Pompili Pierre Zaffalon Luigi 08:45 - 11:10 Provence3 Lausanne		
		T-MobSys El Malki Tewfiq Revuelta Andrés Wagen Jean-Frédéric 11:15 - 13:40 Provence4 Lausanne		
		F-CryptCod Junod Pascal Nicolier Grégoire 15:00 - 17:25 Provence3 Lausanne		
HAC Junod Pascal 17:25 - 19:50 G01 Yverdon-les-Bains	AMS Wagen Jean-Frédéric 17:15 - 19:40 C00.10 B30 Fribourg	T-ITSec Buchs Christian Litzistorf Gerald 17:30 - 19:55 Provence6 Lausanne		

S2

Lundi	Mardi	Mercredi	Jeudi	Vendredi
C-PrivLaw Rey Yves 08:45 - 11:10 Provence6 Lausanne	SEE Russier Daniel 08:30 - 10:55 A09 Yverdon-les-Bains			
	MW2 Liechti Olivier 14:30 - 16:55 G07 Yverdon-les-Bains			
	WAS Buchs Christian 17:25 - 19:50 G02 Yverdon-les-Bains			

The best input quality for the best output quality

You do not select your project managers among your worst design engineers. For it to be worthwhile to undergo an MSE training, we need to admit only the best candidates. The Swiss government expects 20% of those Bachelors coming out of Universities of Applied Sciences to pursue their studies and obtain a Master's degree. This figure relates well with a typical project team in a medium-sized company, composed of one project leader and four design engineers. To reach this percentage, we have opened the doors of MSE to candidates having achieved a Bachelor's degree in the last three academic years with overall grades of A or B (i.e. the best 35%). Beyond three years' time, the grades can no longer be the main criterion. Applications of candidates with over three years of professional practice are examined by an admission committee taking mostly into account the candidate's professional career and certificates. The willingness of their employer to let them start an MSE is also a good selection criterion.

Competition, collaboration and selection

Except perhaps for the largest one, no single cantonal engineering school pertaining to the HES-SO network has enough potential students, professors, floor space and equipment to set up an MSE program on its own. We need to make use of resources spread all over Western Switzerland and attract students from all over that same area. But the cantonal schools are not only partners; they are also competitors bound to haggle about the admission of a single student or the teaching of a single module.
To solve that problem we have chosen to treat all cantonal engineering schools as resource providers (professors, floor space and equipment), on a competitive basis and with maximum transparency.
Unlike what prevails in Bachelor programs, all MSE managerial and administrative tasks are carried out at HES-SO headquarters, including total control of financial matters.
No professor is directly attached either to the HES-SO or to the MSE. They are all attached to cantonal schools and hired by the HES-SO//MSE to teach a particular module in a given academic year. The "rent" is identical for all modules of same size and type. It includes professors, classrooms, labs and equipment required to teach a module, and is paid by the HES-SO//MSE to the cantonal school providing these resources (not to the professors). It does not take into account the number of students attending the module, thus making it possible to teach some modules on special topics attracting only a few students as long as the average attendance per module is sufficiently high.
Therefore, competition is not over cost per module. It is induced by our market-like way of choosing what modules will be taught.
To be allowed to propose modules in the MSE, in addition to meeting some usual criteria regarding their academic record and teaching ability, professors teaching in cantonal schools at the Bachelor level need to prove their worth in AR&D projects financed by companies or research funds. Being contracted by a company or allotted public or private funds by a selection committee to run a project is good proof of a professor's worth. It also ensures that he or she does have enough experience in conducting AR&D projects to impart that experience to MSE students.

Multiplying floor space and equipment

Having read up to the final point, you should already know how we got the required additional floor space and equipment at no extra cost. No well-off sponsor involved. No divine multiplication either. Extending the number of potential work hours per day does the trick. Instead of the usual 8-hour day, MSE students should expect lessons to take place in a 12 hours' time span, from 8 a.m. to 8 p.m. That costless change has produced a 50% increase in the availability of costly resources.
Of course, since the same floor space and equipment are used for both Bachelor and MSE programs, and since MSE professors are also involved in Bachelor programs, MSE time-tables and Bachelor time-tables have to be carefully coordinated. This is accomplished by creating optimised MSE time-tables first and then using that information to build non-conflicting Bachelor time-tables.

Final word

Common sense and a little brain-storming were sufficient for appropriate solutions to be obtained. The same approach and even some similar solutions could be applied elsewhere with little difficulty. There are however two major hurdles on the way.
The first one is technical: you need a specific and efficient information system, as well as optimising time-table software. Developing these essential software aids is a matter of several man-years.
The second one is human and might be the greater: you need to overcome the many fears among professors and school managers, and get enough of them to adhere to the concept so that you can put it to trial and demonstrate its viability. My experience says that, compared to the human hurdle, everything else is child's play.

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