2023 European Conference on Computing in Construction
40th International CIB W78 Conference
Heraklion, Crete, Greece
July 10-12, 2023

INTEGRATED LIFE-CYCLE ORIENTATED TEACHING OF THE BIG-OPEN-BIM METHOD

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Abstract

Building Information Modelling (BIM) is a key success criterion to meet the diverse challenges of the construction and real estate industry across the life-cycle today. Therefore, it is highly important to make students as future working force fit for the current needs in the industry. This paper describes a collaborative effort to teach the Big-Open-BIM method in an integrated life-cycle, application oriented and project-based teaching approach. The authors describe the current state-of-the-art using the Big-Open-BIM method in practice and their current approach in teaching. This approach includes BIM Theory combined with software tutorials, hands-on use of the model centric communication and project-based learning. This concept and related interplay of approaches are described as well as the challenges of teaching in and across different study programs and universities. The authors provide an overview of teaching delivery methods, initial feedback from students and concluded with a preview of future efforts.

Introduction

The Big-Open-BIM method carries large potential in transforming the traditional life-cycle processes of buildings. While the BIM method has further developed in recent years, the teaching at universities is still lagging the current needs in practice. BIM is often taught in a very discipline-specific and isolated manner (e.g. in the context of structural design), while a cross-discipline and cross-lifecycle view with integration is regularly not part of the curriculum. Brokbals and Čadež (2017) for example looked at BIM Teaching in Germany and found that only few courses include model centric communications in their curriculum. Other evaluations of German BIM teaching found that "There is a missing focus on data exchange" (Pieper et al., 2021). First examples exist that model centric communication as key part of the BIM Teaching course is well accepted by the students and produces high quality outcomes and understanding in the classroom (Brandenburger et al., 2021). The project-based learning approach in combination with BIM has proved as a great teaching method (Peterson et al., 2011) to supply students with applied skills for real-world problems.
Thus, the authors established a collaboration to teach a state-of-the-practice BIM course based on their current practical working experience. Each of them brings practical experience of using the Big-Open-BIM method on real-world projects, which allows for a well-rounded and comprehensive approach. In particular, this practical experience includes Heating, Ventilation and Air Conditioning (HVAC) design and coordination, BIM use during Facility Management (FM), BIM use for energy simulation as well as software development for BIM applications. The teaching approach combines BIM-based theory with software tutorials and model-centric communication with project-based learning to make the students fit for their later working environment. This teaching approach aims to not only provide students with a basic and thorough understanding of the BIM method, but also to enable the further development of the BIM method in research and practise.
This paper first describes and explains the Big-Open-BIM method. The authors then explain the interplay between BIM theory, software tutorials and project-based learning. The paper includes an overview of teaching delivery methods, challenges and feedback from the students. Finally, the authors provide a summary and discuss future developments.

State of the art in the industry: Big-Open-BIM

Description

The Big-Open-BIM method (Hausknecht and Liebich, 2016) is gaining more and more momentum. Kim and Kim (2022) state that there is an increasing focus on BIM in the construction industry and Jiang et al. (2019) show that related publications are rapidly increasing. Therefore, it is the most promising method in the construction industry. There are two main characteristics about the Big-Open-BIM method:

- Big: Across many disciplines (e.g. Architecture, HVAC, Structural Analysis)
- Open: by using an open and vendor-neutral standard data format, to enable collaboration between different platforms, e.g. the Industry Foundation Classes (IFC)

These two characteristics provide the basis to use the BIM method across the complete life-cycle of a building as well as to collaborate effectively among all stakeholders of a project (Borrmann et al., 2018).

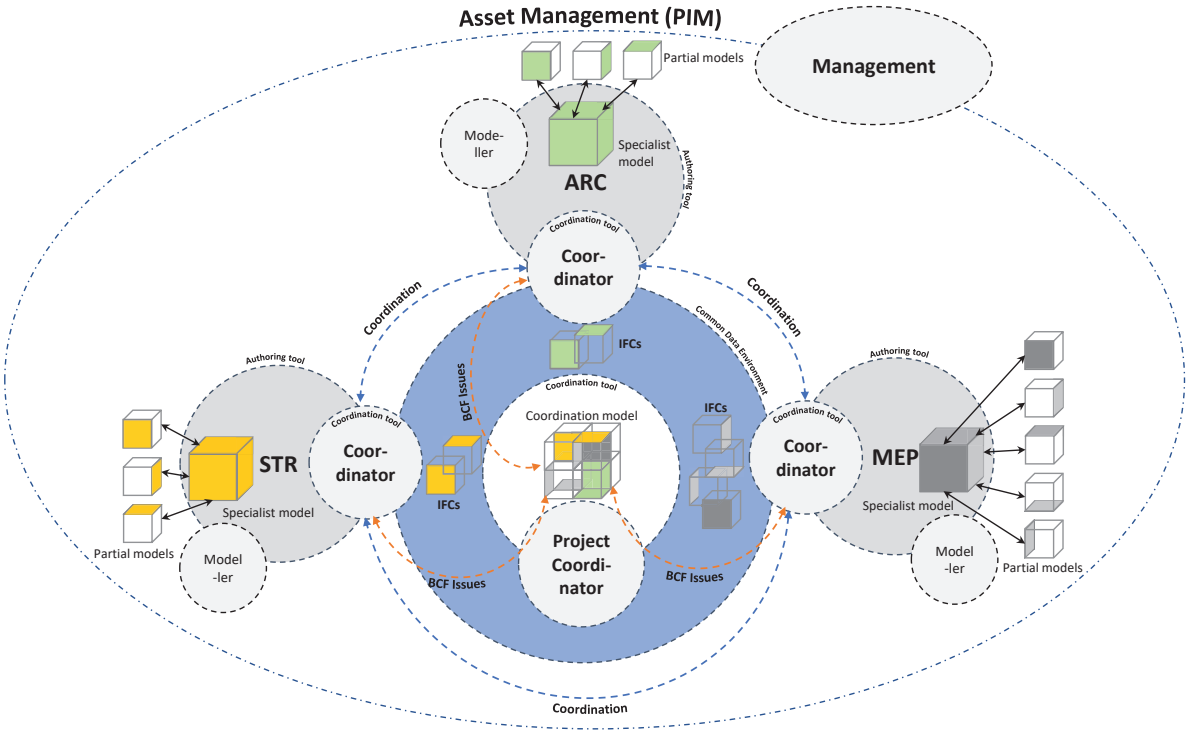

Figure 1: Model centric communication with the BIM Method (Wimmer et al., 2023)

Model centric communication

At the heart of the Big-Open-BIM method lies model-based communication and coordination. Figure 1 illustrates the details of this process. Exemplary three different disciplines are shown: Architectural design, structural design, and MEP design. Each discipline is working on its own specialist model that can itself consist of partial models. For larger projects it is common to divide a discipline into parts by either separating it spatially or by subdisciplines. Each discipline also provides a coordinator to ensure model quality and enable the interoperability between the different disciplines and their tools. Now the different discipline coordinators can interact with the project coordinator and communicate based on the coordination model which is formed by merging the different discipline models. In the Big-Open-BIM application this is typically done by combining the specialist models from the different disciplines, using the non-proprietary format IFC. Based on this coordination model, issues, overlays, and inconsistencies can be found and marked in the context of the model. Another open format is used to enable model-based communication: BIM Collaboration Format (BCF) tickets are used to transfer the issues in the model context between the participants. If this is done in a Common Data Environment (CDE), these BCF tickets can be centrally stored and the basis of an issue tracking system. Within that issue tracking system assignees and status of each issue are tracked and issues can be resolved and verified from the original creator. A BIM Manager typically oversees this overall process and provides support with more difficult to resolve issues spanning multiple disciplines. Overall, this process focusses on the planning and realization phase of a project, thus creating a Project Information Model (PIM) (DIN EN ISO 19650, 2019).

Teaching approach

Overview

The concept for teaching the integrated and lifecycle-orientated Big-Open-BIM method consists of three aspects and is shown in Figure 2.

1. BIM Theory taught through lectures
2. Learning Software Tools though tutorials
3. BIM Practice taught through project-based learning

Within the lectures students learn the essential basics for working with the Big-Open-BIM method, but also actively participate in class through discussions and hands on exercises (see sub section Delivery Methods for more details). The BIM Theory lectures are centered around data, with four major topics:

- Context
- Technology
- Processes
- Actors

These lectures are enhanced by software tutorials so that students gain experience using the relevant software tools. In the practical part student teams actively work on a

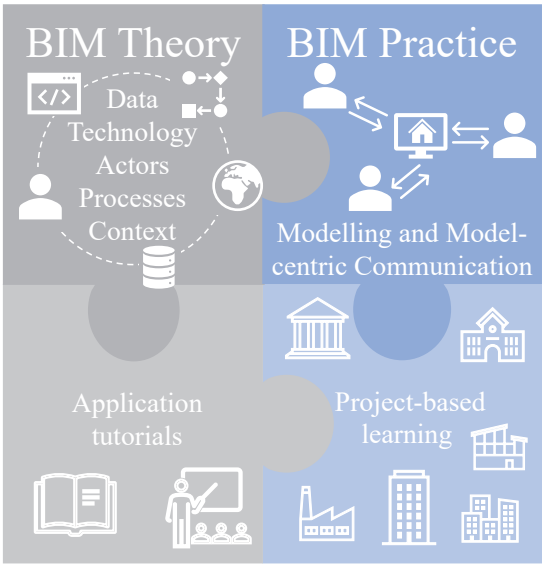

Figure 2: Teaching approach

project that was formalized by the professors. In this context the student teams apply the model-centric communication during their project lifetime. This approach enables the students to learn the theoretical background and to get to know the practical application of the BIM method. Furthermore, the integration of a project-based-learning concept is necessary to design a teaching course that meets academic requirements and makes students fit for their future work environment. Project-based learning is not just a simulation of the real work environment, but a practical approach by applying knowledge within a project. This enables students to study, try out problem-based working, and work in teams as well as to use relevant software tools (Rummler, 2012). Especially in data- and software-based teaching and research areas, project-based learning concepts are commonly used (Matthes, 2020).
By using the concept of project-based learning in combination with lectures, software tutorials and model-centric communication, it is possible to achieve high learning objectives. The well-known and established "Taxonomy of educational objectives" (Bloom, 1956) is used for the evaluation of learning objectives (Volk, 2020). Bloom (1956) define six level of expertise:

1. Knowledge
2. Comprehension
3. Application
4. Analysis
5. Synthesis and
6. Evaluation

Evaluation is the highest level of learning objectives. By implementing a teaching concept, that combines lectures and project-based learning, the level of expertise Synthesis and Evaluation can be reached (Stanley, 2021). Examples in our context are:

- discussing limitations of the open BIM concept
- implementing of BIM processes and responsibilities in teams
- creating new use cases for the implementation of the BIM method.
- judging various software concepts
- establishing interoperability between different tools
- developing new/ tailoring software applications
- implementing new solutions for a cross-life-cycle use

Especially due to the various aspects of the BIM method (as illustrated in Figure 2) the project-based learning enables the students a firsthand experience of the usage of tools in a project context.

BIM Theory

The BIM Theory lectures are centered around data. Four major topics around data are used to guide through the lecture material: Context, Technology, Processes, and Actors. From the start of these BIM Theory lectures critical thinking is encouraged to enable the students to question processes and workflows that may have potential for improvements.

Context

The context or boundary conditions include the knowledge of local standards and guidelines that are relevant for the project and for the Big-Open-BIM method. Among others the German VDI 2552 (VDI, 2020) is a major standard that is heavily used in the lecture. Hereby newly developed documents are discussed in detail such as Employee Information Requirements (EIR) and BIM Execution Plan (BEP).

Technology

The technology context includes a definition of BIM, common goals as well as pros and cons of using the method. Of course, the Big-Open-BIM method itself is also a topic of this part of the teaching as well as the other three major BIM methods including their advantages and disadvantages. Central to the BIM method are object-oriented models. These models and different approaches for data models such as Model View Definitions (MVD) are also included.

Process

In the process section the model-centric communication is discussed as well as documents and workflows used in real world work environments. This section also includes process modelling in the form of the Business Process Model Notation (BPMN) with the goal of identifying the interfaces between the different participants. Only based on these processes it is possible to eventually define the data exchange model. The BPMN thus creates an essential basis for understanding the process within the framework of the BIM method.

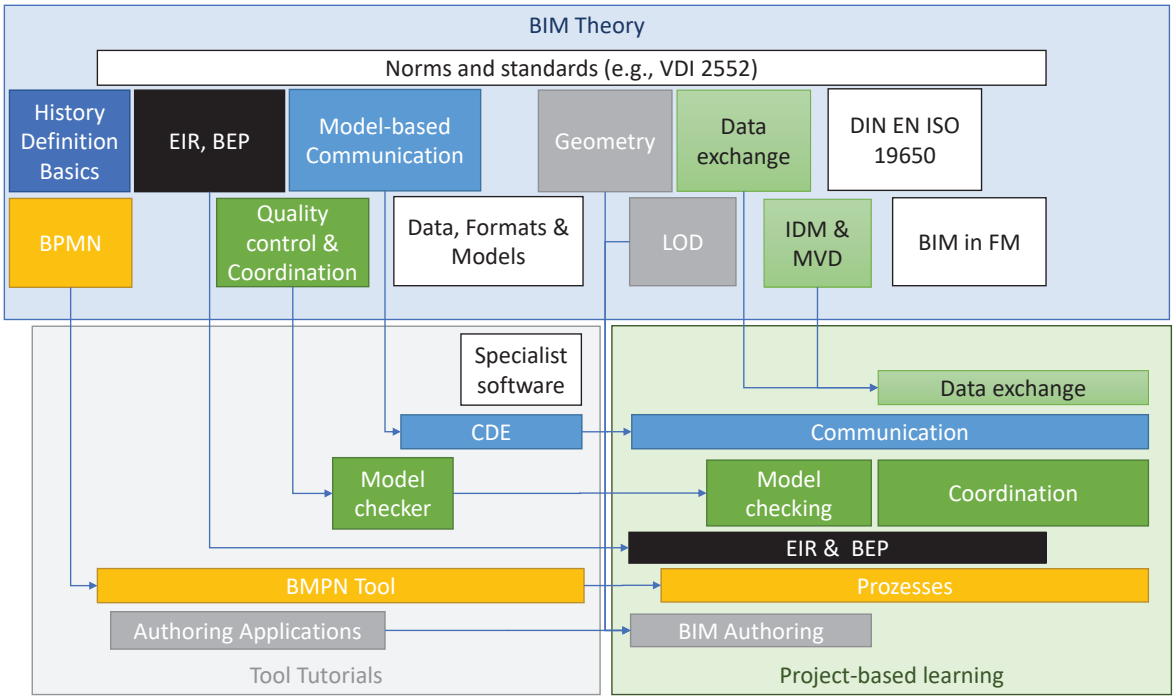

Figure 3: Teaching interplay between theory, tutorials, and project

Actors

Finally, the actors involved in the process are discussed and later in the student project, the student can experience firsthand the different roles in a collaborate project effort. The lectures regarding the topic Actors also enable the students to form, develop and implement BIM organizations to handle their projects in project-based learning as well as in their future practice.

BIM Practice

The BIM Practice section of the course is interwoven with the BIM Theory section as illustrated in Figure 2. Software tutorials are used to establish a basic understanding and usage of various software tools used in the course. Hereby the focus is on "learning by doing" so that the students learn how to create object-oriented models on their own in practical teaching sessions. This encourages self-learning of the students which is an important aspect of using software today were help can just be one-click away. After the basic software training is completed, the students get their project task at hand and start to create and design their own digital object-oriented models. With the first design ready the student teams start using model-centric communication to enhance the design and coordinate different specialist models of their project. The lecturers help and support the student teams as well as intermittent project presentations are great communication events where students exchange ideas, issues, and problems alike to learn from each other. Depending on the students advance in his/ her program data communication issues or enhancements for current software tools can be overcome by creating python code that can use various software APIs.

Combining BIM theory and project-based learning

These two approaches - BIM theory and project-based learning - integrate very well since BIM teaching requires the learning and use of software tools. Without this practical aspect it is very difficult to learn and understand how the BIM method works. For example, false negative errors are best understood by investigating error lists in a real project context. By doing so the students are able to learn the difference by deciding the error importance in this context. Figure 3 shows the interplay between BIM theory topics, software tutorials and project based learning . The focus here lies in the combination of theory and actual use of software tools. Figure 4 shows some impressions of student work in their project.

Delivery methods

To further engage the students within this BIM teaching approach, modern delivery methods are used in the courses to enforce active learning with the students. Here is a list of commonly used techniques in the courses:

Traditional lectures

Traditional lectures still have their place in teaching, particularly at the beginning of the course to cover the basics, introduce new topics and get the knowledge transfer going.

Groupwork

The class project is typically done in groups as well as various group tasks within and outside of the class time. Finding sources and information via internet search is a

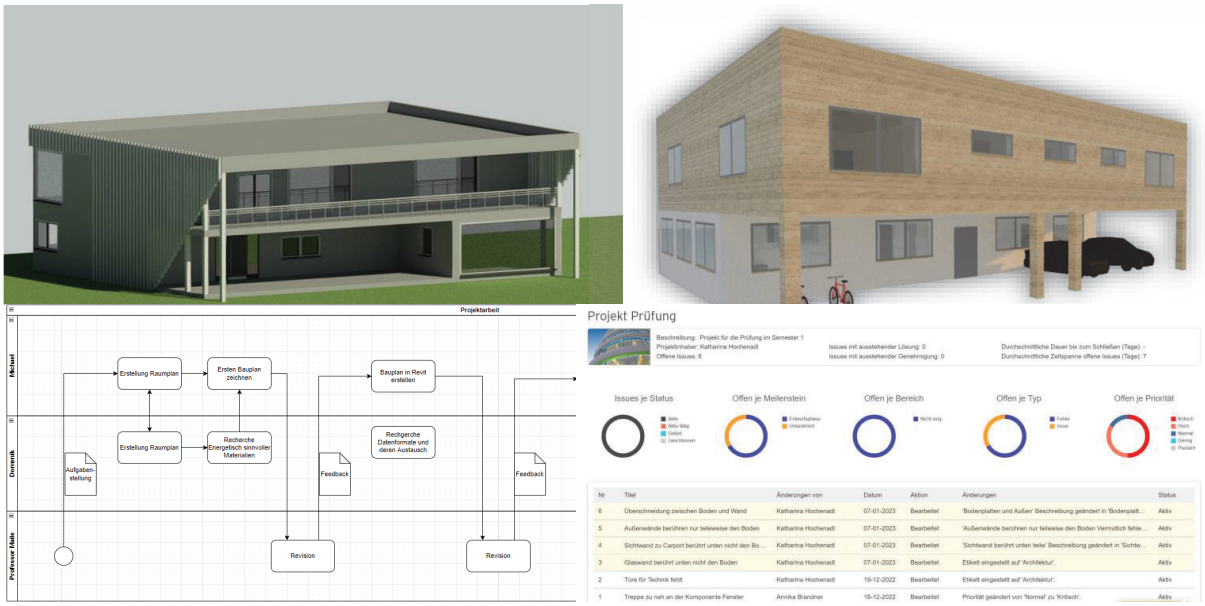

Figure 4: Impressions of student projects at the end of the first semester

popular way to get students to interact with various topics. E.g., when searching for IFC on the web, the students are typically overwhelmed by the number of results they get. While investigating the term they also get a sense that it is very common.

Groupwork to summarize readings

While lots of different standards, norms and other reading resources are used as basis for our lectures, students typically do not look at these references without any specific need. However, a group task to summarize a given standard where each group is responsible for a chapter and later summarizes it in front of the full class. This enables the students to focus on a particular resource. This is a great way for the students to get to know the resource, explain it to peers and get it explained by peers.

Interactive questions

Another method to attract student attention is to use interactive questions. There are different ways to ask questions. In a verbal encounter students and teachers can exchange and discuss questions and answers of a specific topic. In a digital setting the answer can be anonymous and student participation is typically much larger than in a verbal setting. It is a great way to gain an understanding of students' background and later in the course about their understanding of the course materials.

Peer to peer grading

With large student groups, grading of projects can be difficult to manage, thus peer to peer grading is a great way to grade student projects. Not only is the grading effort for the teacher less overburdening, but it is also a very useful exercise for the students to learn from others and think about grading aspects.

Active project participation through use of CDE

Another method to interact with the students and get them organized and motivated is through the use of tasks and issues within the CDE. The data environment can also be used to organize the course and give the students tasks with deadlines to accomplish. Peer to peer communication about the project is easily encouraged with a CDE and becomes natural for the students during the course of the project.

State of knowledge

Another tool we use in our modules is to gather feedback on the state of knowledge of students. Towards the end of the course, the students access how well they understand each of the topics of the course. This serves two purposes. First it allows the student to self-assess this state of knowledge and more importantly his/her weak spots. Secondly it provides useful information to the lecturer about which topics were well covered and understood as well as which topics need further elaboration and focus.

Challenges

These different delivery methods of teaching the Big-Open-BIM method greatly enhance the experience of the students and the teachers. However, for cross study programs and cross university settings various challenges occurred, these are discussed in the following sections.

Challenges of cross program or cross university courses

The first challenge in cross program or cross university teaching is the different existing curricula. Each course of study has its own curriculum of courses and while BIM modules are being included in more and more study programs, their content, size, and semester differ widely. While, for example, the "digital.design and production"

(DDP) program at TH Augsburg contains a BIM Module in the 1st semester, the civil engineering program includes it quite a bit later in the 6th semester. To connect those two modules, one must account for the different levels of knowledge, experience of working on class projects, and different discipline backgrounds. While this collaboration is currently ongoing in the semester of writing, the challange is to carefully design both modules with common theory and interconnected project work in the practice part of the course. The project work can be easily split into the specialties and disciplines of each program. A civil engineering student will oversee the static calculations, cost calculation or scheduling while a DDP student would take on the role of a BIM Coordinator or more digital tasks such as laser scanning. This approach provides quite a good representation of the real project world, where everyone is a specialist in his field but still all work in an integrated and digital manner.

Challenges of different backgrounds

Another challenge in BIM teaching is the different background, experience and knowledge of the students. While this is true for any teaching course, in BIM teaching computer literacy plays a major role. The ability to quickly learn and use new software tools. To tackle this challenge, it is necessary to provide software tutorials on a step-by-step basis, so that students can follow each single step during the tutorials and can finish the tutorials successfully.

Challenges of software issues

In a quickly evolving world of software tools and versions, it is hard to keep up with every software update. Specifically, tutorials need to be kept up to date so that changes in the tool are also reflected in the tutorial. An even more severe problem is software bugs and regressions that collide with class material. Cloud based software applications, while mostly reliable, do have downtime, for example for maintenance and updates. On one occasion this collided with a busy Sunday of student work just before a deadline.

Challenges of data exchange

Besides the software issues itself there can also be issues arising from data transfer between tools. Resolving these issues can be time consuming since it is not always clear in which software tool the error originates in or if it is a quality issue of the model itself. Thus, the courses are designed so that great emphasis is placed on making the students understand how important the quality control of models is and that establishing interoperability is a major topic in the Big-open-BIM method. In addition, to the professors support in those cases.

Challenge of grading

Typically, each BIM module has its own grading basis defined in the corresponding university curricula. Ranging from written exams or project submissions to oral exams. There is an ongoing debate on which grading type is the best fit to the described class. However, a combination of approaches, such as a written exam to test the theory and a project submission to enable the grading of class projects seems most appropriate. Especially since student motivations seem to align quite closely to the grading basis. The authors think that project grading starts with project participation, completeness of submitted materials, key topics such as difficulty, process completeness and use of tools. Grading criteria are defined in ranges to convey different levels of student quality and quantity of work.

Timing challenges

Above all there are challenges with timing. Different semester start and end dates across different states are sometimes difficult to come by. Various extraordinary events, such as vacation times, excursion project weeks at different times across study programs, faculties and universities can further complicate the organization of integrated teaching.

Course evaluations

While a structured and complete evaluation of the courses has not been fully completed yet. The learning outcome of the courses was evaluated in various ways, namely teaching evaluations, workshops and face-to-face discussions with the students. The project-based teaching approach was implemented in one course and the differences between the course with and without project-based learning was evaluated with the course. The evaluation was answered by 35 students (n=35), while 17 students (n=17) evaluated the course without project-based learning and 18 students (n=18) evaluated the course with project-based learning. The evaluation was conducted online and anonymous at the end of the semester. While 1 means that the thesis "applies" to the view of the students, 5 means that the students do "not apply with the statement. Figure 5 shows some of the results of the evaluation and represents the mean values of the evaluation. It can be seen, that the use of the project-based teaching approach supports the understanding of the topic as well as the motivation for the topic and the rest of the study.

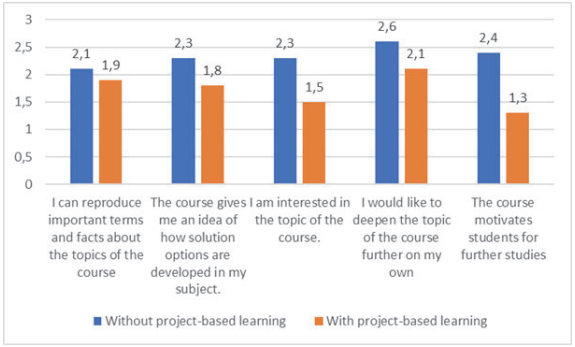

Figure 5: Evaluation with and without project-based learning

Conclusions and outlook

Summary

This paper shows a collaborative effort in teaching the Big-Open-BIM method in an integrated life-cycle oriented teaching approach. The approach combines BIM Theory with model-centric communication and project-based learning to make the students fit for their later working environment. The teaching approach consists of lectures, software tutorials, and project-based learning to enable the students to learn the theoretical background and the practical application of the BIM method. In particular, the model-centric communication as used in practice today is a central aspect of the study course. The professors have different BIM backgrounds across life-cycle phases and thus bring a wide range of practical examples and applications into this collaboration. We illustrate the interplay of BIM theory and BIM practice including software tutorials and project-based learning. We discuss delivery methods commonly used in this collaboration as well as typical challenges. We provide brief feedback from the students and plan to do more sophisticated evaluations in the next courses to come. The professors are currently setting up hands-on collaborations between different study programs and universities to further develop the teaching of the Big-Open-BIM method.

Outlook

While the fundamentals of the BIM course are set and continuously further enhanced, the authors aim to stretch the course across more study programs and across universities. Applying these course principles across disciplines fosters first hand experience of the students in interdisciplinary digital collaboration. Furthermore, we plan to continuously evaluate our approach and extend evaluation to gain insights in the strength and limitations of this approach. The results will allow us to furthre develope the concept and share them with the community.

Acknowledgments

We would like to thank our students for their feedback and creative work during our modules.

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