AC 2011-1864: DESIGNING A NEW EVENLY BALANCED CURRICULUM FOR A CO-OP AUTOMOTIVE ENGINEERING BACHELOR'S DEGREE PROGRAM

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Abstract

The study for a "diploma" degree in the department of Automotive Engineering has been a well established and internationally recognized degree program for years. However, due to the Bologna Declaration of 2000 and new university regulations we are obliged to design a new curriculum for an Automotive Engineering Bachelor's degree program. The main challenge involved was to guarantee the quality of education as well as knowledge sustainability, despite a reduction in available education time. In particular, the implementation of the co-op kernel - the development of a new Project Based Learning program - led to completely new design approach due to the impact of the new regulations in light of the Bologna Accord. Industrial, political and academic expectations were in many cases very contradictory and the price of their harmonization was a hard compromise.

In this work, we describe the necessity of specific subjects which are taught in a defined order, which correlates to the demands placed on future automotive engineers by industry.

Our paper presents the development process, the design criteria and some methods of quality assurance in engineering education. The cornerstones were the bachelor's degree qualification profile, the knowledge sustainability and the curriculum structure.

Very new and important findings were the investigations results of the needs, acceptance and coherence analysis as well as the acceptance test analysis results.

Introduction

Technological progress in the automotive industry has gathered pace quickly in the last two decades. A stress field has been created in the area of higher engineering education due to engineering and material innovations and system complexity on the one hand, and the increased necessity to shorten development periods and cheapen production on the other hand. Companies expect the most well prepared young engineers who are aware of the solid theoretical fundamentals, have project experience and can use the latest tools – both hardware and software. They should also be fluent in a foreign language and international experience is most welcome.

At the same time, governmental higher education funding has not been matched to the new requirements and due to the influence of the Bologna Accord, undergraduate study time has been reduced by one year (an engineering bachelor study in Austria will now take six semesters, instead of eight). The industrial needs analysis (which will be discussed later in this paper in more detail) has shown that three-year engineering degrees only allow their recipients to operate on a small scale – e.g. as test bed operators or assistants, but not in the engineering arena. Therefore, the career opportunities for graduate engineers with a Bachelor's degree (of only three years) are obviously restricted.
For this reason, we decided to design an evenly balanced Bachelor's degree program as a proper foundation to a Master's degree program.

The curriculum development process and design criteria

When starting the development process, we moved away from the well established four-year diploma degree program and begun designing a completely new, evenly balanced co-operative Bachelor's degree program (3 years) to be complimented by a subsequent Master's degree program (2 years).

The main stages were:

- Performing the needs, coherence and acceptance analyses
- Definition of the qualification and profession profiles
- Definition of the most important admission requirements and regulations
- Curriculum design
- Definition of the didactic concept
- Finance calculations

The main design focal points were the degree program content, the program structure, the course balance (theoretical vs. practical), the co-operative component (interaction with the industry), the didactic concept, and knowledge sustainability. The main challenge when planning the subsequent two-year Master's degree program in automotive engineering was that we needed a Master's degree which was perfectly coordinated to the Bachelor's degree, while still synchronous to other, similar undergraduate degree programs. For this reason, we performed a so-called "coherence analysis" which will be discussed later in this paper.

One of the main problems on our diploma degree course was the relatively low persistence rate (c. 70%) and because of a "numerus clausus", we had to perform an admissions test. The selection ratio in the last two years has been 1.5:1; however, during the five years previously, it was 2:1.

The development process for our new undergraduate curriculum was determined in advance by the Austrian Council of the Universities of Applied Sciences[1] (ACUAS). In its directives, ACUAS requires:

- Nomination of a design and development team with at least four members
- Nomination of a chairperson to lead the degree program
- Letter of finance guarantee from the state government
- Needs, coherence and acceptance analyses
- Application for approval of the degree program

Additionally, we performed several meetings with:

- students and alumni,
- external lecturers and industrial partners,
- representatives of ACUAS, and
- potential applicants.

[1] Austrian Council of the Universities of Applied Sciences, ACUAS, (orig. Österreichischer Fachhoschschulrat)

We carried out four surveys and discussed and examined the information and statistics collected. The conclusions were very illuminating and even somewhat surprising for us.
For example, the alumni require much more in terms of theoretical basics and more social competence is expected from graduates. As predicted, our industrial partners are looking for project experience and a mastery of state-of-the-art technical and technological tools as well as excellent English (as an absolute minimum). Potential applicants recognize the advantages of a co-op education and expect, at the same time, the Bachelor's curriculum to be evenly balanced between theoretical and practical elements.

Design and development team

The main task of the design and development team (DDT) was to determine the curriculum and to guarantee the co-operative nature and quality of the degree program. The DDT had to have a chair and three other members at least. It was self-evident that all DDT-members hold a PhD and a minimum of two of them were involved in teaching in the degree program.

The task of the DDT chair[2] was to select the DDT-members. In order to form the most qualified DDT for a co-operative degree program possible, it was very important to invite persons who were highly experienced in industrial and academic terms, who understood the nature of the universities of applied sciences, and who were involved either in automotive engineering or in development of academic degree programs. The main problem in selecting such a team was that the representatives of the industrial and academic fields often had completely different requirements for, and associations with, what they perceived as an engineer's Bachelor's level qualification. In spite of the risk of a conflict of interests of the various fields involved, following DDT was selected:

- The authorized officer of the world biggest private company for automotive engine development
- The education & research director of one of the biggest automotive suppliers worldwide
- The head of the automotive institute at a technical university
- A member of the Austrian Academy of Sciences, whose main research focus was on sustainable development
- An university professor, one of the authors of the first Austrian UASL[3]
- An external lecturer from industry - product executive for automotive engines - who has taught for more than 10 years in our department
- An internal department professor, who has taught for more than ten years in our department and also teaches at a foreign university

The benefits of this DDT configuration were: wide diversity, a very high level of professional experience, and a firm belief in academic education.

Due to the extremely high complexity of the task, the DDT authorized the departmental staff council with the curriculum development and reduced its work to supervising the design process and final control. This decision was justified because

[2] One of the authors was chair of the DDT.
[3] UASL – University of Applied Sciences Low

two of the seven DDT members (the chair and a professor) were directly involved in the design process.

The DDT provided two meetings. In the first, the qualification profile was discussed, as were the potential occupational fields and the main pillars of the curriculum. The chair presented the essential requirements, the restrictions and the financial specifications. The DDT also discussed the first version of the curriculum draft and made a list of recommendations. In the following 80 days, the departmental academic council analyzed the needs, coherence and acceptance investigations, defined the course subject content in detail, determined the acceptance procedure and the admission standards, as well as developed the didactic and co-operative concepts. In its second meeting the DDT verified and confirmed the final version of the curriculum.

Needs, coherence and acceptance analyses

A very important step in the design process was the needs, coherence and acceptance analyses procedure.

In the needs analysis, we collected information from automotive industry companies and public institutions. For this purpose, we surveyed the extended departmental academic council (33 responses from 24 engineers as external lecturers, 9 university lecturers) and our alumni (41 responses). The survey included 10 questions regarding a graduate automotive engineer's most important characteristics, the most essential components for the curriculum, the minimum duration for Bachelor's and Master's degrees, etc. We collected and evaluated the data[4] and reflected the results in our Bachelor's and Master's degree programs design.

The salient points were that we needed an undergraduate curriculum which focused on technical and technological basics (mechanics and electronics), automotive engineering disciplines, soft skills, including at least one foreign language (English), and a large practical component. Neither the industry nor the alumni expected that Bachelor's degree graduates would be able to operate in research and development. Instead, they would act as assistants, laboratory or test bed supervisors, or designers; to be responsible for technical documentation or customer care. Only a Master's degree would qualify them to become fully fledged engineers who could bear project responsibility and work autonomously on new technological research and development.

Two further questions were also significant in the design of the new curricula:
- How important and useful was the knowledge gained in a diploma degree of study for the graduates when starting their career?
- How important and useful was the knowledge gained in a diploma degree of study for the engineers later, in their current position?

Figure 1 shows that 59% of alumni answered in the first question with “very relevant”, 24% “relevant”, and 17% “less relevant”. No one answered second question with “very relevant”, but 63% “relevant” and 37% “less relevant”. The reason for this is obviously due to the fundamentals, as well as the specialized knowledge and the basic project skills that our students learned during their studies, which helped them

[4] Planned for future publication.

to establish themselves and in many cases positively distinguished them from other employees when first starting their employment. At later points in their careers, these engineers required additional knowledge and skills to those taught in the diploma course of studies.

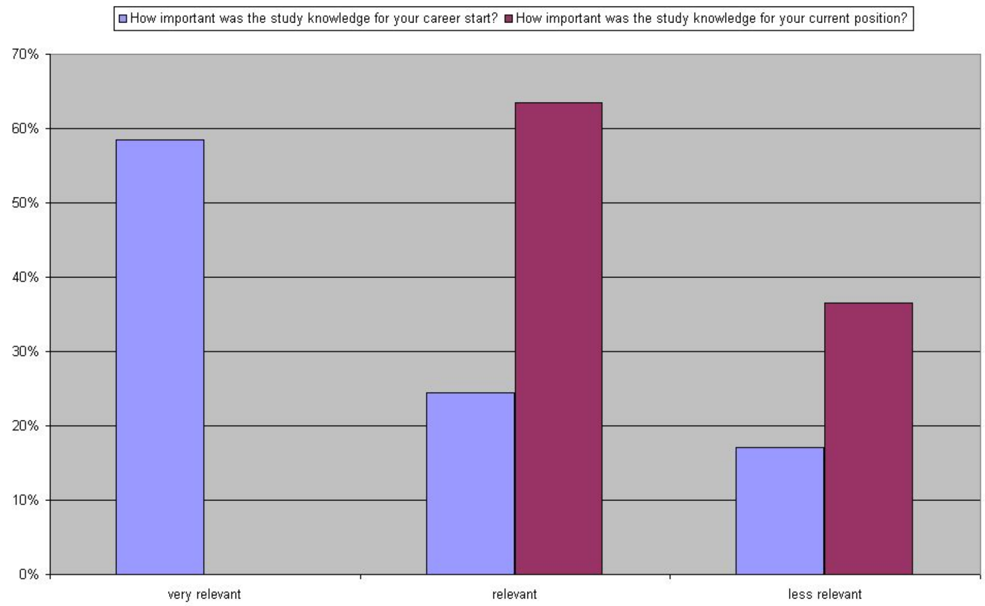

Figure 1: Study knowledge relevance; possible answers: 3=very relevant, 2=relevant; 1=less relevant

Overall, our interpretation of the survey results is that our diploma degree alumni were well prepared for their professional life. In the same survey the alumni commented that the diploma degree program was well balanced in theory and practice, as well as in technological and economic subjects.

Independent of the surveys, we asked the personnel officers of our most important industrial partner companies, as well as the CEO of the Austrian Association of Automotive Industry (AAAI), to send us formal recommendations for the new degree programs. In these documents, they summarized their impressions from the quality of our course of study and alumni[5].

Based on our experience, the survey conclusions and the formal recommendations, we decided to expand the fundamentals, to intensify English as foreign language, and to make the practical components obligatory (see also the next point “Main curriculum focal points”).

The coherence analysis contained an evaluation of more than 30 other Bachelor’s and Master’s degree programs in Austria, Germany, and other European countries. We did not appraise degree programs outside of Europe because the educational systems (i.e. in North America or Japan) differ too much from ours. We have found that, in spite of Bologna Accord, such Bachelor’s degree programs differ extremely. Most of them include a large amount of theoretical and technological fundamentals in the undergraduate studies but less applied and practical courses. Very few offer

[5] In 2010 500 personnel officers in an external independent survey nominated our diploma degree study as the very best in Austria.

foreign languages, and then only as an optional subject. Furthermore, our automotive engineering degree program is unique in Austria; there are very few universities in Europe that offer undergraduate degree programs in automotive engineering – most of them start as a Bachelor's in mechanical engineering and specialize in automotive engineering in the Master's degree. Therefore, drawing parallels between degree programs was difficult, but at the same time encouraging.

The acceptance analysis was based on statistical data regarding the progression and regression of applicant interest. We measured this using the applicant numbers from the last 6 years. Due to the 'numerus clausus' and the university of applied sciences regulations, we are obliged to accept all candidates if the applicant number is less than our total number of available study places. Therefore, we are keen to have as many as possible enrollees. However, a larger number of applicants is not a guarantee for quality although the probability of increased quality does rise.
The number of enrollees and the quality of knowledge they bring with them when they begin their studies, correlate significantly to their study success (see also the point "Some ideas on how to raise persistence rates" later in this paper). Here we would just like to note that the number of applicants has dropped in the last years few years, as have the knowledge levels they bring with them. The main challenge will be to deal with this situation while satisfying the rising requirements of industry and society

Main curriculum focal points

For the purposes of increased clarity and comparability, we have defined five general subject categories: technical basics (TB), engineering subjects (ES), management and soft skills (MS), language education (LE) and project work (co-ops, labs, etc.) (PW), as can be seen in Figure 2. The pie-chart demonstrates that we have achieved a satisfying balance between the fundamentals, engineering and continuative/practical subjects.

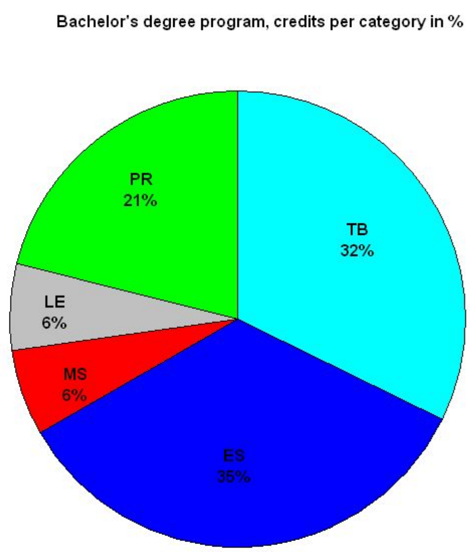

Figure 2: Credits distribution. TB- technical basics; ES – engineering subjects; MS – management and soft skills; LE – language education; PR – project and practical work (co-op).

To further improve transparency, we have reorganized the subject succession illustration into 6 new classes, which represent it with much more regard to content, see Figure 3. The numbers represent the semesters (1-6) and the abbreviations are explained in the foot-legend.

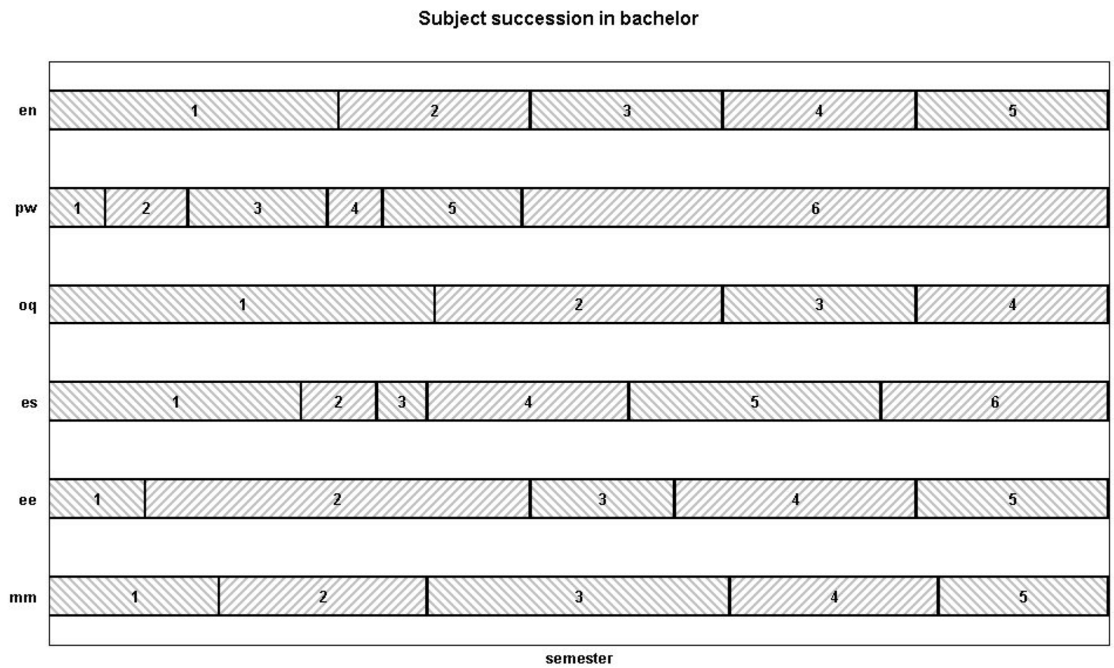

Figure 3: Subject succession: en-English; pw-project work and co-op; oq-overall qualification; es-engineering subjects; ee-electrics/electronics/software; mm-math, mechanics, thermodynamics, fluid mechanics.

It is evident that we have established continuity in education by providing project work and co-operative courses as well as engineering courses from the first to the last semester.

The most important change in the didactic concept, while designing the new curricula, was that we reduced the compulsory attendance and enlarged the autonomous work component – by approximately 20% in the mean. We expect that by modernizing and refreshing the didactic concept, we will improve the learning quality and will increase the persistence rate.

Central elements of our didactic concept are:

- the learning process,
- the teaching and learning forms, and
- the task and the role of the lecturers.

The main objective, and at same time the main challenge, was supporting the students to think and to act autonomously, to be able to work in a team, to be able to identify dogmatic statements, to be tolerant and to co-operate. Young engineers are learners and creators at the same time: they should actively participate in the educational process to prepare themselves for professional life. Our aim is to achieve the highest possible knowledge sustainability and system understanding.

To further improve our didactic methods, we have also carried out investigations into “multiple intelligences” The purpose of these investigations was to identify the students’ preferred learning styles and strong intelligences according to the theory put forward by Howard Gardner in 1983 and 1999. According to this theory, an individual displays varying capabilities in each of the eight intelligences: mathematical-logical, linguistic, kinaesthetic-bodily, musical, naturalistic, interpersonal, intrapersonal and visual-spatial. (3)

These preferred learning styles could be accessed by means of a survey and results were collated according to year group over a period of five years. The results demonstrate that students selecting the automotive engineering diploma degree program generally share similar strengths and weaknesses and therefore a preferred learning style profile. This has been shown to be consistent not only within each year group tested, but, within certain degrees of tolerance, also across all five year groups of students tested to date (further testing is ongoing). As the main intelligences preferred by the students were shown to be interpersonal, mathematical-logical and kinaesthetic-bodily, a learning preference has been defined, which involved elements such as team-work (interpersonal), “hands-on” approaches to learning (kinaesthetic-bodily) and logical reasoning and problem solving (mathematical-logical), (4), (5).

Clearly based on this evidence, we decided to continue with the practice of Project Based Learning and to apply our 3-phase-multi-subject PBL concept, (6), (7), (8). Of course, we also reflected on our experiences of the last 13 years and have adapted concepts to the new curricula.

In contrast to the diploma degree program, we have already implemented project courses in the first semester and facilitated co-op work from the third semester onwards; the co-operative internship (12 weeks) is obligatory. All together the labs, projects and the internship in the last year of undergraduate study account for 26 ECTS points, see Figure 4.

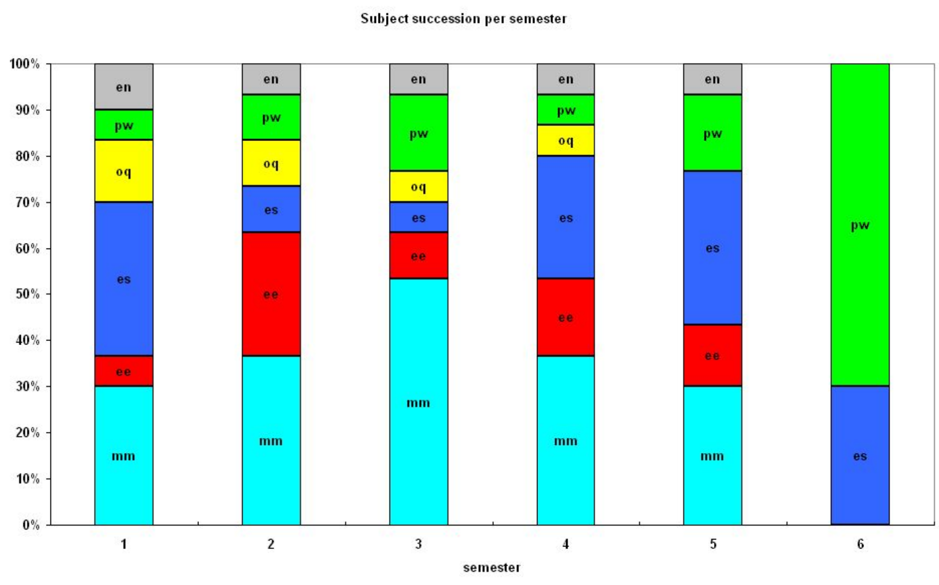

Figure 4: Subject succession per semester in Bachelor: en-English; pw-project work and co-op; oq=overall qualification; es-engineering subjects; ee-electrics/electronics/software; mm-math, mechanics, thermodynamics, fluid mechanics.

Some ideas on how to raise persistence rates

One of the main problems at universities of applied sciences is that students have to finish the degree program in a short, predefined time. In Austria, all Bachelor's degree programs must take only 6 semesters (even those of engineering). Students may repeat a year of study once during the course and in exceptional cases extend their studies by one semester. The lecture schedule is generally predefined and all exams in the current semester must be successfully passed before the end of the subsequent semester. These very rigorous stipulations (determined by university of applied sciences regulations) are contradictory to the level of preparation our freshmen arrive with from secondary education.

The educational system of our country permits a great number of different opportunities to qualify for university entrance, which are not really coordinated – it is possible to gain high school leaving certificates from a general high-school as well as from a high-school that specializes in technical areas (e.g. mechanical engineering), economics, arts, sports, as well as many other fields. Furthermore, each secondary level school and even each teacher, i.e. in mathematics or physics, can individually select the subject's focal points (in their curriculum). In addition, most of candidates have waited for a year at least before applying for the engineering degree program (due to obligatory national service); and yet others come from other countries. By law, we are not allowed to test secondary school knowledge in our admissions test which mainly consists of a written test, proving the ability to solve some easy problems. There is also a personal interview. Our 15 years of experience show that the freshmen have very varied knowledge levels of the basics, and that these levels are unfortunately declining. We have found that it is very difficult, if not in many cases impossible, to close these knowledge gaps during such a short period of study, and a many students do not persist.

We evaluated all 195 freshmen admissions test results between 2006-2008. Figure 5 shows that c. 78% of non-persisters scored less than 60% on the admissions test. All of the drop-outs who scored less than 50%, left the course of study in the first year because of poor exam results (although it is hard to say if the reasons were due to knowledge deficiency or a lack of motivation to learn). Overall, approximately 60% of the non-persisters left because they thought that the study program was too difficult, additionally claiming, too little time was left available to enjoy life. Most of them selected other, non-engineering degree programs, or started degree programs at universities with an open-ended period of time permitted to complete their studies.

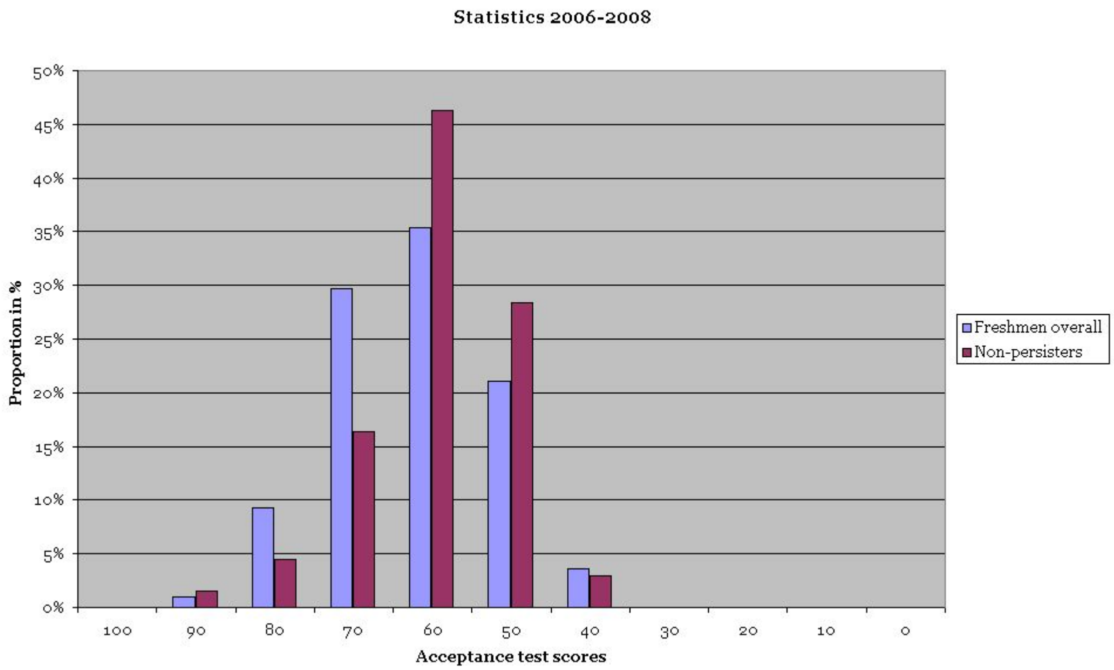

Figure 5: Relation between the admission test scores and proportion of persistence

In (1), the authors suggest that leaving engineering educational fields is usually not a result of poor preparation or conceptual difficulty, but instead, the incitement not to persist is more influenced by the reasons they originally chose the degree program. Our investigations[6] have shown that, as well as persistence in the first semester of study, motivation is a very strong factor relating to the selection of engineering as a topic, but is not enough to guarantee success throughout the complete study course. Knowledge gaps from secondary education, inability to work autonomously, low stamina, and insufficient specialized capabilities (intelligences) are definitely the main reasons for students dropping out of their studies. A decrease in or a complete absence of motivation might also be one of the key reasons for leaving the engineering degree program, but not the main factor.

Several years ago our department offered a so-called “warm-up” course in math. This course began in September, some weeks before the academic year began in October. We decided to closedown this countermeasure because we could not perceive any relevant positive effects in terms of cost-result ratio.
In 2010, our university once again decided to offer such a course. As expected, the results were not very promising, see Figure 6. Two weeks after the course had been completed; all university freshmen (the warm-up participants as well as the non-participants) took an anonymous self-evaluation test, which included 20 mathematical questions related to the topics treated in the warm-up course.

Figure 6 shows that the impact of warm-up course was not significant. It is also important to point out that 2/3 of the warm-up participants scored above average on the admissions test. Although the admissions test does not include mathematical tasks, this picture indicates that the “better” freshmen are much more motivated to

[6] Planned for future publication.

improve, they will apply for additional courses, and the warm-up course did not enhance the math level.

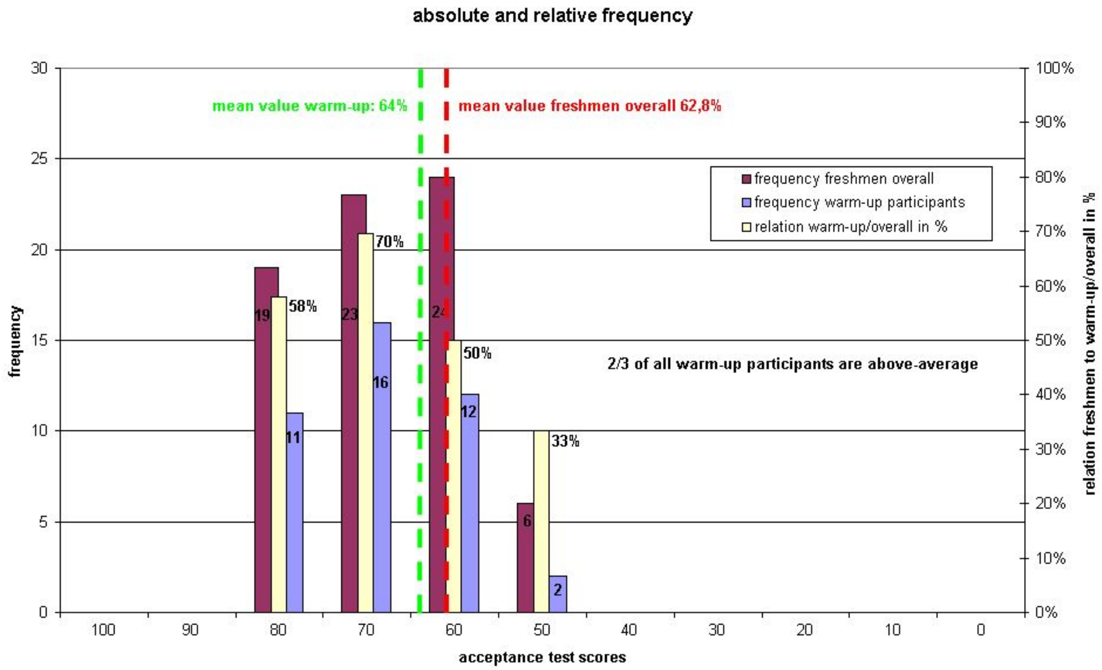

Figure 6: Results of the anonymous self-evaluation test of our freshmen

Therefore, to better adapt freshmen knowledge level in the relevant natural sciences (physics and chemistry) and math, we decided to offer three special, introduction courses in the first semester of the Bachelor's degree: "Selected Math Topics" with 3 credit points, "Fundamentals of Natural Sciences" with 6 credit points, and "Informatics" with 2 credit points. All together, these make up approximately. 30% of all credit points (CP) in the first semester. We intend to bring the freshmen's basic knowledge more into line with a higher standard level. We also expect that by examining the area of applied mathematics and applied natural sciences more closely, freshmen motivation will be boosted as will their desire to understand the objectives and goals of the engineering degree.

Conclusions

Our main objectives designing the new Bachelor's degree program were to guarantee the quality of education as well as knowledge sustainability. We believe that we have achieved these aims as our curriculum is well balanced in both theoretical and practical subjects. We have expanded the laboratory and co-operative areas, as well as the foreign language subject contingent.
The challenge involved in balancing the contradictory requirements of politics and financial limitations on the one hand, and industry and academic fields on the other, was accomplished through an increased harmonization of the learning subjects across all semesters of the degree program and an optimization of didactic methods.

In this work, we described the necessity of implementing specific subjects into the degree program in an effort to increase the persistence rate and to better prepare the freshmen for the coming semesters of study. We believe that student awareness of the requisite fundamental knowledge will decrease their personal uncertainties and sustain their motivation.

We also presented the development process and the design criteria. One of the cornerstones was the quality assurance concerning the definition of the graduate's qualification profile, the main points required and the efficiency of study. For this reason we carried out several surveys which were evaluated and the results were incorporated in the design process. Furthermore, a design and a development team supervised and verified the degree program.

In our opinion, we have designed a modern, attractive Bachelor's degree program, which is both needs and future oriented. The graduates will be able to proceed in their studies to a Master's degree program, either continuing in our department or selecting an alternative external course. They would also be equipped to start a successful professional career. Over the coming years, we plan to verify the concept and continually reflect on this automotive engineering education concept.

Acknowledgments

The authors extend warm thanks to the departmental staff council and especially Günter Bischof for processing and summarizing the demand, coherence and acceptance analysis; to the DDT; to our industrial partners and finally to all students and external lecturers who have supported us graciously with significant and highly useful information and statements.

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