New Framework for Civil Engineering Programs in Germany

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Conference Key Areas: democratic involvement in educational processes

Keywords: professional civil engineering, educational standards, accreditation, reference framework

ABSTRACT

A common European labour market requires a transparent presentation of professional standards. This is particularly important for civil engineers for three reasons. Civil engineers create products with long life cycles, important resources are bound and buildings have an impact on people, environment and society.

Who defines the prerequisites for the exercise of a profession in civil engineering - universities, state, and chambers of engineers? Due to the diversity of the courses of study, the Chambers of Engineers ultimately want to assess the professional qualification. In the case of academic training, however, teaching and research are free. The design of the curricula is the sole responsibility of the university.

ASBau agreed a compromise. In the voluntary association ASBau a frame of reference for bachelor courses in civil engineering was developed. The ASBau incorporates universities, universities of applied sciences, the construction industry, trade unions, chambers of engineers and students.

The reference framework defines learning objectives and competences and it is subdivided into the subject areas "Fundamentals of Engineering", "Planning", "Assessment" and "Construction Management" with 135 credit points (ECTS). This ensures the necessary breadth and depth of academic training in civil engineering (Bachelor) and professional qualification. The reference framework is a compromise. The application of the frame of reference is optional for the universities, but recommended. It ensures that the definition of professional qualifications in civil engineering programs may remain in the responsibility of the universities. In Germany, civil engineering is the first engineering discipline to succeed in such a framework.

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1. INTRODUCTION

The entitlement to use the professional title of civil engineer is regulated differently at international level. In North America, for example, study courses for civil engineers are accredited by professional associations such as ASCE (American Society of Civil Engineers) or Engineers Canada **[4]**. The intention is to guarantee the professionalism of the graduates in the sense of the professional association. In Europe, too, the European Network for the Accreditation of Engineering Education (ENAEE) has established an international, specialist accreditation network. This has not yet played a role in Germany.

The European Council of Engineers Chambers surveyed the state of training of civil engineers in the countries of the European Union. Annex VI of the report suggests ways to develop "Common Training Principles for Engineers" (CTP) **[2]**.

In Germany, the title "Civil Engineer" has been associated with the university degree "Diplom-Ingenieur" for about 150 years. Law in Germany has regulated the title since 1970. For this purpose, engineering laws were introduced which fall within the competence of the federal states. There are currently 16 different engineering laws. In order to avoid difficulties in mutual recognition, the engineering laws follow a coordinated "Model Engineer Act", which is drafted by the Conference of Ministers of the Federal States responsible for Economic Affairs.

Previously, the study of a technical or scientific discipline with a diploma and a standard period of study of at least three years at a state or state-recognized training institution were sufficient to earn the professional title of "engineer". All the experts involved have so far accepted this pragmatic legal regulation as good and sufficient.

As a result of the Bologna Process and the European Professional Recognition Directive an adaptation of the engineering laws was necessary (compare: Directive 2005/36/EC amended by Directive 2013/55/EU), The replacement of diploma degrees by Bachelor and Master Degrees because of the Bologna reform has led to uncertainty in professional practice. Experts criticized the fact that some names of degree programmes do not allow clear conclusions to be drawn about the competences taught. As a reaction, law regulated the required study content in the engineering laws of individual federal states through the definition of study content. For this purpose, the formulation that the course of studies must be predominantly characterized by the fields of mathematics, computer science, natural sciences and technology was mostly chosen for simplification purposes. In some federal states, the statutory chambers of engineers have also attempted to exert influence. The Chambers of Engineers proposed to combine the right to use the professional title of engineer with a membership in the chamber.

The Universities see both legal regulations governing study content and mandatory chamber memberships for their graduates as inadmissible interference with their constitutionally guaranteed freedom from research and teaching. ASBau therefore developed the reference framework presented here for civil engineering (ASBau (2019)). In order to describe the professionalism, recommendations were developed for study contents and requirements to the mediated competences. A study programme matrix was developed for reviewing these recommendations, enabling each higher education institution to weight the course content specifically and to make it clear to what extent it deviates from the reference framework. Thus, the description of professionalism in accreditation procedures should be transparent.

2. Study system in Germany

Civil engineers were trained from the middle of the 19th century until the 1960s. Initially, this took place at polytechnic academies. These gradually acquired the status of Technical Universities. Due to an acute shortage of engineers from the 1960s there were many engineering schools in the individual federal states. Here the formal university entrance qualification (Abitur) was waived. Thus, more practitioners were to be introduced to the academic construction task. At the beginning of the 1970s, these engineering schools were integrated into the newly founded universities of applied sciences nationwide.

Today, these „Fachhochschulen (FH“ or „Hochschulen für angewandte Wissenschaften (HAW)“ are generally referred to as "Universities of Applied Sciences" even with this english words. They are a successful model of academic education with the aim of directly qualifying graduates for a profession. The Universities of Applied Sciences are oriented towards the classical German dual education: theoretical knowledge is tested in practice. Practical knowledge is backed by theory. To this end, practical phases are integrated into the course of study. The professors of the universities of applied sciences are usually doubly qualified: academically-scientifically with a graduation (Dr.-Ing.) and by a professional experience of many years in leading position in an enterprise outside of the university or in the public building administration.

3. From Diplom-Ingenieur to Bachelor Engineer

The degrees at the universities/technical colleges on the one hand and at the universities of applied sciences (FH) on the other hand were called differently, namely either Dipl.-Ing. (Univ.) or Dipl.-Ing. (FH). The FH graduates were very well received on the labour market, especially in all tasks of planning, work preparation, construction execution and site management. The appreciation of FH civil engineers in terms of salary was not inferior to that of university engineers. However, a systematic salary difference was made in the public building administration. University of Applied Sciences engineers were rated one salary level lower than university engineers.

In the course of the Bologna Process in the European education area, the concept of knowledge transfer changed. In short, from frontal teaching by the professor to learning outcome. This can be casually formulated as "what gets stuck with the student". Today, this Learning Outcome is specified and extended with the concept of the mediation of competences **[5]**. With all the difficulties in measuring "competence".

A further objective of the Bologna Process was the differentiation of the courses offered. The aim was to respond more flexibly to the graduate needs of industry. The inclinations and talents of the students should be developed better and more precisely in these differentiated study programmes.

Today's understanding of education in Europe is based on diversity, but equivalence on academic (tertiary) education. Tertiary education no longer distinguishes between types of higher education institutions. It differentiates only in education levels. Consecutive, building on one another, i.e. in Bachelor's, Master's and doctorate degrees. Thus, a Bachelor's degree is a Bachelor's degree and a Master's degree is a Master's degree. The additions "Univ." and "FH" before the Dipl.-Ingenieur are therefore obsolete. And by the way: we (old) "Diplomingenieure" have to give up this title.

There are now 20,000 courses of study in Germany. This diversity is often deplored today. Students or their parents as well as employers are unable to find the right course or graduate.

In civil engineering, too, there are various engineering courses related to civil engineering. But from the point of view of those involved in ASBau, these are not civil engineers if a certain canon of subjects is not taught in terms of scope and depth (frame of reference).

4. Civil engineer's responsibility in society

The "classical" civil engineers, or rather: those who perform the classical construction task, have a special responsibility for their actions. With construction measures, capital is tied up for the long term, the built environment is shaped and the energy and resource requirements are decisively determined. The state has delegated this task and responsibility to the Chambers of Engineers on a self-organising basis. In Germany, civil engineers are often self-employed and part of the state-supporting middle class and perform important public tasks. There are 16 state chambers of engineers in Germany and the Federal Chamber of Engineers is the umbrella organisation. These chambers are so-called public corporations, i.e. they have an independent role between state and engineer, a self-organized part of society.

The professors, with the constitutional right to freedom in research and teaching, are also a special species in the German understanding of the state. The professors are civil servants for life (the German variant of the tenure track) with special duties towards state and society. Thus it is the duty and right of professors to contribute to the development of their subject area/course of study.

The collisions between the two groups resulted from this competing task of the state, on the one hand to the Chamber of Engineers and on the other hand to the professors to continue the development of civil engineering education.

The solution is - a compromise with which all groups can live. The dispute has been settled. The result is a frame of reference for civil engineering courses.

But other regions of the world are also working on uniform standards of civil engineering education with regard to teaching content, the social responsibility of engineers and uniform ethical principles, such as in East Africa **[7]**.

The Engineering Assoziation in Canada has already formulated such standards:

"- Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest;

- Impact of engineering on society and the environment: (…). Such ability includes an understanding of the interactions that engineering has with the economic, health, safety, legal, and cultural aspects of society (…)

- Ethics and equity: An ability to apply professional ethics, accountability, and equity" **[4]**.

5. Bachelor: is there a difference between the University and the University of Applied Sciences?

The university degrees are the same in the individual (federal) states, and between universities and the University of Applied Sciences they are of equal value, but different in orientation.

The Universitys of Applied Sciences attach particular importance to the (immediate) professional qualification of the graduates. This is achieved by the academic and practical qualification of the professors.

Research in the construction industry in Germany is low compared to other sectors (e.g. pharmacy, automotive) according to the classical key figures (research expenditure according to turnover). This is also due to the special structure of the construction industry in Germany. We have 760,000 employees in the main construction sector and more than 70,000 companies plus so-called self-employed individuals. This means an average of 10 employees per company. What is special about this is that these (craft) enterprises do not make any strategic considerations due to their small size. To a certain extent, craft enterprises work "on demand" by definition and not according to a marketing concept.

Innovations in the construction industry are often brought in as a result of practical research. Immediate solution concepts for a practical construction task. This is the typical business of professors before their teaching activities.

6. The compromise "frame of reference"

From the point of view of higher education institutions, the professional design of curricula in terms of freedom of research and teaching must remain their own responsibility. In Germany, the selected qualification goals are reviewed within the framework of accreditation procedures according to the rules of the Accreditation Council Foundation. The German accreditation system is closely related to the objectives of the study structure reform and the Bologna Process in connection with the meanwhile established European and international standards of quality assurance. These include

- the quality responsibility of the universities;
- uniform standards with regard to qualification goals, studyability and the quality of the processes;
- Freedom from research and teaching as well as the free choice of educational institution guaranteed by fundamental law;
- Diversity, comparability and transparency;
- Expert-centred accreditation procedure;
- Stakeholder participation;
- Orientation towards qualification goals and competences.

In addition to the technical aspects, the qualification goals also include scientific qualification and the ability to take up qualified employment, see Accreditation Council (2015).

To evaluate the vocational qualification and employability ("Beruflichkeit") of the graduates of a study programme in the accreditation procedure, an outcome-oriented reference framework for study programmes in civil engineering (Bachelor) was developed in a voluntary association of stakeholders (asbau.org). The participants included universities, universities of applied sciences, the construction industry, the building trade, the Oberprüfungsamt für den höheren Technischen Verwaltungsdienst (governmental examination board), students and chambers of engineers. The reason was also the concern of the participants that the accreditation procedures could promote the predominance of individual scientific opinions in the evaluation of professionalism.

The reference framework describes fields of competence in a volume of 135 credit points (ECTS) which should be covered within the framework of a Bachelor's programme in civil engineering. This is intended to ensure the necessary breadth in academic education. In order to assess professionalism, a learning objective-oriented matrix is defined in which the competences taught in the subject areas "Fundamentals of Engineering", "Planning", "Dimensioning" and "Construction Management" can be compiled and compared with objectives across all study programme modules. The frame of reference refers only to Bachelor's programmes in civil engineering, the application is voluntary.

A very large circle of stakeholders was represented (e.g. 85,000 companies in the construction sector), so that the frame of reference received broad attention. It is also helpful for accreditation practice that universities and universities of applied sciences have jointly agreed on a uniform job description for civil engineering. The stakeholders involved will work to ensure that the frame of reference at all universities and colleges in Germany that offer study programmes in civil engineering is taken into account in the design of studies and made the basis of accreditation procedures.

7. Presentation of the frame of reference

The goal pursued by the stakeholders involved was to impart a broad, well-founded basic knowledge of civil engineering to bachelor's degree courses. This profile of an all-rounder is regarded as a prerequisite for employability as well as for an individual professional deepening, which can take place within the framework of Master's programmes.

For this reason, the frame of reference reflects the areas of competence which the members of the ASBau consider to be essential and which should be covered within the framework of a Bachelor's programme in Civil Engineering. These fields of competence are summarised in Table 1:

Kompetenzfelder	**Fächer des Bauingenieurwesens**
Fachliche Grundlagen	Mathematik, Ingenieurinformatik, Digitales Bauen, Bauphysik, Technische Mechanik elastischer Körper, Bau-Konstruktion, Baustoffkunde, Geodäsie, Ökonomie, Rechtswesen, Ökologie
Konstruktiver Ingenieurbau	Baustatik und Tragwerksplanung, Massivbau, Stahlbau, Holzbau, Geotechnik
Wasserwesen	Wasserwirtschaft, Wasserbau, Siedlungswasserwirtschaft
Ressourcenwirtschaft	Abfallwirtschaft und Altlasten
Verkehrswesen	Verkehrsplanung, Verkehrstechnik, Straßenbau, Öffentliche Verkehrssysteme, Stadt- und Regionalplanung
Baumanagement	Bauprojektmanagement, Bauprozessmanagement, Baubetriebswirtschaft, Bauplanungsmanagement

Tab. 1 Essential fields of competence which should be covered from the point of view of professional practice within the framework of a Bachelor's programme in Civil Engineering, ASBau (2019)

Knowledge, skills and competences are listed in the frame of reference in order to concretize the fields of competence. These should serve as a guideline as to which topic complexes should be the subject of the courses. There is no claim to completeness, nor is full implementation expected in every case. The selection and focus of each course will be left to the specific course design. The basis was the knowledge, skills and competences in the core studies of Bachelor's programmes in Civil Engineering at Universities of Applied Sciences of the Fachbereichstag **[6]**.

It is assumed that the competence fields are to be covered in their breadth in 135 credit points (ECTS). This is equivalent to a total of 4.5 semesters of study. This leaves sufficient time to set priorities in optional modules and to pursue one's own specialist interests.

The construction industry has so far hardly complained about a lack of subject- and occupation-specific knowledge among graduates. It was regarded as usual to "familiarise" entrants with the job for some time and to introduce them internally to the job requirements. At the beginning of their career, graduates are usually accompanied by a suitably qualified, experienced and responsible person.

For the first time, the ASBau reference framework takes into account the level of competence of graduates required from the point of view of construction practice: The construction industry and the building trade criticised the fact that so far the competencies of the graduates in the areas of basic principles and dimensioning have strongly predominated (Fig. 2).

In contrast, a higher proportion of competences in management, design and planning are required for the exercise of a profession. Civil engineers must be able to assess the implications, consequences and economic viability of decisions. In the Bachelor's programme, the course must be set for this and the mandatory basic competences must be imparted and a corresponding awareness developed For this reason, the stakeholders involved regard the ratio shown in Fig. 3 as necessary for the competences taught in the Bachelor's programme as a whole in order to guarantee professionalism.

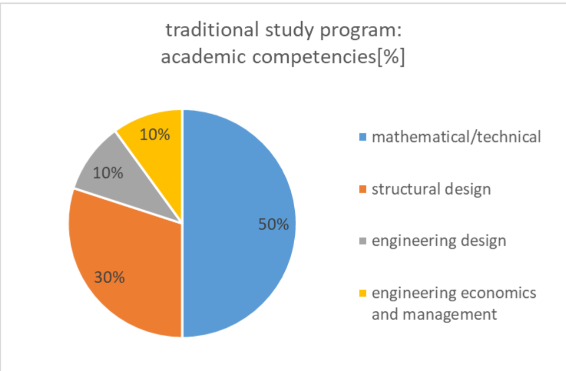

Fig 2 Sample of the percentage distribution of competences in conventional degree programmes

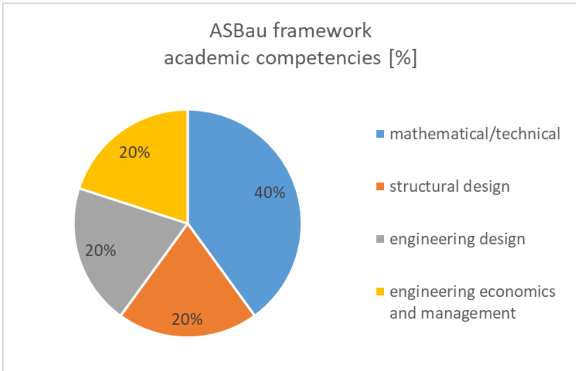

Fig 3 Percentage distribution of compe-tences required from the practical point of view to ensure profes-sionalism in the design of courses of study

This requirement was chosen in order to give the universities sufficient flexibility in designing their degree programmes. The stakeholders involved agreed not to make any concrete stipulations with regard to the weighting of the individual fields of competence. Rather, an overarching recommendation was made that 40% of the entire programme should cover the competence dimension "Fundamentals of Engineering" and 20% each the competence dimensions "Planning", "Assessment" and "Construction Management". Large parts of the course will cover all four areas **[1]**.

Since there are complaints in accreditation practice about an overweight of formal testing procedures, the criteria applied and the procedure for checking the distribution of competences should be transparent and easy to handle. For this purpose, the ASBau study programme matrix was developed with which the competence profile of a study programme or of individual study and specialisation fields can be worked out and compared with the competence distribution 40%/20%/20%/20% recommended by the ASBau according to Fig. 2.

What is new here is the approach that the ratio of competences taught is not to be achieved on a modular basis, but on the average of all compulsory modules, based on 135 credit points. For this purpose, the distribution of competences for each module must be determined and summed up. The procedure is explained in Table 2. 1 credit point corresponds to 30 hours of student work. A total of 180 credit points are awarded for a 6-semester Bachelor's programme.

The distribution of competences depends on the individual design of the module. For example, a module such as "Structural Engineering" can contain elements from planning, dimensioning and construction management. Individual modules may therefore cover all four competence dimensions, each in different proportions. This should at the same time make clear the complexity of construction tasks and the current reality of engineering activities in the construction industry.

Acquired competences→ Modul↓	ECTS	basics	Design and planning	Dimen-sioning	Mana-gement
building physics	5	70%	15%	15%	0%
solid construction	5	10%	30%	50%	10%
hydraulic engineering	5	20%	40%	30%	10%
Management	5	0%	10%	0%	90%
Other Module	5	x	x	x	x
Subtotal	20	100%	95%	95%	110%
Mean obligatory module	135	3,7%	3,5%	3,5%	4,1%
recommendation ASBau	135	40%	20%	20%	20%

Tab 2 Principle of the ASBau study programme matrix: In the compulsory area, the competence shares in the competence dimensions "Basics", "Planning", "Assessment" and "Management" are recorded in each module and weighted based on 135 credit points in total. The table shows an intermediate status for five example modules. The distribution of competences depends on the individual design of the module. Overall, the distribution of competencies should be 40%/20%/20%/20% as shown in Fig. 3.

A sample table with instructions for use is available for download to simplify processing during accreditation. The "mandatory programme" listed in the frame of reference should correspond to at least 135 credit points. The additional credit points required will be awarded within the framework of the Bachelor's thesis as well as with the acquisition of further, possibly interdisciplinary competences.

Further criteria are the equipment of the university and the imparting of "soft skills". The frame of reference proposes a questionnaire for reviewing the equipment. Soft skills must be the subject of higher education, but cannot be assigned to any field of competence in terms of content. For this reason, a selection of competences is defined that should be integrated into the teaching of subject content. In addition, the ASBau recommends an internship of at least 12 weeks during the course of study.

The recommended distribution of competences 40%/20%/20%/20% should not be applied rigidly in a formalistic manner, but provides an orientation framework. However, deviations are made transparent and can be justified in the accreditation procedure.

8. Summary

The presented frame of reference describes the current professional understanding in civil engineering in Germany in a transparent and goal-oriented way. It was developed by a very large circle of stakeholders and contributes to ensuring that the professional qualification of graduates in all Bachelor's programmes in civil engineering remains the responsibility of the universities. In Germany, civil engineering is the first engineering discipline to have succeeded in describing a profession in this way on an academic basis. In addition, universities and universities of applied sciences have agreed on a common job description for civil engineers despite their different qualification goals.

For the first time, the reference framework takes into account the level of competence of the graduates required from the point of view of construction practice. A higher proportion of competences in management and in design and planning are required for the practice of the profession. Civil engineers must be able to assess the implications, consequences and economic viability of decisions. In the Bachelor's programme, the course must be set for this and the mandatory basic competences must be imparted and a corresponding awareness developed. The frame of reference provides criteria for this that give universities sufficient flexibility in designing their degree programmes and do not restrict the legally guaranteed freedom of research and teaching.

This paper is intended to contribute to the discussion of professionalism and occupation in accreditation practice also in an international context. The presented reference framework is a successful example for „democratic involvement in educational processes“.

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