

INNOVATIVE COURSE-RELATED INTERDISCIPLINARY PLANNING PROJECT FOR SMART BUILDING ENGINEERING STUDENTS

Lina Schulze-Buxloh*, Rolf Groß

FH Aachen University of Applied Sciences, Bayernallee 11, 52066 Aachen, Germany

Abstract

The interdisciplinary course Smart Building Engineering combines the disciplines of architecture, civil engineering and electrical engineering and information technology into a new course that prepares students for the new and digital problems in the construction industry. For practical training, a real building was developed as a course-related planning project across all different involved trades that realistically depicts the interacting planning components of a larger construction project, just as the students would expect in their later professional life. The building was completely planned and developed during the course of study in six consecutive semesters. The complexity increases with each trade and the resulting interfaces and influences over the course, although they are always embedded in overarching questions and tasks relating to the "digital twin" and the entire planning process of a building. A central component is interdisciplinary and team-oriented project work in the different modules representing all involved trades, which becomes more and more complex during the course of study. This course-related project gives students the opportunity to use and practice what they have learned into a higher-level practical context and to apply it directly. Decisive skills for a future digital world of work are expanded, in particular process and system thinking and interdisciplinary skills such as project organization, teamwork and creativity, combined with special digital skills such as collaborative online work. The project is therefore also a good preparation for the thesis, in which the students should independently work on a real task within a given timeframe in order to show that they can practically apply the skills required for the engineering profession.

Keywords: Smart Building Engineering, Digital twin, Planning project, Curriculum development

1. INTRODUCTION

In view of diverse and often dynamic development processes, today's societies are faced with the challenge of shaping the future sustainably under great pressure to change. The complexity of anthropogenic influences on global events will require an interdisciplinary approach to solve the associated problems in the field of university teaching in the future. The construction industry is also facing major challenges: the planning, construction, operation, maintenance and dismantling of buildings, properties and infrastructure must be rethought and reassessed from scratch. This is the only way to successfully, economically and sustainably achieve the federal government's medium-term sectoral targets in the climate protection plan, the desired restructuring of European energy supply, especially in light of the current political events in Eastern Europe. The targeted teaching of the skills required to record and analyze the central issues and their interactions with each other, such as sustainability, climate change, demographic and economic developments, digitization and resource conservation are essential in order to develop suitable solutions and the associated opportunities and risks adequately in the overall context to be able to rate. [1][2][3].

The interdisciplinary Smart Building Engineering course at the FH Aachen combines the disciplines of architecture, civil engineering and electrical engineering and information technology into an innovative course that prepares the students for new and complex issues. An important aspect is the increasing digitization in the construction industry, i.e. the establishment of the Building Information Modeling (BIM) methodology, interdisciplinary cooperation, the digital value chain and the cradle to cradle philosophy. The practical question of which concepts offer the greatest possible potential, also considering a complete life cycle, requires an interdisciplinary view and approach with increasing integration of digital methods and processes. The primary goal of the new course is to actively counteract the shortage of skilled workers, especially in the fields of smart building technology and digital planning

methods in construction (Smart Building Engineering, SBE), and to express a new "culture of building" through interdisciplinary cooperation and teamwork.

Basic subjects		
Mathematics, building physics, materials science, law/business administration		
Technical building equipment	Electrical engineering and information technology	Building construction and architecture
Thermodynamics	Electrical measurement, control and regulation technology	Building culture and history
Fluid mechanics	Information and communication technology	Building construction
Energy Technology	Electrical Systems	Structural theory
Building climate	Building Automation	Building in stock
Systems Engineering	Smart Control	Building management
Media supply	Smart Connect	Interior design/facades
Interdisciplinary cross-sectional modules		
Energy efficient building		
Thermal building simulation		
Fire protection		
Lighting design and technology		
Building information modeling (BIM) 1/2		
Special topic 1/2		
Object-oriented 3D Computer aided design (CAD)		
Integrated planning and building		
Plant engineering/pipeline construction/supply technology		
Integral project 1/2		

Table 1. Overview of the curriculum for the Smart Building Engineering course

Source: Groß, R.: "An Integrative Approach for Innovative Smart Building Engineering", Proceedings PLX Congress Hasselt, 2018

Modules that deal with digitization in the construction industry like "thermal building simulation", the "object-oriented 3D CAD" and the "SBE project" take up a lot of space in the course. A special emphasis is put on the "BIM 1/2" modules dealing with the methodology and tools of Building Information Modeling. This methodology is based on an integral planning approach and requires holistic knowledge of the building, the technical building equipment, the energy and media requirements, the use-related

comfort requirements and the socio-ecological environment over the entire life cycle of a building, i.e. from the first draft of the architecture to the management towards demolition or revitalization. The basis for this is an object-oriented digital model, the so-called "digital twin", which is created and maintained by all trades involved in construction and operation.

2. NEW APPROACH FOR A CROSS-SEMESTER TEACHING PROJECT

Based on the basic idea of an interdisciplinary planning project throughout all semesters of the SBE degree program as an intended bracket around the curriculum and as a guideline for the students, who hereby have the opportunity to always apply what they have learned directly into a higher-level practical context. It serves to enable students to better understand and classify the connections between the processes and procedures in the individual sub-disciplines of planning and building. In addition, key skills for a future digital world of work are expanded. This primarily includes methodological operationalized skills, in particular process and system thinking and interdisciplinary skills such as project organization, teamwork, self-motivation and creativity, combined with special digital skills such as collaborative online work.

In order to be able to achieve these learning goals, the project builds up specific teaching and teaching elements in the addressed modules in terms of time, method and subject matter. A real building as a long-term and cross-trade project represents the interacting planning components of a larger construction project much better and more realistically, just as the students expect in the planning office or on the construction site. The building is thus gradually being completely planned and further developed. The complexity increases with the trades and the resulting interfaces and mutual influences over the course. A central component is mostly interdisciplinary and team-oriented project work in the addressed modules, which becomes more and more complex over the course of the course, although they are always embedded in overarching questions and tasks relating to the "digital twin" and the entire planning process of a building. This project also serves as preparation for the thesis, in which the students have to work on a real task independently within a given timeframe in order to show that they can apply the skills required for the engineering profession in the context of smart building engineering in a practical way. In addition, it represents direct preparation for later professional life and enables students to gain their first practical experience in the field of the new digital planning culture.

Another goal of the project should be, in addition to the increased teaching of Future Skills in the context of selected modules through project-related tasks, to give the students a complete sample project folder as a compendium for their further professional life after completing their studies. All essential steps in the planning process of a future-oriented, sustainable and resource-efficient building are shown, additional explanations of the individual steps and processes as well as a large number of standard documents for further use in everyday work are included.

3. IMPLEMENTATION

3.1. Workflow of the Project

The project is intended to accompany the students throughout their bachelor's degree until they complete their thesis. They should plan a model completely, as will be expected of them in their professional life, and also use and practice the BIM methodology. They should deal with as many relevant trades as possible and get to know and learn to use the respective special features. The project is therefore designed in such a way that it begins with rather simple tasks in the first semester and then more and more trades and information are added, which all have to be coordinated so that a complete plan is available at the end. The complexity increases with each semester. The following table gives an overview of the planning steps in the first implementation in the curriculum of the Smart Building Engineering course and the subjects of the course that are participating in the project in the first implementation.

Semester	Module name	Content
1	Integrated planning and building	Presentation of the building and the project map, first small BIM project as a team task
1	3D-CAD and Introduction in BIM	Digital model, building architecture, component dimensions, attributes, materials
2	Building physics	Key data for thermal insulation, sound insulation, moisture protection, sustainable material concepts
3	Basics + Project Smart Building Engineering	Proof of thermal insulation, heat load calculation, heating technology components
4	Building climate	Cooling load calculation, ventilation and air conditioning components, optimization of control and building physics
5	Thermal building simulation	Dynamic calculation of heating and cooling loads with simulation tools
5	Digital recording of building stock	Laser scanning, workflow from a point cloud to a 3 dimensional model
6	Plant engineering/ pipeline construction/supply technology	Central heating/air conditioning, network hydraulics, project management
6	Smart Home	Building automation, building control technology

Table 2. Workflow of the project in the course of Smart Building Engineering with increasing planning progress and complexity over the semesters

Source: own representation, FH Aachen 2022

The project is designed in such a way that it can be expanded to other subjects of the course without any problems and can be implemented in the course of the project. Especially the subjects after the basic studies can be gradually included in the project. The following modules could well be integrated into the project in a second implementation step, since their content could be easily adapted to the new project.

Semester	Module name	Content
4	Electrical building technology 1	Electrical supply, electro technical components
4	Building information modeling (BIM) 1	Methods and tools for BIM, digital twin
5	Electrical building technology 2	Alarm systems
5	Media supply and disposal	Networks for cold and warm water, dirty and rainwater, gas supply, compressed air
5	Building energy systems	Needs-based and sustainable provision of heat and cold

Table 3. Other modules of the Smart Building Engineering course also suitable for the project.

Source: own representation, FH Aachen 2022

3.2. Requirements for the building

In order for the students to be able to get to know all the relevant trades and planning steps during their studies, the building that has to be planned in this project must also meet a number of requirements: On the one hand, it must be complex enough to realistically present all the problems that typically occur between all different involved trades during a construction project. But on the other hand it should be simple enough so that even freshmen are already able to work on the first steps. The complexity should increase during the course, but the basic geometry should be kept rather simple to avoid problems at the beginning.

The building should be scalable and have adaptive elements such as balconies, garages, etc. in order to create a separate but still equal project for each year group and to allow the students to work on different variants in small teams. In addition, various technical planning variants such as different heating concepts, different materials and different usage models can be generated individually. The use of sustainable building materials and the adaptability of the building to different life situations also cover current issues regarding innovative living and building concepts.

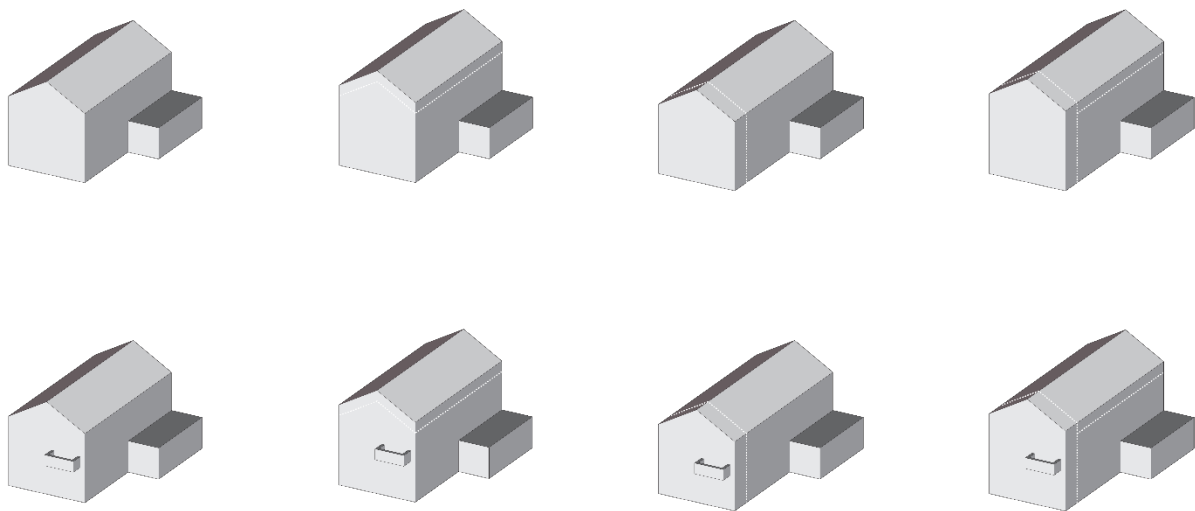


Fig. 1. Examples of different variants of the building due to different dimensions (ridge height, length, width, number of floors) and adaptive elements (balconies, garages, etc.)

Source: own representation, FH Aachen 2022

3.3. First three-dimensional model

Based on a real building, which was also built in this way and can therefore also be visited with the students as part of an excursion, the new project building was implemented and adapted to the needs of the individual teachers and their respective focal points. In addition to a planning variant as a kind of model solution, the task for the students was developed for each individual module and tested immediately. Particular attention was paid to the interfaces between the individual disciplines, so that the project can be processed in a meaningful way throughout and the requirements increase due to the increasing complexity [4].

The three-dimensional model was implemented with AUTODESK REVIT (version 2020), an upgrade to the newer version 2022 is currently in progress. [5].

4. RESULTS

Based on the plans of the real building, the architecture and geometry were first transferred into a three-dimensional model and the construction of the digital twin of the building began. At the same time, when designing this project for teaching purposes, the BIM methodology was implemented and documented as in a regular construction project. In addition, several variants of the building were created so that planned model solutions will later be available for all variants that the students should work on.

In the sequence of the modules in the curriculum of the Smart Building Engineering course, the respective lecturers involved were asked about adjustment requests or special features and the building was further planned for the respective trade. Nothing was allowed to be changed retrospectively on the models, so that the complexity increases with each new trade. The digital twin of the building was continuously developed, so that in the end a fully planned project including documentation and tasks developed in parallel was available for the students. The first use in teaching has already started successfully.

The following illustrations give an insight into the planning process of the building as the students are then supposed to work it out. According to the architecture, including the room layout (depending on the variant of use) and the creation of the three-dimensional model, the material characteristics are then assigned and thus the material is selected. Later in the course e.g. the heating and ventilation technology as well as components of the building automation as well as the furniture corresponding to the usage variant.

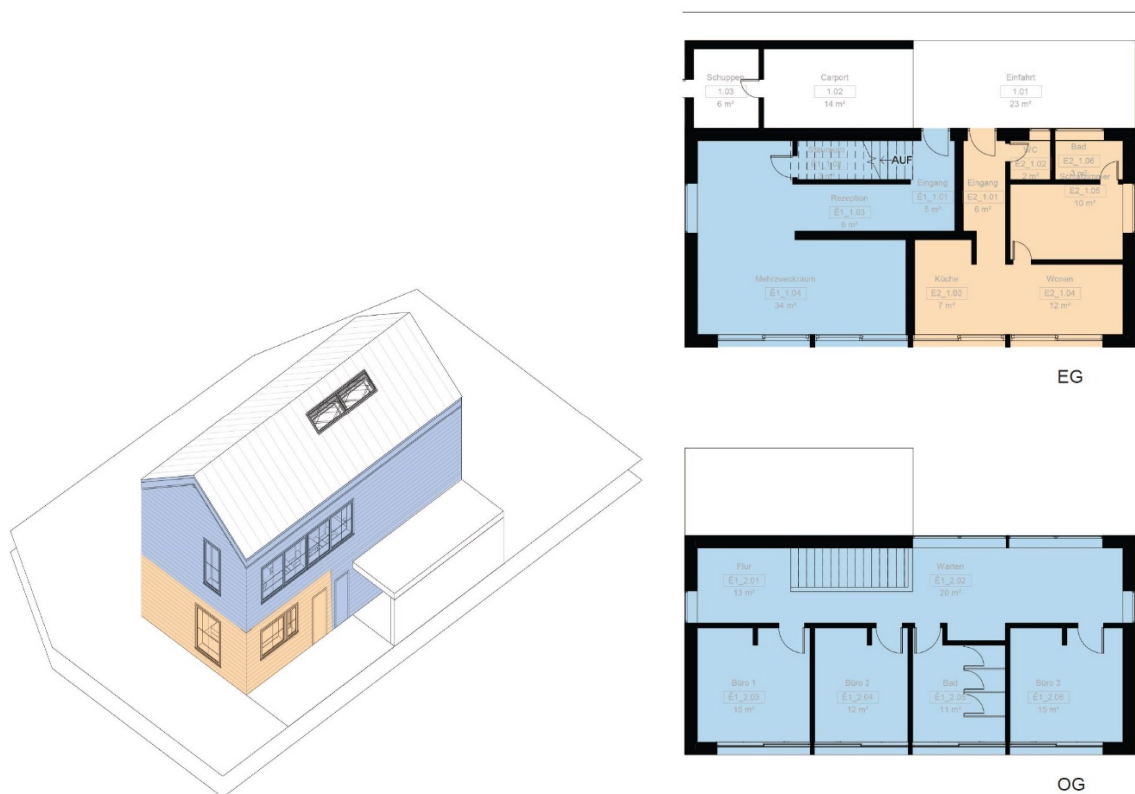


Fig. 2. Example of one of the different uses of the building. The living area is shown in orange, the office area in blue. (three-dimensional exterior view on the left, floor plan of both floors on the right)

Source: own representation, FH Aachen 2022

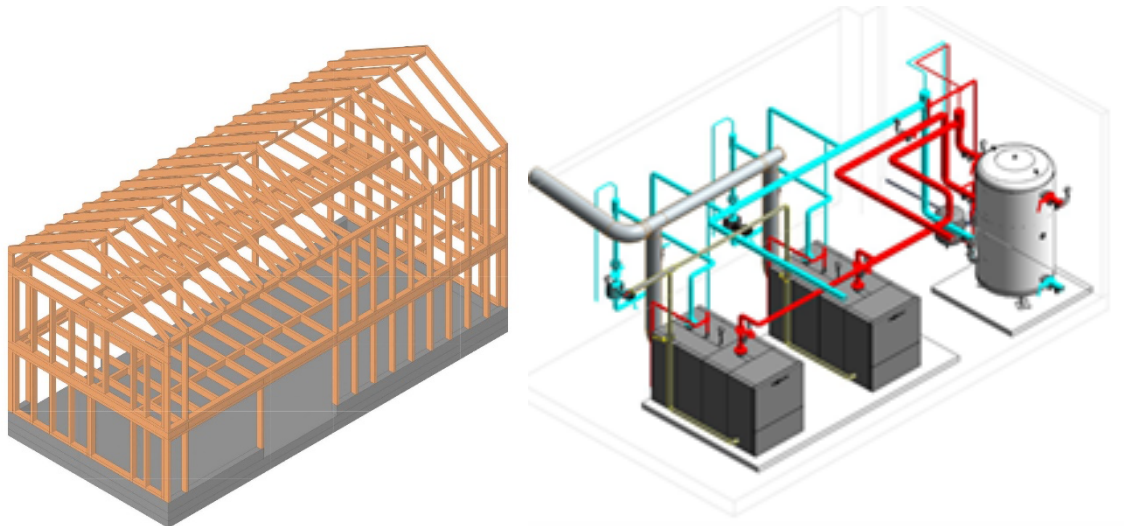


Fig. 3. Examples of solution variants for individual trades. Timber structure (left), central heating system (right)

Source: own representation, FH Aachen 2022



Fig. 4. Exterior view (left) and interior view including furniture (right) of a variant of the project building including a business unit.

Source: own representation, FH Aachen 2022

5. DISCUSSION AND CONCLUSIONS

The graduate's profile improves because of the curricular development in so-called future skills like problem-solving, critical thinking, collaboration, creativity and communication skills. A proactive approach, digital and intercultural competencies are promoted and expanded by this project as well over the entire course of Smart Building Engineering. As a result, students and graduates do not only have the option of applying the skills once per module, but is a recurring theme through the course and leads to a permanent further development of these skills. The implementation of a holistically completed project over the entire course of studies not only promotes technical expertise at a higher level through the detailed and permanent examination of the interaction of architecture, environment and technical trades. It certainly also serves to develop personality by strengthening confidence in one's own (team) abilities by taking on project responsibility and the respective sense of achievement when goals are achieved.

The students also have a much better overview of the learning objectives of the individual modules. In addition, it is easier for them to recognize the connection between the modules. Most students also found it more interesting to deal with typical problems during a planning and construction process than simply listening to the lectures. All this leads to a better understanding of the goals of this interdisciplinary course and have a more precise idea of their possible future professional life. This project enables the students to better assess and successfully process complex and technically demanding questions at the end of their studies. Of course, the similarity to real projects helps them a lot when starting their careers. Both the first students taking part in this project and the first employers of graduates from industry gave very positive feedback. The aim of giving the student an impression on the challenges and solutions in building projects with many different technical trades and their points of view was very well achieved and should definitely be continued in the future.

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