Innovative Teaching in Civil Engineering With Interdisciplinary Team Work

Eva-Maria Heinendirk
Technical University of Dortmund, Chair of Real Estate and Construction Management, Faculty of Architecture and Civil Engineering, Germany
eva-maria.heinendirk@tu-dortmund.de

Ivan Čadež
Technical University of Dortmund, Chair of Real Estate and Construction Management, Faculty of Architecture and Civil Engineering, Germany
ivan.cadez.@tu-dortmund.de

DOI 10.5592/otmcj.2013.2.6
Research paper

Keywords

Civil Engineering, Group Work, Method-, Social- and Self-Competences, Flexibility, Education, Teaching

REGARDING THE REQUIREMENTS OF TODAY'S WORK LIFE, STUDENTS SHOULD LEARN – BESIDE THE TECHNICAL KNOWLEDGE – HOW TO WORK IN TEAMS. Successful team work, especially by interdisciplinary teams within construction processes, requires a wide range of competences and skills. Integration of these opportunities into education of construction engineers is discussed in this paper. The "Shift from Teaching to Learning" (WILDT, J. 2003) provides a strengthened focus on education of competences such as method-, social- and self-competences. Different types of courses and lectures have been analyzed regarding competence-oriented teaching. It can be seen that courses with focus on self-dependent learning like project work are appropriate for competence based teaching. A project work supported by tutors is shown as an example for interdisciplinary education of engineers. Focus was set on the project based development of competences and technical knowledge. The evaluation results show good impact on the development of the students' skills.

INTRODUCTION

Group and team work is a big part of civil engineer's work life. Different disciplines are working together with many interfaces over the work process. The demands on civil engineers have changed: more interfaces between different participants in the process of planning and building, more cost pressure and higher demands on the results (Bauer, H., 2007). Due to this, it is necessary that civil engineers learn to communicate and work together with architects, other engineers, clients and investors to reach the best possible result of the construction project. Another characteristic of civil engineer's work life is project work. Building construction is a project with different team members, different duration and individual requirements. The ability to understand other points of view and to interact to achieve the best solution of a project work needs to be trained in civil engineer's education.

Students of civil engineering should learn how to deal with these various demands during their work life. Besides the obligatory transfer of technical knowledge in the different subjects, a more competence-oriented way of education could be an answer to this challenge. Students should learn more method-, social- and self-competences. Furthermore, they should learn how to collect, analyze and question information and data; a demand, which is a key factor in their following work life. One way to fulfill those demands is a self-dependent way of learning. This so called "*Shift from Teaching to Learning*" (Wildt, J., 2003) focuses on the education of these competences. Students should learn more independent and be self-organized. This goes along with the idea of "*problem-based learning*", in which students should learn how to solve problems and develop new ideas in team work. (Lang-von Wins, T.,von Rosenstiel, L., 2005).

Therefore, different types of courses will be analyzed in terms of their potential to support this shift from teaching to learning and to integrate competence oriented learning in education of civil engineering. As an example, the findings of an innovative teaching project in the Master Program *Real Estate and Construction Management* at TU Dortmund will be provided.

Innovative teaching in Civil Engineering

Bachelor-Students, who graduated in civil engineering at universities in 2009 have been asked one year after their graduation about the content of their studies. The findings show the students' opinion, that competences like method competence (96 %), social competence (86 %) and competence for self-organization (90 %) are more important in their work life than a broad technical knowledge (76 %) (VDI, 2009). These competences give the students the ability to work successfully in teams. This proves the necessity of defining competence oriented teaching and learning. *Competence* is understood as communicative and personal abilities, which show up in various activities. The term competence has to be separated from the term *qualification* which means the ability to transfer objective and describable knowledge into specific tasks (Fuchs, S., 2011).

Competences and qualifications are in the university didactic discourse often separated into three groups: method-, social and self-competences. *Method-competences* cover contents such as learning and organizing, project management and competences in consulting and research. *Social competences* are qualifications such as the ability to work in a team, conflict management, mediation ability or social and entrepreneurial responsibility. *Self-competences* are abilities such as motivation, creativity or consciousness (Redlich, A., Rogmann, J., 2007). Looking at further survey results, it becomes evident that the implementation of competence-based teaching and learning as method of innovative teaching is not yet completed. The students have been asked about their experiences in teaching. Only 44 % of the students said, that there was a variety in methods of teaching; 42 % confirmed, that they have been encouraged to actively participate in courses and a minority of 29 % pointed out that discussions and debates in courses have been promoted in lectures and seminars (VDI, 2009).

Competence oriented education in Civil Engineering

Currently classical lectures with little interaction between lecturer and students can be often found at universities. Innovative forms of teaching, e. g. in project work or internet-based learning are not yet state of the art. It is difficult to substantiate and quantify the effect of different types of courses on the development of students' interdisciplinary competences, nevertheless some types of courses support this development better than others. In the following figure, different types of courses and competencies are matched to show, which way of teaching can support which development of competence. The course formats are sorted in ascending order from little to much student activity.

Competence-oriented types of courses can be distinguished by an active role of the students. Participating students with an active role in designing the course usually learn better than passively listening students. Project work, seminars with close interaction and Bachelor- or Master Theses are highly appropriate for competence based learning. In work life of civil engineers, interdisciplinary team work is part of the daily work. There are many interfaces, e.g. with other engineers, architects or clients. To prepare students properly for this challenge, especially interdisciplinary projects are useful. In project work, especially social competences, conflict

Course format / Competence / Knowledge	Lecture	Internet based learning*	Case studies	Seminars and tutorials	Project work	Theses
Technical Knowledge						
Knowledge based on latest research	xx	xx	x	xx	X	xx
Knowledge to solve practical questions	xx	x	xx	xx	xx	xx
Ability to reflect knowledge and problems in a multidisciplinary context	x	x	xx	xx	xx	xx
Method Competence						
Learning competence	o	xx	x	x	xx	xx
Competence in information retrieval	o	x	x	x	xx	xx
Competence in organization and project management	o	x	x	x	xx	xx
Competence in consulting and research	x	o	x	xx	x	xx
Social Competence						
Ability to transfer knowledge	x	x	xx	xx	xx	xx
Competence to work in a team	o	o	x	x	xx	o
Conflict management	o	o	x	o	xx	x
Mediation ability	o	x	x	o	xx	x
Social responsibility	x	x	xx	x	xx	x
Self Competence						
Motivation	xx	xx	x	x	xx	xx
Creativity	o	x	xx	xx	xx	xx
Conscientiousness	x	x	x	xx	xx	xx

xx: high suitability
x: suitability o: little impact

* Internet-based learning is basically the organization of courses, the distribution of working material, information and tasks. Furthermore with internet-based learning tools the communication between students and lecturers regarding organizational and other content can be structured.

Figure 1. Possibilities of competence-oriented learning in civil engineering (Čadež, I. et al. 2013)

management or mediation abilities and self-competences such as conscientiousness and motivation can be trained. Less useful for the development of multidisciplinary competences are courses, in which the focus is set on knowledge transfer without interaction with the students, such as lectures. Lectures can be useful for developing complex technical knowledge.

For the transfer of technical knowledge internet-based learning can be a good solution as well, however it should be mixed with physical attendance at university. In online-tutorials, students can acquire knowledge independently without time or space limitations. In meetings at university, questions can be answered and discussions can be made. Here the role of the lecturer, professor or research assistant is changing from a broadcaster of knowledge to a coach, who is supporting the students' process of learning. Therefore, a well deliberated mix of courses seems to be useful in students' education. It is important to be sensitive while changing the way of teaching and learning. Students and also lecturers may need some time to get used to new lesson formats, roles and responsibilities in their teaching and learning.

Besides the competence-orientation, a second component is rather important in education of civil engineers: the practical requirements of civil engineers daily work life (Wildt, J., 2007). External lecturers and close collaborations with enterprises can fulfill these demands. Actual requirements can be transferred from offices and construction sides to lecture halls and

the academic view can be transferred the other way around. In the Master Program at TU Dortmund, a mixture of lectures held by professors and academic staff and external lecturers turned out to be a good basis, either to focus on theoretical or practical needs. Besides the technical knowledge, external lecturers can also point out needs of competence oriented skills. These are particularly personnel management and social and entrepreneurial responsibility. Furthermore, experts from enterprises can act as role models to the students.

Interdisciplinary project work

Team and project work had been identified as one of the best ways to train competences and the ability to work in a group. A critical factor for success of group work is an aim to which the whole group is committed (Metz-Göckel, H. 2013). Projects in civil engineering and architecture normally have different aims for different disciplines, which should all merge into one aim: a successful construction project. For civil engineers it might be the construction of the bearing structure or the result of a feasibility analysis, for architects it might be an appropriate design of a building.

Team work is an appropriate way to train the demands of work life of engineers and architects, especially when students from different disciplines are working together in one project. Students learn how to communicate; they learn self-organization, cooperation and advocating their interests. So, project work fits to the goals of problem-based learning, which wants to (Lang-von Wins, T.,von Rosenstiel, L., 2005)

- stimulate effective competences for solving problems,
- provide a basis for life-long learning and
- increase the intrinsic motivation to learn.

Nevertheless, there are some threats in student group work as well. Due to more difficult identification of single achievements in group work, some students tend to so called *'social loafing'* or *'free-riding'*. This means that they lower their own effort and let other people work. The ones doing the effort might realize this and lower their effort as well for not being the only one working. If these effects appear, the success of the group work is in danger. The bigger the group of students is the bigger is also the risk of these effects. To minimize these effects, student groups should not be bigger than five persons (Metz-Göckel, H. 2013) and should be well organized. Furthermore, supporting persons like coaches or tutors could be close to the groups and support them in their work process. They can see closely which students are pushing the work and which do not. At TU Dortmund tutors have been coached for supporting the students in their process and to minimize negative effects of project work.

'Project 3' as an example for interdisciplinary project work

In the Faculty of Architecture and Civil Engineering at TU Dortmund, Architects and Civil Engineers are educated within one faculty. Beside two Bachelor programs there are three master programs: *Civil Engineering, Real Estate and Construction Management* and *Architecture and Urban Development* (fig. 2). Within these Bachelor and Master programs, students of all disciplines are educated in shared projects and basic subjects together. They are also educated in separate subjects to gain specific knowledge in their actual topic. Thus, students are able to work in a team with different disciplines early in their studies, which is very useful regarding their future work.

A focal point is the so called *Project 3* in the master programs. Here, students of the three master studies work together on one project. Within the Master Real Estate and Construction Management they are additionally supported by specially trained tutors to increase the quality and learning outcome for the students and to minimize the negative effects of project work. Training of tutors and complex support of students has been analyzed in a research project regarding innovative teaching, which was supported by the Center of University Didactic at TU Dortmund.

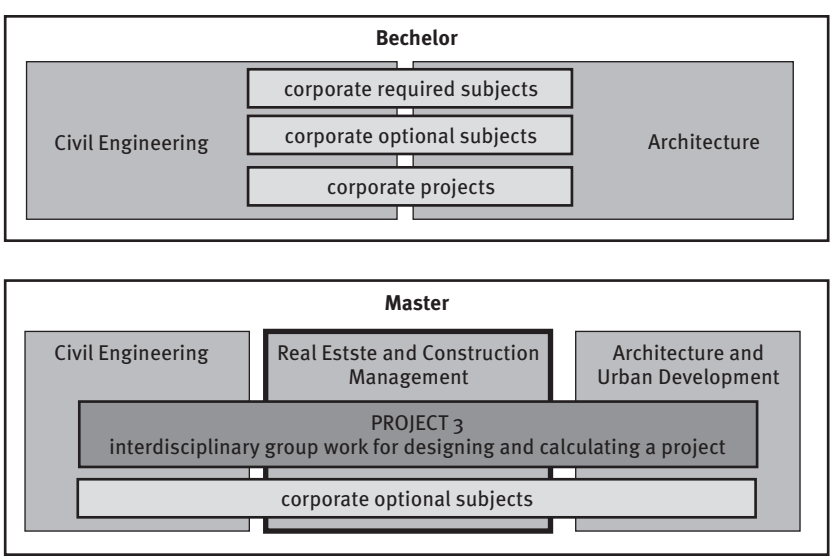

Figure 2. Interdisciplinary project work in Civil Engineering and Architecture at TU Dortmund

Project 3 is an outstanding opportunity for improvement and learning of competences like method-, social- and self-competences by group work. Within this project, students of the master program Architecture and Urban Development are designing a building on a certain space with a defined conceptual formulation. These students are supported by students of the master program Civil Engineering, who are planning the bearing structure of this building in close cooperation with the Architectural students. The students of the master program Real Estate and Construction Management are developing an economic feasibility study of the project. This feasibility study is focusing on the whole lifecycle of the building. The students are calculating financing, planning and construction costs, operation costs and operation returns in a dynamic feasibility model.

A huge part of co-work between the different disciplines is the individual work of the different groups and combined presentations from students to students of all subjects. Students of Civil Engineering as well as Real Estate and Construction Management attend revision of architects; students of Civil Engineering are explaining their calculations and students of Real Estate and Construction Management present their results and the point of view as an investor to the other student Groups. The focus of the presented research project is the economic feasibility study in the master program Real Estate and Construction Management.

Project work supported by tutors

In summer semester 2013, an innovative teaching project *Tutor coaching in Project 3* was developed for education of tutors. Aims of this project were, on the one hand, optimization of students' support in their *Project 3* and, on the other hand, to educate students of higher semesters regarding their development of competences as a team leader and to prepare them for these requirements on their later job. In Project 3 at TU Dortmund, tutorial work can be defined as a continuous support of students through their project and their semester regarding questions to project work and structuring of the work process in group work. Here, qualification of the tutors bases on two effects. On the one hand, these students have already passed the project work themselves one year ago with above-average results. On the other hand, they have been trained in a structured process regarding their technical and multidisciplinary skills.

The training concept had a major focus on developing multidisciplinary competences of tutors in order to qualify them to work as a tutor and for their later demands on the job. The concept can be divided into three parts. The first part focuses on technical knowledge of the tutors. They should be able to answer questions of students and to support the students' work process. The second part focuses on multidisciplinary competences. Here, the focus is set on method competences in a teaching and supporting process. Basic input was given on topics of communication and moderation, learning psychology and team work. Besides these workshops – as third part – two reflection meetings with the tutors and a research assistant were conducted during the semester. The current statuses of the coaching process, questions and further steps have been discussed.

The structure of the training was separated into parts with input-presentations and a big part of discussion and case studies. Most important was to gain a deep understanding of the tutors' own competences and requirements of their tutorial employment. Also important was to get a certain basis and understanding of tasks and aims for tutors in general, especially because they worked in different student groups. Due to this, a basic standard support could be ensured. Within the tutorial coaching, three tutors had been coached. These tutors evaluated the workshops. It could be noticed, that the content of the workshop has a very positive impact on necessary competences and knowledge for the tutorials. The tutors were content with the workshop and agreed that it fits to the needs of the tutorials. The workshops also had a positive influence on the motivation and the tutors' approaches to teaching. These findings correspond with experiences of project work. The tutors had a strong identification with their project and with the student groups they worked with. They were motivated to deepen their knowledge, in order to be able to support the students properly.

Project 3 as an example for interdisciplinary group work

The concept of the Project 3 structure was separated into frame meetings and three different modules, which rotated weekly (see fig. 3). Module A was the tutorial coaching, in which the tutors worked with little groups of students. They gave students a structure to work with and answered their questions. Module B consisted of different meetings together with the students and lecturers of the other master programs. Here, students of all master programs presented their work results. Aim of these meetings was the discussion of the project between the different participants regarding different approaches to the project work. Architects gained knowledge about economic issues, students of Real Estate and Construction Management learned about the design of buildings. Due to this, students of the different master programs trained a multidisciplinary approach to complex building projects. Module C included teaching of professor and research assistants. In this module, the focus lay on discussing results of tutorial coaching and working results and presentation of next steps in the project.

Module		Content	Participants
Frame	introductory course and final presentation	kick of meeting: discussing the task final presentation: discussing the results	professor, research assistant, tutors, lecturers and students of Architecture and Civil Engineering
A	6 tutorial coaching	coaching and support of students in their work process, clarifying questions	tutors
B	concept and design colloquium	presenting of results, especially architectural and constructive design	professor, research assistant, tutors, lecturers and students of Architecture and Civil Engineering
C	3 workshops	presenting and discussing status quo of the project, imput from the professor and research assistants	Professor, research assistant, tutors

Figure 3. **Structure of Project 3 in master program Real Estate and Construction Management**

Due to this structure, research assistants and the professor could focus on strategic points of the project and provide advice in complex questions, whereas the tutors were the direct contact persons to the students for operational problems. Both, tutors and students, had a significant learning outcome on multidisciplinary competences. For example, tutors gained knowledge in leadership and students worked strongly on their multidisciplinary skills. Team work and interaction combined with professional presentations for other disciplines led to outstanding results.

The tutorial support has been evaluated by the students. Aim was, to measure the success of the tutors and the project concept. As shown in figure 4, the average answer was agreement (2.05-2.38) on learning success within the project. The students could work autonomously and got knowledge about the practical application of the content.

Tutors received very good results in the evaluation. They explained the structure and objectives of the project clearly (1.7), answered questions and gave support (1.52) and created opportunities for the students' participation (1.43). The didactic and methodic design of the tutorial and project work was evaluated well. The sequence of the topic and workshops was good (2.05) and learning outcomes and tasks were clear (2.09).

Conclusion and Outlook

It can be derived, that neither interdisciplinary and specialized education, nor development of technical knowledge and multidisciplinary competences are excluding each other. Future challenge is the development of a mixture of different types of courses and the focus on different aims in the study programs, while the number of students is increasing and the budget of universities is decreasing. The optimized *"shift from teaching to learning"* has to be found individually for each study program.

Implementation of competence based education and interdisciplinary project work needs to be pushed on different organizational levels. On the one hand, the dean and the faculty have to sensitize professors and lecturers for the need of interdisciplinary group work and competence based teaching. The professors and lecturers themselves should get knowledge about different possibilities of education. A possibility to strengthen didactical skills is attending in workshops, which can often be found at universities' didactical centers.

The political visibility of education should be improved to ensure enough academic staff for high quality education. Courses and lectures with a strong interaction need more time in preparation to ensure an optimized support of students. The organizational work increases in interdisciplinary projects as well. Nevertheless, the good evaluation results of Project 3 show the value of this effort. Both, tutors and students, had a big learning outcome regarding their technical knowledge, ability for team work and their development of competences for their later work life.

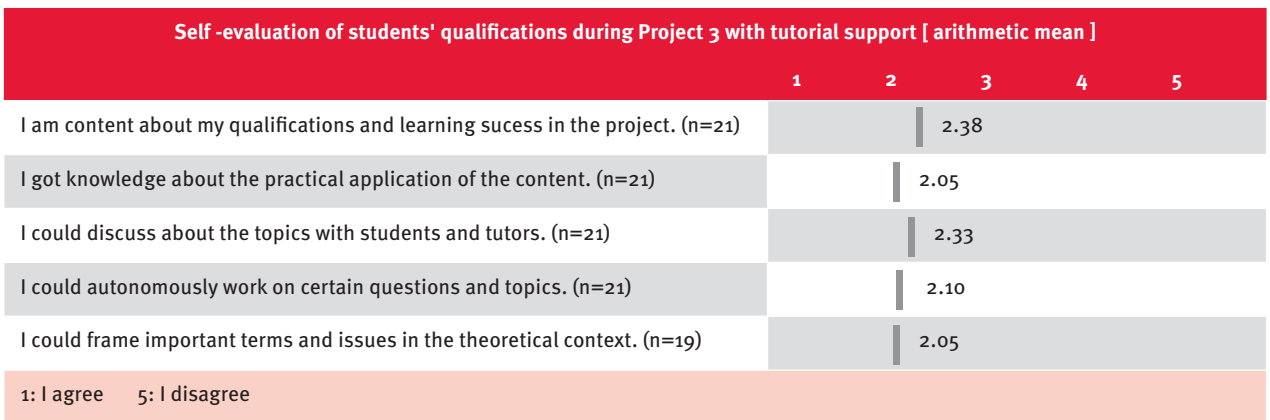

Figure 4. Self-evaluation of students' qualifications during Project 3 with tutorial support

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