

On-professional Competences in Engineering Education for XL-Classes

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Abstract—Far reaching changes in university higher education have taken place in the last ten years. Different factors, e.g. necessity of on-professional competences in engineering education, rising or vast student numbers and new technical possibilities, have influenced the academic teaching and learning process. Therefore interdependence between requirements and didactical-educational possibilities is given. Because of changed circumstances an adaption of teaching methods and concepts is required. At the same time Bologna arrogates students to be placed in the centre of the teaching and learning process and claims on-professional competences for today's students. Especially for XL-Classes this is a specific challenge. One of the questions ensuing is how to increase learning success by the use of specific didactical methods? With a research approach connecting different proven didactical concepts and considering the previously shown conditions, the concept of the lecture “communication and organizational development” (KOE) at RWTH Aachen University has been redesigned. This lecture, organized by the Institute Cluster IMA/ZLW & IfU at RWTH Aachen University, is mainly frequented by up to nearly 1.300 students of the faculty of mechanical engineering and inherent part of the bachelor-curriculum. The following practical example prospects the multi-angulation of didactical concepts and shows up innovative educational teaching.

Index Terms—engineering education; audience response system; on-professional competences; best-practice

I. INTRODUCTION

Innovative teaching techniques and concepts have been developed in the last years against the background of different factors of influence in the teaching process of higher education. This paper presents a best-practice example, which implements and combines different didactical concepts in higher education. The combination of different concepts is necessary as set out in chapter II – Challenges in context of higher education.

In the course of years multifarious didactical concepts have been created. Research reveals different human learning types and success, depending on learning environments [1]. It follows and carved out that integration of learning methods and styles is essential.

Bologna claims the design of student-centered education formats and conveyance of on-professional competences [2], which is challenging especially in large-audience courses, the so-called “XL-Classes”. On-professional competences are understood as competences which enable students to deal with their theoretical specialized knowledge and prepare them for working life.

These competences comprise e.g. methodological-, social-, self-reflecting- and media-skills.

By means of the lecture “communication and organizational development”, organized by the Center for Learning and Knowledge Management (ZLW) of the RWTH Aachen University, it is highlighted, how and against which backdrop the lecture was subjected to a whole redesign to cope with the changed influence-factors, technical possibilities and student-requirements. This redesign is mentioned in chapter III – Redesign of the lecture ‘KOE’.

II. CHALLENGES IN CONTEXT OF HIGHER-EDUCATION

During the last decade far reaching changes in higher education teaching took place. Different factors have influenced the design of higher education, for example conveying on-professional competences in higher education, the high number of students at German universities and (new) technical opportunities. These most important challenging factors will be elaborated in the following.

A. The challenge ,XL-Classes‘

In Germany, many Universities face the challenge of a vast number of students each semester, especially in engineering education degrees at RWTH Aachen University [3]. This challenge is tightened by the reduction of school time by one year due to a change in German educational policy. In addition to that the demand for engineers in Germany is growing [4]. More than ten years after implementing the Bologna Declaration, the higher education system in Germany has changed significantly [2]. Since then students and their learning process represent the core of the teaching and learning process. This change, also known as a ‘shift from teaching to learning’ [5], is a more student-centered and involvement-oriented design of teaching. ‘It is characterized by innovative methods of teaching which aim to promote learning in communication with teachers and other learners and which take students seriously as active participants in their own learning, fostering transferable skills such as problem-solving, critical thinking and reflective thinking’ [6]. Instead of being ‘content-oriented’, which means focusing on the transmission of content, the design of teaching now focuses on ‘learning outcomes’, hence the students’ learning results and the way of achieving these results. This is, however, a major challenge to lecturers of XL-Classes, as they predominantly focus on the transmission of content due to their difficulties of involving a large number of students at the same time. Therefore the question arises how a lecture can be student-oriented in XL-Classes.

B. Conveyance and promotion of on-professional competences

Due to the huge number of students attending lectures-XL-Classes have the problem of a content-oriented focus. Therefore the conveyance of on-professional competences to students in XL-Classes is often in a theoretical way. Indeed the transmission of on-professional competences plays an important role in higher education in general and particularly in engineering degree programs [7]. Not only professional knowledge is required to be the output of higher education, but also soft skills like method-, self-, organizational - and social competences are expected from today's students [8].

Against this background the required competences are considered at the redesign. From its multidisciplinary and holistic approach, the ZLW aims at designing and conducting lectures also including the transmission of on-professional competences. Thereby the ZLW tries to accomplish one major goal of the Bologna Process, which is "to create a European space for higher education in order to enhance the employability [...]" [2]. Students should be educated in a way which makes them available for the employment market in a fast, efficient and adequately educated manner [9]. This means students should be enabled to convert learned knowledge in higher education in later working life [10].

C. Combination of didactical concepts

Didactical concepts are the tools of today's lecturers. Those concepts and methods are combinable and applicable in various ways. Due to the didactical diversity of methods a student-centered alignment of lectures is possible. The students learning process is further supported through didactical multi-angulation [11].

Additionally, the students obtain skills in dealing with various methods through methodical diversity (e.g. with presentation techniques). Böss-Ostendorf and Senft confirm that useful methodical diversity is a factor of success for university education, because of the multiplicity access to teaching content [12]. The reasons for integration and combination of different didactical concepts are mentioned by Flechsig [1]:

- Various learning styles and types of students with different learning success
- Diversity of study motivation and interest
- Variety of competences and fields of knowledge
- Variety of context in which learning is placed

Any didactical method aims at enforcing learning and knowledge permanently [13]. As a result a sensible combination of didactical methods and concepts to increase learning-success for students is necessary. As a consequence concepts, explained in the following, have been integrated in the lecture 'KOE'.

III. REDESIGN OF THE LECTURE 'KOE'

The compulsory lecture "communication and organization development" (KOE) is held every winter term. Almost 1300 students, mostly engineering students, participate in this weekly lecture. In addition a laboratory session takes place, in which students experience a simulated company situation in an authentic environment [14]. Based on the changed influence factors, which are men-

tioned before, and with the premise to maximize learning success and also among the maxim of sustainable teaching of practice-oriented and on-professional contents, the lecture is continuously refined and was subject to a complete redesign in the winter term 2012/2013. Existing elements were further developed and new didactic elements were implemented. The lecture's elements (shown in Figure 1) will be explained in the following.

A. Theory input and lecture modules

The lecture consists of twelve modules, including the basics of communication and organization development, learning- and knowledge management concepts and intercultural aspects of global work division management as well as system-theoretical approaches and practical inputs by experts from industry. The whole concept of teaching follows a linear structure. Practical lectures tie in with earlier taught theoretical contents. Thus an ideal transfer from theory to praxis is established. At the end of every module contents are reflected and summed up. For this purpose the 'KOE funnel' is applied (Fig. 2). Both the systemic view and the different levels of a company are included. Thereby communication and organization are regarded as the most important requirements for the development of interaction between humans, technique and organization on the different organizational levels, for example within departments or project teams.

Didactical multi-angulation of the lecture 'KOE'	
A	Theoretical inputs and lecture modules
B	Practice oriented theoretical inputs through expert-lectures with professional practice
C	Interaction in XL-Classes through Audience Response Systems (ARS)
D	Learning on demand through medial preparation
E	Teaching and learning online portal/platform
F	Simulation based learning through organizational simulation
G	Online examination system

Figure 1. Didactical elements 'KOE' lecture at RWTH Aachen University

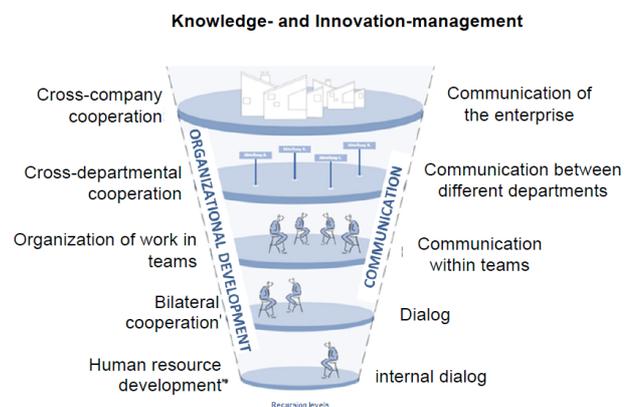


Figure 2. 'KOE' funnel/recursion-layers [14]

B. Expert lectures

As already stated the lectures redesign aims for an increasing relation to practice applications and does not only focus on technical expertise. Additionally it also aims at increasing the ability of understanding the complexity of working life. The inclusion of on-professional competences in studies is not only an issue since the Bologna reform [15]. Furthermore it is important to connect the studies with professional practice, not only from the student's perspective, but also from the perspective of company representatives [16]. For this reason, it is more important to connect teaching with practical insights [15]. Based on this, guest speakers with professional industrial background give an insight into their companies and working experiences (e.g. Vodafone Group, Capgemini, p3 group, inside group of companies). For example: Lecture contents are the experiences in handling international projects as well as interdisciplinary challenges. The experts as well as the lecturer try to establish the connection between already taught theoretical contents and the meaning of communication and organization development in daily processes. In this way theories are linked to praxis and relevance is outlined. In order to solve the area of conflict between the teaching of basic sciences and practical teaching at the expense of theoretical essentials [17] the distribution of proper contents and basics is kept reasonable.

C. Interactivity through the application of "Audience Response Systems"

As outlined by Prensky, that "our students have changed radically" and that "today's students are no longer the people our educational system was designed to teach" [18], (new) technologies e.g. in the form of 'Audience Response Systems' (ARS) may improve the learning outcomes of students [19]. Due to the application of an ARS, students are further involved in the education process.

The ARS is a valuable didactical element as already mentioned by Brinker/Schumacher in 2009 [20]. Capabilities to participate in a lecture are quite diverse for students, which means that they can choose particular contents, recap their knowledge, interpret, reflect and prepare for examinations. Taxonomies of learning goals, like knowledge, understanding, application and analyzing [21] [22] are addressed holistically by the use of knowledge and comprehension checks. As a result problem-solving skills can be improved. The barriers for participation are marginal. Only an end device with access to the internet is required.

To satisfy the student's demands and with the objective to enable interactions between lecturer and students [23], an ARS is used since the winter term 2012/2013. The implementation of the described system demands a redesign of the lecture with special regards to the content. Questions have to be developed that allow the students to interact with the lecturer as well as with each other. This variety of questions ranges from multiple-choice questions to the inquiry of calculation results etc. [19]. Furthermore iteration-loops, to repeat misunderstood content, can be taken into account.

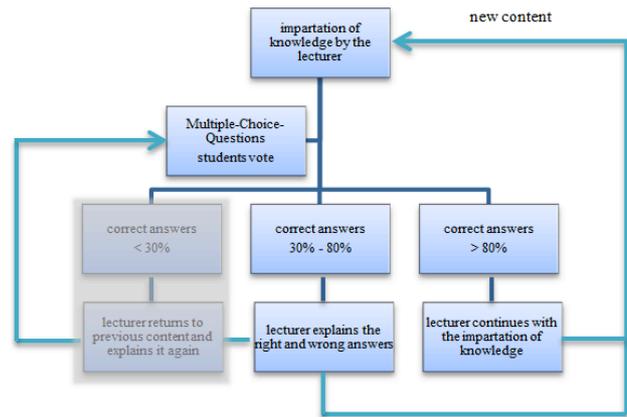


Figure 3. Didactical concept of using the ARS [23]

Figure 3 illustrates the didactical concept of an Audience Response System, which is treated in the 'KOE'. Two fields are shaded grey, as this case is not applied in the lecture. If there are less than 30% correct answers, an explanation on the right answer is given. Provided that the content is understood (>80% correct answers), the lecturer switches to the next topic.

Evaluations of the success of the implementation of ARS in large university lectures show that the application of this "tool" has led to e.g. higher motivation of attendance, more attention of the students during class and even higher knowledge acquisition than in conventional (non-interactive) classes [19]. If and how the new didactical implementation of the media Audience Response System influences the learning process of students in the lecture 'KOE', has to be evaluated during the next terms.

D. Video documentation

In the winter term 2012/2013 the whole lecture was recorded by a professional camera crew, edited and afterwards provided to the students via the online teaching and learning platform L²P of RWTH Aachen University to support the learning process in auto-didactical-phases of the students. As shown in Figure 4 it is a matter of an interactive video documentation. For each module the chapters can be retrieved individually. Knowledge is thereby no longer appropriated as a lecturer-reserve, but accessible for students on demand. This form of making content available for students resembles the concept of learning on demand [25] and results in time saving potential for student learning [26]. Through this video documentation, the students can recapitulate content without any limit and at any time. Furthermore the presentation papers and manual sketches as well as animations and explanations of the lecturer are shown (see Fig. 4). The moderator works as a mediator and presents contents using different channels based on corporate learning. This way offers the possibility to review important contents and especially the preparation of exam papers could be done in a more efficient way. The result is an approach to the teaching for "individual learning", because students can decide when, where and how fast they organize their learning process [27].

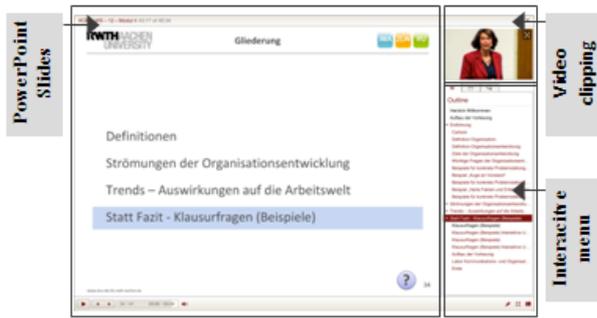


Figure 4. Surface of the video recording of the lecture

E. Exchange and dataplatforms

As a reaction to the various influencing factors like the new technical possibilities, the teaching and learning platform L²P is used since the end of 2007. The learning platform is password secured and is just accessible for registered students.

The platform is implemented in order to provide important contents like teaching materials (e.g. lecture notes, videos and presentations of experts) and (further) literature for the students on a web based server to support time-consuming and complex teaching and learning processes [28] [29]. Additional L²P can be used to conduct surveys and simulate electronic tests.

Moreover the students have the possibility to discuss certain topics in an online forum talking to professors, mates or coaches and to obtain important clues to further arrangements. Thus discussion and dealing with lecture-content is supported and promoted. The aim is to influence the learning process to the effect that knowledge is understood by the students and can be applied. According to Palloff & Pratt the use of L²P in the lecture 'KOE' can be described as a "web-enhanced course" [30]. That implies physical as well as virtual components and thus copes with the European university-tradition in independent preparation of subject-specific content [31].

F. Laboratory tutorial

XL-Classes are faced with the challenge of a theoretical conveyance of on-professional competences to students. During the lecture 'KOE' not all contents can be taught within XL-Classes [32]. Therefore parallel to the lectures a laboratory tutorial of one and a half days takes place. The laboratory tutorial is based on the concept of 'simulation-based learning' which is a research or training method that tries to create a realistic experience in a controlled environment [33]. According to this, simulation replaces or boosts real experiences [34] and thus offers enormous advantages in mediating knowledge long-acting [34] [35]. In groups up to 40 students a foundation of a fictitious automotive company with different branches is simulated. Target systems and various strategies are developed and communication ways are defined and coordinated. An innovative vehicle is constructed under the guidance of 40 professional coaches. The basic knowledge for the realization of this task is mediated via microteaching units. In the next step, earlier learned theoretically basics are applied practically during a company simulation in order to obtain first practical experiences in organizational communication and working processes. Students try to construct an abstract concept in a theoretical framework to finally put

their findings in an active experiment. The teamwork and the communication between the different branches demonstrate the importance of the lecture as well as the relation to working life. Additional to the contents of the lecture 'KOE', key skills such as team building, time management and project management are applied, experienced and trained in the simulation.

G. Online examination system

In order to examine around 1300 students efficiently and content orientated, a digital online examination system (called OPS = Online-Prüfungssystem | developed externally especially for 'KOE') is used and applied since 2007 [36] [37]. Examination questions are derived from the lectures contents and distinguished in different taxonomy levels (degrees of difficulty). Thereby the whole taxonomy-spectrum by Bloom 1956 [25] on a cognitive base is addressed to the students. The taxonomy levels are: knowledge, comprehension, usage, analysis, synthesis and evaluation. For the preparation of exam questions it is important to take into account, that the taxonomy levels are hierarchically arranged [38]. Hence the mediated competences for each taxonomy level must gain a specific manifestation before they can be applied in the next taxonomy level [39]. For example, without knowledge, usage of taught content (transfer capacity) is impossible [39].

Supported by a holistic handling of the mentioned difficulty degrees, the OPS enables to retrieve the student levels of awareness. With the help of the OPS knowledge and transfer capacity can be interrogated and evaluated electronically within a few minutes, so that no further staff is required.

IV. CONCLUSION & VISION

Each semester a university and lecture wide evaluation is stated. First evaluation results indicate that the adaption of the lecture concept and the implementation of new technical and didactic elements have a positive impact on the student evaluation of the course, especially the use of technical aids and demonstrations as part of the lecture as well as the teaching of contents by the lecturer. The average evaluation grade rises in the order of 0.5 (arithmetic average; scale from 1 (very good) to 6 (very bad)). For example the usage of devices and demonstrations in the lecture are evaluated with 1.7 (arithmetic average). The mediation of contents also has a positive trend. Lecture records as well as implementations of ARS Systems are inter alia reasons for that.

Altogether the multi-angulation of various didactical concepts can be outlined as a success for the lecture 'KOE'. This educed concept states that students are centered in educational learning process. In a next step the transferability of the redesigned concept of the 'KOE' lecture must be elaborated. Therefore indicators for a survey will be operationalized and developed.

Based on the already mentioned scientific studies of combining various methodical concepts to increase learning-success and the first positive evaluation after the 'KOE' redesign, more innovative teaching and learning methods will be developed, taken up and implemented for this purpose in the next few years.

Furthermore there is still potential for a continuous and appropriate optimization of the lecture 'KOE'. A long-term goal is to implement additional to the existing con-

cepts the method of ‘just in time teaching’ to optimize and adjust lecture contents [40].

Accordingly presence lectures are not used anymore for conveying contents, but rather to motivate the students to participate and interact in the presence lecture and to discuss questions and problems with the lecture content. Therefore questions and tasks are provided online before every presence lecture. So the lecturer can see the student’s results before every lecture ‘just in time’ and develop the lecture according to the level of awareness. This method is used to obtain feedback related to the student knowledge. This can be used in order to precisely react to the students demands on certain contents. In addition, students get to know on-professional competences while formulating their own questions as well as working on tasks independently. The continuous development of the lecture ‘communication and organizational’ primarily serves the goal of creating demand-oriented and target group-oriented courses for XL-Classes.

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