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Concepts for Purposive and Motivational Teaching and Learning in Engineering Design Courses*

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New technologies demand new qualifications and new teaching concepts. Sole reliance on intuition and previous experience is insufficient. The Technical University of Berlin uses a systematic approach to learning/teaching which adopts a holistic approach to problem solving embracing the new technologies. This ensures that the way of teaching changes as much as the way of learning.

INTRODUCTION

DUE TO THE application of new technologies, modifications of tasks and organizational structures, more complex customer requirements of technical products and services as well as increasing international dependency of economies, design engineers are confronted with new qualification demands. The classical technical-scientific qualification has to be extended by transdisciplinary knowledge and skills, which enable creative problem solutions, cooperative social behavior with leadership abilities and communication competencies as well as a holistic view of technical problems [7].

To face these new qualificational demands, a systematic approach to learning/teaching concepts comprising all relevant dimensions of teaching and learning has to be worked out to ensure a conscious and deliberate process of teaching and learning that can be both influential and capable of communication.

THE BACKGROUND OF ENGINEERING DESIGN EDUCATION IN GERMANY

Looking at the tradition and development of engineering design education in Germany, one first has to realize the double-tracked structure of Germany's higher education sector and in consequence the double-tracked tradition of mechanical engineering programs. Within the 3-year programs at *Fachhochschulen*—which can be translated best as 'colleges of applied sciences'—there is a strong focus on a practice-oriented readiness for job and profession. In contrast the mechanical engineering education within a 5-year university program is aiming at a scientific and theory-based qualification, leading to much more general professional abilities. But even at university, where the curriculum has a strong emphasis on fundamental knowledges in mathematics and basic sciences, the main study shows a distinct orientation towards practice and applied engineering subjects.

Considering the general conviction that design is based probably much more on problem solving experiences and a 'feeling' for the adequate reduction of complexity than on exact scientific methods and strategies, engineering design courses represent an exception within the strong deductive structure of mechanical engineering curricula. Their structure and tradition is inductive, leading from concrete examples to abstract concepts, from real products to models, strategies and processes of general applicability.

This has to be seen in contrast to the tradition and development in the Anglo-Saxon context where, for example in the US as a consequence of the Grinter report [3], since the 1950s the importance of applied engineering subjects declined against the proportion of basic and engineering sciences, although that was only one of the total of 10 recommendations of the Grinter committee. Actually the Grinter report propagated an adequate balance of humanities and social sciences, mathematics and basic sciences, engineering science, engineering specialty subjects and electives. Germany (and most of continental Europe) has not gone through this extreme scientification of engineering education that the US experienced by misinterpreting the Grinter Report. As a result, design methodology like that established by Pahl and Beitz [6] or documented in [8] is considered as being very theoretical in Germany's engineering community. However in

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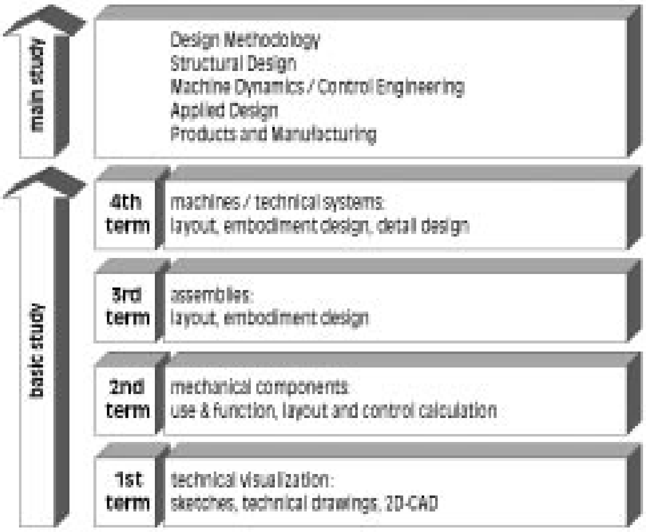

Fig. 1. Engineering design curriculum within mechanical engineering programs at German universities (by way of example of TU Berlin).

the Anglo-Saxon context it is considered as being very applied.

THE INTENTIONAL DIMENSION OF ENGINEERING DESIGN COURSES

Purposive teaching and learning means that first of all one has to define the pursued teaching objectives. As one example Beitz and Helbig questioned German industry and university experts about deficiencies of the past engineering design education and about future demands in this sector [2].

One outcome is a qualification scheme consisting of the 'five pillars' *subject-specific, methods, systems, personal/social* and *practice competencies*, which can be regarded as a new holistic set of teaching objectives for engineering higher education (Fig. 2).

An inquiry among engineering design teachers at TU Berlin executed by the author refined this global set to a level manageable for planning engineering design courses and exercises in the basic study. As one result, each of the four global teaching objectives has been differentiated to a profile of competencies to be imparted to the students [1].

LEARNING/TEACHING CONCEPTS FOR ENGINEERING DESIGN COURSES

Usually in concepts for courses and exercises the main attention is directed to the choice of teaching topics to be treated (e.g. shafts, clutches, gearboxes). This causes a natural emphasis on classical subject-specific competencies without *explicit* and *conscious* treatment of transdisciplinary knowledge and skills. A modern learning/teaching concept has to combine the four dimensions: *teaching objectives, teaching topics, teaching methods* and

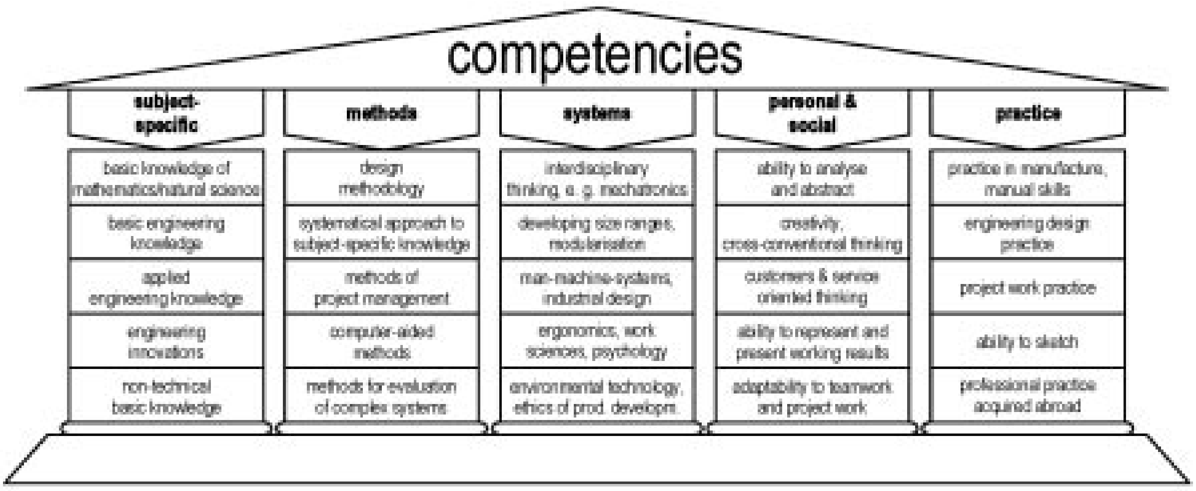

Fig. 2. The 'five pillars' of qualification—global teaching objectives for engineering design education [2, p. 55].

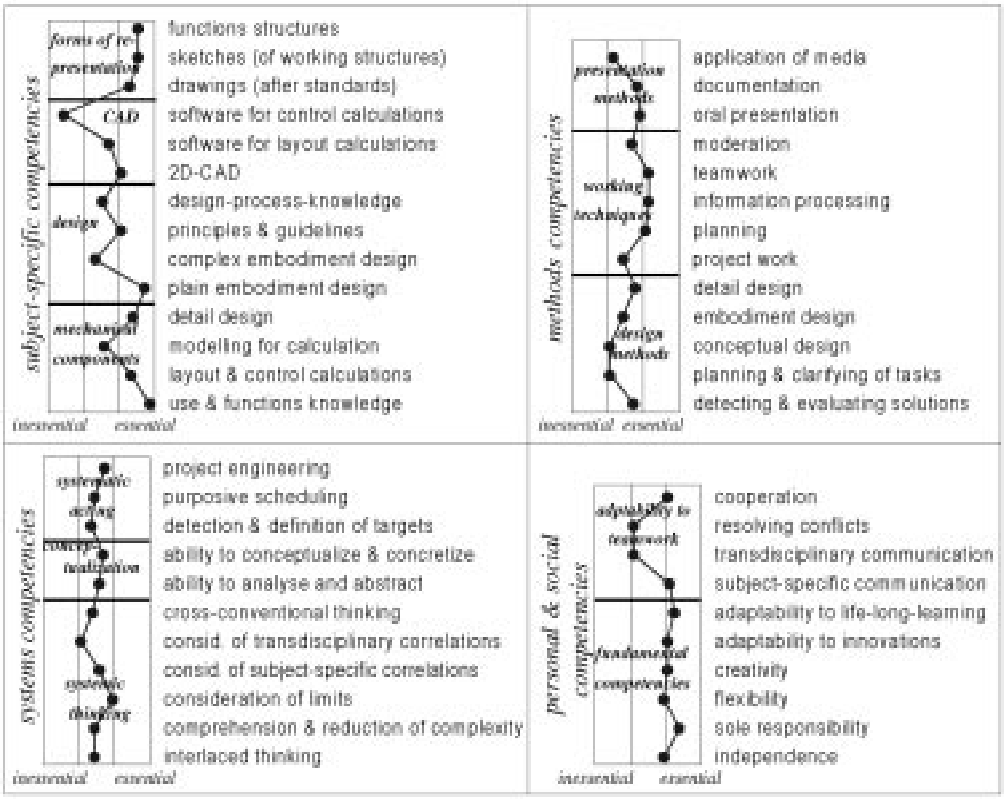

Fig. 3. Profiles of competencies for engineering design courses (basic study) [1].

teaching media, in consideration of didactical cognitions.

A didactical model suitable for engineering design courses is represented by 'Kolb's cycle of experiential learning', which differentiates the four phases *concrete experience*, *reflective observation*, *abstract conceptualization and active experimentation* [4], cit. after [5] (Fig. 4).

In order to make sure that this cycle will be closed for each teaching objective, teaching methods and media have to meet appropriate student workforms. One can visualize the correlation of the four learning/teaching dimensions with the four design phases: *planning and clarifying the task*, *conceptual design*, *embodiment design* and *detail design* [6, p. 65] and appropriate student workforms in a portfolio that gives good advice for the conceptualization of engineering design courses [1] (Fig. 5).

Teaching objectives, teaching topics, student workforms and coordinated forms of teaching methods and media can be combined in such a way that enables a step-by-step integration of transdisciplinary teaching objectives.

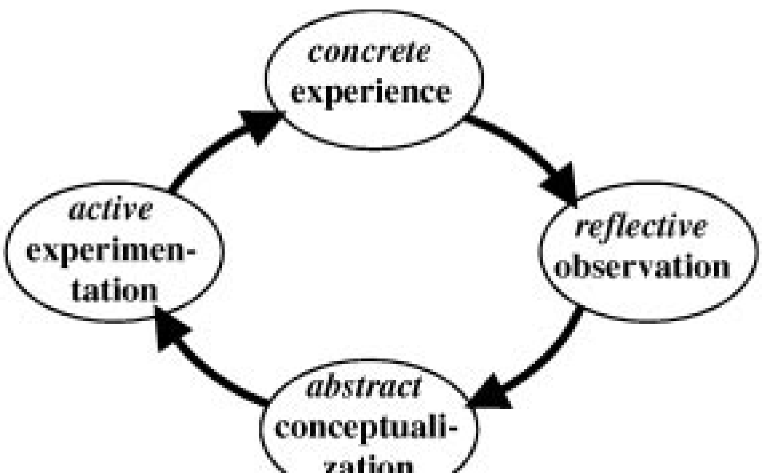

Fig. 4. 'Kolb's cycle of experiential learning' [4] cit. after [5, p. 32].

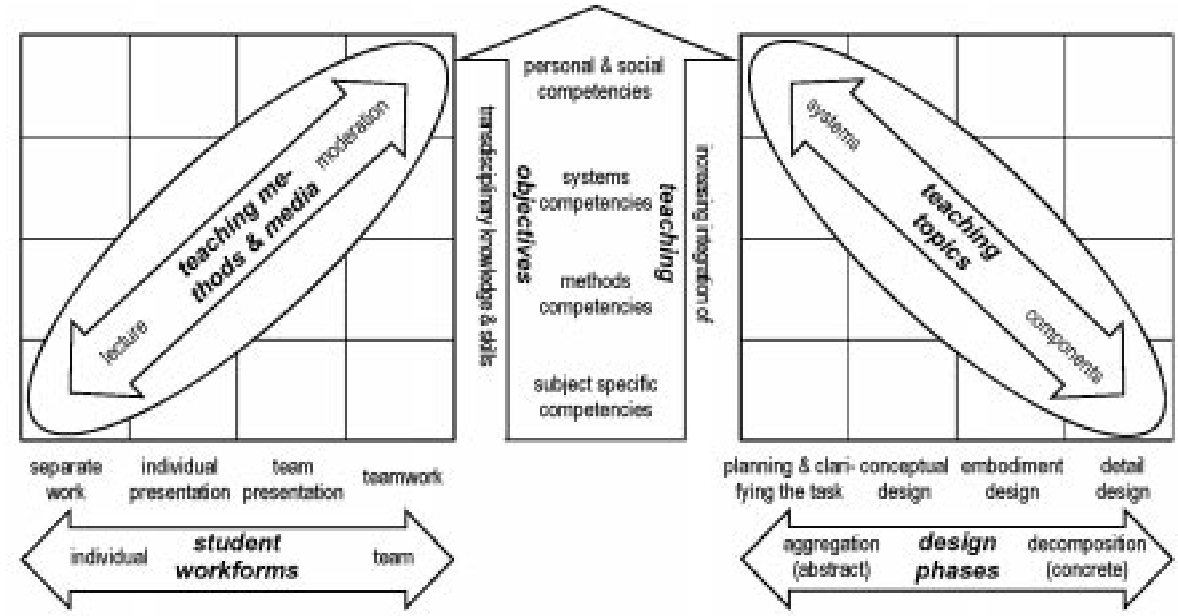

Fig. 5. Correlation of learning/teaching dimensions with design phases and student workforms [1].

MOTIVATION AND THE ROLE OF THE TEACHER

Motivation is a key to keeping the process of learning like that described in 'Kolb's cycle of experiential learning' active. To increase the students' self-motivation to deal with teaching topics on their own and with enthusiasm, teachers have to grow into a new role being not so much a classical lecturer but more a trainer and partner of the students by coaching their approach to the teaching topics and moderating or modulating the process of learning, Fig. 6.

There has to be an appropriate application of teaching methods and media to balance *instruction*, *feedback*, *observation* and *moderation* on one hand and a continuing *modification* of the teaching topics on the other hand to fulfil this new role successfully.

At TU Berlin, in recent years efforts like that shown in Fig. 6 were undertaken to achieve the qualification targets mentioned. The result is a learning/teaching concept tested in practice, which develops the students' transdisciplinary knowledge and skills in the basic study in three terms. The student workforms *separate work*, *oral presentation* (individual or in teams) and *methodically supervised teamwork* are applied to

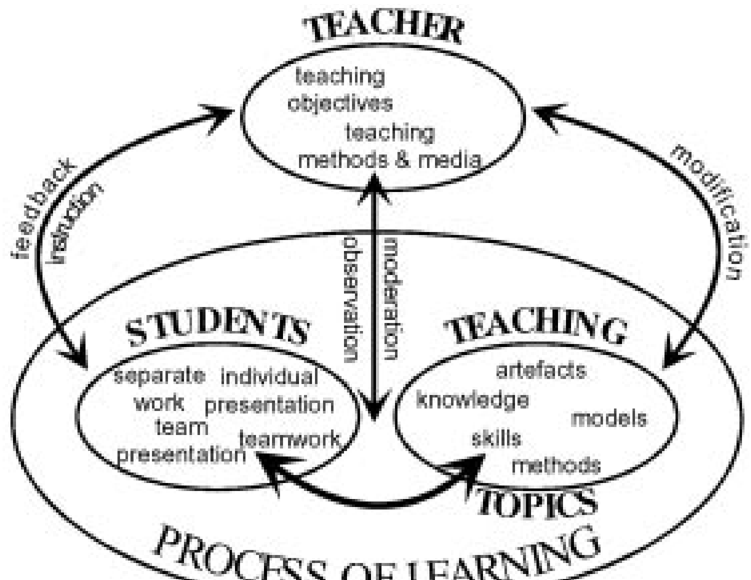

Fig. 6. Teachers' role in modern learning/teaching concepts.

the classical treatment of subject-specific topics during common lecture-room exercises. That causes an improvement of new competencies to be applied and deepened in the final fourth term in the context of a teamwork and problem-based *study project* which is described in [5].

For further training in the main study this learning/teaching concept finds its consequent termination in an engineering design *project seminar* containing a two-days project management training for the students, which has been successfully tested in the last years.

HOW DO WE LEARN NEW TEACHING?

A rarely considered problem is that introducing the new role described above causes an enlargement (and enrichment) of the teachers' tasks. All of this points to the fact that their competencies also are to be extended. Traditions and experiences are important cornerstones of successful teaching but permanent reflection on objectives, topics, methods and media, the adaptability to communication, innovations and life-long learning are challenges to be faced not only by the students.

As we know by experience, it is more difficult to change the way of teaching than to change the way of learning because personal convictions and long-term teaching traditions show a tendency to be carried on without being questioned. The best way to achieve sustainable changes in this field is to establish a new culture of teaching which is at the same time a culture of life-long learning of the teachers and the faculty.

Today in Germany there is not yet a convincing solution for this problem but at the Institute of Engineering Design at TU Berlin we have successfully tested a mix of approaches to achieve a change of culture like that mentioned above within the last few years.

To prepare all teachers for their job in coaching student teams, instead of holding one-way-lectures 'at' them, we established two days training workshops containing the topics *project management*, *presentation*, *communication* and *moderation*. There is also a weekly teachers' conference with all teachers being involved in a one-term course taking part to discuss actual problems and to synchronize strategies and concepts for team coaching in running study projects. For the future we also plan to regularly take part in external trainings and workshops related to these topics.

After a few years of practice in this field we now can realize a step-by-step change of the teaching culture really can be achieved. But, however, the biggest problem remaining is the question of sustainability of these cultural changes due to the lack of continuity in human resources caused by the regular 5-year rotation of the academic staff in Germany.

CONCLUSION

Experienced teachers may well master the four dimensions of teaching, learning, choice of topics and teaching methods/media all by intuition. Nevertheless for facing new qualificational demands, university education should beware of *sole* reliance on intuition and prior experience. The fact remains that *new qualifications* do not only require *new concepts*. Without a new *teaching culture* and a *new type of teacher* we will not get *new students* with *new competencies* coping with the challenges of the 21st century.

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