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# COACHING STUDENTS INTO THE CONCEPT OF DESIGN ENGINEERING

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*Keywords: design education, definition of design, student approaches*

## 1 Introduction

In Sweden the engineering education in product development is moving towards design and product realization. The reason behind this can be to improve our competition capability and to attract more students. The reason can also be a result of national research programs in engineering design [1] and product realization [2].

In August 2003 a new Master of Science program, Design and product realization was launched at the Royal Institute of Technology in Stockholm, Sweden. This program was introduced as a program in design engineering, the aim of which is to educate design engineers, capable of developing attractive products. With an attractive product we mean a product that is appealing, functions well, is easy to use and has 'charisma'.

The aim of this paper is to present results from a study of the students' definitions of the concept of design engineering, the ambition and the strategy of the faculty to coach the students in their development of their understanding and the progress and development of the students' understanding of the concept.

### 1.1 Objectives

The new Master of Science program, Design and product realization attracted 250 first hand applicants and compared to the other 15 engineering programs at KTH, it was rated as the third most popular program. 106 students were accepted for the first year. In August 2004 the program attracted approximately the same number of applicants, and the same number of students was accepted. In 2003 a study was performed to analyze the ambition, aim and motivation of the students, mainly by studying the reasoning behind their choice of educational program and their individual understanding of the concept of design [3]. Among the results from this study was evidence of discrepancies between the students' concept of design and the established academic definition of engineering design. Basically the students had expected an educational program with a higher degree of artistic subjects, aesthetic values etc.

During the first three years of the Master program, extensive courses in design engineering are given, starting with the purpose of giving a perspective of the program, the concept of design engineering and the future professional role as design engineer, and continuing with the aim of teaching design engineering in a setting characterized by project-organizations, cross-discipline and student motivation.

The main objective of this article is to present a study of how the students' concept of design changes during the educational efforts, primarily during the first three semesters, and how the students' prior expectations of artistic subjects diminish in favor of the subjects of design engineering.

## 1.2 Methods

In this article two groups of students are studied, students accepted August 2003 and students accepted August 2004. Within each group one class of approximately 25 students constitutes a focus group (P03 and P04). The students in the P03 focus group were subject to enquiries twice during the first year, at the start and the end of the first semester and interviewed during mid-semester. During the first semester of 2004 the P04 focus group was subjected to the same study. Both focus groups were again questioned and interviewed in the spring of 2005, at the beginning of their second respective fourth semester.

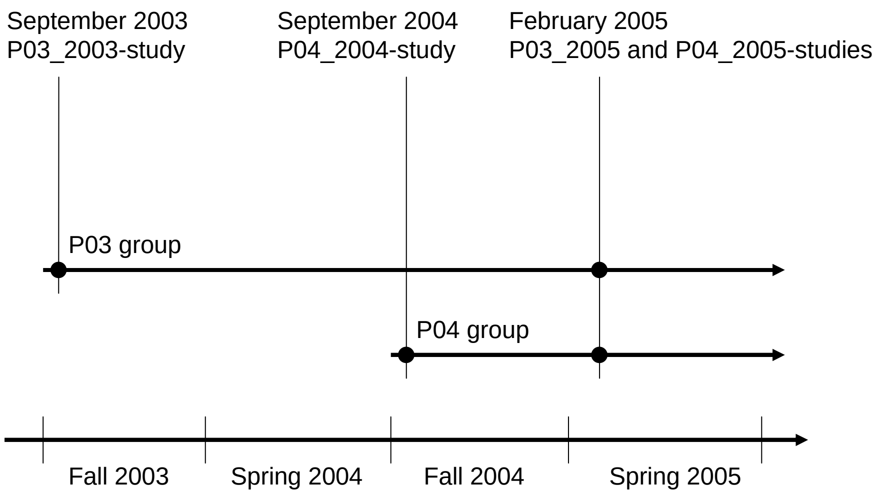


Figure 1. Timeline of the four studies performed of the two focus groups

This setting provides data to enable a comparison between the students accepted the first and the second year. The setting also provides data for a longitudinal study to investigate the process during the first year and half of the students' education, the process where the students' concept of design changes – toward the established academic definitions of design engineering in favor of the students prior ambitions towards more aesthetic subjects.

# 2 Context

## 2.1 Design, Engineering Design and Design Engineering in Sweden

In Swedish, the term *design* (written and pronounced as in English) is most commonly understood solely in terms of aesthetic values such as shape and appearance. It is not used when referring to functionality. Thus industrial design, both as programs at universities and as a profession, relates primarily to an aesthetic education, even if it does encompass areas such as ergonomics and aerodynamics. Education for industrial design in Sweden is normally not an education in engineering. This is also apparent from the fact that the Swedish translation of 'engineering design' is *produktutveckling* or *konstruktion,* with no reference to the word 'design'.

However, in recent years the concept of *design* has been introduced in an engineering context in Sweden in the form of new engineering programs such as the Design and product realization program. Similar programs are offered at other technical universities. The intention was to introduce this area as design engineering, not to be confused with engineering design.

In this paper, we are not setting out to define the concept of design engineering, either in terms of how it is envisaged by KTH or by the faculty. Our intention is only to investigate the students' concept of design.

## 2.2 The industrial context

The engineering education in Sweden is a vocational training, i.e. students are trained for a certain profession, that of an engineer. Many times students are assumed to take assignments in industry and consequently industrial product development becomes of great importance when redefining an educational program. It is a strong ambition that graduated students should be employed in close connection to the area of their degree. Therefore coaching students into certain conceptions is part of coaching students to become professionals as well as providing opportunities to train a professional competence, including social skill and attitudes in relation to technical skills.

Industrial product development is characterized by high demands on effectiveness (doing the right thing) and efficiency (doing the right way). This demand high technical skills among engineers and also skills as working autonomously, performing plans of work, evaluating functionality and social skills for team work and customer contacts.

## 2.3 The educational context

Design engineering represents a multi-disciplinary subject that involves areas both in traditional academic subjects such as mechanical engineering and electrical engineering, as well as in areas traditionally defined as non-technical, subjects such as project management, communication and visualization etc. In a previous attempt to describe the introduction and establishment of the concept of design engineering in Sweden [4], the identity of design engineering is defined according to the concept of synergy; the purpose of design engineering can be seen as finding the synergy between form and function, between choice of materials and functionality and between choice of a mechanical solution and usability, ergonomics, attractiveness etc.

The identity of design engineering therefore points toward the ability to make use of knowledge and skills in disparate subjects, as well as to combine this knowledge and skills into synergistic, or attractive, products.

The legitimacy of a subject, according to the didactical analysis introduced by Dahlgren [5] is defined as the relation between the demands put by the hiring industry on the educated engineers and the actual outcome from the educating university. According to [4], the legitimacy of design engineering can be considered as functional, meaning that the requirements of the hiring industry is described in functional terms instead of formal specifications. The hiring industry is searching for graduated students with skills in product development rather than students with knowledge in certain areas; or rather the design engineering graduates are distinguished by their abilities in product development where for example mechanical engineering graduates are distinguished more according to analytical skills.

To summarize, the above described identity and legitimacy of the subject of design engineering points toward the importance of integrating complementary knowledge and skills into the education, in particular areas such as teamwork skills, project management skills, abilities to collaborate and communicate with professionals from different areas etc.

## 2.4 Design as a social activity

In a comparison between design engineering and more traditional academic subjects such as mechanical engineering or electrical engineering the above analysis gives that one possible approach to integrate complementary skills such as teamwork skills is to treat design as a social activity, which, according to the identity and legitimacy of the subject, would be advantageous by way of providing the overall picture of the professional role as design engineer to the students. To treat design as a social activity in education is then a way of showing students how design engineers work.

Teaching design as a social activity implies a need for collaboration. This collaboration manifests itself in three ways: teamwork between students and faculty, between the university and industry or society; openness toward other students, the university, and society; and interest from all participants [6, 7, 8].

## 2.5 From teaching to learning

With a well-cited article in Change [9], Barr and Tagg created considerable discussions around the world regarding their analysis of the paradigm shift that took hold of higher education beginning in 1995. The paradigm shift meant that the former traditional way of teaching, called the instruction paradigm, is being replaced by the new learning paradigm.

The learning paradigm is represented by a move from formal legitimacy towards functional legitimacy, by focusing on the development of the individual skills by means of increasing feedback, individual support and coaching instead of focusing on formal assessment methods, course content, marks or grades.

The move towards the learning paradigm is motivated by rising cost of academic education, by a will to change the rigid and complex structures that constrains higher education, and primarily by teachers' will to increase student learning by ways of increasing motivation, flexibility etc, but in the case of design engineering a parallel can be made to the notion of regarding design engineering as having a functional legitimacy – according to Barr and Tagg [9] the move towards the learning paradigm will increase the "quality of learning for students" as well as enhance "intellectual skills such as writing and problem solving and social skills such as effective team participation". In this context, the move towards learning will therefore benefit the subject of design engineering both by increasing the quality of learning, as well as by moving towards more functional skills instead of formal knowledge.

## 2.6 The CDIO-initiative (as a response to the above)

In design engineering, it is important to integrate complementary knowledge and skills into the education, in particular in areas such as teamwork skills, project management skills, abilities to collaborate and communicate with professionals from different areas. Education in engineering design at KTH also has for a very long time (>25 years) made this integration of complementary knowledge and skills with traditional technical subjects.

Several of the challenges faced in the new education program and in the development of the new training activities (courses) are supported by the so called CDIO Syllabus. The CDIO Syllabus has worked as guidance in the course development, supported by that KTH is a member of the initiative. In short the syllabus stands for an initiative to develop engineering education to include more skills than theoretical technical subjects include, for instance problem solving, system thinking, individual and personal skills, professional skills, team work skills, communication skills etc. Besides, the CDIO Syllabus also drives that an engineering education should encompass all phases in engineering work: conceiving, designing, implementing and operating, i.e. the C-D-I-O [10]. The syllabus describes in detail all the skills that the members in the initiative have defined as important to train in an engineering education, which could work as a model to compare courses and program with. With a program perspective the required skills can be trained in different courses, meaning that in one course the training of a certain skill can be started, followed by further training in another course. Such skills identified for the design and product realization course block is among others: team work, visualization, problem solving, product analysis, holistic perspective on design and product realization, environmental trade-offs.

# 3 Students' concept of design

## 3.1 The students' definition of the concept of design

In February 2005 all students in both focus groups were asked to define 'design'. The students' answers were divided into four categories, and are presented in the table below.

Table 1. Students' definition of 'design' (February 2005)

| | P03 | P04 |
|---|---|---|
| Design is about appearance, and it has nothing to do with functionality | 26% | 20% |
| Design is shape, appearance, color etc | 11% | 20% |
| Design is about aesthetic pleasure with a special purpose, such as ergonomics | 21% | 13% |
| Design is about both aesthetic pleasure and functionality | 42% | 47% |

As shown in Table 1, less than half of the students associate design with both form and functionality; for the majority of the students design is associated solely with form; appearance etc.

## 3.2 Relation between engineering and design based on the students' definitions of the concept of design

During the first respective semester the students in both focus groups were asked to quantify how much of their education they would like to be focused on design as they defined it. This choice was presented in a questionnaire on which the students were asked to identify their preference on a scale between two extremes, defined as follows:

1. Engineering, defined as mathematics, physics, mechanics, mechanical engineering, industrial production, environmental protection, etc.

2. Design, defined as sketching, visual thinking, theoretical and applied aesthetics, interaction of color, perception, etc.

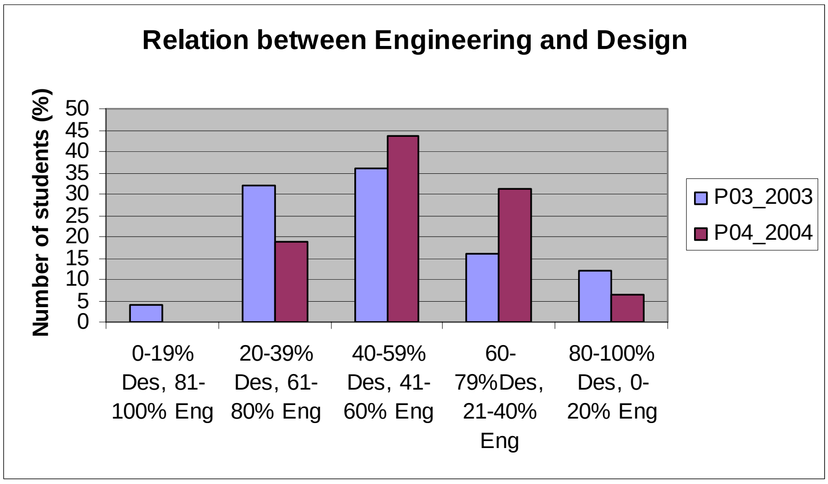


Figure 2. Students' preferred division between engineering-related areas of study and design-related areas (according to the students' own definitions of design). The statistical data is gathered during the students' first semesters, in September 2003 (the P03 group) and September 2004 (the P04 group)

The students' answers are shown in the figure above. From this data, it can be concluded that in average, the students in the P03 focus group would prefer 47% of their education to focus on design-related areas as defined above, and the P04 focus group would prefer 53% of the same.

## 3.3 Relation between engineering and design based on the students' definition of the educational program

On the basis of the results from the previous questionnaire, a different approach was adopted. The students were asked to choose which of the following three professional degrees they would prefer to receive after completing their education.

1. Mechanical Engineer, that is, someone who is as competent in engineering as a graduate from a mechanical engineering or similar program, but who has taken 2 or 3 courses in design-related areas.

2. Design Engineer. A person who has taken some courses in mechanical engineering, production, mathematics, and physics, but who primarily is a design engineer.

3. Industrial Designer.

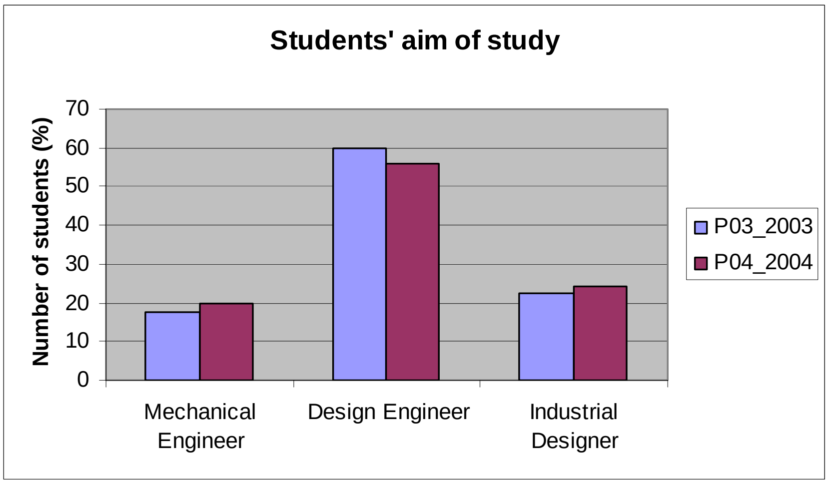


Figure 3. Students' preferred choice of professional title as graduates. The statistical data is gathered during the students' first semesters, in September 2003 (the P03 group) and September 2004 (the P04 group)

According to Figure 3, the majority of students preferred the idea of becoming a design engineer, even though the questionnaire implied that such an engineer would have fewer courses in traditional engineering subjects than a typical mechanical engineer. The students preferred to decrease the number of traditional subjects in favor of design-related courses.

## 3.4 Relation between engineering and design based on the students' preliminary choice of master's program

The next study was undertaken to further investigate the relation between design and engineering. The students were asked to make a preliminary choice between four possible master's programs offered to the Design and product realization program.

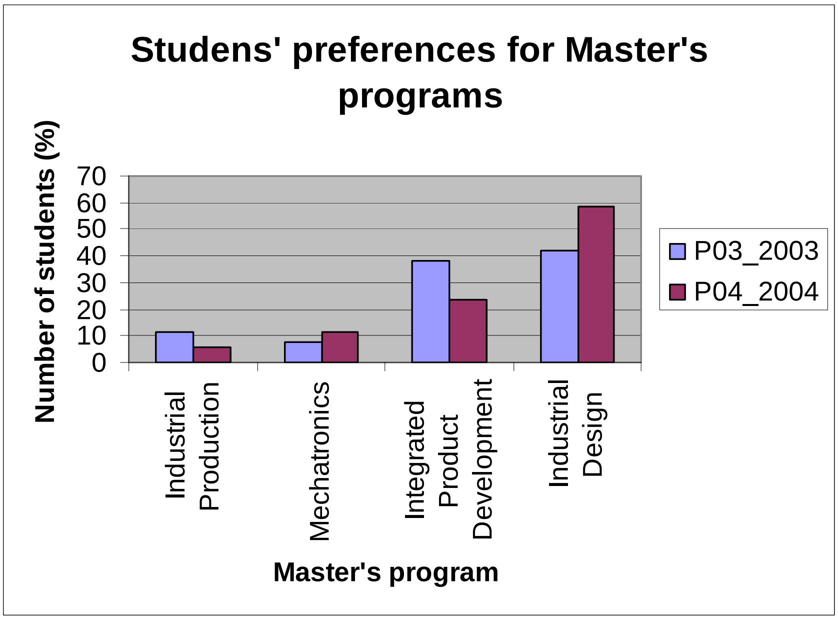


Figure 4. Students' preliminary choices of master's programs. The statistical data is gathered during the students' first semesters, in September 2003 (the P03 group) and September 2004 (the P04 group)

Of the four master's programs, Industrial production and Mechatronics do not include any courses or aspects that relate to the areas defined as design by the students. Only a minority of the students chose these two programs.

## 3.5 Summarizing students' concept of design

Less than half of the students' associate design with both form and functionality, according to queries made during the students' second and fourth semester. Approximately 40% of the students associate design solely with appearance. When comparing students in the two focus groups, only small differences are noted.

In average, the students would prefer approximately 50% of their education to be focused on what they define as design; sketching, visual thinking, theoretical and applied aesthetics, interaction of color, perception etc. When comparing students in the two focus groups, only small differences are noted.

More than half of the students choose their preferred future professional title as design engineer in favor of mechanical engineer or industrial designer. In this choice the students are made aware of the fact that by choosing the title of design engineer, this implies that the students will be less competent in areas such as mechanical engineering, mathematics and physics in favor for courses in design-related areas.

The fourth study shows that when choosing their individual specialization less than 20% of the students choose specializations that focus more on technical aspects and less (if at all) on design-related areas.

# 4 Coaching students into the concept of design

## 4.1 The program of design and product realization at KTH

To be able to assess the coaching of students, the learning activities during the education in design and product realization must be known. The new program has had several goals that should be fulfilled in practice. Some of the most important goals are the following:

- A holistic view on subjects is important in design engineering, meaning that industrial design, engineering design and industrial production should be treated as aspects of the same subject. (Also life cycle and economical aspects of products must be included at a certain point.)

- Theory will be learned alternately with practice.

- Professional engineers will be able to collaborate within and between different disciplines. They will be autonomous in making work progress, and creative and inspiring in an environment where development work takes place (compare the influences from the CDIO initiative).

These goals are comprised by the program goal, as presented in the introduction.

In order to support the goals of a holistic view, alternating theory and practice and vocational training the students meet the subject of Design and product realization from their first day at KTH. During their first semester they take a course in the subject that provide insights into the different sub subjects and tools they will meet and train during their education. They also conduct a product development project. This course is called Perspectives on design and product realization.

After their first year they meet a block of three courses holding sub subjects as industrial design, engineering design and industrial production. This block of courses encompasses 27 ECTS credits.

The three courses will focus on different subjects, though there are several common elements and objectives in the courses. The first course (6 ECTS credits) focus on industrial design related to users, usage and production systems. Sketching and building models that visualize form and aesthetics is thoroughly trained. In the second course (12 ECTS credits) focus is on engineering principles, selecting and giving dimensions to product components. Also production principles are further focused and sketching is trained. The course takes departure in a product analysis, meaning that students disseminate a physical product and relate calculations and analysis to this product. The third course (9 ECTS credits) is a project course with a focus on product synthesis. Giving shape and analyzing technical features is further trained, however the major part of the course is a product development project including training on project planning and organization of development activities as well as team work.

Smaller projects will be conducted in all courses, in the sense of goal-oriented commissions with clear time limits.

An important principle in the courses is that there will not be an exact quantity of e.g. any machine elements included in the course block. Rather than teaching a quantity of machine elements, the students should learn to understand the technical principles of a few and how to select and give dimensions to them. The ability to seek the facts of machine elements is more important than that of presenting facts without a certain context at a given occasion. Consequently, the principle is taken in order to enhance deep learning. The same principle is directly comparable to production methods for which the sequence described above is central.

In the end of the second year students select Master’s programs. Students within the Design and product realization program can choose from a variety of Master’s programs and are guaranteed a place within four programs: Industrial design, Integrated product development, Mechatronics and Industrial production. The Master’s program includes specific courses, an intermediate thesis project and a master’s thesis that differ between Master’s programs. The intermediate thesis project will include training in modeling and simulation of products (also the computer tools) as well as an individual work in the specific subject field.

As stated before the CDIO syllabus has supported the course development in the new program. In figure 5 the introduction and training of certain skills are illustrated and how these are divided between the different courses, according to the CDIO syllabus [11].

| Course / Skill | Perspectives on D&P | D&P A | D&P B | D&P C | Intermediate thesis project |
|---|---|---|---|---|---|
| Analyze technical solutions | ● | ● | ◉ | ⊚ | |
| Team work | ● | ◉ | ◉ | ◉ | |
| Written presentations | ● | X | X | ◉ | ⊚ |
| Oral presentations | ● | X | X | ◉ | ⊚ |
| Sketching | ● | ◉ | ◉ | ◉ | |
| Etc. | | | | | |

● Introduced ◉ trained ⊚ ability requested X occurs unspecified

Figure 5. The table in the figure describes how different parameters of an engineering competence is progressively trained in different courses in the Design and Product Realization program

# 5 Students' change of preference

In February 2005 all students in both focus groups were again asked the same questions as in 2003 and 2004. In this section a comparison will be made between the answers given by the students during the first intervention (in 2003 for the P03 focus group and in 2004 for the P04 focus group) and the second intervention (2005).

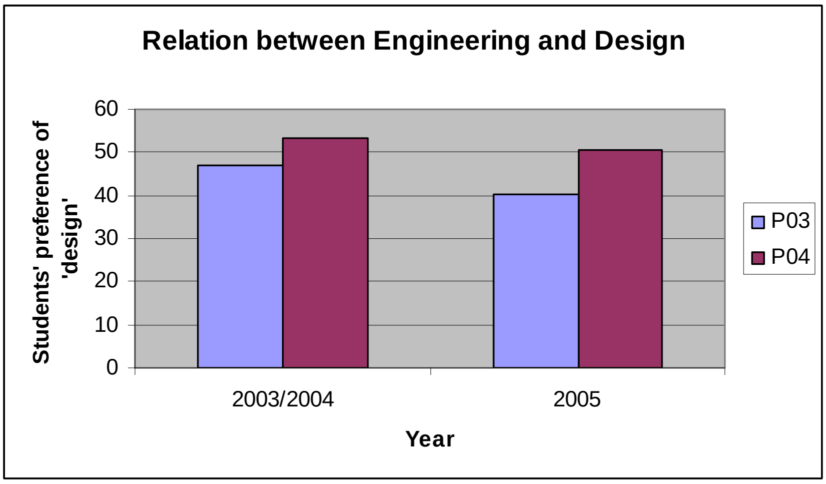


Figure 6. Students' preferred division between engineering-related areas of study and design-related areas (according to the students' own definitions of design). The figure illustrates the difference in this division between two measurements; between the students first semester (September 2003 for the P03 group and September 2004 for the P04 group) and February 2005.

When again asked to quantify how much of the education they would like to be focused on design (according to the students' own definition of design) respectively engineering, both focus groups showed a move from design towards engineering. The P03 focus group had changed from 47% to 40%, and the P04 focus group from 53% to 50%. The change in the P03 group had happened during the time from October 2003 to February 2005 and the change in the P04 group from October 2004 to February 2005.

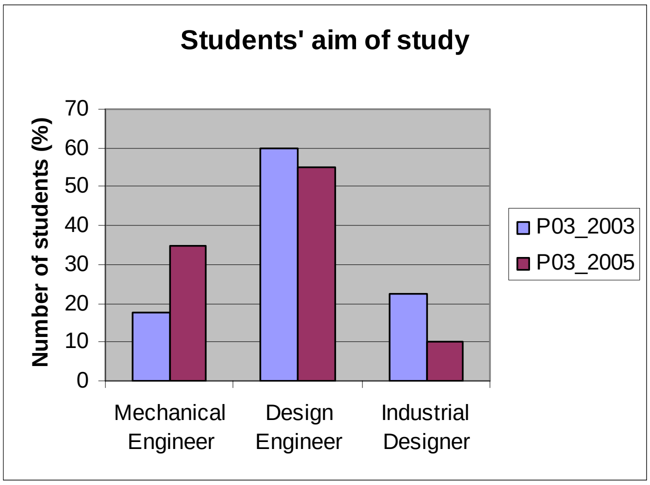


Figure 7. Students' preferred choice of professional title as graduates. The figure shows the change that has taken place within the P03 group between the two measurements, from September 2003 to February 2005

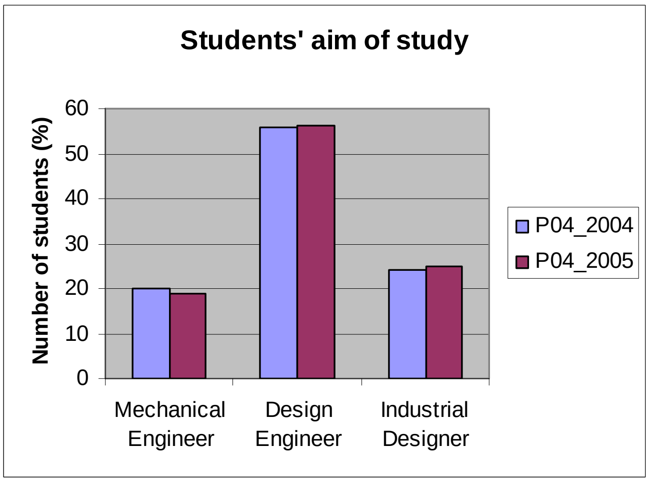


Figure 8. Students' preferred choice of professional title as graduates. The figure shows the change that has taken place within the P04 group between the two measurements, from September 2004 to February 2005

When studying the change in the students' view of the educational program the students were once again asked to choose which professional title they would prefer to hold after completing their education. The P03 focus group showed a considerable change. Fewer students expected to become industrial designers, and there was also a considerable move from becoming design engineers to becoming mechanical engineers. In the P04 focus group no change was seen at all. Apparently, the change in the students' expectations required the longer time period of the P03 focus group.

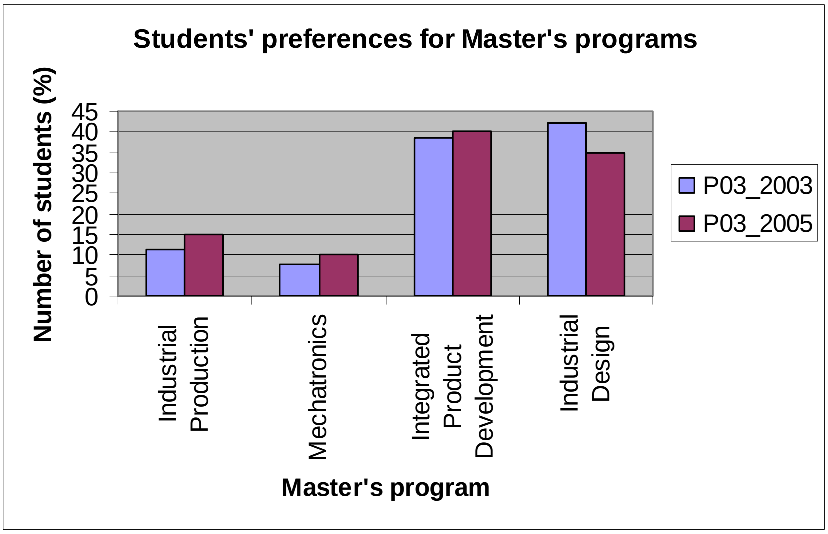


Figure 9. Students’ preliminary choices of master’s programs. The figure shows the change that has taken place within the P03 group between the two measurements, from September 2003 to February 2005

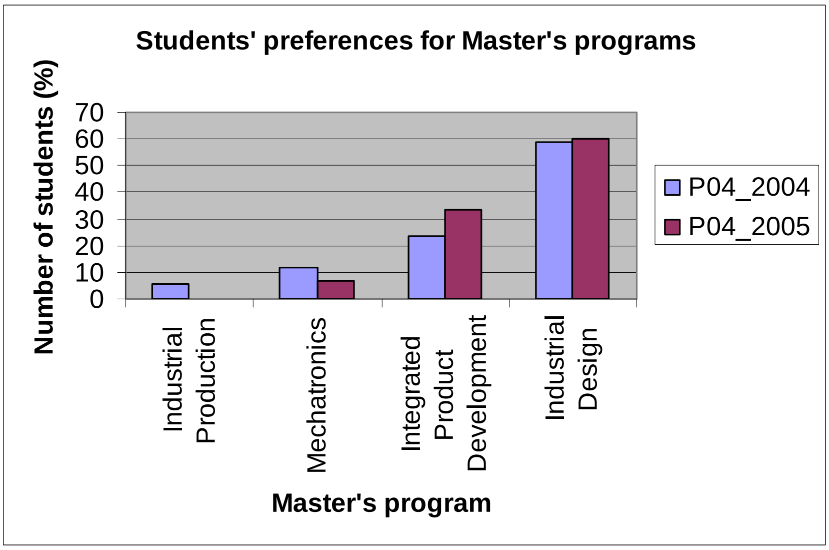


Figure 10. Students’ preliminary choices of master’s programs. The figure shows the change that has taken place within the P04 group between the two measurements, from September 2004 to February 2005

A similar analysis can be made in relation to the second study of the students’ preference for Master’s programs. The P03 focus group showed a move from Industrial design towards the other three programs, with the largest increase in the two programs that do not include any courses or aspects that relate to the areas defined as design by the students. The P04 focus group did not show this trend, the number of students aiming for the industrial design program remained constant, however some students changed between the other three programs.

# 6 Discussion

When comparing the results from the three different measurements, the following conclusions and observations can be made:

The two focus groups are showing similar results, when comparing the results from both groups first semesters. The conclusion is that both groups have a similar definition of the concept of design, and similar expectancies. Some differences are shown when comparing both groups' preferences for Master's programs. Probably the two groups received different information regarding the Master's programs, particularly since these were not established during the first groups first semester, which could account for this difference.

When comparing the results from the P03 group's first and fourth semester a slight change in student focus; from 'design' to 'engineering' can be identified. This change is also noted with the P04 group, but considerably less with the latter group than the former. The most probable reason for this is the fact that the P03 group had spent one and a half year between these measurements while the P04 group spent only a half year.

When comparing the results from the student choices of professional title, a considerable difference is noted between the two groups. The P04 group does not show any difference between the two measurements, but the P03 have changed considerably, from 'industrial designer' and 'design engineer' to 'mechanical engineer'. The conclusions from these measurements is that the students keep their preferred choice of professional title during the first one and a half semester, but several students change their choice between this time period and the fourth semester. A similar conclusion can be made from studying the students' preference for Master's programs. The program of industrial design attract an equal number of students in the P04 group on the two interventions, but when comparing the P03 results from the first and the fourth semester, the P03 students opting for industrial design is decreasing.

When analyzing the statistical data one final factor must be taken into account; that some students drop out between the interventions. According to our statistical data approximately 15% of the students in the P03 group dropped out between the first and the fourth semester. In the P04 group approximately 20% of the students dropped out between the first and the second semester.

One further explanation to the change in the students' concept of design would be that the students who dropped out of the program had a definition of design and different views and expectations than the majority of the groups, which could account for the differences between the measurements. There is no ethical way of removing the dropped out students from the measurements performed during the first respective semesters and we would instead argue for the following:

Primarily it is considered irrelevant whether the students who dropped out changed the average conception since the study shows that the common or average conception has changed, and the relevant issue is that this happened. Whether this is caused by the drop outs or by the teaching efforts would have to be investigated in another study. However, some signs points toward the idea that the drop outs should be considered average in their understanding, preference and view. For example, in the P04 group extremely small variations are noted between the first and the second semester regarding the students' choice of professional title. 20% of the students dropped out between these measurements, and since the average choice did not change, the students who dropped out could be considered being in average as a group. Also, the number of drop outs is larger in the P04 group than the P03 group which further motivates this since the change in the P03 group is considerably larger than in the P04 group.

# 7 Conclusions

This paper presents results from a study of students' definition of the concept of design, and a hypothesized connection between the teaching efforts provided by the faculty and an identified change in the students' understanding of the concept, choice of study and preference of Master's program. The majority of the students accepted for the first year showed large discrepancies between their expectations of the program and the actual program, and a majority of the students defined design as purely aesthetics.

However, when comparing the results from the first semester with results from the second and fourth semester, the students' attitudes are changing – slightly in some areas and considerably in others. The interest for industrial design is diminishing in favour for mechanical engineering for example. We believe that the effect of the educational efforts is that the students' concept of design is approaching the traditional academic definitions, and that the students appreciate this definition as their preferred future professional role.

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