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Integrating Research and Education in Engineering Design Programs

Dr. Martin Edin Grimheden, Royal Institute of Technology (KTH)

Martin Edin Grimheden is an associate professor in Mechatronics at KTH, Royal Institute of Technology, Stockholm, Sweden, and head of the Mechatronics and Embedded Control Systems Division. Martin Edin Grimheden is also Program Director of the KTH Degree Program in Mechanical Engineering.

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Abstract

This paper addresses some of the challenges related to integrating academic and professional skills in European higher engineering programs in light of the relatively recent conversion to the three cycle system. The study has been performed in a Mechanical Engineering program at KTH, in Stockholm, Sweden, where one of the main issues has been the addition of new learning goals relating to scientific methods and research.

The author presents three models for how research and scientific methods can be integrated with engineering work in a thesis project context. We show that it is indeed possible to perform the integration synergistically, providing the various sets of requirements are clearly communicated particularly to any industrial representatives.

Introduction: professional and academic degrees

Many Universities in Europe have adapted to, or tried to adapt to an educational structure that facilitates exchange and mobility often referred to as the Bologna process. This structure is based on three degree cycles: Bachelors, Masters and Doctoral [1]. The structure is sometimes referred to as the “3-5-8”-structure, with a 3-year bachelors program, a 2-year masters program and a 3-year doctoral program.

In several countries in Europe, traditional engineering professional degree programs of four to six years existed long before the ambitions to create a uniform structure emerged. In some countries, more academic oriented programs coexisted in parallel with the professional programs. At the moment, various countries and educational systems have either transformed their existing professional programs to adapt to the new systems, introduced new programs in parallel, or developed combinations.

In 2003, a number of pilot programs were launched at KTH Royal Institute of Technology, Stockholm, Sweden [2]. Until 2003, KTH and most technical universities in Sweden offered three programs: a professional 3-years bachelors program, a professional 5-year masters program and a 4-year academic doctoral program. Some universities, both technical and non-technical, also offered academic bachelors and masters programs that better prepared students for an academic doctoral program [3, 4].

These 3-year professional bachelors programs were distinct from the 5-year professional degree programs, which has been one of the main issues when adapting to the three cycle structure (see figure 1). The same structure could be seen in several European countries, for example Germany.

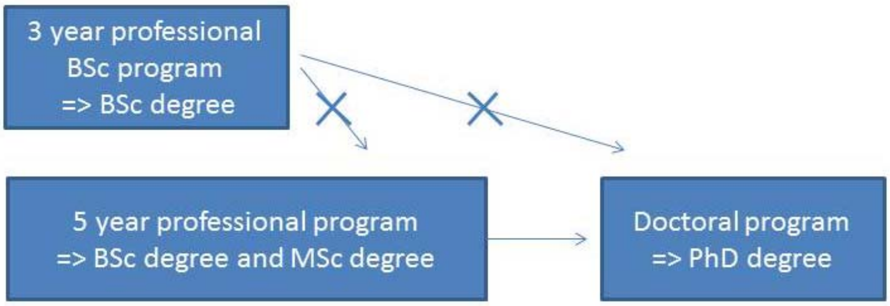

Figure 1. Preparing to adapt to the three cycle system. The 5-year program was divided into a BSc and a MSc program and awards both degrees. The 3-year professional BSc at KTH (and other European universities) did not prepare students for an MSc or PhD. In reality, a student taking the 3-year BSc program was not qualified to continue their studies at the MSc or PhD level.

Terminology

For the sake of clarity, the following terms will be used for describing the programs in this article.

Program	Degree	Comment
academic bachelors program	BSc	Supports further study in most two-year masters programs within the subject area.
professional bachelors program	BSc	Supports further study only in a select few two-year masters programs adapted for these BSc programs.
2 year academic masters program	MSc (2 year)	Open to students from most 3-year academic bachelors programs within the subject area.
2 year professional master program	MSc (2 year)	Some examples exists, but will not be discussed further in this article.
5 year professional program	MSc (5 year)	This is the main focus of this article. May be composed of a 3-year academic bachelors plus 2-year academic master. The MSc degree awarded here is different to the MSc degree awarded after the 2-year masters program.
3-4 year doctoral program	PhD	Will not be discussed further in this article. Could be divided into academic and professional, as well as in 2-years, 3-years and 4-years programs.

Table 1: Defining the programs and degrees. Note that there are two varieties of the MSc degree ; MSc degree (two years) and MSc degree (five years).

As seen in Table 1, there is a great potential for misunderstanding. In Sweden, a Swedish name is used for the 5-year masters program and degree (civilingenjör) that is different from the name for the 2-year masters program, a name that also exist in several other countries such as Germany, Spain and France. This name translates into English as masters of science, which then needs to be separated from the 2-years masters programs (i.e. MSc 2-years or MSc 5-years).

Integration of professional and academic degrees

Beginning in 2003, the 5-year professional engineering programs were divided into two parts, to correspond to the international bachelors and masters programs while keeping the professional focus. The distinction between the academic and professional degrees was not easy to distinguish since as per the Bologna reform, all bachelors and masters programs should prepare students for the next cycle, and, in particular, prepare for the doctoral program which is primarily an academic degree.

The implications for the Swedish university system were as follows.

1) The existing 5-year program was divided into two related parts - a 3-year bachelors program and a 2-year masters program.

2) The new requirements for mobility and exchange meant that the masters program had to become less dependent on specific courses from the bachelors program.

3) Integration between the two programs became difficult, with gaps and overlap between courses.

4) Learning goals for the two programs included academic goals such as research methodology and scientific theory, to prepare for the doctoral degree.

In the pilot programs at KTH, the above reform issues were put in perspective alongside the traditional values of the professional degrees:

1) A student who studied both the bachelors program and the masters program at KTH would receive the 5-year professional degree as well as the bachelors and masters degrees. This would be valid only for specified combinations of bachelors and masters programs in the same subject area.

2) A student who studied a bachelors program elsewhere (at another university) followed by the masters program at KTH could not receive the 5-year professional degree unless they provided proof that their combination of BSc courses was more or less identical to the KTH bachelors program.

A student who studied both programs at KTH, i.e. all five years, was believed to have acquired more professional skills and knowledge, and to have synergistically used these skills during the last two years in the masters program so that KTH could award the 5-year professional degree only to this group.

Formal requirements

The Swedish Higher Education Authority specifies the overall learning goals for all programs and degrees, including the three types of programs mentioned in this paper. As outlined above, the goals for the 5-year professional degree include all the learning goals of the bachelors and masters degrees, plus additional goals. Or, to put it another way, the bachelors and masters degrees individually are a subset of the 5-year professional degree, and the sum of the bachelors and masters degree is also a subset of the 5-year professional degree (see Figure 2).

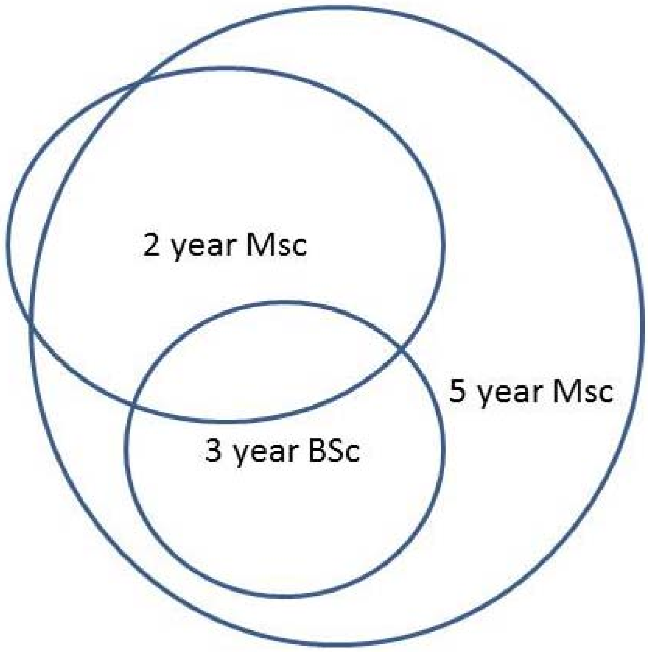

Figure 2. Illustration of the learning goals of the three degrees. The learning goals overlap. The MSc program overlaps (repeats) some of the BSc program goals. The 5-year MSc program includes most learning foals of both programs, but not all.

Furthermore, when introducing the separated bachelors and masters programs at KTH, a decision was made that the existing 5-year professional program should include the learning goals of the two new programs. As these had academic goals that the 5-year program did not have earlier, a structural change was necessary, i.e. to integrate the scientific goals.

Today, the 5-year professional engineering program fulfils requirements of three degrees; the professional 5-year degree, a bachelors degree and a masters degree. This was basically achieved by introducing academic learning goals in the existing 5-year programs.

Table 2 shows examples of learning goals for the three programs mentioned, plus a professional bachelors program. This table shows only one of the learning goals, one that relates to both engineering knowledge and academic knowledge and skills. As seen in the table, the academic programs have higher requirements for knowledge and understanding about scientific base, applicable methods and research issues. The professional programs places a lighter focus on these, but on the other hand demands working knowledge and proven experience.

Other learning goals would show the opposite. The professional programs for example have goals such as ”the student must show ability to develop products, processes and systems…”. This goal does not exist at all in the academic degrees.

Academic BSc degree	For the BSc degree, the student must show knowledge and understanding within the main area of the program, including the scientific base of the area, knowledge about applicable methods within the area, specialization within one or several aspects of the area and orientation about current research issues.
Professional BSc degree	For the BSc degree, the student must show knowledge about the scientific base and proven experience of the chosen area, and knowledge about current research- and development activities.
MSc degree (two years)	For the MSc degree, the student must show knowledge and understanding within the main area of the program, including both broad knowledge of the area and substantially deepened knowledge within certain parts of the area and deepened insight into current research- and development activities. The student must show deepened methodological knowledge within the main area of the program.
MSc degree (five years)	For the MSc degree, the student must show knowledge about the scientific base and proven experience of the chosen area, and insight in current research- and development activities.

Table 2: learning goals of four types of program and the related degrees.

Summarizing the differences between degrees

The professional 5-year degree is recognized by industry as a professional engineering degree, where the program prepares students for an engineering career. Key differences between the 5-year MSc degree and the 2-year masters degree are that the former includes professional skills and competencies such as industrial engineering and management, communication skills, ethics etc, whilst the latter focuses on preparing students for a future academic career.

Serving all needs

After five years of studies, a student following the system(s) described above could be entitled to three degrees. These degrees have slightly different learning goals. In order to award all three degrees, the university needs to assess and assure that the learning goals are achieved. How can this be monitored, and is it even possible? Some previous publications [3, 4] suggest that it is possible but requires a lot of effort in adapting program goals to course goals and ensuring a high standard in the curriculum design.

In the rest of this paper we will focus on one aspect of the studied programs, namely the compulsory thesis projects. These projects manifest the differences between academic and professional requirements.

Thesis projects

Historically, thesis projects in the 5-year program have been designed and undertaken as professional engineering projects, simulating a professional task and work environment. In reality, most projects in both professional BSc and MSc programs have been done in collaboration with industry and in most cases performed by a student located within an industrial company with a combination of academic and industrial supervisors . The projects have been designed to fit the educational background of the student and with the purpose to apply previous knowledge and skills into a realistic project.

Now, when introducing academic learning goals, this picture changes. To be able to fulfil the requirements of the academic MSc degree, the thesis project also needs to include learning goals relating to scientific content, approach, method and academic rigor.

The crash

Basically, at this point the system crashed. As the universities tried to introduce new scientific requirements on all students and projects, it proved very difficult to combine the previous successful approach with the thesis projects as an engineering development project and with results evaluated as an engineering accomplishment. Neither the students, the supervisors nor the industrial companies were prepared to transition from an engineering project to a purely scientific research project.

Integrating academic and professional requirements in thesis projects

To facilitate the process for the students and industrial partners, a model was introduced where the sets of requirements are grouped into two: engineering skills and scientific skills. A MSc thesis project requires scientific skills and an engineering thesis project requires both engineering skills and scientific skills.

We present a model for how the engineering skills can be integrated with research skills in one of three modes where an engineering thesis project is based on research and results in new knowledge (1) performed following a scientific process (2) or performed as engineering work and evaluated using scientific methods (3).

Thesis projects are based on research and results in new knowledge (Model 1)

The first model relies more on research and scientific method than the other two. Basically, the model could be described as “performing research”. It could either be a scientific problem or an engineering task. In either case, any problem solving or development should be based on a scientifically proven method, relate to previous research in the field and the results should contribute to the scientific body of knowledge.

This model could be more relevant for programs focused on academic and scientific goals than it is for the professional engineering programs.

Engineering thesis projects are performed following a scientific process (Model 2)

In this model, the thesis project constitutes an engineering project, most likely an engineering problem to be solved, or the development of a new product etc. If adapting this model, all steps in the development process and problem solving activities should be scientifically approached and solved.

As with the previous model, this can be difficult. In many cases, decisions are made on other grounds, even if very rational indeed. Proven experience for example is often made in assumptions and delimitations, which is hard to document in a thesis report. On the other hand, to show enough knowledge and skills within this area, it can be sufficient to document the major design decisions for example, by use of appropriate scientific methods.

Engineering thesis projects evaluated with scientific methods (Model 3)

In this third model, students typically spend most of an engineering thesis projects doing engineering and not research. In our preliminary study we identified many projects where the students postponed the issues of research and science until the very end and found difficulties when writing up the report. In these cases, students could still show knowledge and skills in scientific methods if, for example, evaluating the results of their engineering work using scientific methods.

Comparing the models

These three models have been developed as a tool to combine professional and academic learning goals into one thesis project. The first model basically dictates that the thesis work should be undertaken as a research project, the engineering aspects should be done “scientifically, as research”. This model exists basically to help to understand the other two models. Meaning, if the project is not undertaken as a research project, then one of the two other models should be used.

The second model views the project as an engineering project rather than a research project. The student applies a scientific method or process to certify that the results are scientifically correct and thereby proves that he or she can master a scientific method.

The third model could then be a last resort. Assuming that the project is an engineering development project rather than a research project. A scientific method or process has not been used during the work itself, but instead applied to evaluate the results of the engineering project.

In comparison, any of the models would be sufficient to prove scientific achievement. The first model would be more difficult to show engineering achievement. The third model is more uncertain since it basically puts forward a non-scientific development process.

Learning outcomes of the three models

As described above, each of the three models proposes a different focus. The first model focuses on research and scientific work. The second model focuses on engineering challenges and scientific methods and processes. The third model focuses on engineering processes and adequate evaluation methods.

Results

In this article, only anecdotal results are presented. The author has studied 30 thesis projects undertaken within the subject of Mechatronics during 2015, and we realize it is not possible to make adequate conclusions based only on these projects. There are too many uncertain factors, relating to supervisors and supervision, different background of students, and the fact that the author themselves have been part of the process.

However, some ideas can be presented, which needs to be studied further. For example, none of the 30 projects followed the first model. Some followed the second and third model. But the absolute majority of the projects did not follow any of the models and as such could not be said to have any substantial focus on research or scientific methods at all.

This motivates further action and studies of the problem and the area. Could the students of projects without scientific focus have included proof of these learning goals if they had been coached to follow the second or third model?

Conclusions and discussion

This paper presents challenges relating to integrating academic and professional skills in engineering programs. Most engineering programs in Europe are undergoing a transition moving from a professional engineering focus to also include a scientific research-based element. The complexity of the system have been illustrated by showing the development of the programs and learning goals as KTH endeavors to adapt to this situation.

The authors present three models for how research and scientific methods can be integrated with engineering work in a thesis project context.

In conclusion, the integration of research and engineering have been studied in the above cases. We show that integration can be achieved, that the various sets of requirements need to be communicated clearly, in particular to industry representatives, but that it is indeed possible to perform the integration synergistically.

In this paper we however only show anecdotal descriptions of thesis projects and student action. In a further study it would be necessary to study a sample of thesis projects and reports, to classify according to the models described above, and to relate these to the overall outcome and assessment of the thesis.

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