AC 2010-1520: PRAXIS-ORIENTED ENGINEERING EDUCATION IN VEHICLE TECHNOLOGY STUDIES - CHALLENGES AND SOLUTIONS

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Praxis-Oriented Engineering Education in Vehicle Technology Studies - Challenges and Solutions

Abstract

Universities of applied sciences have to fulfil two main requirements: They should provide praxis-oriented education *and* engage in applied research and development .

The approach used to meet these requirements at our department of Vehicle Technology can be described by a three-pillar model.

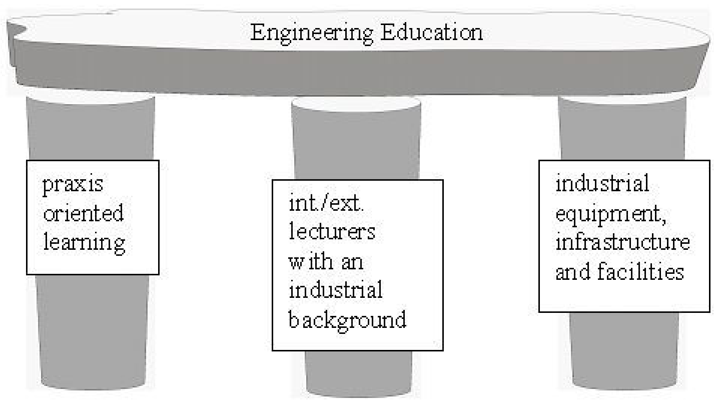

Figure 1: Three-pillar model

Praxis-oriented learning includes project and problem based learning, as well as a focus on the application of theories and methods learned in core engineering subjects (i.e. mathematics, mechanics, electrics). The main challenges are the coordination of the lectures with regard to content and timing, and lecturers' motivation. Furthermore, project and problem based learning demands much more time in terms of supervision than standard lectures. Involving students in industrial projects is not without risks and we have to ensure that such projects are completed to the satisfaction of our partners in industry.

All departmental staff who teaches engineering subjects is required to have at least 3 years of industrial experience. 82% of all lecturers are external and work directly in the automotive, in the railway industries or in research institutes. The benefit for the students is that particularly these external lecturers give regular input on topics and practices which are state-of-the-art. This contact between undergraduate engineering students and professionals from industry is very important but it also creates additional work such as the coordination of timetables, didactical methods and course materials. Moreover, we have to harmonize assessment criteria and standards with the objective of identifying the correlations and incongruities between academic and industrial requirements.

Access to professional equipment, combined with good infrastructure and facilities, provides an excellent basis for quality in engineering education. The usage of modern instruments and test beds, for example, greatly motivates students as well as lecturers and facilitates a smooth transition from university to industry for the graduates. All investments and services should be financed by the department itself and, therefore, we are asked to share resources at all levels. The close interdependence between our education and R&D activities is one of our trademarks, but poses a further set of challenges in which confidentially issues, strict project deadlines, adherence to norms and standards, and occasional shortages in terms of personnel and structural resources all play a role.

This paper presents some of the structures and methods developed in order to tackle these multiple challenges, and thus ensure optimal interaction between praxis-oriented education and applied research and development.

Introduction

As a department at the University of Applied Sciences our task is to provide a degree program which acts like a bridge between secondary level education and the professional field of vehicle technology. As described in ([8]), attracting students to enroll in engineering programs is a challenge in itself, but retaining these students *and* matching the needs of industry and society raises further challenges.

One of the main problems is that our freshmen have quite different levels of basic knowledge, even if all of them fulfill the formal requirements, have passed the entrance test, successfully completed a personal interview, and qualified to enroll. Because of a numerus clausus and a selection ratio of at least 2:1 (number of candidates: study places) we could assume that all freshmen come with a similar level of background knowledge, are dedicated and highly motivated to study their chosen discipline. Unfortunately, the reality is different. The level of knowledge of mathematics, and indeed general knowledge, appears to be decreasing rapidly with each generation. In secondary schools, teachers apply teaching and assessment methods that do not prepare the young people for higher education, self responsibility, holistic thinking, and autonomous work. Furthermore, the students' motivation seems to have mutated to a kind of trial-and-error behavior. This may be because there are no tuition fees and student grants are guaranteed even after switching majors and/or third-level institutions.
The costs of marketing and student support (among others) are rising permanently, but are not matched by equivalent increases in government funding.
Additionally, our partners – industry, other academic and research institutions, public service, etc. – expect that enough highly-educated, well-trained young engineers graduate each year to meet the needs of the vehicle technology market.

In this context, we are in an area of conflict – we have to deliver consistently high quality, while experiencing worsening conditions and rising costs.

In addition to implementing innovative teaching methods and providing an optimum balance between theoretical and practical lessons (seminars, labs, etc.) as well as modern infrastructure, intensive interaction with partners in industry and research, we carry out intensive marketing of our degree program, projects and supervision system to attract the best candidates.

Discrepancies in basic knowledge levels

More than three-quarters of all students who enroll in the degree program of Vehicle Technology are younger than 24, and the half of them start studying straight after finishing

high school (Figure 1)[1]. Most of them are interested in studying automotive engineering because of a passion for cars, and in the past few years they are also appear to be motivated by the dream of designing new technology for higher sustainability and safety. Most enrollees have little or no industrial/work experience. Some of them have insufficient knowledge of or even a romantic notion about engineering studies and engineering as a profession.
Our degree program is unique in the country and as a 4-year undergraduate program unique in a wide area of Europe. Therefore, we have a high number of candidates and can select from a pool at least twice the size of the number of actual study places. But are the freshmen really dedicated, truly motivated and well informed about the workload entailed in gaining an engineering degree (see also Figure 6)? Do they have the necessary endurance, strength of purpose, team spirit and essential interest in science and engineering combined with simple common sense? Unfortunately, a lot of them do not. In spite of the rigorous selection procedure, we have a relatively high drop-out quota (varying between 20% and 50%) because of unsatisfactory GPA (grade point average) and incapability and/or reluctance to cope with heavy workload.
The drop-out problem is a very pertinent issue in general, but we will discuss it, and the corresponding countermeasures, in another paper.

In this paragraph we will concentrate on the discrepancies in basic knowledge levels amongst the freshmen/sophomores.

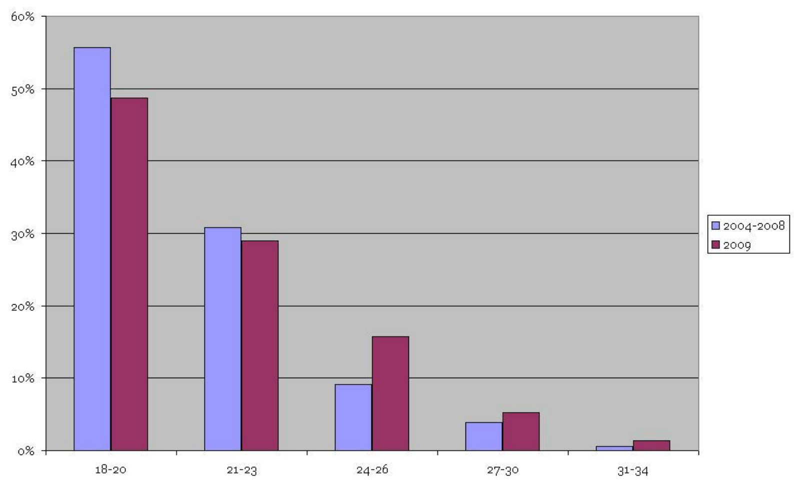

Figure 2: Freshmen ordered by age, enrolled in 2004-2009

Our enrollees have a variety of different certificates of access to higher education (Figure 3). In our country there is no standardized score or certificate system (i.e. like SAT). Furthermore, there are differences even within the corresponding certificates (different schools, states, etc.). This, in combination with the compact nature of the degree program and the high demands placed on our graduates, makes it extremely difficult to bring students up to the same level in terms of background knowledge before starting with technical fundamentals or engineering subjects.

[1] In Figure 2 and Figure 3 we have separated the statistics for 2009 from 2004-2008 because they differ significantly, but we will not discuss the differences in this paper. With the utmost probability the differences depend on the economic crisis in Europe but do not affect the conclusions concerning this topic.

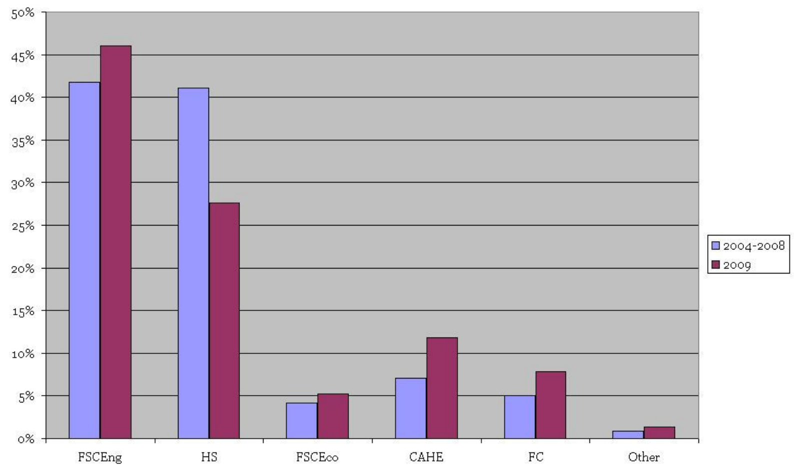

Figure 3: Freshmen ordered by certificate of access to higher education, enrolled in 2004-2009. FSCEng: Federal Secondary College of Engineering; HS: High School; FSCEco: Federal Secondary College of Economics; CAHE: Certificate of Access to Higher Education; FC: Foreign certificate

Figure 4 shows the distribution of the selection procedure scores (min. 0, max. 100) for enrollees in winter semesters 2006 through 2009. We can see that with the exception of 2006 most freshmen gained more than 50% of the scores (see also Figure 5). It is important to note that the selection procedure consists of a multiple choice test and an interview (approximately 30 minutes) with every applicant. Neither mathematical nor technical knowledge is tested directly, but rather logical thinking skills and motivation for the field of study.

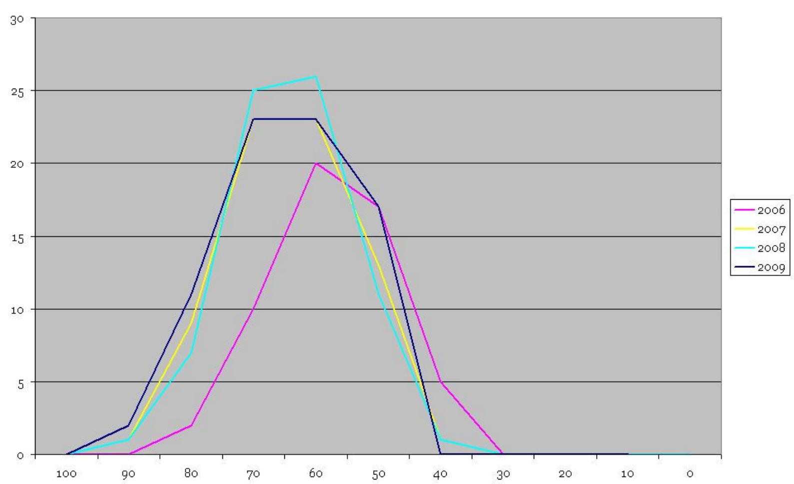

Figure 4: Distribution of the selection procedure scores of freshmen, enrolled in 2006-2009

If we take a close look at the data in Figure 5, we find that the mean scores value of all tests is just about 60% and less, and fewer than 50% of the candidates have higher than average results.

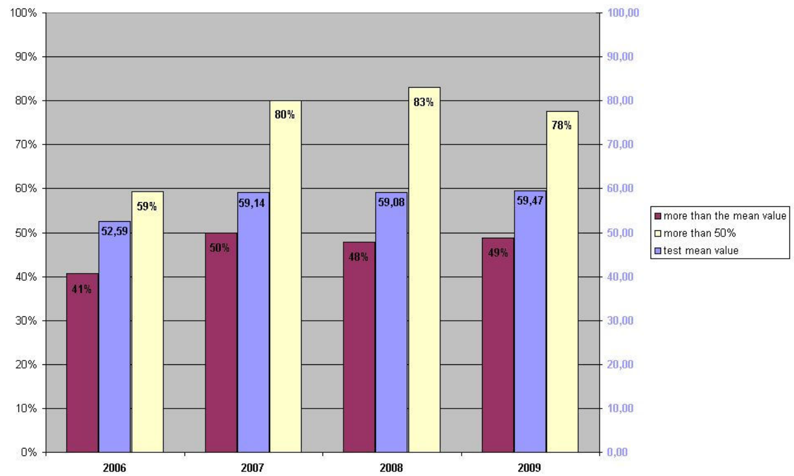

Figure 5: Mean values of the multiple choice test scores of freshmen, enrolled in 2006-2009

Figures 1, 2, 3, and 4 do not comprise and display any information about the mathematics background of our freshmen. But every year we are faced with significant differences in knowledge levels, particularly in this fundamental subject in engineering education. Therefore, at the beginning of the first academic year we carry out an anonymous survey of all enrollees, the results of which will be presented in another paper. Unfortunately, we have discovered that most of our enrollees have problems with calculations with compound fractions, functions, graphics, trigonometry, appraisal and interpretation of calculation results, etc. Later, they cope well with integrals, non-linear differential equations or finite elements calculation but sometimes the deficit from the high school remains[2].

To help students in the freshmen year to compensate the gaps in their knowledge of mathematics from the high school, we introduced an additional seminar four years ago, which is not part of the curriculum, called Mathematics Aid Direct (MAD). In parallel to the regular lessons, students can participate in this seminar on a voluntary (and anonymous) basis. They are supervised by two math-teachers from a Secondary College of Engineering. Two years ago we also introduced a further course called MAD+ which starts at the end of the first semester. We assumed that most students, who believed they were good enough at mathematics in the first semester but discovered they were not, would thus be motivated to invest additional time in the “dry fundamentals”. Furthermore, our mathematics lecturers implement a variety of practical examples in lessons and seminars in an effort to increase the students’ motivation. We are still collecting and evaluating the data, but there are clear indications that while both MAD and MAD+ have a positive impact in general, this impact is neither strong enough to reduce the dropout rate significantly, nor can it fill the aforementioned ‘gaps’ from high school.

Motivation and workload

It goes without saying that a direct relevance to praxis strongly motivates students to learn more and to delve into theoretical subjects. Therefore, the curriculum structure and the workload are of crucial importance for the students’ success.

To survey the students’ workload we decided to define five different subject areas: LSS = Language, Soft Skills, Support; E = Engineering; TF = Technical Fundamentals; EML =

[2] It would be interesting to carry out the same beginners’ survey at the end of their course of studies.

Economics, Management, Law; WDP = Workshop and Internship, Project Work, Diploma Thesis. In Figure 5 we show the distribution of students' workload in percentages over the full eight semesters of study as determined by the curriculum-based and the additional, project-based workload.

Technical fundamentals (TF) account for the highest percentage, followed by workshops, internship, project work and the diploma thesis. The pie-chart shows that more than one-third of the students' time is spent in praxis- and output-oriented learning activities. Here they gather valuable experience which will help them to be successful in their future professional field. It is hard to say if the subject classification in technical fundamentals or engineering is really correct but if we consider both subject areas together we can see that there is a good balance between the technical aspects of the program and other topics.

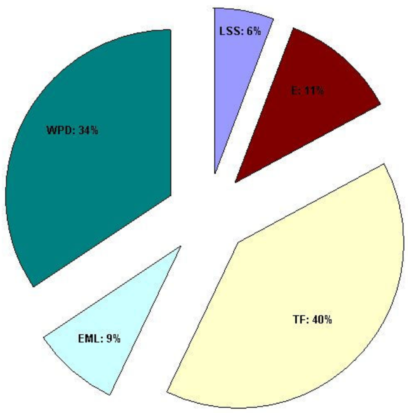

Figure 6: Students' workload in %. LSS = Language, Soft skills, Support; E = Engineering; TF = Technical Fundamentals; EML = Economics, Management, Law; WDP = Workshop and Internship, Project Work, Diploma Thesis.

Figure 7 shows the workload distribution for each subject area in each semester. Here we see that in the first three semesters the TF prevail. The WPD quota reaches a maximum in the junior and senior years of study.

The continuous implementation of project-based learning (PBL) starting in the second semester in the freshmen year[1,2,3,4,5,6] is also readily identifiable. Its impact is extremely positive because PBL allows for a variety of learning styles and utilizes various modes of communication. Students are encouraged to be innovative and to work in teams. Projects are multi-language (English and German) and multi-disciplinary in nature and promote meaningful learning, connecting new learning to students' past performances. The assessment is congruent with instruction, i.e. performance-based. But not all students are excited about working on projects particularly in the freshmen and sophomore years, maybe because they can not recognize the benefit for themselves. Some of them can not yet understand and accept that engineering often happens on the computer or on a piece of paper. A lot of them dream of breathing in the fumes of machine oil and fuel, of assembling an engine or driving a new car on the proving ground.

As shown in Figure 7 the project workload increases greatly in the junior year. This project work gives students the opportunity, for example, to conceive, design, build and compete with a small formula-style racing car. Thus the budding engineers are challenged to prove their knowledge, creativity and imagination. The main challenge for staff supervising juniors in this second phase of our Multi Subject Project Based Learning is that while the students are highly motivated to work on real-life engineering tasks, they are often only partially able to cope with all the problems that arise because of lack of professional experience or knowledge[2].

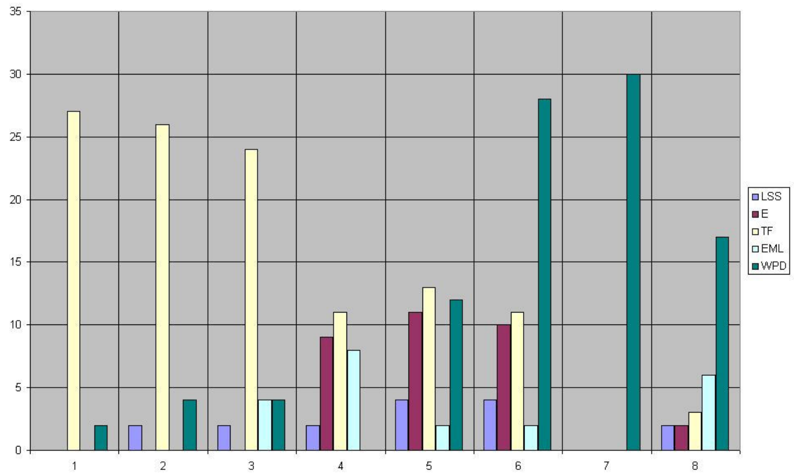

Figure 7: ECTS credits per semester. 1 ECTS is equal to approx. 25 h. LSS = Language, Soft Skills, Support; E = Engineering; TF = Technical Fundamentals; EML = Economics, Management, Law; WDP = Workshop and Internship, Project Work, Diploma Thesis

Coordination of internal and external lecturers

The subject areas WDP and E (see Figure 6) constitute further challenges concerning the coordination of the lectures with regard to content and timing, and lecturers' motivation. Furthermore, project and problem-based learning demands much more time in terms of supervision than standard lectures. Involving students in industrial projects is not without risks and we have to ensure that such projects are completed to the satisfaction of our partners in industry.

Of the 67 lecturers currently working in our department, 82% of them are external. They are employed either in the automotive, or in the railway industries, or in research institutes. However, the amount of teaching hours over the curriculum is shared almost equally between the internal and external lecturers.
The external lecturers teach primarily in the first, fourth, fifth and sixth semesters because of the higher number of subjects in technical fundamentals and engineering (see Figure 7 and 7). In the senior year the internal lecturers come more into play because of internship and diploma thesis supervision.
The coordination in terms of time and content is very difficult not only because of very large number of people involved, but also because of the very short information renewal cycle in vehicle technology.
Therefore, we have defined two regular meetings for all lecturers: one at the end of the winter semester and the other before the academic year starts. At these meetings the head of department reports about the activities and challenges in the previous academic year and according to the agenda the participants discuss new topics. Finally, the timetable for the next semester is presented and all participants can consult each other about changes and updates. The internal lecturers meet as a group every week and reflects respectively discusses the impact of changes in the time schedule and curriculum as often as possible.

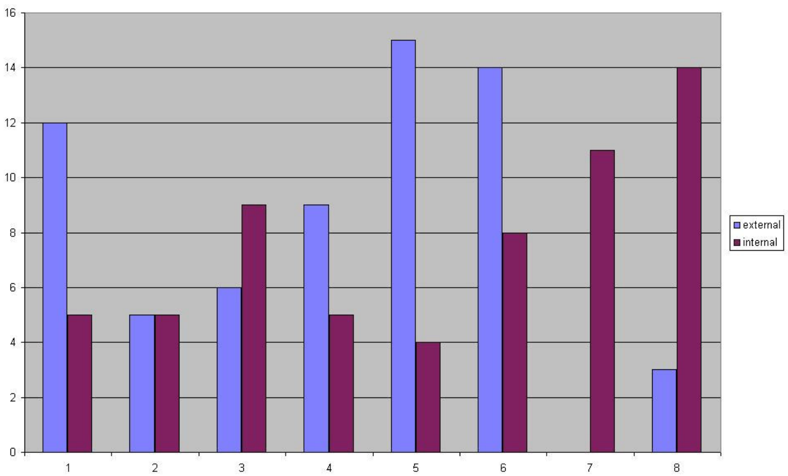

Figure 8: Distribution of the internal and external lecturers by semester

Sharing the resources – human and machines – of the test beds also requires careful and precise planning. Students, teachers, engineers and project customers use the same facilities. On the one hand, we have to cope with an extremely high degree of confidentiality, but on the other hand there are unique opportunities for young engineers to work on real projects, in real facilities and with professionals.

Industrial equipment, infrastructure and facilities

Access to industry-relevant, professional equipment is an essential factor in the training of young engineers, not only in terms of ensuring that they will be able to cope with the demands of the workplace, but also in terms of motivating the students to get through the less 'hands-on', more theoretical parts of their education in the early semesters.
One of the trademarks of the degree course is close interdependence between the engineering education provided to undergraduates and the R&D activities carried out by the technical staff in the department's state-of-the-art testing facilities, Figure 9, Figure 10, and Figure 11.

Figure 9: Testing facilities. More than 10 test beds: engine, power train, acoustics, SHED, etc.

The equipment in the testing facilities comprises a chassis dynamometer, stationary and dynamic engine test beds, a transmission and clutch test bed, an air/fuel mixture test bed, a titling bed, an acoustics laboratory, a SHED emissions testing system, a rapid prototyping machine, as well as a skid resistance tester and equipment for measuring e.g. flow quantities and strength of materials. R&D activities are usually performed in cooperation with partners from industry, whereby the majority of projects are acquired from OEMs, suppliers and other institutions and performed in-house.


Figure 10: Drive train test bed

While students cannot always be directly involved in such projects for reasons of confidentiality, they do have regular access to the equipment for a variety of project activities from semester 2 through semester 6 of their studies, thereby benefiting not only from hands-on experience, but also from the expertise gained by the technical staff who are closely involved in both teaching and supervising capacities, particularly in higher semesters.


Figure 11: Power train test bed

In the 6th semester (summer semester of the junior year of study) we provide 73% of all lessons, seminars, and workshops in the testing facilities and laboratories. In the mean, 40 – 45 students participate in the courses. They are separated in three groups and supervised by ca. 15 teachers and engineers.

Aside from the testing facilities, the department has two fully-equipped design studios with 30 workstations, Figure 12. Due to group divisions, this means that each student has their own workstation for the duration of the design courses in semesters 5 and 6 respectively. In addition to individual workspaces, they also receive tuition on a group and one-to-one basis from both internal and external lecturing staff, the latter coming exclusively from the vehicle industry. In addition to providing essential skills for the workplace, the combination of excellent facilities and expert advice has in no small way contributed to the recurring successes of the student racing team in international competitions over the past five years.

Figure 12: Designing the racing car with CATIA V5

Additional facilities include a state-of-the-art computer laboratory, electronics laboratories, multi-media lecture rooms, as well as project rooms and designated study areas, Figure 13. We motivate students to work autonomously and in teams. The young engineers have to perform special tasks (not only projects) and to write a final report. The report consists of the task description, requirements analysis, calculation and measurements description and summary of the results. All reports are evaluated with respect to form, content, structure and quality of the results. We encourage students to take a feedback and to reflect their work.

Figure 13: Supervising the students in small groups during laboratory seminar in electrics and electronics

Conclusions

The three-pillar model – praxis oriented learning, employing lecturers with an industrial background, and using industrial equipment, infrastructure and facilities – describes the most important requirements for successful engineering education. A well-designed and balanced curriculum is the necessary foundation for this but does not necessarily guarantee successful graduates. The contact between undergraduate engineering students and professionals from industry is very important but it also creates additional work such as the coordination of timetables, didactical methods and course materials. Moreover, we have to harmonize assessment criteria and standards with the objective of identifying the correlations and incongruities between academic and industrial requirements.

For engineering students, project work and direct relation to praxis lead to a higher motivation to learn and a willingness to delving into new areas of development and engineering. Today's young engineers challenge and question content and teaching methods much more than ten years ago. They are strongly interested in getting the best education they can.

The main challenge in the coming years will be to cope with the area of conflict – delivering consistently high quality, while experiencing worsening conditions and rising costs.

From our point of view the next steps should be a re-design of our degree program with a view to reducing the students' workload and clearing outdated content out. We also aim to establish optimum conditions for efficient project-based-learning. In addition, we need to complete our research into the reasons behind the high drop-out rate and implement countermeasures. Finally, further harmonization of assessment criteria of external and internal lecturers is also essential.

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