PRACTICE-ORIENTED ENGINEERING DESIGN EDUCATION – AN INSTITUTIONAL COMPARISON

Markus VOß[1] and Hans LAUTNER[2]
[1]DHBW Baden-Wuerttemberg Cooperative State University Mannheim, Germany
[2]HDA Darmstadt University of Applied Sciences, Germany

ABSTRACT
The German education system knows two types of institutions endowed with a practice-oriented mission in tertiary education: Universities of Applied Sciences and Cooperative State Universities. Despite their common dedication to practical application both types of institution offer different learning environments. The authors compare the BEng programmes in Mechanical Engineering of both systems, illustrate the findings on the example of two neighbouring practice-oriented universities in the South of Germany and work out practical consequences for teaching Engineering Design. The scientific contribution of the article is in objectivising the discussion of the existing organisational differences between different practice-oriented types of institution in tertiary education. The main differences found between both types of institution are in the pacing of learning and in the time frame for applying the acquired theory to practice.

Keywords: Practice-orientation, engineering design education, German higher education system, comparative study

1 INTRODUCTION

In Germany, prospective Engineering students seeking a quick entry into the labour market after their studies usually chose to enrol in Universities of Applied Sciences or Cooperative State Universities [1, p.5]. Both institutions offer more practically oriented teaching in the first stage of tertiary education. Their programmes do not lead directly to an advanced research qualification. Both programmes correspond to level 5 of UNESCO's international standard classification of education (ISCED) [2, p.19].

Universities of Applied Sciences have been incorporated by several Federal States in Germany in the beginning of the 1970s in order to respond to a growing demand of highly qualified labour force, particularly in the Engineering sector. But it was not until 1976 that they have been raised to the legal level of tertiary education [3]. Their educational objective is in qualifying students for the application of scientific methods in professional practice [4, §4(3)].

In the federal state of Baden-Wuerttemberg, **Cooperative State Universities** look back on a 39 year's tradition of combining academic studies and workplace training in close cooperation with industry. The institution changed its legal status and became university in 2009 [5, §1(2)5]. Companies are far more than loosely associated partners, they are full members of the university. According to the Higher Education Act [5, §9(1)] approved companies delegate representatives to work in executive committees at all levels (board of management, university council, commission for quality assurance, expert commissions). Thus, companies select eligible students, supervise observance of training curricula during workplace training and involve students in projects and processes. The campus at Mannheim is one of the largest locations of Baden-Wuerttemberg Cooperative State University and has been founded in 1974.

2 APPROACH

Model. As topological guideline for structuring our comparative study we use a model of the learning process by Hubka and Eder [6, p.226ff]. In order to demonstrate its universal deployability, they have applied their famous Theory of Technical Systems (TTS) to education in general and Engineering Design education in particular, see Figure 1. They understand education as a transformation system (TrS). In this model learners 'whose state of knowledge, abilities, skills and experience' changes are the operand (Od) of a transformation process (TrP) – i.e. the learning process – that they submit to. The academic and technical staff as well as the students themselves (!) are classed as human system (HuS) and act as operators of that process. Teaching also requires a technical system (TS), i.e. textbooks, media, computers, laboratories and so on. The information system (IS) contains ‘the knowledge that is to be taught’ as well as ‘the knowledge about how to teach’. Finally, the management and goal system (M&GS) sets the institutional framework for enabling the learning process in the form of study programmes, examination regulations, etc.

Criticism. Although this transformation model sees the learner in a dichotomous role of being operand and operator, it is often criticised for not emphasising enough that learning should be a self-regulated process. Indeed, it may pretend that students enter a ‘factory’ (= university) as ‘rough diamonds’, go through a ‘cutting’ and ‘polishing’ process (= lectures) and leave the ‘factory gate’ as ‘precious gems’ (= graduates). Therefore, other authors advocate partner models where students take responsibility for their education at eye level with teachers [7, p.6f].

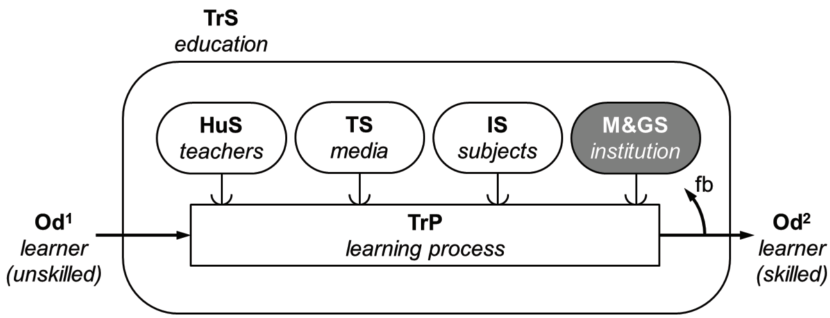


Figure 1. Model of the learning process [6, pp.24,230]:
TrS transformation system, TrP transformation process, fb feedback,
HuS human system, TS technical system,
IS information system, M&GS management and goal system,
Od operand, ^{i} in state i

Our **aim** in this article is
(1) to compare practice-oriented Engineering Design education at tertiary level (offered at Universities of Applied Sciences and at Cooperative State Universities) and
(2) to work out the suitability of the offered study programmes for different learner characteristics

As **working hypothesis** we formulate that
(1) the management and goal system of an educational institution influences the learning process crucially and creates a specific learning environment
(2) the learning environment that an educational institution offers should match the learners’ characteristics and learners’ history

Methods. In our study we exploited existing statistics, compared systematically study programmes and examination regulations and talked with colleagues at both institutions.

3 COMPARISON

Recently, the eighteen month project ‘Konstrukteur 2020’ outlined the challenges in Engineering Design education in Germany and tried to answer the question which educational paths lead students to the profession of a design engineer [8, p.13]. Although Universities of Applied Sciences teach about 1.3 times as much Engineering students as universities [9, pp.71-74] that study is centred very much on education in (research-oriented) universities. An electronic survey in that study questioned 91 % of professors from universities, only 9 % came from Universities of Applied Sciences [8, p.19]. Cooperative State Universities which offer a unique education model in cooperation with industry have not been mentioned at all.

Therefore, the particular interest in our study is in analysing practice-oriented Engineering Design education in Germany, cf. [10] for a similar study. As typical representatives for institutions in that domain we describe Mechanical Engineering education at Darmstadt University of Applied Sciences (HDA) and Baden-Wuerttemberg Cooperative State University (DHBW) in Mannheim.

3.1 Human System (HuS): teachers

At Universities of Applied Sciences, teaching is mostly covered by own academic staff. At Cooperative State Universities, nearly 60 % of lectures and laboratories are held by external lecturers. Partly they come from other universities; partly they are skilled professionals from industry.

3.2 Information System (IS): study programme

With respect to content and workload, the Engineering Design lectures at both institutions are very similar, see Table 1. The freshman Engineering Design courses at Darmstadt University of Applied Sciences (HDA) and Baden-Wuerttemberg Cooperative State University (DHBW) Mannheim both cover the basics of engineering communication in introductory courses to technical drawing in the first or second semester, respectively. At the beginning, the courses are more focused on design guidelines. In the following semesters the focus shifts to calculations, based on failure theories. Thus, in the higher semesters Machine Elements are taught. The lectures are supplemented by problem-based tutorials, cf. [11]. Also, an introduction to Computer-Aided Design is given at both universities. The cumulated workload ranges between 264 and 270 class hours and the courses altogether are credited with 20 credit points according to the ECTS-standard at each university.

Table 1. Engineering Design courses in the Mechanical Engineering curriculum

institution	HDA			
type	University of Applied Sciences			
	rS	*course*	h	CP
	2	Engineering Basics	30	10
	3	Machine Elements 1 lecture	75	
		Machine Elements 1 tutorial	30	
		Computer-Aided Design	30	10
	4	Machine Elements 2 lecture	75	
		Machine Elements 2 tutorial	30	
			270	**20**

institution	DHBW Mannheim			
type	Cooperative State University			
	mS	*course*	h	CP
	1	Engineering Design 1	36	5
		Design Project 1	12	
	2	Engineering Design 2	48	5
		Design Project 2	12	
		Computer-Aided Design	36	
	3	Engineering Design 3	48	5
		Design Project 3	12	
	4	Engineering Design 4	36	5
		Design Project 4	24	
			264	**20**

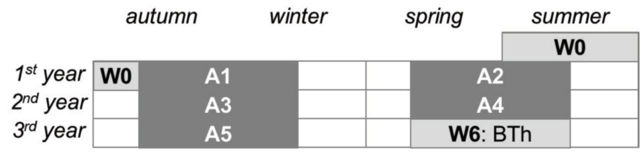
r *recommended,* m *mandatory,* S *semester,* h *class hours,*
CP *credit points according to the ECTS-standard*

3.3 Management and Goal System (M&GS): institutional framework

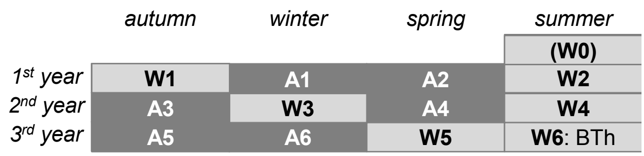
The Mechanical Engineering **curriculum** at Darmstadt University of Applied Sciences (HDA) nominally takes six semesters, see Figure 2a. Without vocational training, students must do an 18 weeks industrial placement in industry with a main focus on manual manufacturing processes before the enrolment. The semesters have 15 weeks, with no activities scheduled in between the semesters. The capstone of studies is a practical training semester where students also write their bachelor thesis.

Cooperative State Universities offer workplace training and academic studies that alternate seamlessly in three-monthly intervals, see Figure 2b. Throughout the workplace training, students document their practical projects in technical reports and reflect if practical experience matches with what they have learned in theory. The workplace training in the sixth semester includes the bachelor thesis. The duration of studies is fixed to three years (no extension provided).

Class attendance. Like at many other universities, class attendance in lectures is recommended but voluntary at Universities of Applied Sciences. Not so at Cooperative State Universities: As the students hear lectures ‘during their labour time’ and are remunerated by their employer for doing so, class attendance is obligatory.



(a)



(b)

Figure 2. Engineering Design Curriculum: (a) HDA, (b) DHBW Mannheim, W workplace training, A academic studies, 1-6 semester, () voluntary, BTh bachelor thesis

The **examination regulations** at Universities of Applied Sciences (recommend but) do not predetermine when to pass an examination. That allows students to plan their studies according to their individual learning progress. It also opens a door to engage in extracurricular activities. Students that have failed an examination in first attempt are due to a resit in the following semester. In case of repeated failure students have to undertake their third attempt in the semester thereafter. If still not passed, the written examination is reassessed in an oral amendment examination within a period of eight weeks. The flip side of this coin: If repetitions are needed the examination procedure at Universities of Applied Sciences inevitably protracts the duration needed to complete the study programme.

By contrast, at Cooperative State Universities examinations are tightly scheduled: Tests are taken one week after the lectures have finished. If a second attempt is required, the resit takes place in the second attempt examination period four weeks after the first attempt. In the case of failure in the second attempt, students have to pass an oral examination another four weeks later. But students can only claim one oral examination per study year. All in all, only eight weeks pass from first attempt until the final decision if the studies can be continued or not. This requires students to be test-wise and they must be trained to 'deliver' their knowledge right to the point.

3.4 Operands (Od): learners

Entrance qualification. The learners at both institutions also differ significantly in their learning history. About half of the students (45 %) enrolled in the Mechanical Engineering programme at Darmstadt University of Applied Sciences (HDA) have completed vocational training, see Figure 3a. With their studies they seek to add an engineering view to the occupational knowledge they have already gained in industry. The rest of the students (55 %) enter with the general university entrance qualification.

University entrants going to a Cooperative State University usually come directly from a secondary school, just having obtained their university entrance qualification, see Figure 3b. In Mannheim, most of them (87 %) have the general school leaving examination that qualifies them for entrance at any type of university. Those having a qualification for entrance at Universities of Applied Sciences (12 %) must pass an additional examination for enrolling at a Cooperative State University. Otherwise, admission is not restricted (e.g. through a numerus clausus system) on the part of the university. But a signed training contract with a company is a prerequisite for enrolment. So it is the companies that 'select' the best students in job interviews.

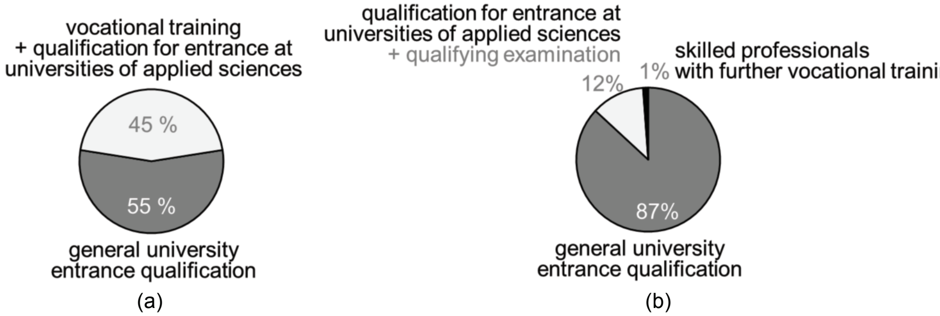


Figure 3. Beginners by entrance qualification:
(a) HDA (Mechanical Engineering), (b) DHBW Mannheim (School of Engineering, 2009)

Cultural diversity. Teaching culturally diverse students challenges Universities of Applied Sciences much more than Cooperative State Universities. Internationality is a central concern in the mission statement of Darmstadt University of Applied Sciences. Universities of Applied Sciences in the federal state of Hesse succeed in attracting a high share (13.4 %) of foreign students [9, pp.10,14]. This confronts teachers, for example, with cultural differences in motivation (the role of collectivism and the family) and socio-cultural stressor conditions [12, p.158f]. With respect to Cooperative State Universities, the question can be raised why it is not more attractive to companies to employ students originating from other countries.

3.5 Transformation Process (TrP): learning process

Acquisition of practical engineering knowledge. As mentioned in the previous section, many students at Universities of Applied Sciences have successfully completed vocational training before enrolling on an Engineering programme. Another source of practical feedback for some is a job on the side in a company. Towards the end of the studies, Universities of Applied Sciences have a practical training semester, designated W6 in Figure 2a. But in interviews, lecturers from Universities of Applied Sciences state that the band width in the acquisition of engineering knowledge is very broad between the students (inhomogeneous distribution in a course).

At Cooperative State Universities, the regular workplace training in ‘their’ company makes students forge close links to engineers in different departments. This helps them to develop engineering judgement at an early stage of their studies. Due to their quasi-similar learning history, students at Cooperative State Universities are (more or less) homogeneous learners whose engineering knowledge is growing (almost) linearly over the course of six semesters.

Completion of studies. Compared to universities, the drop out rate of students who have to abandon their studies because they repeatedly have not passed an examination is very low in practice-oriented institutions: In the Mechanical Engineering department at Darmstadt University of Applied Sciences only 11 % of the students enrolled in the period 2002-2006 had to give up as a consequence of a failed examination. This number was similarly low (15 %) in all faculties of Baden-Wuerttemberg Cooperative State University in Mannheim in 2009. The rest of the students (85 %) at Baden-Wuerttemberg State University in Mannheim nearly all completed their studies and obtained a bachelor degree. This high rate is partly due to the job interviews that companies lead with future students before the enrolment to test the students’ abilities and motivation for taking up these studies, and partly due to the good perspectives for permanent employment in the company (90.6 % of the graduates in 2010). By contrast, at Darmstadt University of Applied Sciences there are a significant number of students that enrol at another university or in another study programme.

4 CONCLUSION

Universities of Applied Sciences and Cooperative State Universities do not compete directly for students because they offer different learning environments for different types of learners with a different learning history.

Universities of Applied Sciences create 'room to manoeuvre' for learning and personal development. Study and examination regulations allow students to set their own pace for learning. They can choose when to pass examinations according to their individual learning progress. This potentially helps students to catch up with learning when they encounter problems in specific subjects. Many Mechanical Engineering students use their free time and semester breaks to work in an engineering office. Some have even raised their own business. But the price they often pay for this freedom is a longer duration of their studies.

In comparison, CSU curricula are closely clocked. The programmes require structured and strategic learning from the beginning of the studies. 'Strategic learners know when they understand new information and, perhaps even more important, when they do not. When they do encounter problems […], they use help-seeking strategies [12, p.293].' For example, students who fail an examination need to take a resit examination four weeks later. This rigour in learning is rewarded with an 'institutionalised' gaining of practical experience in a company.

This article has sketched a more differentiated picture of the academic landscape in practice-oriented education at tertiary level in Germany and hopefully will stimulate discussion about comparing the results with experience from higher education systems in other countries. e.g. as in [13].

REFERENCES

[1] Eurydice network: The structure of the European education systems 2012/13. Schematic diagrams. 2013 (European Commission, Brussels)

[2] ISCED 1997. International Standard Classification of Education. 2nd ed., 2006 (UNESCO Institute for Statistics, Montreal)

[3] Hochschulrahmengesetz (In German: Framework Act for Higher Education), 1976 (Federal Ministry of Education and Research, Bonn)

[4] Hessisches Hochschulgesetz (In German: Higher Education Act of the Federal State of Hesse), 2010 (Hesse State Ministry of Higher Education, Research and Arts, Wiesbaden)

[5] Gesetz über die Hochschulen in Baden-Württemberg (In German: Higher Education Act of the Federal State of Baden-Wuerttemberg), 2012 (Baden-Wuerttemberg State Ministry of Science, Research and Arts, Stuttgart)

[6] Hubka V. and Eder W.E. *Theory of Technical Systems. A Total Concept Theory for Engineering Design.* 1988 (Springer, Berlin).

[7] Beverungen J., Saller D., Beedgen R. and Melzer-Ridinger R. *Qualität in der dualen Lehre (In German: Quality in cooperative education)*. (DHBW, Mannheim)

[8] Albers A., Denkena B. and Matthiesen S. *Faszination Konstruktion. Berufsbild und Tätigkeitsfeld im Wandel. Studie der Deutschen Akademie der Technikwissenschaften. (In German: Fascination Engineering Design. Changing job profile and field of activity. Study of the German Academy of Science and Engineering).* 2012 (Springer, Berlin).

[9] Bildung und Kultur. Studierende an Hochschulen. Wintersemester 2011/2012. Fachserie 11, Reihe 4.1 (In German: Education and Culture. Students at Universities. Winter semester 2011/2012.) Preliminary report, 2012 (Federal Statistical Office, Wiesbaden)

[10] Melzer-Ridinger R. and Backfisch M. Positionierung des 'Dualen Originals' in der Landschaft der Hochschulabschlüsse. Abgrenzung von dualen Studienangeboten und exemplarische Vergleiche zwischen Studienangeboten der DHBW, Universitäten und (Fach-)Hochschulen. (In German: Positioning the 'cooperative original' in the landscape of university degrees. Delimitation of cooperative study programmes and exemplary comparison between study programmes of DHBW, universities and universities of applied sciences.) *Studium Duale.* 2011, 16 (DHBW, Mannheim), pp.44-54.

[11] Voß, M. Students response to open-ended problems in an Engineering Design project. In Buck L., Frateur G., Ion W. et al. *14th International Conference on Engineering and Product Design Education, E&PDE 2012,* Antwerp, September 2012, pp.343-48 (Design Society, Glasgow)

[12] Svinicki M. and McKeachie W.J. *Mc Keachie's Teaching Tips. Strategies, Research, and Theory for College and University Teachers.* 13th ed., 2011 (Wadsworth, Belmont).

[13] Christiaans H. and Almendra R.A. David and Goliath crossing the bridge. In Boks C., McMahon C., Ion W. and Parkinson B. *12th International Conference on Engineering and Product Design Education, E&PDE 2010,* Trondheim, September 2010, pp.575-79 (Design Society, Glasgow).