
ENGINEERING PEDAGOGY AT UNIVERSITIES IN CHILE - A RESEARCH AND FURTHER EDUCATION PROJECT OF TU DRESDEN AND UNIVERSIDAD AUTÓNOMA DE CHILE

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This article outlines an approach to a common project of the Technische Universität Dresden and the Universidad Autónoma de Chile for the development, implementation and testing of a postgraduate further education course with integrated e-learning components aiming at the development of competences in the field of arranging teaching and learning processes in academic university education. The goals of this engineering-pedagogical qualification are derived from an empirical demand analysis. The modular structure of the postgraduate course is based on the structure of the studies of the International Society of Engineering Pedagogy to become a so-called International Engineering Educator (IGIP). The project has started on January 1, 2014.

Keywords: *Engineering Didactics, Higher Education, Engineering Education*

Understanding of "Engineering Pedagogy"

Engineering pedagogy has a very long tradition at Dresden University of Technology. The discussion on technical education and technical teacher training at TU Dresden (at that time Royal Technical Educational Establishment in Dresden) can be retraced to 1851. With the establishment of the Institute for Engineering Pedagogy by HANS LOHMANN in November 1951, teaching and research in the field of engineering pedagogy could be institutionalized. LOHMANN focused his research on the relationship of technology and technical teaching. Therewith he laid the foundations for an understanding of engineering pedagogy the matter of which is the targeted design of technical and technologically-specific teaching and learning.

A central role in Lohmann's approach of engineering didactics played the concept of technology. He defined the technology on their function "to transform the natural world" (cp. Lohmann 1953/54, p. 619). The task of the engineer is to develop this technology. Engineers are therefore qualify so that they are able solve technical design problems. In contrast to this, the activity of natural scientists is focused on the discovery of relationships in the world and thus to solving scientific knowledge problems. Invent and discover require different ways of thinking and thus different methods of academic training.

Concept of a demand-oriented "Engineering Pedagogy"

For teaching and research in the field of engineering pedagogy, an object-related reasoning shows the scientific level. Verifiable pedagogical and/or psychological qualifications are legally fixed requirements for a teaching career at all levels and in all types of schools of general and vocational education. In contrast, in the sector of higher education it is assumed that lecturers have teaching abilities due to their high academic qualifications.

The evaluation results of the teaching quality in higher education significantly show that this assumption is only partially correct [cp. Krempkow, R.; König, K.; Ellwardt, L., 2006]. A major reason for that is the complexity of the influence factors and relationships concerning the design of a demand-oriented education in engineering sciences. In this context, the term "design" includes planning, implementation and evaluation of teaching and learning in engineering education.

The requirement to gear engineering education to the demands of the economy, which is determined by the specifics of the engineering labour, is meant when speaking about demand-oriented and employment-based engineering education respectively.

Requirements are understood as necessary personal dispositions for successfully managing the profession-specific work activities. They are thus determined by the prevailing structures of production and service. The change from TAYLORistic production structures to structures of lean production in the past 40 years has considerably changed the engineering activities, and with them the requirements on engineers. A reference in this context is a study by FRIELING [cp. Frieling 1993], who investigated these changes in the German automotive industry in the 90s in detail, and who characterized the new production structures as follows:

- Process-chain-oriented company organization instead of functional hierarchies
- Customer-orientation instead of product-orientation
- Responsibility for the project/venture and budget instead of hierarchically structured task management
- Working in teams or groups instead of working alone
- Complete operations instead of individual/single acts
- Self-regulation instead of standardized input/guidelines
- Involvement instead of heteronomy
- Continuous improvement instead of hope for innovation. (cp. Frieling 1993, p.32)

Modern engineering education has to consider these developments in its curricula and training methods.

Influence factors of engineering education

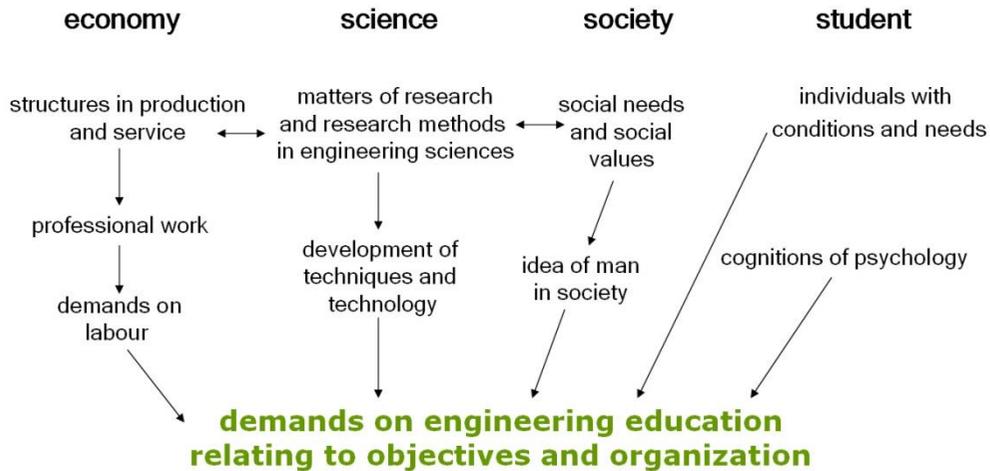


Figure 1: Factors influencing on demand-oriented design of engineering education

In addition to these dynamic requirements, a variety of stable long-term requirements related to the personality dispositions of engineers result from the typical engineering activities. An example is the typical way of the thinking/reasoning of engineers. For instance, in the analysis or the design of technical systems the thinking in the categories of “part – whole” in the relationship between structure and function plays a vital role. The calculation of technical systems by deductive structures of thinking is based on trusted statements or laws. However, in technologically diagnostic processes progressive-reductive patterns of thought in cause-effect relationships play an essential role. Such considerations lead to scientifically-based decisions for teaching methods in engineering education in order to support the development of such structures of thinking.

A second major factor influencing the training of engineers is the field of engineering sciences itself. A scientific discipline is defined by their particular matters and methods of research. Regarding the matters of engineering sciences, the terms technique and technology play a key role. Technique and technology contain processes of change (form and structure), transport and storage of material, energy and information [cp. Wolffgramm 1994]. The views on what technique is and which function it has in relation to nature and society, is also subject to changes. A change of the matter of a scientific discipline has an impact on teaching in this discipline. The systems of statements in engineering sciences (descriptive matters), the systems of typical action rules for engineering activities (regulatory matters) and the systems of typical standards for engineering activities (normative matters) are different from those 60 years ago. Without adaption, LOHMANN’s approach to teaching technology is likely to hardly meet the requirements of modern engineering education. However, it can be considered a suitable starting point for the development of modern concepts of engineering education.

Closely related to the term "technology", is the society as a factor influencing engineering education. Technique not only arises from the application of natural laws and theories in engineering sciences but

is also part of the technical possibilities and the socially desirable aims [cp. Heidegger/Rauner 1989, p. 20]. In this respect, the development of technique and technology is also driven by social needs. In addition, a society also has an idealized image of its members. Maturity ability to democracy, the willingness to active shaping are just a few personality traits that are included in this ideal. From this follows also an educational mission of our universities.

The fourth important factor influencing the engineering education is the low rate of success students have at German universities which is often explained by deteriorating levels of education in preceding educational institutions and the resultant lack of ability to study. I do not agree with such a general statement. But even if this thesis were true, it is economically not justifiable to let half of all young people who are interested in engineering fail in their educational intentions.

So why not use concepts of engineering education which consider these changes in anthropogenic conditions of the students and which are based on the latest findings of educational and developmental psychology in the design of teaching and learning in higher education? Perhaps the obstacle is the inadequate funding of universities and the resulting poor student-teacher ratio, but certainly also the largely inadequate insight of the teaching staff at universities in these complex relationships of engineering pedagogy.

Project “Engineering Pedagogy at Universities in Chile”

The starting point of the project, which has been implemented in cooperation of TU Dresden and Universidad Autónoma de Chile since January 2014, is the relationship between teaching quality and student success. It is assumed that a systematic, demand-oriented further education in the field of higher education / engineering pedagogy for the teaching staff at Chilean universities will contribute to improving teaching in engineering sciences and therefore the rate of student success.

Qualified engineering activities are the foundation of any long-term economic development. Therefore, the prime task of universities is to provide academically trained professionals for economy. The Chilean economy has experienced steady growth of 5% or more in the last 3 years. Chile is next to Argentina and Uruguay to the 3 strongest economic countries in Latin America. The key economic sectors of the country are located in the mining, manufacturing, trade and construction industry. Largest growth sectors are the energy sector, the trade and construction. The economic development of the country as well as the increase of more qualified activities in manufacturing, services and research increasingly require well-trained engineers that meet the requirements in the economy and society. To this end, the project will contribute by improving the quality of academic engineering education.

The aim of the project is the development, implementation and testing of a course of postgraduate study /further training with integrated e-learning, to develop abilities for designing teaching and learning processes in academic engineering education. The development of postgraduate learning programs is based on the modular structure of the curriculum "Engineering Educators" of the International Society for Engineering Education. Currently, various universities from all continents of the world are working to provide special modules for this curriculum for an online study.

	Module Description	CPs at least*
	Totally	20
	Core Modules	7
MC1	Engineering Education in Theory	2
MC2	Engineering Education in Practice	3
MC3	Laboratory Didactics	2
	Theory Modules	5
MT4	Psychology	2
MT5	Sociology	1
MT6	Engineering Ethics	1
MT7	Intercultural Competence	1
	Practice Modules	5
MP4	Presentation and Communication Skills	2
MP5	Scientific Writing	1
MP6	Working with Projects	1
MP7	ICT in Engineering Education	1
	Elective Modules (1 CP per subject)	3
ECP8	Evaluation of Student Performance	1
ECP9	Quality Management	1
ECP10	Portfolio Assessment	1
ECP11	Creative Thinking	1
ECP12	Coaching and Mentoring in Education	1
ECP13	Collaborative Work	1
ECP15	Teaching Subject in English (CLIL)	1
ECP16	Info Literacy	1

IGIP Prototype Curriculum (Berlin, 12 March 2013)

* One credit point (CP) corresponds to 25 to 30 hours of work.

The approach of learning organization for modules in engineering pedagogy at Chilean universities is directed to a concept of blended learning.

In the first stage of the project in 2014/2015 the development and implementation of four study modules each with two credit points are planned. For the correct decision regarding the modules an empirical demand analysis was realized.

Summary of Results on the experience in engineering pedagogy at one Chilean University

With the idea of quantifying the perceptions of teaching needs in relation to engineering courses, was considered necessary to develop and design an opinion survey as an instrument, to explore four major topics in engineering pedagogy (using the Delphi method to ensure that experts in engineering pedagogy could appreciate the questions): i) Teachers general information, ii) Experience in engineering pedagogy, iii) Needs in engineering pedagogy, and iv) Open questions to identify strengths and weaknesses of teachers, and conditions to face future (improvement) training. The instrument was applied to a deliberate sample of 53 teachers engaged in engineering classes.

To ensure the results of the implementation of the instrument, the following issues were tested for reliability: "Engineering pedagogy experience" as it is a topic built with type Likert scaling and the topic "Engineering pedagogy needs" built in form of a questionnaire of dichotomous closed questions, the idea was to determine whether the instrument is consistent and accurate to measure the intended characteristics. Only one sample is taken and the SPSS@20 statistical program and the model of internal consistency of Cronbach was used.

With the results was observed that "Theoretical and practical knowledge about the didactics for the teaching and learning process in engineering" and "Evaluation and assessment of the students' learning achievements" reach the highest value (96%) as Engineering pedagogy needs ; on the other hand "Activity planning for individual study" (65%), "Analysis of the social scope of engineering in Chile" (64%) and "Analysis of the personal scope of engineering in Chile" (64%) are valued as the less necessary.

If a relative frequency of $\geq 85\%$ is established as a criterion for considering an aspect highly important (highly necessary and necessary), then these aspects ordered from the highest to the lowest frequency in general, are the following:

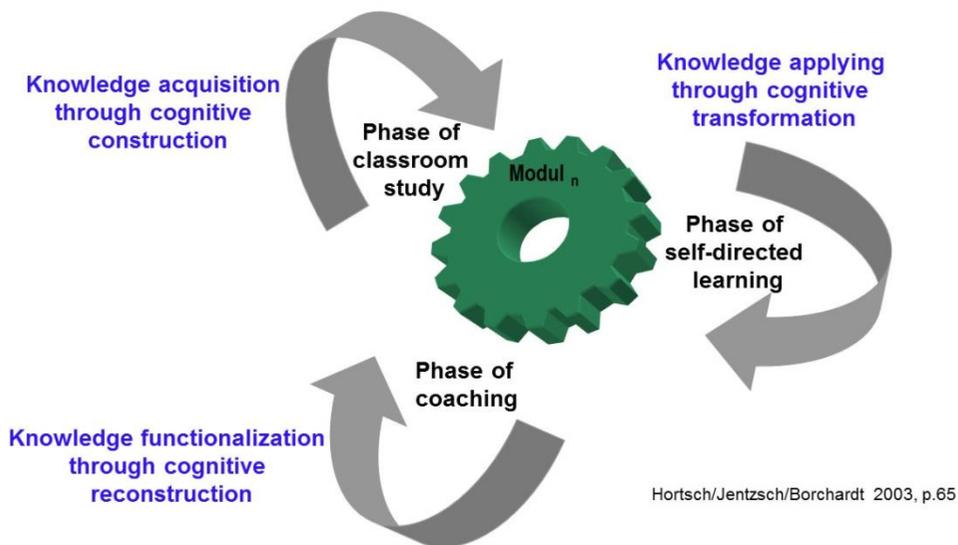
1. "Theoretical and practical knowledge about the didactics for the teaching and learning process in engineering"
2. "Evaluation and assessment of the students' learning achievements"
3. "Knowledge about the design for the effective measurement of the learning accomplishments"
4. "Didactics principles for the teaching and learning processes in engineering"
5. "Knowledge of special forms for teaching at the university level"
6. "Organization of teaching and learning processes for the scientific formation of engineers";
7. "Use of didactic resources and of information and communication technologies (ICTs);
8. "Knowledge about the procedures for the recollection and measurement of the learning achievements"
9. "Analysis about the concrete activity of engineering and the knowledge coming from the engineering sciences"
10. "Knowledge about the scope of action of didactic resources"
11. "Structuring of teaching and learning processes for the scientific formation of engineers";
12. "Knowledge about the design of didactic resources for the teaching and learning process";
13. "Knowledge and ability for the preparation, execution and feedback of the teaching process";
14. "The fundamentals to determine the technical subject matters within the field of engineering"

About the moduls

The different modules are systematically based on each other. All modules are aimed at the development of scientifically-based, application-oriented action rules for the planning, execution and analysis of academic teaching and learning in engineering sciences.

The didactic concept of the training program provides teaching-learning arrangements in coordinated phases of classroom study, self-directed learning as well as individual coaching.

Structure of a learning and teaching arrangement



In particular, the phases of self-directed learning and individual coaching are supported by internet-based learning scenarios. The selection of the tools of e-learning is determined exclusively by its didactic purpose and functions.

All modules are represented in a contemporary learning content management system. These are arranged similar to the course structure and include the multimedia-based learning materials. This includes the learning content, exercises of varying difficulties, examples of teaching and learning scenarios and tests. In addition, extensive tools for communication between learners and experts are available: chat, forum, wiki, email, podcasts and blogs. The participant can store his files in a private folder and documents his progress in a portfolio. In addition to designed and managed online courses with extensive features, it is also possible to form individual online learning and working groups. The managing of the course-content, the access control and the communication can be done by the teaching staff or by skilled management personnel. For the mobile learning is a special mobile version available.

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