**INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07**
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

# THE PRODUCT DEVELOPER: EDUCATION AND PROFESSIONAL ROLE

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## ABSTRACT
The aim of this paper is to present results from a study examining the relation between the educational background and professional roles with engineers engaged in product development. Derived from previous studies, the product development engineer ought to be a multifaceted engineer, knowledgeable and skilled in several fields. This engineer should work interdisciplinary, integrative and with the aim to be creative and innovative.
By using a substantial data set consisting of 300 engineers in Swedish product development organizations, we derive some important research propositions. The data shows that there are correlations between organizational responsibilities and educational program, in particular regarding focus on design, system integration, project management and technical coordination.
If we want to understand how the engineering education affects the professional role of an engineer; we believe that it is critical to further investigate the developed propositions. One example is mechanical engineers; the data shows that the studied mechanical engineers rarely work with design. Our proposition is therefore to investigate the identity and legitimacy of these programs to further clarify the professional role.

*Keywords: Engineering education, professional roles, product development*

## 1 INTRODUCTION
The structure of this paper is as follows: The first section provides an introduction and sets the stage for our research. In the second section we present and discuss previous research aimed at identifying and defining the academic subjects and the related academic programs. This results in a number of categorizations of the relevant programs and subjects, which all have the purpose of creating dichotomies to better illustrate the differences in future professional roles. In the third section we present the methodology used and introduces the empirical data set which the analysis is based upon. In the fourth chapter we relate the statistical analysis with the characterized differences in educational background and present a discussion regarding possible explanations for these differences.

### Engineering education in Sweden
Engineering education in Sweden is offered at a number of universities. The engineering programs are divided into B.Sc. and M.Sc. programs; with the B.Sc. programs offered at 23 universities and the M.Sc. programs at 12 universities. Each university decides which programs to offer, and also the design of the respective curriculum. Therefore large differences can exist between programs offered at different universities. In this study the respondents were asked to choose one of a number of educational backgrounds, in the following called programs. The list of studied programs, together with a list of which university that offer the particular program is presented in Table 1.
In the original study the subject of Industrial engineering and management was given as a seventh option. In the analysis this subject and program was later removed due to difficulties in classification and characterization in this paper. In brief, most industrial engineering and management professionals considered themselves to work with *all subjects*, on *all levels* and the questionnaire did not take this into account.

## Trends

The current trend in higher engineering education in Sweden can be characterized by two dominant factors; the decreasing number of applying students and an increased diversification of the existing programs. Basically all engineering programs in Sweden are struggling to cope with a decreased number of students which in itself relates both to the demographic situation but also to a drastically increased number of programs and positions. The trend with an increased diversification can relate both to an ambition to create new, modern and attractive programs to increase student interest but also to an ambition of adapting existing traditional programs toward the changing industrial situation and increased complexity in product development.

*Table 1. Studied educational programs and universities*

| Studied programs: | Studied universities: |
|---|---|
| • Computer science (CS)<br>• Electrical engineering (EE)<br>• Engineering physics (EPh)<br>• Mechanical engineering (ME)<br>• Mechatronics (MTr)<br>• Vehicle engineering (VE) | • Chalmers University of Technology<br>o Offers: CS, EE, EPh, ME, MTr<br>• KTH, Royal Institute of Technology<br>o Offers: CS, EE, EPh, ME, VE<br>• Linköping University<br>o Offers: CS, EE, EPh, ME<br>• Luleå University of Technology<br>o Offers: CS, EE, EPh, ME<br>• Lund University<br>o Offers: CS, EE, EPh, ME<br>• Umeå University<br>o Offers: CS, EPh<br>• Uppsala University<br>o Offers: EPh |

# 2 BACKGROUND

In previous research [5][6] academic subjects such as Design Engineering, Machine Design and Mechatronics has been characterized in the light of a didactical analysis, as introduced by [3]. Didactics is here defined as a field of educational studies referring to research aimed at investigating what's unique with a particular subject, and how the particular subject ought to be taught. The purpose of the didactical analysis is to identify and describe the identity and legitimacy of the subject (what is *X*, and why should *X* be taught?) as well as its implications on the educational methods (what of *X* should be taught, and how?). In this article, the didactical analysis is used to illustrate difference between engineering subjects, as a tool to categorize and find similarities between various disciplines of engineering and science.

## Categorizing academic subjects according to the didactical analysis

When applying this method on engineering subjects the analysis is illustrated according to four dimensions, or "questions", resulting in descriptions with parameters such as identity and legitimacy. Figure 1 below shows an illustration of these parameters.

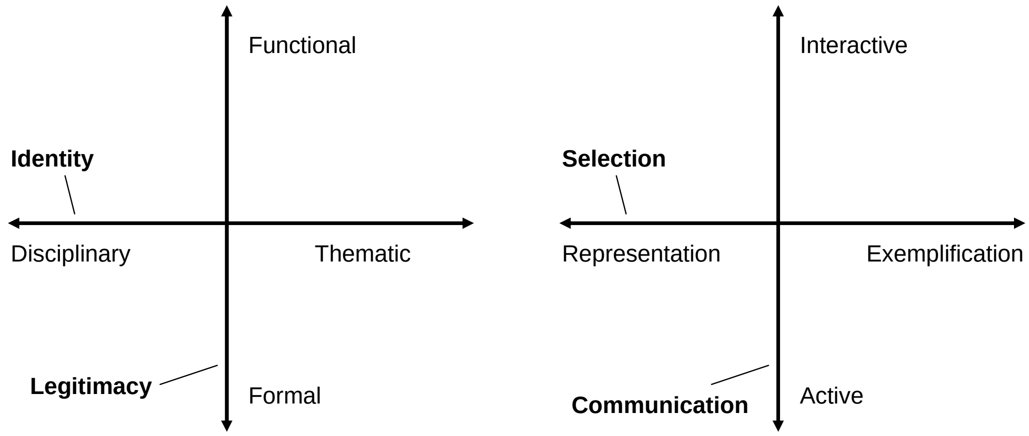


*Figure 1. The four dimensions of the didactical analysis*

The first two dimensions, or questions, illustrates and characterizes the subject and the two later dimensions illustrates educational implications, basically how the subject ought to be taught in accordance with the prior two dimensions.

***The subjects' identity***

The first dimension is the question of identity. The identity can be mapped on a scale between two extremes, from disciplinary to thematic. The question of identity is defined as "what distinguishes the particular field of knowledge?". Most traditional subjects such as mathematics, chemistry and physics are commonly viewed as disciplinary, meaning that there exists a strong consensus in the surrounding society regarding the contents of the subject, the classification and organization of the contents etc. In several cases, the knowledge is organized and developed systematically, and the created knowledge is easily classified into the existing structures.

In many cases the question of identity relates to the age of the subject, which in turns relates to how well this subject is established in the universities and societies. New subjects are usually introduced as cross disciplinary activities, as thematic activities spanning several research groups for example.

***The subjects' legitimacy***

The question of legitimacy is defined as the relation between the actual outcome of the educational efforts undertaken by the university and the actual demands that are put upon the students' abilities by the society and/or industry after graduation. This relation can be described according to two extremes – either formal legitimacy or functional legitimacy. In a simplified model the formal legitimacy relates to formal knowledge, for example knowledge gathered from textbooks that are read by the students. The functional legitimacy relates to functional skills such as the ability to perform concrete work tasks as part of product development. The functional skills are usually not learnt during traditional lectures or by reading textbooks but rather developed during hands-on exercises, laboratory experiments, trial and error etc.

In this article subjects related to product development are chosen, or rather engineers working with product development and their education is studied. The legitimacy should therefore relate to industries active in product development.

***The identity and legitimacy of product development***

The subject of Mechatronics has been thoroughly studied previously [1], and in studies of subjects such as design engineering and embedded systems [2] [4] references to the subjects of mechanical engineering, computer science, electrical engineering, vehicle engineering and engineering physics is made. In these studies, mechatronics is characterized as being considerably more thematic than mechanical engineering, electrical engineering and computer science, which also results in a more functional than formal legitimacy. Equally, vehicle engineering is considered more thematic than mechanical engineering and engineering physics.

The subjects of mechatronics and vehicle engineering therefore stand out in contrast to the other subjects, as having a more thematic identity and more thematic legitimacy. These subjects both have a cross disciplinary theme as identity; in the case of mechatronics the identity is usually related to the concept of synergistic integration of knowledge and skills in various subjects and in the case of vehicle engineering the identity and legitimacy relates to vehicles and the ability to design and implement actual vehicles.

The subjects of engineering physics and computer science stand out in an opposite way. These subjects are considerably more established and defined. A subject that is defined as "the science of…" doesn't leave much room for alternative interpretations. These subjects are therefore seen as considerably more disciplinary than the others, which results in a more formal legitimacy which often is due to the subject being established with a scientific consensus.

The subjects of mechanical engineering and electrical engineering is more vaguely mapped somewhere in between the others. Mechanical engineering has, at least in Sweden, recently seen a transformation from a subject studying the science of machines to a more design oriented subject dealing with product development. Electrical engineering has been subjected to an opposite transformation; electrical engineering used to attract students fascinated with soldering and designing electrical projects. The field of electrical engineering has though changed faster than most other subjects due to inventions and development in the area so that increased theoretical competence in signal analysis, programming, digital signal processing etc. puts different requirements of the students. In a largely simplified model the subject of mechanical engineering therefore seems to be moving from disciplinary to thematic and from formal to functional. The subject of electrical engineering seems to be keeping a disciplinary identity but transforming from a functional legitimacy toward a formal. See Figure 2 for an illustration of these trends.

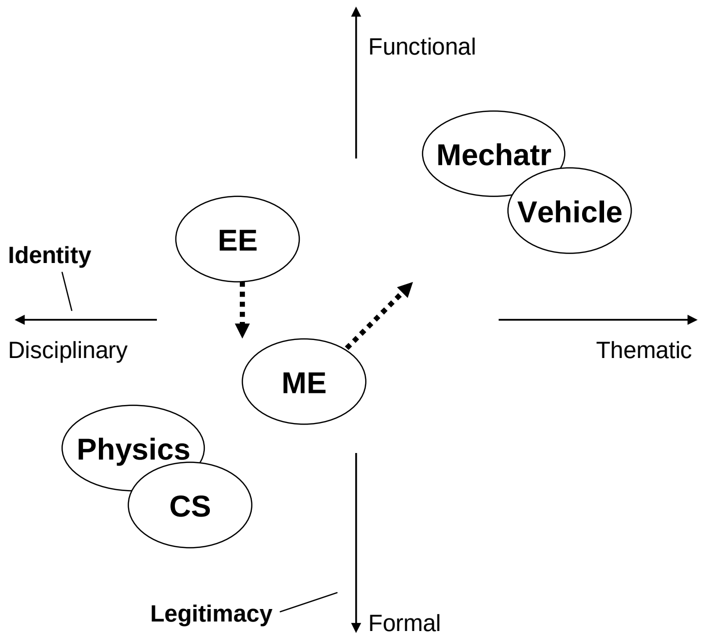


*Figure 2. The identity and legitimacy of the studied subjects*

## Theoretical or applied subjects, science or engineering

Of the six studied subjects, all can be compared according to the amount of theoretical courses versus amount of applied. It is however difficult to define a theoretical or applied course and the curriculum are also varies across various universities. Still, a very rough categorization can be made which is based on the identity of the subjects, as taught by the universities in Sweden, by using largely the same material as in the didactical analysis. In this categorization three rather distinct groups are identified (Figure 3). Three subjects clearly have a stronger applied base than the other; mechanical engineering, mechatronics and vehicle engineering. Mechanical engineering has traditionally been seen as an applied subject. Mechatronics is, due to the functional legitimacy, relying on the application of knowledge and skills. Vehicle engineering is an application in itself; the application of other subjects on the theme of vehicles.

Engineering physics and electrical engineering has traditionally been given more room for theoretical courses and less focus on experiments and applied activities. These subjects are also more referred to as subjects of science rather than of engineering.

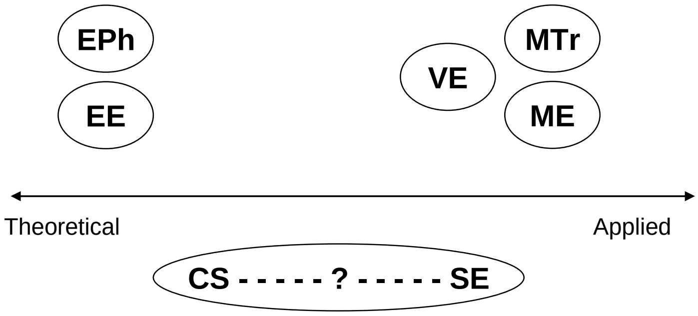


*Figure 3. Theoretical or applied subject, science or engineering?*

The subject of computer science is more difficult to categorize. In this study no distinction between computer science and software engineering is made which could have clarified further. In [7] a comparison between software engineering and computer science was made. It was found that software engineering was more thematic than disciplinary and also that the identity of software engineering was changing from a traditional knowledge-based identity toward a functional profession were other skills were important as well. This study also showed that programs in software engineering often had a clear and distinct goal of educating engineers for an existing industry with specified demands while programs of computer science rather educated computer scientists. In this perspective, computer science should be regarded as considerably more theoretical than software engineering. Computer science could therefore be considered theoretical similarly to engineering physics and electrical engineering and software engineering could be classified together with mechanical engineering, vehicle engineering and mechatronics. But, in this particular study, computer science includes software engineering as well, and particularly since the engineers studied are working in product development, it is possible that these have a background in either computer science or software engineering.

### Popularity (number of applicants)

The third and final characterization of the subjects is performed in perspective of the trends of popularity of the educational programs associated which each subject. The statistical data regards only educational programs in Sweden. The purpose is only to show trends and provide a rough illustration of the number of applying students. Statistical data from 2001 and 2006 are used to show signs of trends.

In Figure 4 statistical data from all universities in Sweden are used, of students applying for M.Sc. programs in the various subjects. Two programs exist at only one university (vehicle engineering and mechatronics) why these numbers are considerably less than the other programs. Computer science, engineering physics, electrical engineering and mechanical engineering are given at between five and seven universities each.

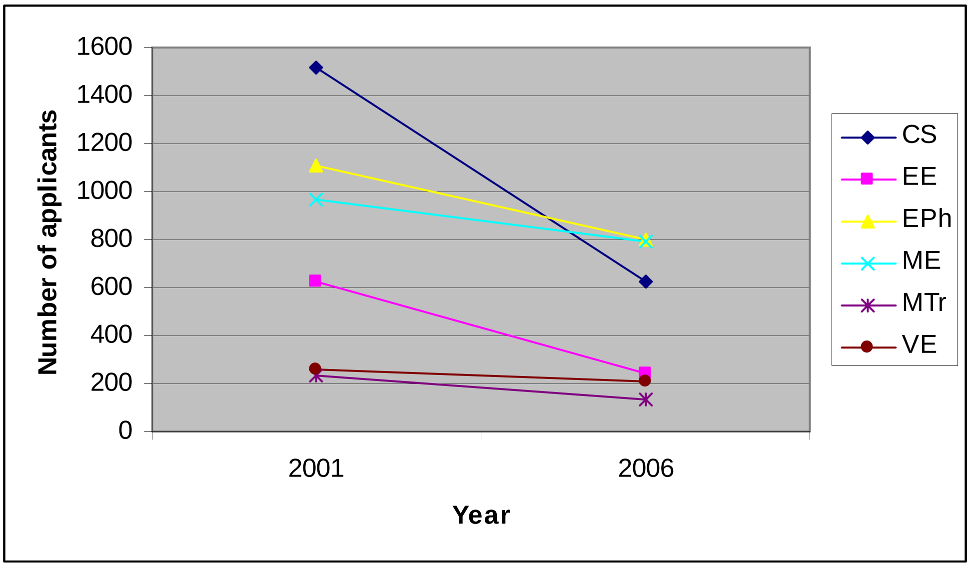


*Figure 4. Number of students applying for various programs*

Two trends are identified in the statistical data. First, all programs show decreased number of applying students. Four programs show a similar decrease; engineering physics, electrical engineering, mechanical engineering and mechatronics. This trend can be traced to the common decreasing trend in Sweden which is due to a combination of increased number of offered programs at an increased number of universities. However, the second identified trend is that computer science and electrical engineering show a considerably higher decrease in student interest than the other programs. This is further illustrated in Figure 5 below.


*Figure 5. Decrease in student interest, in number of students applying for M.Sc. programs*

### Concluding characterizations of academic subjects and engineering programs

The purpose of the section above was to characterize the academic subjects, or engineering programs, in three different perspectives. We will now turn our focus to the statistical study performed on employees in product development companies, to see how the professional role correlates to the educational programs and the characteristics of these.

## 3 METHOD

The data analyzed in the presented study is drawn from a data set which was collected during February, 2006. The study covers product developers in eleven R&D settings in nine Swedish manufacturing companies. The branches in this study were robotics, transportation drive systems, advanced medical technologies, laser systems, commercial vehicles, automotive electronics suppliers, and automation systems.

The study group was comprised of 303 product developers, 11% women and 89% men, with a mean age of 39 years and the mean value of company tenure was nine years. Out of 303 product developers 265 had a university degree and the distribution between different programs are shown in Figure 6. Data were collected by means of a web-based questionnaire. A total of 397 unique invitations were distributed and 303 of these completed the questionnaire. Two e-mail addresses were invalid, resulting in a response rate of 76.7%.

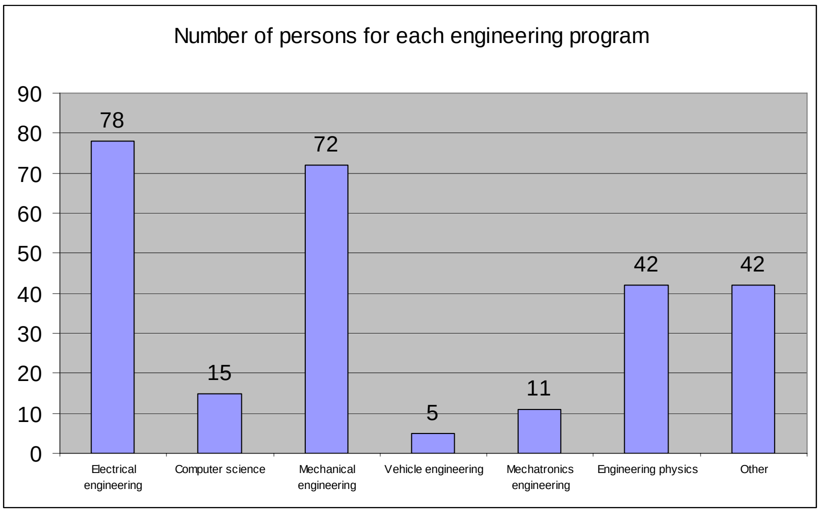


*Figure 6. Distribution of persons for each engineering program*

The specific data used in the analysis presented in this paper includes age, sex, company tenure, educational background, technical work areas, and organizational responsibilities. Principal component factor analysis with orthogonal Varimax rotation was used for item analysis and possible data reduction. Three factors were identified which corresponded to three main technical work areas (electronics, software, and mechanics). Items included in these factors had magnitudes greater than 0.5, and tests of reliability were performed where applicable using Cronbach's α [8].

Multivariate analysis of variance (MANOVA) with LSD post hoc tests was performed on the data set to distinguish any significant differences between (1) educational background and technical work areas and (2) educational background and organizational responsibilities.

## 4 RESULTS AND DISCUSSION

A number of graphs derived from the analysis of the results will be presented in this section, and based on these results we will develop a number of research propositions which we promote to be used in further research in the area of engineering education.

The first illustration (Figure 7) illustrates the overall view of different educational programs and what organizational responsibilities to which the respondents refer themselves to. In general we can identify that people with an education in computer science works more with design related responsibilities than with integration-related issues, and instead they experience that they work with technical coordination to a rather large extent. Electrical engineers are rather focused on design issues. People with an education in mechatronics or engineering physics seems so far to be rather general in terms of organizational responsibilities, whereas mechanical engineering and vehicle engineering are also somewhat general, but not to the same extent.

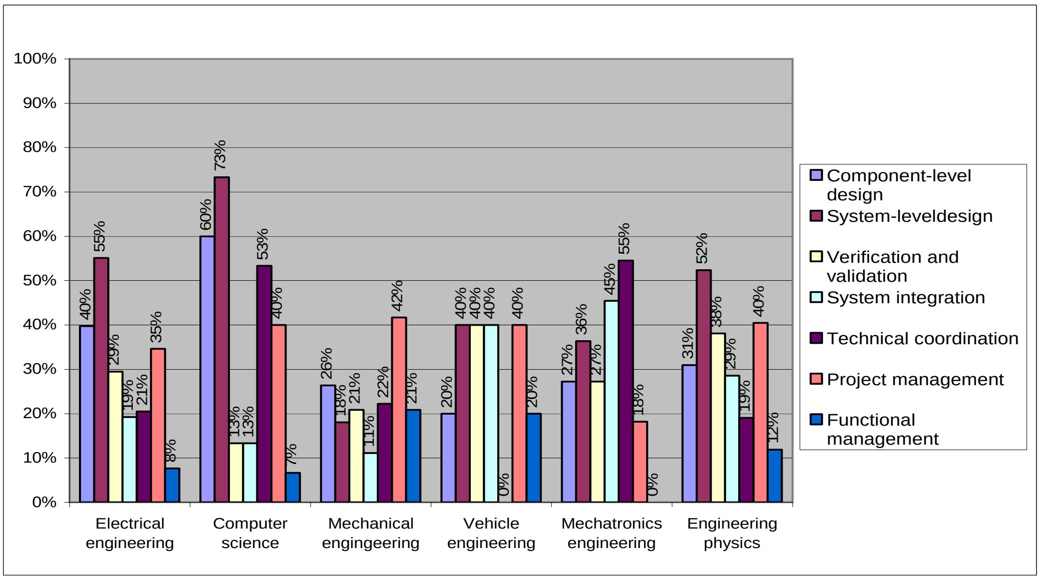


*Figure 7.The overall view of different educational programs and organizational responsibilities.*

## Component-level design contra system-level design

If we dig deeper into the subject of design responsibilities (illustrated in Figure 8), we can see that it is mainly people with an educational background in electrical engineering and computer science which claim that they work with both component-level and system-level design, followed by people with an education in engineering physics. In the studied companies, it seems like mechanical engineers do not primarily work with design-related issues, in relation to the level stated by people with a background in electrical engineers or computer science. A possible explanation is that mechanical engineers work more either with project management and coordination, or with technical analysis, calculations and dimensioning which in the Swedish language context is considered different than design. Figure 6 shows that mechanical engineers commonly state project management as their responsibility, but no explanation for the low percentages in design is found.

Mechanical engineers are the only group which considers that they work more with component-level design than system-level design. This could point towards a more traditional role of mechanical engineer primarily being an engineer and not a designer.

As a result, we believe that the studied mechanical engineers may be reluctant to characterize their responsibilities as design and hence product development. The discrepancy between the functional legitimacy and thematic identity of the mechanical engineering program and the mechanical engineers' perception of their responsibilities calls for further studies of the characteristics of the mechanical engineer's tasks and conception of responsibility.

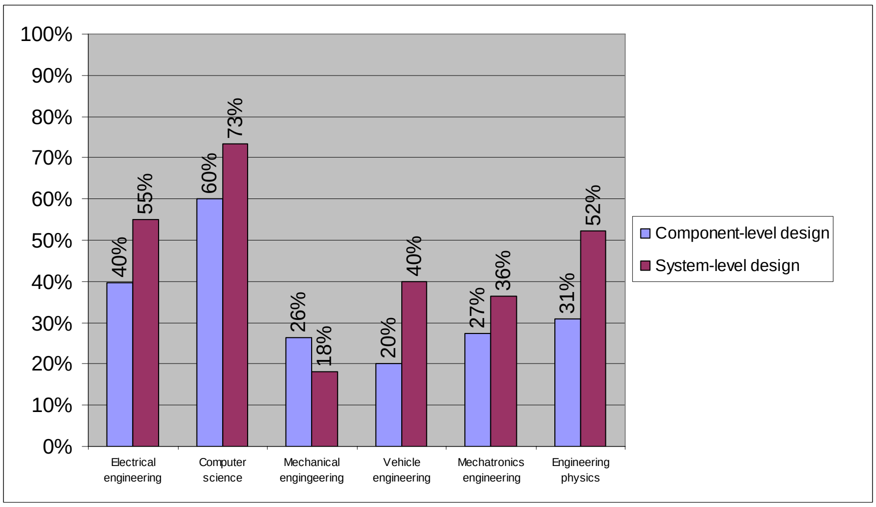

*Figure 8. Component-level design contra system-level design*

### Verification, validation and system integration

When considering verification, validation and system integration the result are shown in Figure 9. The mechatronics engineers together with vehicle engineers are the categories that show the highest percentage concerning systems integration responsibilities. Engineering physics and vehicle engineering are instead the dominant groups, when verification and validation responsibilities are considered. Regarding characterization of the programs, engineering physics is considered more advanced in theory than most other programs, and vehicle engineering are considered the more theoretic of the applied program. We can therefore observe a possible trend that engineering from the theoretical programs more often work with verification and validation while the engineers from the applied programs works more often with system integration.

Mechanical engineering and computer science engineers are two groups which do not work considerably with verification, validation or system integration. The mechatronics engineers are the only group which expressed that they work more with system integration than verification and validation duties.

From this discussion and the discussion regarding the identity of the programs, we find that even if the mechanical engineering program positions itself as a product development program it is not manifested in the work responsibilities of the mechanical engineers. In other words, mechanical engineers in this study do not considerably work with design, verification and validation or with system integration.

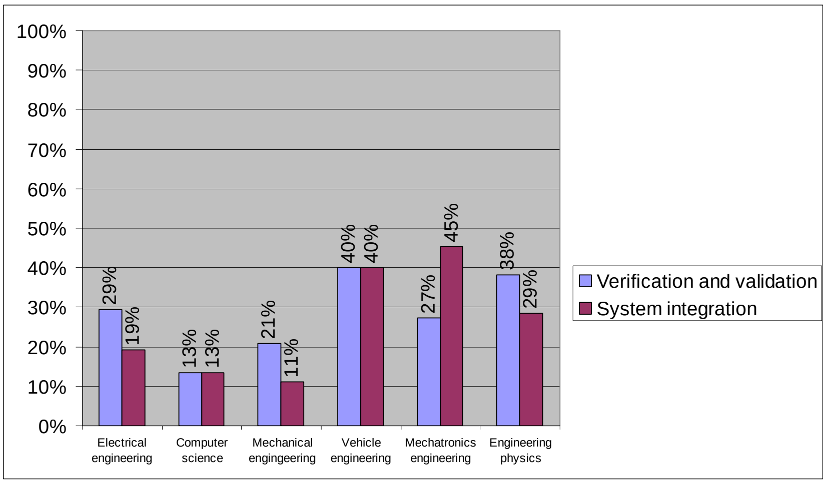


*Figure 9. Verification, validation and system integration*

### System integration and technical coordination

Responsibilities regarding system integration and technical coordination are illustrated in Figure 10. When these responsibilities are considered, it is identified that computer science and mechatronics are the two main groups working with technical coordination. This could be explained by the fact that software development has become one of the predominant activities in development of traditionally manufactured goods. However, there exists one difference between computer science and mechatronics. Mechatronics also deals with system integration, which in part could be explained from a higher capability and ability in more applied system thinking and integration than the computer science engineers. Compared with the classification of the programs, this difference can be explained in the identified differences between the two programs where mechatronics is a more applied and multidisciplinary program than computer science.

Mechanical engineers in this study seem to be the group which works the least with system integration responsibilities. Once again, this is somewhat contradicting since mechanical engineering in most cases is positioned as a product development program. The earlier possible explanation that mechanical engineers either work as specialists in a narrow field or with project management is feasible, but needs to be studied further.

The specific status of the mechatronics engineers concerning system integration responsibilities and technical coordination could without difficulty be tracked back to the specific identity of this program.

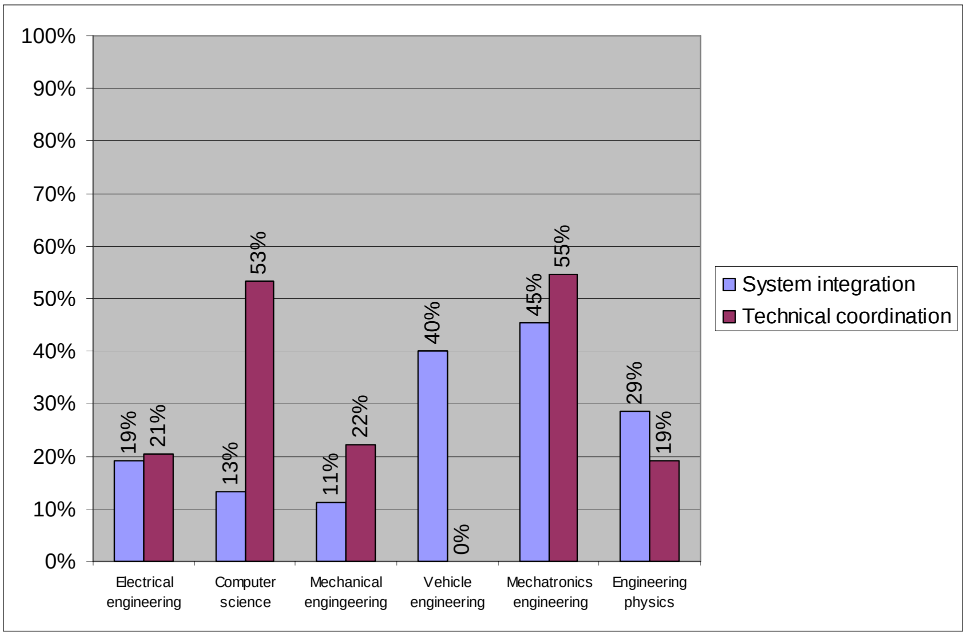


*Figure 10. System integration and technical coordination*

**Project management and technical coordination**

The next illustration regarding work responsibilities is shown in Figure 11, and shows technical coordination, project management, and functional management. This illustration provides some explanations to the earlier discussion. In organizations which are part of this study, a great deal of the mechanical engineers work with project management duties. The mechatronics engineers however are not, indicating that they are more focused on managing technical aspects of product development rather than managing the people within the organization. Mechanical engineers together with vehicle engineers are the most common groups when functional management is evaluated. This might be explained by the governing traditions in these traditional manufacturing companies.

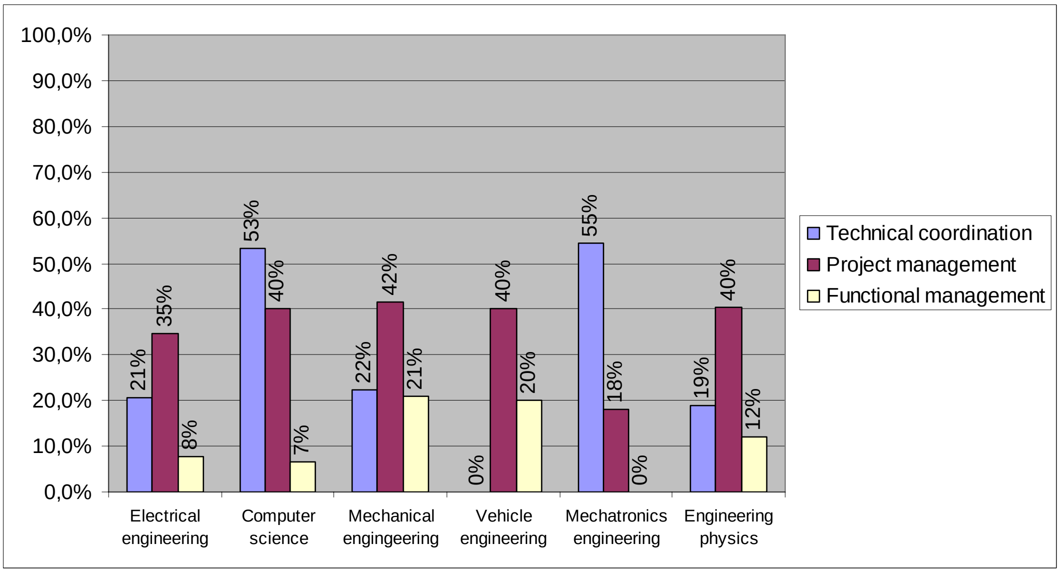


*Figure 11. Project management and technical coordination*

### Aggregated results concerning work responsibilities

By extracting three different factors from the factor analysis described in the research method, we are able to compare three main types of work responsibilities; 1) Design, 2) Integration, and 3) Coordination. These aggregated results are shown in Figure 12.

One explanation to that computer science do not primarily work with integration may be found in the types of companies which are included in this study. Since there are no organizations which do solely develop software systems, instead they develop embedded software systems, computer science have so far not been involved in the integration activities.

Computer science, electrical engineering, mechanical engineering are the ones which show higher levels of design responsibilities than integration. Vehicle engineering and mechatronics are the groups which show the opposite.

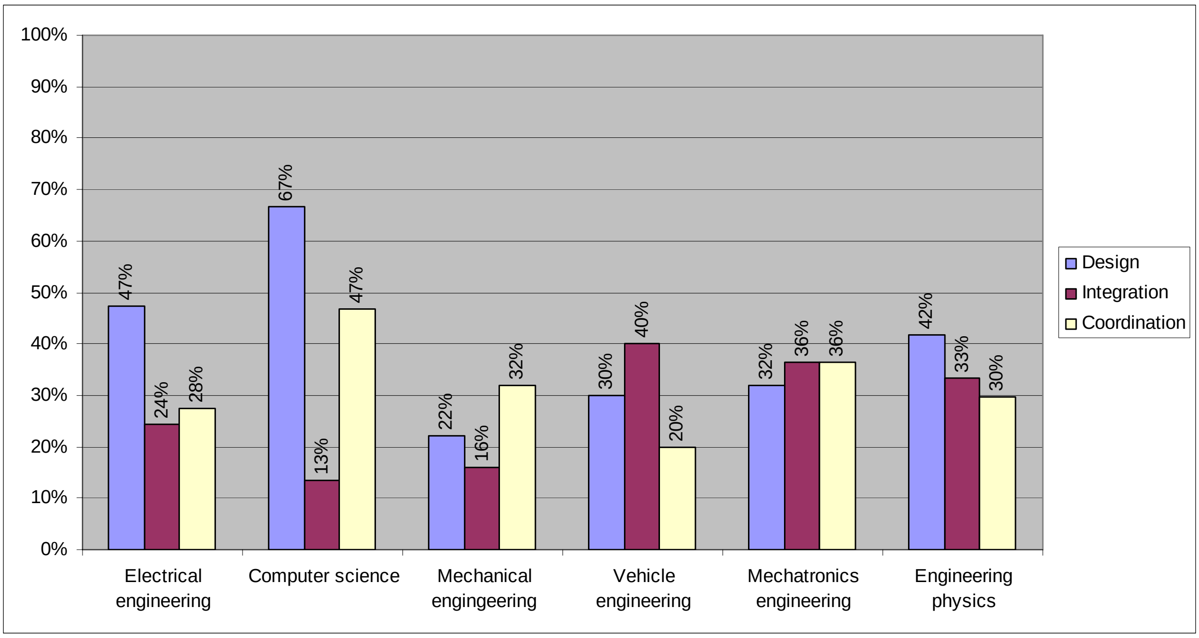


*Figure 12.Three main work responsibilities obtained from factor analysis.*

### Technical responsibilities

The concluding illustration shows the technical areas (software, electronics, mechanics) which the engineers work with, Figure 13. The group which shows the most homogenous distribution is the mechatronics engineers. They seem to be working with all three technical areas, which correspond to the classification of the program.

Electrical engineering works mainly with software and electronics, which seems reasonable with respects to the classification of the education. They show a similar profile as the vehicle engineers, since they work more with software and electronics than with mechanics. However, the vehicle engineers show higher levels than the electrical engineers for both software and mechanics. Engineering physics as a group is also rather general, but with a small emphasis on software.

The two extremes are found in computer science and mechanical engineering. Computer science does primarily, and almost only, works with software. In addition, the mechanical engineers do work primarily with mechanics, and rather seldom with electronics and software.

From this illustration there are two indications that can be identified. Firstly, mechatronics and vehicle engineering are the two groups that work as system integrators and are involved in technical problem solving in many different technical areas. Secondly, computer science work with technical coordination, but since they are solely involved in software issues, this implies coordination only of software. Since they only work with software, they are not likely to be involved in technical integration, something also shown in Figure 11.

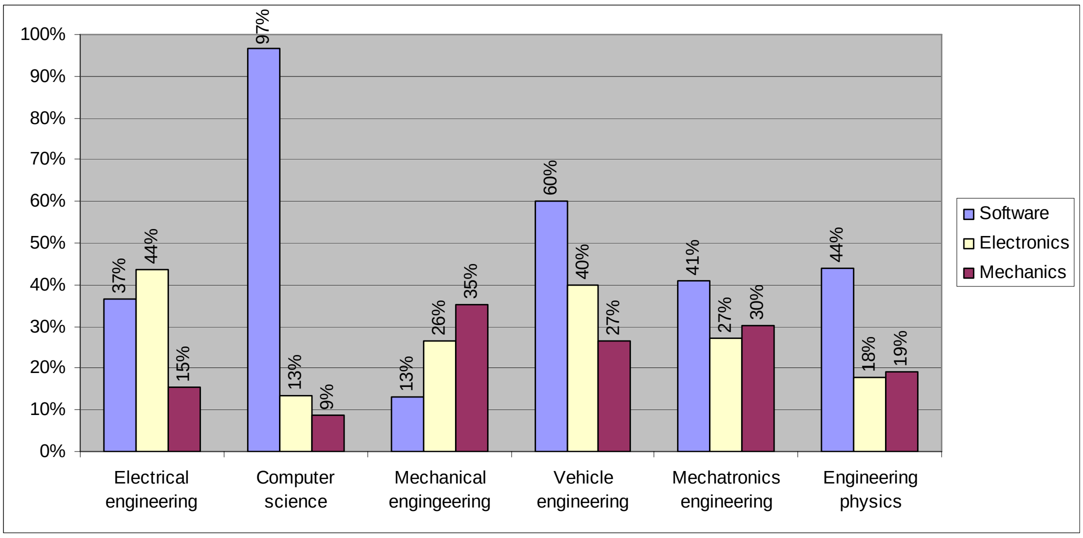


*Figure 13. Distribution of how engineers work with different technical areas.*

## 6 CONCLUSIONS AND RESEARCH PROPOSITIONS

We have in this paper discussed some initial results which relate the engineering educations in Sweden to the professional role of an engineer in product development organizations. Our results provide some tentative results which we use to derive some research propositions. If we want to understand how the engineering education affects the professional role of an engineer, we believe that it is critical to further investigate the following propositions:

*Proposition #1* The professional role of the mechanical engineer is unclear due to a ambiguous identify and legitimacy of the educational program.

*Proposition #2* The limited organizational responsibilities of engineers with a background in computer science are due to a deficient product development approach in the educational identity.

*Proposition #3* Programs with a functional and thematic focus are superior in providing skills suitable for working across technical areas and with system integration.

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