Does the education of engineers in Europe fail to meet practical requirements?

La formation pratique des ingénieurs en Europe est-elle défaillante ?

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ABSTRACT Graduates from different colleges and universities in Europe usually possess a sound knowledge of their particular specialization, for example geotechnics. Initially, however, their direct contribution in contracting companies is limited, since although they have learned standard geotechnical design methods, they have usually not been taught to develop innovative alternative proposals.

Additionally, the basics of Sales and of Construction Marketing are usually missing. In Europe, Faculties of Construction Marketing can be counted on one hand, although all contracting firms need to learn how to stand out from the crowd of construction companies. And universities do not teach things like how sales negotiations between client and contractor should be conducted, or how basic sales errors can be avoided. There is also a lack of interfaces between civil engineering and mechanical or electrical engineering, or computer science, which would help understand, for example, how construction plant and soils interact.

Companies which value the practice-orientated training of graduates need to commit a great deal of time and money to compensate for this training deficit. For this reason, Keller some years ago started to offer a systematic training scheme in which graduates learn both the lateral thinking between different ways of executing a project, as well as the basics of Marketing and Sales. Key points of this paper are an explanation of the main features of the scheme, and recommendations for future education of engineers at colleges and universities.

RÉSUMÉ Les diplômés issus de différentes universités et écoles en Europe possèdent en général une formation solide dans leur domaine de spécialisation, par exemple en géotechnique. Cependant, dans les premiers temps, leur contribution en entreprise reste limitée, car bien qu'ils aient acquis les méthodes de dimensionnement géotechnique usuelles, ils n'ont en général pas été formés à développer des offres alternatives innovantes.

De plus, les bases en termes de compétences commerciales et de marketing de la construction manquent en général. En Europe, les facultés de marketing de la construction peuvent être comptées sur les doigts d'une main, bien que toute entreprise ait besoin de faire en sorte de sortir du lot des autres entreprises. Les universités n'enseignent pas la manière dont une négociation entre le client et l'entreprise doivent être menée et comment les erreurs commerciales de base peuvent être évitées. Il y a également un manque d'interaction entre le génie civil et le génie mécanique ou électrique, ainsi que les services informatique, ce qui aiderait à mieux comprendre comment la structure et le sol interagissent.

Les entreprises qui mettent en avant la formation pratique des diplômés doivent investir beaucoup de temps et d'argent pour compenser ce déficit s'enseignement. Pour cette raison, Keller a commencé il y a quelques années à proposer un programme de formation systématique pendant lequel les diplômés apprennent aussi bien la structure horizontale entre différentes méthodes d'exécution d'un projet ainsi que les bases du domaine commercial et marketing. Les points centraux de cet article sont l'explication des principales caractéristiques du programme, et les recommandations à donner pour la formation des ingénieurs en universités et écoles dans le futur

1 INTRODUCTION

An international company gathers experience with academically trained employees from very different backgrounds. It is interesting to realise that conditions of study which at first glance appear contradictory produce a similar number of graduates – insufficiently prepared for the realities of the relevant working environment. "Against stupidity the gods themselves contend in vain", claimed Schiller's Maid of Orleans. This quote is old, but to this day it has lost none of its topicality. The laws of human stupidity were scientifically investigated by Prof. Carlo Cipolla (Cipolla, 1976). Theories are advanced, which he calls laws, such as "the probability that a certain person is stupid is completely independent of any other characteristic of that person". According to Professor Cipolla, this applies equally to various occupational categories, such as workers or craftsmen. It is also independent of the level of education. "Even more impressive was the result among professors. Whether I looked at a large university or a small institute, famous or unknown, I always found the same proportion of stupid professors."

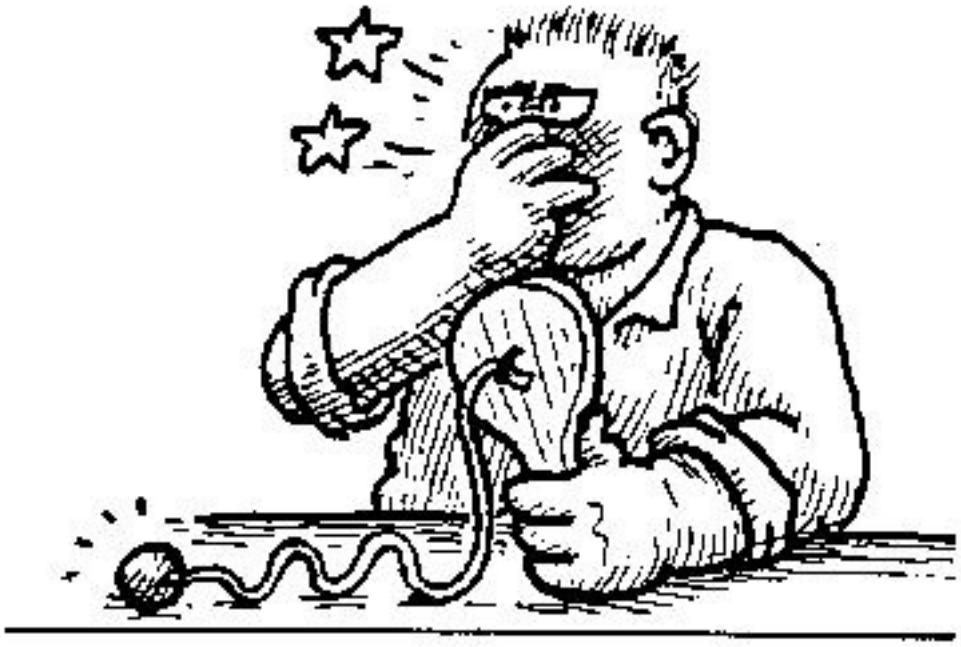

Figure 1. The basic laws of stupidity (Cipolla 1976)

That being so, professors also have to struggle with the stupidity of their students, but also to some extent with shortcomings in their own teaching skills. This remark is in no way meant disrespectfully, since it confirms, both positively and negatively, that similar opportunities exist for effective education in different systems of study.

In examining whether the education of civil engineers at German universities is practically orientated, different European higher-education systems are first compared to the German system.

2 THE STUDY OF CIVIL ENGINEERING IN EUROPE

The following comparison of the different higher-education systems in European countries does not claim to be exhaustive. It is based not only on literature reviews, but also on the personal experience of the authors.

The following countries are analysed in alphabetical order.

2.1 France

Studying in France is divided into 3 stages: The 3-year 'Licence' (equivalent to the Bachelor's degree), the 2-year Master, and the approximately 3-year Doctorate (PhD). Civil Engineering can only be studied at the Grandes Écoles, not at universities. The first ten Grandes Écoles in annual rankings compiled by magazines (Le Figaro 2014) are regarded as elite universities. Engineers only pursue a PhD if they are aiming for a career at a University, or a job in a research institute.

Study in France is much more school-like than in Germany. There is a little less homework, but more tests; and mainly teacher-centred lectures, in which the lecturer presents and the students only listen. When German students go to France, they are often initially irritated, since during the lecture questions are fairly uncommon.

Unlike in Germany, there is no numerus clausus at French Grandes Écoles and tuition fees (€ 200/semester) are fairly low. The basic difference to all other countries is the two-year entry examination, without which the student cannot commence study. Initially, the lecture theatres and libraries are usually crowded. Because of the large number of demanding intermediate exams and the nationally standardised final examination – the only relevant test – many students fail at this stage already. The final exam may be repeated once after an additional year. After this, the actual study is relatively easy, as it places less demand on scientific and theoretical basics and the final mark at the end of the course is not really important for companies.

2.2 United Kingdom

The Bachelor's Degree takes 3 years in the UK with the exception of Scotland with 4 years. The Master's Degree, to which only a few British students aspire, requires an additional year. In Great Britain there are only universities, no universities of applied science (Fachhochschulen). The universities

enjoy a high degree of autonomy, are less dependent on the State, and can recruit their own staff. With one scientific staff member to four students, the staffing of the universities is much better than in Germany. Here, the ratio at some universities/colleges is up to 1:20.

Other positive aspects are a comprehensive career service, speedy assistance in the Secretariat, and the good accessibility of the lecturers (usually without fixed consultation times), with concrete assistance with study-related problems. The student body is very international, particularly so in the courses leading to a Master's Degree. Negative is that the British system is very structured and leaves little room for personal options. The focus is on written examinations, and this is fundamentally different from the German system. The exams concentrate on topics already covered in written tests and then learned by heart for repetition in the examination. The significantly increased tuition fees of GBP 9000 a year led to protests in 2012. Curiously, the Bachelor's degree in Scotland is free for Scottish and EU-foreigners; English students must, however, pay GBP 9000 a year!

2.3 Austria

The Bachelor/Master system takes three plus two years in Austria. The tuition fees have been reduced from 380 € to 20 € per semester, but this only applies during the standard period of study.

There are three State universities (Graz, Innsbruck, Vienna) at which civil engineering can be studied, and several universities of applied science which offer courses in civil engineering, construction management and construction planning.

Just as in France, courses are relatively crowded, as there is no numerus clausus. A selection of the students takes place in the first phase of study by means of difficult tests in basic subjects; these are of limited practical relevance. The hierarchies between professors and students at the universities are more pronounced than in Germany.

The almost complete absence of tuition fees, the lack of admission restrictions and the absence of any language barrier are important reasons why ever more Germans study in Austria. At the moment the universities are working on changing the Master's Degree into English in order both to better prepare the students for the international market and to attract more foreigners.

3 COMPARISON OF HIGHER EDUCATION IN EUROPE

A comparison of higher education in the countries mentioned above shows that, while the final degrees bear the same name, the training is very different.

Figure 2. Sleeping students – future engineers?

In non-German-speaking countries, much more emphasis is placed on detailed theoretical basic knowledge. In addition, there are no universities of applied science in France and the UK, with the result that the engineers have little practical experience and cannot initially be used effectively in construction companies. There is an increasing tendency towards ever more school-like study with less project work. There is a lack of comparison of different construction methods and alternative solutions, which are decisive in obtaining orders in practice. Basic knowledge of both sales and construction marketing are usually completely missing.

4 HARMONISATION OF HIGHER EDUCATION

The Bologna process aimed to standardise higher education by the end of 2010. A memorandum of the German Construction Industry Associations in March 2009 states: "The Bologna higher-education reforms currently compromise the quality of civil-engineering education in Germany. Courses are being renamed, the duration of study reduced to a minimum – and this at the expense of professional proficiency." (Wragge).

Two months later, the President of the Confederation of the German Construction Industry, Herbert Bodner, commented: "It is not acceptable that the introduction of the Bachelor's Degree means that engineers are trained who cannot be described as professionally competent." (Wragge, 2009).

The fundamental question as to what skills a civil engineer graduating from university requires, needs to be discussed first. From a company point of view, four areas of expertise are absolutely imperative (Erman Tekkaya 2013):

1. Professional skills involving scientifically based specialised knowledge and the capacity for critical and interdisciplinary reflection.
2. Methodological skills including strategies for learning, for information retrieval, for organization and for advising.
3. Social skills including team and moderation skills, and conflict management.
4. Personal skills including creativity, commitment and a sense of responsibility.

Unfortunately, universities mainly strengthen professional skills and, to a certain extent, the methodological skills. As a rule, social and personal skills are scarcely taught at all. This has been scientifically analysed and confirmed in the BMBF-project "USuS – Investigation into courses of study and academic success" in several academic institutes in the years 2008-2102.

This situation is highly unsatisfactory for construction companies, as it is no longer sufficient for them simply to plan and build well. Without economic and legal skills, no construction project can be mastered today, and social skills and psychological strength are an absolute must in the typical working day of a site manager. All of these should be included in courses of study leading to a Bachelor's degree. Specialisation should then be made in the Master's programme. Minimum standards for Bachelor's and Master's degree courses have already been set under the leadership of the Confederation of the German Construction Industry with the help of the Accreditation Agency (Schmidt 2011).

What this means is of course not specialization in all peripheral disciplines, but a clear awareness of the importance of legal issues, marketing and machine technology in the working day of the civil engineer. Skills in business administration and languages are often more decisive for personal development in a company than knowledge of design methods and stability calculations.

What is needed is a combination of improvement or adaptation of the in-house training programmes with teaching at universities, as neither companies nor the universities will be able to meet the challenges alone. The following two subsections explain the development concept which has evolved in the Keller company, and how the change in teaching at universities should be carried out – if this has not already been done.

The following remarks are derived from the subjective point of view of a company specialising in geotechnical engineering. Since the majority of construction companies have one or more specializations, however, these approaches to practically orientated further training should be transferable.

5 CORPORATE TRAINING

To supplement university studies, the Keller company in Austria has offered the so-called "Keller Academy" since 2008. This basic concept was originally initiated in 2007 in Italy for the selection of young engineers; it has been modified and since 2012 it is held once a year throughout Europe, the Middle East and Africa with an international group of participants.

The Academy is now divided into 10 modules:

1. *Crash Course Geotechnical Engineering*

   In this module all geotechnical-engineering topics covered at the universities are revised or refreshed.

2. *Software for geotechnical design*
   Both commercial analytical geotechnical programs, in-house programs, and an FEM program and sample calculations are carried out.

3. *The Deadly Sins of a site manager*

   This training includes details of the processes developed by Keller (deep vibration, jet grouting, etc.) and a wide range of general solutions in geotechnics. Young engineers are surprised to realise how many of their decisions impact the future course of a project. To keep the course content interesting and practically relevant, mistakes made on completed construction projects are explained with pictures. An additional part of this course covers errors in geotechnical-calculation methods.

4. *Soft skills of a site manager / leadership*

   First, on the basis of a psychological self-test, the engineer learns to better assess himself/herself and also to perceive the different characters and roles of other participants in a more differentiated way. Then, in various role-playing exercises, the ability to listen and question is trained, the priorities of the opposite number are worked out and conflict resolution practised. After this, the strengths and weaknesses of each participant are presented in a feedback session. Based on the previously assessed characteristics, and on the basis of practically relevant construction sequences, role-playing exercises are planned in which discussions and conflicts between the construction parties are acted out. The structured confrontation is the core of the module.

5. *Sales and negotiation*

   In this part the sales process of the Keller company, including risk management, is explained. An important component is the preparation of pictorially documented tender documents, including the use of the detailed reference database. In addition, customer needs are discussed and customer enquiries filtered and rated. Again, role-play takes place between potential clients and contractors.

6. *Construction Marketing*

   Here, the company's Corporate Identity is presented with the uniform logo, internet and trade shows. Participants learn how to structure site-information sheets, technical papers, PowerPoint presentations and scientific publications.

7. *Costing and contract*

   Here, the civil engineer learns the basics of costing including the performance approach, taking into account site preparation, site installation/-deinstallation and interruptions. The contract section covers tender conditions, deadlines, payment conditions and penalties; these are explained using practical examples.

8. *Construction law*

   This module covers parent-contract models, contract risks, risk management and insurance issues. Country-specific specialities (VOB, FIDIC etc.) are offered separately in each country.

9. *Machine technology*

   Presentation of the various types of plant and their application depending on the construction method. Here it is essential that the interfaces between construction, mechanical engineering and electrical engineering are highlighted.

10. *Geotechnical Workshop*

    The Academy culminates in a project lasting several days on the subject of excavation pits and foundations. On the basis of several concrete construction projects, the entire process including geotechnical design, tender preparation, sales and presentation is simulated. Of particular interest is that at the end, the participants build a scale model of the construction project and subject it to trial loading, see Figs. 3-6.

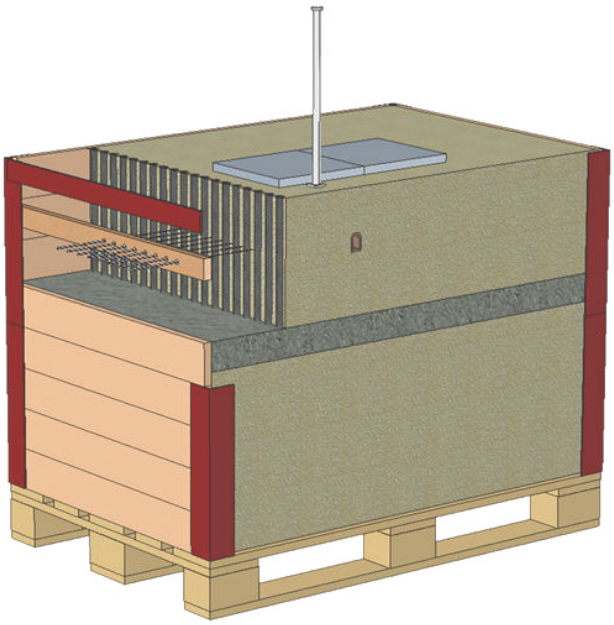

Figure 3. Test set-up for an excavation project

Figure 4. Team work in "pile construction"

Figure 5. A proud team of young engineers presents the first self-made excavation support with almost all the features of a real project

Figure 6. After the serviceability testing, the model is loaded to failure

It would be highly desirable if elements of the modules presented were adopted by universities.

6 REORGANISATION OF TEACHING AT UNIVERSITIES

The following suggestions can be divided into two groups. The first group lists proposals which can be implemented at low cost in terms of both personnel and money:

- A proposal already implemented by the Technical University of Munich is the awarding of prizes for the quality of lecturing. And the State of Bavaria is now involved in this initiative.
- Students with international experience/language skills are essential for internationally orientated companies. Particularly noteworthy in this context are a tri-national course at the universities of Basel, Strasbourg and Karlsruhe (Hochschule Karlsruhe), and international exchange programmes between various universities, as is offered for example at the Technical University in Braunschweig.
- As individual learning is better for students with different learning speeds, lectures could be recorded for revision purposes (Fischer 2011) or for preparation in online self-learning phases (Erman Tekkaya 2013).

Figure 7. Example of a lecture available on the Internet

This is already offered at the RWTH in Aachen for the lecture course "Concrete" (Hegger). This concept is also applicable to laboratory tests, as practised in the course "Properties of Materials" at the Technical University of Munich; this has received a teaching award (TU München - Sanchez). And an e-learning system already exists in the course on "Mechanics" at the TU in Dresden, in which courses are planned, scripts are edited online during the lecture on tablet PCs, exercises are solved, and students are able to check the correctness of their answers immediately (Baublog Dresden). An online examination system has already been introduced (Erman Tekkaya 2013).

Figure 8. Practical exercises are an ideal introduction to practical subjects

- Switching between lecture and exercise phases within a double period is more interesting for students, so that theoretically acquired knowledge can be immediately applied in context.
- To take proper account of the economic aspects of civil engineering in the degree course, a combination of civil engineering and business administration is advantageous. But the emphasis should still be on civil engineering and should not result in a 50:50 solution, as is the case in many of the 11 universities that already offer this combination in Germany. The danger is that such courses produce generalists only semi-proficient in the specialities.
- External speakers should be invited to student seminars more frequently to present their (local) authorities, their companies, their consultants' offices and their fields of work.

The second group of proposals requires more time and human effort, which is only possible through structural changes in the universities:

- a reduction in frontal teaching (Fischer 2011),
- mentor programmes by students in higher semesters (Erman Tekkaya 2013),
- more project work with practical relevance (Erman Tekkaya 2013),
- more construction projects at model scale which students can build themselves (Erman Tekkaya 2013),
- more hands-on laboratory testing where students work with real soils,
- student presentations with video feedback and group work,
- strategy games with virtual construction-site workflow (Fischer 2011), (Erman Tekkaya 2013),
- A good idea for motivating students is TheoPrax (Kamenz & Wehrle 2007), (Eyerer), where students act in group work like entrepreneurs and solicit orders from external clients. The money earned by the students goes to their respective academic institutions. The practical work is accompanied by lectures on the theoretical aspects.

7 SUMMARY

A few years ago, Keller started offering systematic training across its European subsidiaries in order to make university and college graduates "ready for the job". Both lateral thinking between different methods of executing a job as well as the basics of sales and marketing are explained and practised.

This step towards self-help has become necessary because more and more European universities only teach the theoretical basics at high speed, and practice-oriented project work is lacking. In some countries, such as France, Italy and the UK, universities of applied sciences with a clear connection to construction practice are completely lacking.

Recommendations for the future training of engineers in colleges and universities are divided into two groups; it is possible to implement the proposals of the first group with little personnel or money. Examples include the awarding of prizes for excellent teaching, international cooperation between universities, and online lectures/learning aids. For the second group, a greater effort in both time and human resources is required; this is only possible with structural changes in higher educa-

tion, such as mentor programmes, model-scale construction projects, and strategy games with virtual site workflows.

Preparation for construction practice is neglected with the argument that few academic graduates go into practice. This points to a model in which the work of the engineer is done at the desk, and the actual site work is in the hands of people with very varying educational backgrounds. The situation on construction sites every day shows that this is not a practicable solution; what was planned often turns out to be unworkable in practice – for a multitude of reasons. And this mismatch unfortunately results in the typical construction disputes, which appear to allow lawyers to take centre stage. The aim of those active in construction should rather be a balanced preparation for a complex field of work; this will enable designers, contractors, and employees of public authorities to conduct a dialogue on equal terms.

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