WCTE 2016
World Conference on Timber Engineering
August 22-25, 2016 | Vienna, Austria

INTERDISCIPLINARY DESIGN PROJECTS AND PRACTICAL PROJECT WORK IN THE EDUCATION OF CIVIL ENGINEERS

Samuel Ebert[1], Philipp Dietsch[2], Stefan Winter[3]

ABSTRACT: The original and primary objective for Universities is the education of students to become skilled and responsible professionals, e.g. engineers. Therefore, the balance between theoretical knowledge transfer and practical application has to be managed with care. Within this realm, the call for suitable and practice oriented education including the conveyance of knowledge from adjacent domains and interaction to these is getting louder. This paper illustrates an educational approach developed at the Chair of Timber Structures and Building Construction that tries to balance the teaching and related testing of theoretical, high-standard academic knowledge with the acquisition of important practical skills and experience. The latter is best being achieved with practical projects. These begin in the second semester with a simple structural design task, increase successively in complexity and thematic range over the years, and end with an inter-disciplinary design project in the last semester of Master`s studies.

KEYWORDS: education, civil engineering, architecture, design projects, interdisciplinary work

1 INTRODUCTION

This paper presents the educational concept developed at the Chair of Timber Structures and Building Construction of the Technical University of Munich (TUM) as a part of the education for future Civil Engineers. The importance of practical project works and the balance between theoretical knowledge transfer and practical application is outlined along the educational suite followed by the Master`s students and recently adapted and improved Bachelors Curriculum.

2 MAIN EDUCATIONAL CONCEPT

The Chair of Timber Structures and Building Construction at the Technical University of Munich (TUM) in Germany concentrates on two main teaching areas during the Bachelor`s and Master`s Studies.

One is the general education in *'Building Construction'*, which is material unspecific and covers a number of basics necessary for every Civil Engineer, no matter what she/he will specialise on in the future. These courses start in the Bachelor`s Program during the very first semesters with the basic courses in building construction, descriptive geometry and the design of structures. These subjects are deepened in the higher semesters. Within the Master`s Studies and in particular in the area of specialization in Building Construction, the education is extended in the fields of specific principles of building construction, damage control, fire safety and life cycle engineering.

On the other side, the Chair has a strong focus on *'Timber Structures'*. Courses covering this subject start during the late Bachelor`s Program with the basics of structural timber design, followed by a course on the design and construction of timber houses. Students can largely extend this knowledge during their Master`s Studies in the fields of timber engineering, timber bridges, timber in construction (materials science), and small structural design projects.

As part of the TUM standard for excellent teaching, the structure of the courses is based on the concept of 'Constructive Alignment'. This principle describes the alignment of examination methods according to pre-formulated learning results (see Figure 1). This guarantees the conformity of the students' goal to perform well in the exams with the teaching goals. In addition, the methods of teaching and learning can be adapted to match the intended learning results. Important elements within this

[1] Samuel Ebert, M.Sc. samuel.ebert@tum.de
[2] Dr.-Ing. Philipp Dietsch, dietsch@tum.de
[3] Univ.-Prof. Dr.-Ing. Stefan Winter, Technische Universität München, winter@tum.de
Chair of Timber Structures and Building Construction, Technische Universität München

are the visualization of the learning content, a well-balanced interweaving of self-study and attendance time as well as the motivation of students to cooperate and to think for themselves during the lecture [1].

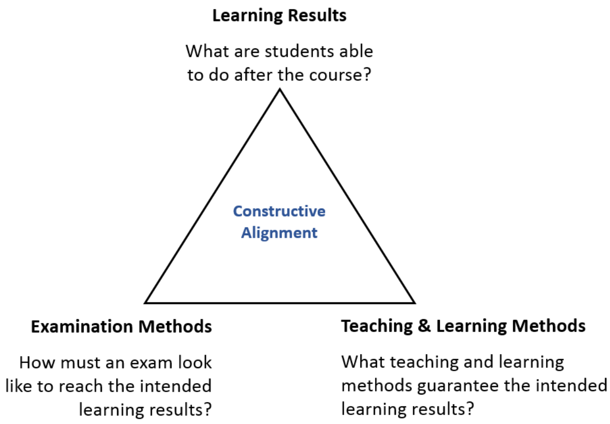

Figure 1: *The concept of Constructive Alignment [1]*

The Chair tries to follow this concept by adapting appropriate examination methods and suitable course concepts to the formulated learning results for each course and teaching area.
As a result of the objective to align theoretical knowledge transfer and practical application, the Chair tries to follow one simple principle throughout the entire education concept:

"As few exams as necessary and as much practical design work as possible."

Lectures are the main teaching method though only selected parts of their content can be tested in written exams. Written exams cover the theoretical aspect but fall short on important skills. Written exams can result in a preparation that emphasises on the theoretic testing environment and focuses on short-term knowledge. Future working life situations are the motivation for the strong focus on practical Project Work as a method to test skills practically already during education. In real life, young professionals need the ability to analyse problems, to separate complex matters into sub-problems and to solve these problems without losing sight of the whole picture. Instead of specific one-dimensional exam questions, the students face diversified and complex tasks, which they have to analyse and transform into solvable sub-tasks. For this challenge, they often work in small groups where they also have to learn how to articulate technical problems and solution approaches, either by traditional means like sketches and plans or by written reports, oral presentations or posters.
When confronting the students with a new learning approach with multi-dimensional aspects, the task description and problem setting has to be carefully adjusted to the level of the student body. If the complexity of the tasks exceeds the ability of the group, the learning effect likely ends in frustration and resignation. Therefore, the approach is to start with a very simple and motivating project and to slowly increase the difficulty and dimension of the project works. Besides testing the students' knowledge, imitated real life projects imply the great opportunity to provide them with all the skills described above.

3 CONVEYING KNOWLEDGE - COURSE DISCRIPTION

3.1 BACHELOR`S COURSES

In the Civil Engineering education at the Faculty of Civil, Geo and Environmental Engineering at TUM, the Chair of Timber Structures and Building Construction is responsible for the Bachelor`s courses during the Semester 1-6, listed in Figure 2. The following description of courses is given in a chronological order starting in the first semester.

BUILDING CONSTRUCTION	TIMBER STRUCTURES
Written Exam	*Written Exam*
Project Work	

BACHELOR	Building Construction	Timber Structures
1	Descriptive Geometry	
	Building Construction 1	
2	Design of Structures 1	
	Design-Build Project	
4		Timber Structures – Basic Module
5	Building Construction 2	Timber Structures – Suppl. Module
	Design of Structures 2	
6	Building Construction 3	

Figure 2: *Flow Chart of the Bachelor`s Courses given by the Chair of Timber Structures and Building Construction*

1st Semester
In *'Descriptive Geometry'* the students learn different ways to produce graphical representations of technical objects. The course focuses on the transfer of three-dimensional objects into a two-dimensional drawing and how these drawings are professionally processed, so that finally a standardized technical drawing evolves. Different additional drawing methods are shown and applied. The students have to attend this course during the first semester and it is finalised with a written exam.

The extensive knowledge to be conveyed on *'Building Construction'* is taught in three stages over the first three years in the Bachelor`s Program. In the first semester *'Building Construction 1'* covers all knowledge about different construction materials like timber, steel, concrete, masonry and the typical ways they are processed, built and joined. Additional lectures cover the topics of insulation, sealing and foundations of buildings, interior work and aspects of a typical planning processes. Tutorials about the design and construction of typical building details complete the courses content. The students have to write an exam to finish this first course.

2nd Semester

The knowledge to be conveyed on the *'Design of Structures'* is also separated into two consecutive parts. *'Design of Structures 1'* takes part in the second semester and represents the first confrontation of the students with structures. Therefore the students are first of all taught the basic technical terms and functions that are related to structures. They then learn how to identify load bearing structures in a building, how to break down structures to abstract load bearing systems and how these systems act separately or as part of a more complex total system. Another important part of this course is the description of standardized loads, the way they act on the system and finally the materials reaction to the load. For these parts, the students have to write an exam to finalise the course.
Part of the course 'Design of Structures' is a *'Design-Build-Project'*. This project work introduces the students to their first self-designed project and is accompanied by tutorials. The students work together in groups. They learn how to approach a specific problem, by firstly analysing the problem, secondly developing alternatives, and in the end derive and implement a structure, work out details and present their work in writing and as a built (small) structure (see Chapter 4.2.1).

4th Semester

In the fourth semester the students are given material specific lectures. *'Timber Structures – Basic Module'* is the first course for students with a focus on timber.
The aim of the introductory course is to connect the knowledge obtained in the basic courses in structural analysis and mechanics with the design according to standards and under consideration of the special characteristics of timber as a building material. The content stretches from timber properties, structural elements and dimensioning to ultimate limit states design as well as serviceability limit states design. A strong focus is laid on connection techniques and the correct design of connections. The course is finished with an introduction into durability and fire protection. The course is divided into lectures and exercise sessions with voluntary assignments for training purposes and finishes with a written exam.

5th Semester

'Building Construction 2' in the fifth semester covers the remaining basics of building construction such as glazing, windows, building envelope, membrane structures and the completion of the interior and stairways. In the end, students are able to plan and represent the construction of external and interior construction methods.

The scope of the course *'Timber Structures Supplementary Module'* is to give the students an understanding of the particularities in the design and planning of timber houses. The course begins with an introduction of construction methods, covers the topics of prefabrication and assembly of elements and houses, followed by lectures about passive houses, thermal aspects, wall, floor and roof structures and design as well as moisture, sound and fire protection.
An indispensable part of this course is the *Condetti Workshop*, which allows students to individually design timber elements and details of timber houses and discuss these and their effects and possible consequences with fellow students and the lecturer (see Chapter 4.2.4).

The course *'Design of Structures 2'* in the fifth semester builds upon the acquired skills and knowledge of the first part as well as the combination of several additional aspects of their education in statics, mechanics and structural material sciences (e.g. steel, timber, solid construction). In addition to the lectures, a series of tutorials is used to demonstrate the approach and the structure of a structural calculation of a building. As part of a project work, the students have time to work out their own structural calculation in groups. This project is meant to teach the students the application of their knowledge acquired in the courses on 'Design of Structures' on real life calculation tasks or for subsequent more complex design projects (see Chapter 4.2.4).

6th Semester

The third part *'Building Construction 3'* is called "Building in the Building Stock". It views building construction from another standpoint. Aiming at equipping the students with skills to analyse typical existing buildings, they receive a brief introduction in building and architecture history, followed by lectures about typical historical and era-specific constructions and their weaknesses. Experiences from building damages, typical deterioration symptoms and feasible methods of analysis and corresponding monitoring or measuring equipment are also an essential part of this course. The second half of the semester is dedicated to the students focussing on the analysis and rehabilitation of an existing building, which simultaneously represents the examination work for this course (see Chapter 4.2.2).

3.2 MASTER`S COURSES

3.2.1 Structure of the Master`s Program

In the Master`s Program of the Faculty of Civil, Geo and Environmental Engineering of TUM the students specialise their knowledge in four different fields of choice. The Chair of Timber Structures and Building Construction is the only Chair responsible for two areas of specialisation during the estimated four semesters in the Master`s Program, both are shown in Figure 3. In addition to that, the Chair offers courses in other Master`s Programs, e.g. Master in Environmental Engineering and Master in Energy-efficient and Sustainable Building.

	BUILDING CONSTRUCTION	TIMBER STRUCTURES
	Written Exam	*Written Exam*
	Project Work	

MASTER

Semester	Building Construction	Timber Structures
7	(CC) Basics of Fire Protection	(CC) Timber Engineering I
	(CC) Principles in Building Construct.	(CC) Timber in Construction
	Transient System Simulation 1	
	Life-Cycle Assessment	
8	(CC) Experience through Damage	(CC) Timber Engineering 2
	Transient System Simulation 2	Design of Timber Bridges
	Fire Engineering	Design of Timber Structures
9	Special Topics in Building Construction	Special Topics in Timber Engineering
	Interdisciplinary Design Project	

Figure 3: *Flow Chart of the Master`s Courses given by the Chair of Timber Structures and Building Construction (CC means Compulsory Course)*

Every specialisation comprises compulsory as well as optional courses from which the students have to choose a certain number. Half of the optional courses have to be chosen from the related specialisation, the other half may be chosen from other areas.

3.2.2 Specialisation in Building Construction

The Specialisation in Building Construction consists of three compulsory courses (‘Basics of Fire Protection’, ‘Principles in Building Construction’ and ‘Experience through Damage’) and various optional courses covering specific aspects of Building Construction like the simulation of buildings (‘Transient System Simulation 1 & 2’) and sustainability (‘Life-Cycle Assessment’).
Most courses offered during the Master include individual design projects, which are, compared to the Bachelor`s Level, much closer to the practice of a design engineer. In the following, the courses are briefly described.

Compulsory Courses (CC)
The Module ‘*Basics of Fire Protection*’ covers all major themes of fire protection divided into basic knowledge, passive and active fire safety measures. The basics cover topics as fire origin, fire spread and fire exposure, building materials and elements, fire protection concepts, causes of fire, fire behaviour of materials and constructions, preventive fire protection. Within the passive fire protection, the requirements of building authorities will be considered, which are mainly influenced by the life safety and safety for loss of property, including the building itself, neighbouring property, requirements and design of building elements, structural calculation methods for fire exposure as well as means of escape. Active five protection measures include topics, such as equipment and strategies of fire departments, fire inspection and fire protection concepts. The course finishes with the elaboration of a customised fire protection concept regarding the safety goals of building authorities.

The compulsory module 'Advanced Building Construction' consists of the two courses *'Principles in Building Construction*' and *'Experience through Damage*' that take place during winter semester and the following summer semester.
The course *'Principles in Building Construction'* aims to supplement the knowledge obtained in 'Building Construction 1-3' and teaches the abstract principles of building construction on a material independent level. The course stretches from topics like safety principles, basics of joining, to extended criteria for the choice of building materials or building components and construction types. Moreover, interdisciplinary aspects like architectural principles of building construction, interaction between people and buildings as well as the integration of technical building equipment in buildings and load bearing structures are covered.
The course *'Experience through Damage'* teaches students how to detect causes of damage, analyse the damage extent and apply methods of repairing the damage. The course topics are linked to current research and include multiple types of material. In addition, students will learn about typical types of damage, analysis methods and methods for refurbishment with a focus on examples of damage and restoration, as well as sampling and material testing. One essential element of the course is a student project work on a case study. The students will apply the course content by documenting and analysing a real building and present the results with a short presentation and a written building inspection report (see Chapter 4.2.3).

Optional Courses
The optional courses in the specialisation area ‘Building Construction’ cover a relatively wide range of interdisciplinary topics.
‘Transient System Simulation 1’ is a course that deals with the modelling of transient thermal systems with the Thermal Building Simulation software TRNSYS. Students learn how to define simulation models, to construct simulation models successively and to evaluate these and their results critically. By means of self-established models the students shall be enabled to evaluate the effects of the choice of glass quality, shading, mass, insulation and type of infiltration, the occupation and utilisation of the building and additional building services. After the successful participation in this course, students will be able to make energy and climate related planning decisions quantifiable, distinguishable, and justifiable. To finish the course, the students have to write

a report about their individual simulation project, explaining the solutions they have developed (see Chapter 4.2.4).

In the following semester, the topic is continued with the course *'Transient System Simulation 2'*. This course focuses on the simulation of renewable energy sources as well as the illustration of building energy systems and their physical properties in TRNSYS. The content addresses the topics of thermal solar energy (solar collectors, tanks, pumps, heat exchangers), electrical island systems (PV cells, wind turbines, battery banks, inverter) and adapt these to the specific user demand profiles and the individual project works. After completion, the students will be able to apply different types of energy sources to individual buildings and their respective usage patterns, as well as simulate and design these in combination with each other.

The course *'Life-Cycle Assessment'* teaches the methodology of assessing the environmental performance of systems, e.g. buildings. The content begins with an overview of the necessity and importance of life cycle assessment (LCA) as one method to measure aspects of sustainability. Following that, aspects like process and work-flow systems, inventory analysis and environmental impact analysis are taught and completed by special requirements for building LCAs, national and international regulations, product declarations (content and benefits), life-cycle of materials and construction as well as other evaluation methods. An interactive workshop imparts the application of LCA-software-tools like LEGEP or GaBi.

'*Fire engineering'* extends the content of the previously taught course 'Basics of Fire Protection'. This course provides an understanding of analytical and experimental methods in fire engineering in respect to fire and smoke spread, the structural design, the design of escape routes and occupant safety. The content covers topics from fire risk assessment, design fires, structural design methods for the case of fire, smoke spread and smoke simulation via evacuation analysis finalizing with fire safety for special structures and fire protection in the building stock. The lectures are extended by seminars and two voluntary homework assignments to apply the obtained knowledge individually.

The *'Interdisciplinary Design Project in Building Construction'* brings the previous courses and their content to application in a unique task to be fulfilled in a team with Architects and other Engineers, see Chapter 4.3.
'Special Topics in building construction' see Chapter 3.2.3.

3.2.3 Specialisation in Timber Structures

The second Specialisation area offered by the Chair is 'Timber Structures', consisting of three compulsory courses ('Timber Engineering 1 & 2', 'Timber in Construction') and further optional courses for application of knowledge in design and detailing ('Timber Bridges', Design of Timber Structures" and 'Special Topics in Timber Engineering).

Compulsory Courses (CC)
The compulsory module 'Timber Engineering'' consists of the two courses *'Timber Engineering 1'* and *'Timber Engineering 2*' which take place during winter semester and the following summer semester.
The course *'Timber Engineering 1'* gives the students a deeper comprehension of the particularities in the design of large-span timber structures. The content stretches from timber products and the design of structural elements for large-span timber structures to bracing systems and secondary structures. This is followed by the design of notched members, holes, cross-connections and their reinforcement and finalized by gluing and glued structures. The lectures are supplemented by exercise sessions and excursions. In the individual assessment, the students have to realize the structural design of all primary structural elements of a typical hall structure.
The following course *'Timber Engineering 2'* conveys additional knowledge and specialities in the analysis and design of timber structures and connects the education on timber structures with the state of the art in research. This includes new developments and applications like plane timber structures from timber-concrete-composites and cross-laminated timber. In addition, the students will be introduced into robustness measures and dynamic analysis. The second major element in this course is the concentration on the assessment reinforcement and maintenance of existing timber buildings, including materials testing. A written exam concludes this module.

The second mandatory module *'Timber in Construction'* focuses on material related aspects in the application of timber as a building material. The topics taught in this course can be separated into two main blocks. The first block offers a comprehensive treatise of the specific characteristics of timber as a building material, e.g. wood species and their identification, mechanical and physical properties and test methods, gluing and wood-based products as well as rheology and time dependent properties. The second block offers insight into the theoretical background and practical issues in selected fields of application of timber in construction from reliability, safety factors and load sharing via analysis and FEM modelling of timber structures and connections, durability and service life performance to the behaviour of timber structures in earthquakes.

Optional Courses
The aim of the module *'Design of Timber Structures'* is to convey an understanding of structural systems, their realisation and approximate dimensioning. It all starts with an overview of existing design tools from teaching basic techniques to develop primary structural designs and construction details. This is followed by understanding of structures, trained on the basis of existing timber buildings, where the associated structural systems shall be recognised and abstracted into a static model. Finally the students work out solutions for construction details (e.g. joints) according to a given

structure or static model. The course is finalized with a design task, see Chapter 4.2.4.

The optional course *'Design of Timber Bridges'* starts with the history of timber bridges, focusing then on typical structural systems by examination of exemplary projects. This is followed by design-related aspects like specific load compilation, fatigue verification, verification of vibrations or ensuring durability by suitable construction principles. The chosen teaching method is to complement the lectures with presentations by the students on exemplary timber bridges followed by the presentation of individual design solutions developed by the students for a specific design case. These already form part of the examination in addition with a written exam (see Chapter 4.2.4).

'Special Topics in Timber Engineering or Building Construction' gives students the opportunity to address a specific chosen topic independently. The exam consists of a written project report similar to a student thesis, outlining the results and expertise in the discussed topic.

The *'Interdisciplinary Design Project in Timber Structures'* follows a similar structure and objectives as the design project in the specification of building construction, see Chapter 4.3.

4 APPLICATION OF KNOWLEDGE

4.1 BACKGROUND

The main objective of the educational concept for Civil Engineers at the Chair of Timber Structures and Building Construction is to give the students everything they need to become well-educated and responsible engineers. Theoretic knowledge has to be profound and deep but cannot provide all necessary skills. It has to be complemented by important skills gained in practice. With the graduation, the students should be able to tackle real life problems drawing upon the education they received.

The following Sections will focus on the courses of the program that include practical project work and design projects as an integral part of the course or its finalization, showing them in chronological order. The aim of these chapters is to highlight the process of increasing proximity to real life planning processes and the qualification the students receive while undergoing this process.

4.2 PRACTICAL PROJECT WORK

4.2.1 Design-Build Project (Design of Structures)

The 'Design-Build-Project' as part of the course 'Design of Structures' is called *'Bridge out of the bag'*. Students work in a group of five individuals, having to design a bridge according to a number of strict specifications, like span-width, height, weight and the maximum dimensions. The structure has to fit in a 120 litre waste bag even though the total dimensions of the final bridge exceed the dimensions of the bag by far. The goal is that the professor can cross the bridge appropriately. Additional aspects like the design concept or special materials used can also be considered in the grading of the final result. The design process takes place during the whole semester and is accompanied by tutorials, exercises and lectures. Finally, the professor tests the bridge during a large event at the end of the semester (see Figure 4). In addition, the students have to hand in a written report of their project work consisting of a documentation of the design process, evaluation of the structure, basic calculations and plans and sketches.

Figure 4: *Bridge testing at the inner courtyard of TUM*

The bridges have to be erected by the team in less than 30 minutes prior to testing and have to withstand every weather condition (see Figures 5 and 6).

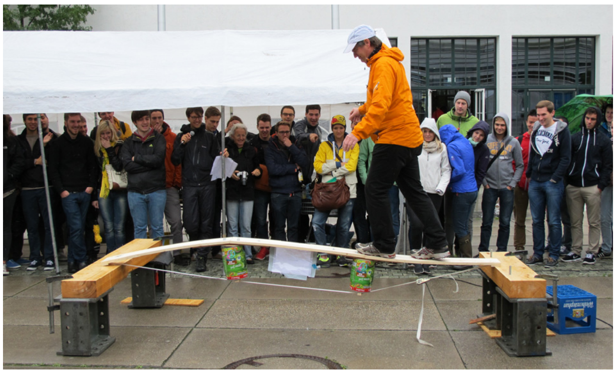

Figure 5: *Bridge testing under heavy rain*

Figure 6: *Teamwork in 30 minutes bridge assembling*

The primary learning objective for the students is to tackle a problem together by firstly analysing and understanding the problem, developing variant solutions and finally evaluate, ponder and execute one solution. Furthermore, the students learn time management, the ability of abstraction, independent teamwork and thorough execution (see Figure 7).

Figure 7: *Thoroughly detailed and worked out bridge design*

At the end of the bridge testing, the winners of different categories are selected and honoured. Prices are given for the lightest bridge and special credits are given for design or reusability (see Figure 8). The results of the previous year's show a consistent high effort and excitement of the students with a great variety of different solutions (see Figure 9).

Figure 8: *Winner for 'Best Design' for a foldable bridge design*

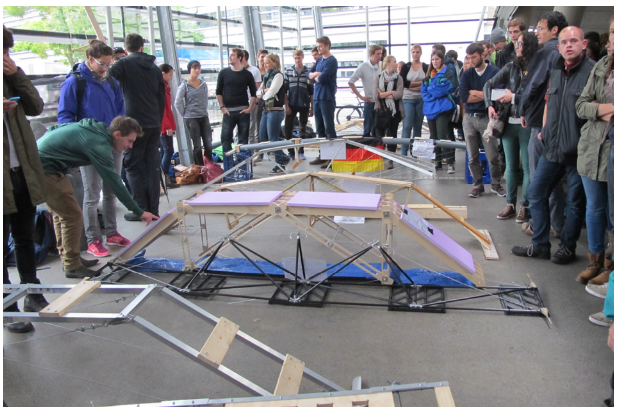

Figure 9: *Variety of bridges being assembled and waiting to be tested*

4.2.2 Building Construction 3

The project work in *'Building Construction 3'* changes regularly over the years. The focus lies on buildings in the existing building stock. For the last years, it was the renovation and modernization of different alpine shelter buildings from the DAV (German Alpine Club) in such a way, that the renovated structure would comply with modern energy requirements and local boundary conditions. In the beginning, the students receive lectures about building history and how to approach the analysis of existing buildings. During an excursion, the theory comes into practice by classifying the building in consideration historically, by measuring and drawing the existing structure and by assessing its quality in comparison with a modern standard and with regard to the future hypothetical use or refurbishment (see Figure 10). In a second step, the students have to conceptualise ways to modernise the building. At the end of this stage, the future renovation concept has to be qualitatively clear and well distinguishable from alternative concepts. The final part is a detailed planning of the implementation steps that have to be followed, both in terms of the demolition of parts of the structure and in terms of new-built parts.

In comparison with the first project *'bridge out of the bag'*, the students have to deal with a problem that is far more complex as it is situated in a real-life surrounding. The variety of parameters they have to consider stretching from the geometry of the building, structural behaviour, materials, loads and stresses to aspects of thermal, moisture, acoustic and long-time behaviour forces the students to think in a nuanced way for solutions. In addition, they have to involve restrictions that are characteristic for the planning with existing buildings. At the end of the course, students are able to plan and represent a building survey and restoration of building constructions. The participating students are regularly supervised during the semester by a mixed team of Civil Engineers and Architects.

Figure 10: *Students at work analysing the 'Riesnhütte'*

4.2.3 Experience through Damage

The project work in the course *'Experience through Damage'* was quite recently developed and established. The main task of this project is to write a building inspection report in groups of maximum four students. The student project work on an exemplary case of building damage is built upon the content of the lectures and pursues and deepens the skills acquired in the project of 'Building Construction 3'. The students start with a complete and independent mapping and description of the object in the field (see Figure 11) focusing on a comprehensible and thoroughly documented damage report. Afterwards the damages are analysed in the whole building context according to the damage type, damage extend and the underlying damage cause has to be worked out consistently (see Figure 12). The nominal condition has to be determined and compared to the actual state to figure out all inconsistencies. Finally, the students have to make suggestions for refurbishment according to the prior damage analysis. The results have to be displayed in a final presentation as well as in a clear and comprehensible written inspection report with a full documentation of plans, sketches and calculations. Compared to the analysis of buildings in the Bachelor`s Program, this project work demands a more detailed documentation and a thorough analysis by applying the whole knowledge gained so far to build up a stringent argument of damage causes. Students develop skills to document, analyse and evaluate damages in buildings and to apply repairing methods.

Figure 11: *Building with severe façade damages, exemplifying one case study in 'Experience through Damage'*

Figure 12: *Analysis of causes for damage on the example of crack monitoring*

4.2.4 Additional Practical Project Examples

The Chair of Timber Structures and Building Construction offers a lot more of practical project works and several courses and modules, which cannot be explained in detail in this paper. A short overview of the courses and outline of the practical work is presented below.

In the Bachelor`s Program the content of the studies in Timber Structures (Basic and Supplementary Module) is deepened by practical workshop called *'Condetti Workshop'* [3] in which solutions for detailing presented at first and secondly developed individually by the students in order to apply and understand the science of structural, thermal, moisture and acoustic behaviour. The format of a workshop offers the opportunity to discuss open questions together, to close outstanding knowledge gaps and to go into detail if necessary.
The project work in 'Design of Structures 2' leads the students to the application of the theoretical knowledge and shows quite clearly how deep their comprehension of the syllabus stretches. The calculation of a whole building and the correlation within prepares the students simultaneously for exercise in practice as well for subsequent design projects in the Master`s Program.

Additional practical project works in the Master`s Program are implemented in the courses *'Transient System Simulation 1 & 2'* wherein the lecture is built upon an exemplary building and the students have to follow up by simulating their own part of a building of choice. The second course is established subsequently and uses the prior simulation to extend the simulation and analysis. The close working environment with the students on examples offers the best learning results in handling the software properly.
In the course 'Design of Timber Structures', groups of four students are given the task to design the primary structure of a showroom. In the course 'Design of Timber Bridges' groups of four students have the choice between two design tasks for a pedestrian bridge. In both courses, the students are asked to realize variant studies, preliminary dimensioning of the primary structure, to draw structural plans and to detail two connections of choice. The final design is presented and defended in front of fellow students. A written report, documenting all the work is handed over to the supervisors.

4.3 INTERDISCIPLINARY DESIGN PROJECTS

4.3.1 Background

The interdisciplinary design project during the ninth semester is the final and outstanding point of the contribution of the Chair of Timber Structures and Building Construction to the students' education in Civil Engineering.
At this final stage of the students' education, the least internalized abilities are the following:

- to integrate divergent requirements that come from different disciplines into a whole concept and to justify their decisions either quantitatively or qualitatively,
- to follow a process that starts at a conceptual stage, goes on to a reasonable choice of design options which are then accepted or rejected and which finishes at the thorough detailing of the final design,
- to present results precisely, be it by drawings, written reports or oral presentations.

The design project is a cooperation between the Chair of Timber Structures and Building Construction at the Faculty of Civil Engineering and the Chair of

Architectural Design and Timber Construction (Prof. Hermann Kaufmann). Architecture students work together with engineering students in groups of three or four.
The supervision is very close to not overexert the students. Meetings between supervisors and students are held on a weekly basis with fixed presentations and discussions. At the end of the semester, the students present their final design in front of the professors and an independent jury of the Munich Association of Architects and Engineers who assess the different student projects and award prizes to the three best results.

4.3.2 Kindergarten Raithby/South Africa, Design-Build-Project

Kindergarten for 80 children in Raithby (DBP), South Africa (2008-2009)
For the first Design-Build-Project realized within the cooperation between the two Chairs, the interested reader is referred to [4]

4.3.3 Green School Zambia, Design-Build-Project

Prototypical school building Woodlands, Lusaka (DBP), Zambia (2013-2014) followed by the project Green School Zambia (DBP), research cooperation (2014 – ongoing)
In 2012, the design task was the development of a new prototype primary school building in Lusaka, Zambia in cooperation with the Ministry of Education and the University of Zambia (UNZA). The goal was to improve the indoor climate conditions, to use local materials and to minimize the impact on costs and the environment.

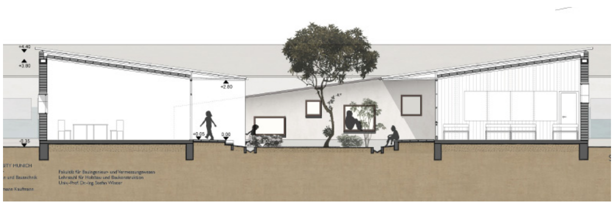

Figure 13: *Winning Design "Green School Zambia"*

Figure 14: *"Green School Zambia" finalised building*

This specific Project was planned not only as a Design but as a Design-Build-Project. The concept of Design-Build-Projects (DBP) consists of a theoretical design phase at the universities and the implementation by students in the country itself in the second stage. In summer 2013, the winning design was erected together with the students and local workers in the centre of Lusaka (see Figure 14).

After completion of the prototype School Building the focus of the ongoing cooperation and research now lies on the installation of a complementary monitoring system to measure the indoor climate conditions as well as on the further development of new construction methods, the energy supply system and an additional biogas concept.
On an interdisciplinary level, a newly developed education system called "iSchool" is planned to be fully implemented in the architectural and energetic layout.

4.3.4 Desertwood

Desertwood, multi-functional building at the Ain Sham University in Cairo (2015 – ongoing)
In summer 2015, an intercultural collaboration project took place designing a multifunctional building at the campus of Ain Sham University in Cairo. Against the background of the future availability of timber from afforestation areas irrigated by treated sewage water from Cairo, an international group of both Egyptian and German students developed different building solutions with timber (see Figure 15).

Figure 15: *Winning Design "Desertwood" presented in Cairo, Egypt.*

The focus of this project lay on the intercultural and interdisciplinary collaboration as well as on an international knowledge transfer in the area of timber architecture and engineering, funded by the DAAD (German Exchange Service). Part of the project were several excursions in Egypt and Germany to prepare the students for collaboration and an intercultural workshop for better communication in the groups (see Figure 16).

Figure 16: *Intercultural Workshop with Egyptian students*

4.3.5 'Neue Heimat' – Homes for Refugees

Communal accommodation building for refugees in the city of Munich (2015-2016)

In the winter term, 2015/16 the design project was linked to the arrival of hundreds of thousands of refugees in the summer of 2015 and the need for appropriate accommodation facilities. The project covered aspects of socially appropriate answers for living, low-cost solutions and a high demand of flexibility.

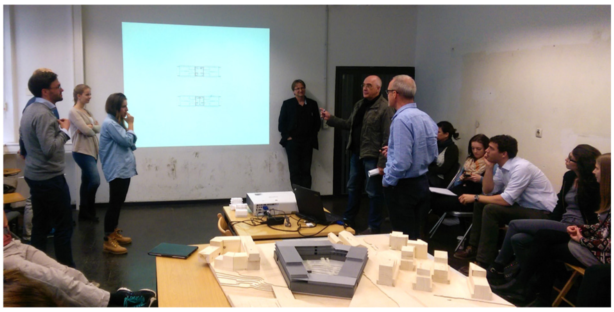

Figure 17: *Discussion of intermediate results*

In the end, the struggle with the high complexity in combination with the dimension of the project ended with some unique solutions (see Figure 18).

Figure 18: *Winning Design "Neue Heimat"*

5 CONCLUSIONS

This paper outlines the importance and various benefits of practical project work and design projects in the education of Civil Engineers on the basis of the teaching program and corresponding experience of the Chair of Timber Structures and Building Construction at the Faculty of Civil, Geo and Environmental Engineering of TUM.

The core of this idea is to place extensive project work next to classical lectures. The successive increase in complexity, interdisciplinarity and thematic bandwidth as well as depth and difficulty in the projects is outlined. This illustrates the development of the students, gaining profound knowledge and skills with practical links to their future professional life.

Via the interdisciplinary design project at the end of their Master`s Program, the students are able to apply and combine their knowledge and skills in a very realistic design task. This concept is complemented by the idea of design-build-projects where the whole effort of the design phase is put into practice and being realised. Especially intercultural projects involved a high demand for communication and social interaction, a multi-dimensional beneficial aspect that has a vast impact on our traditional view of education. On the one hand, these projects develop an unmatched enthusiasm and participation among the students involved, combined with the satisfying awareness to contribute to sustainable development. On the other hand, the academic education benefits from the unique challenge in interdisciplinary collaboration and the development of social skills that future Architects and Engineers desperately need, e.g. to communicate and to solve fundamental differences. Moreover, the chosen topics often show high relevance to similar fields of research on academic level.

The link between the theoretical knowledge transfer and the possibility of practical application and implementation plays a very essential role in an integral and excellent education of Civil Engineers. The projects shown in this paper present various options how this link can be realised.

ACKNOWLEDGEMENT

The authors wish to extend thanks to all people who have been supporting of the projects in any way, e.g. by providing suitable buildings and objects to work on, by assisting with advice or by funding expenses and prices.

REFERENCES

[1] Basic Course of good academic teaching; ProLehre TUM

[2] Handbook of Modules offered by the Chair of Timber Structures and Building Construction, TUM

[3] Winter, S., Borsch-Laaks, R. et al., Condetti & Co.-Details im Holzhausbau, Kastner Wolnzach, 2003

[4] Gampfer, S. et al.; Building - a new experience in Africa, Proceedings 11th World Conference on Timber Engineering, Riva del Garda, Italy 2010