Integrating foreign studies within the constraints of European Harmonisation:
A BIM e-learning course

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INTRODUCTION

Working on international projects with project partners from all over the world is common practice in almost all engineering disciplines nowadays. To prepare students for this part of their professional lives a study period abroad is probably the most effective way. Spending several months in a foreign country will not only develop the necessary language skills of future engineers but also lead to an understanding of cultural differences which can be crucial for their professional success when collaborating within multinational engineering projects.

In addition to these soft skills, the management of data between project partners is a big challenge in large engineering projects. Access, exchange and consistency of data have a huge influence on completion time and budget. This applies in particular to construction projects over the whole life cycle, i.e. during planning, execution and operation of buildings and facilities. Over the past ten years, the concept of building

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information models (BIM) was introduced and most likely, BIM will become state-of-the-art in large construction projects in the future.

1 CONTEXT

At the University of Kaiserslautern we developed a curriculum for an M.Sc. program in Facility Management at the faculty of civil engineering, starting in fall 2015. To address the requirements of future workplaces, we decided to integrate international studies into the third semester of a two years program.

Integrating foreign studies as mandatory part of the curriculum following the stipulations of a European harmonisation is not as easy as the inventors of the European Credit Transfer System (ECTS) intended. We found two main barriers to the implementation of a study period abroad:

1. A full semester of studies at a foreign university requires partner universities, which offer 30 ECTS in courses that fit into the overall program at the home university.

2. Foreign institutions of higher education often require high tuition fees. Grants and other funding options are often not accessible to foreign students. In Germany, education is usually tax-financed and free of tuition fees.

For the new M.Sc. Facility Management we decided to use a mixed strategy to integrate foreign studies, project oriented teamwork and globalisation issues into our education concept. Beside 12 ECTS credit points that have to be obtained from international studies we offer several e-learning courses that students should take during this period and which explicitly reinforce the learning goals of project oriented teamwork in a globalized environment [1, 2].

The Building Information Modelling (BIM) e-learning course in M.Sc. FM and Civil Engineering programs is a sound example of how these soft skills [3] can be combined with teaching an innovative, technology-oriented approach that will play an important role in future civil engineering practice.

2 COURSE CONCEPT AND CONTENTS

2.1 Learning objectives

With BIM, future buildings are represented as digital models, which can be shared and exchanged among project participants, between different software applications and across the entire building lifecycle. Due to the improved exchange of information using digital means, the construction domain can seize the benefits of global networked cooperation.

After successfully completing the course, the students know the application area of building information modelling and its impact on a continuous flow of information across disciplines and lifecycle phases. They know the content of information models, relevant paradigms, standards and software which supports BIM workflows. They are able to employ BIM across domains and in globally distributed project teams.

The course consists of a theoretical and a project work part.

2.2 Theory contents

The theoretical part of the course introduces the students to the idea of BIM, the concept of interoperability across domains, during the whole building lifecycle and between different software applications. Basic principles of information modelling, such as objects, attributes, and relations are introduced with respect to the construction domain. Since three-dimensional geometry is an essential part of building information models, a distinct topic is dedicated to geometric representations.

In real engineering projects as much as in the e-learning course project partners need to access and exchange information from different locations at different points in time. Therefore, the data have to be persisted in files or databases using shared meta-models and common data formats. The most well-known and by now wide-spread standard is Industry Foundation Classes (IFC) which evolved in the early 1990s as a construction specific modification of STEP, the mechanical engineering standard for the exchange of product model data [4]. IFC is built from schema layers and covers both the core of construction projects as well as domain specific information. However, other domain specific meta-models, data formats and standards evolved in parallel, such as the Construction Operations Building Information Exchange (COBie) format, or GAEB - a German standard for tender, bidding, awards and accounting. The theoretic part of the course also covers the creation of domain specific model views, the formulation of model requirements, and the validation of model content.

In distributed work-flows, BIM servers provide remote access to building information models. In this context, it is an essential issue to handle concurrent access, to guarantee consistent data and to allow rollback in case of accidental damage to the models. A further subject of the course is how BIM servers provide this functionality. The original idea of building information was a central repository shared among all project participants. This has been superseded by more flexible paradigms in recent years. These new paradigms will also be introduced during the course: Multi models allow for the loose coupling of partial models with reduced constraints for consistency and higher tolerance for inconsistencies [5]. BIM infrastructures increasingly resort to service architectures, with the BIM server being only one of many different BIM services - the data service [6].

Finally, national regulations and recommendations are discussed [7–9]. The theoretical part of the course is rounded off by notes on software certification, assessment and selection of appropriate software, and the implementation of BIM processes in engineering practice.

2.3 Applied project work

During the course of a practical project, students are introduced to BIM enabled software and get hands-on experience with a distributed work-flow. They become acquainted with two different types of software: on one hand specialized software to carry out domain specific tasks which is able to import and export standard compliant building information models, and on the other hand software to exchange, store and distribute building information models, and to facilitate collaboration in construction projects.

The task specific software covers three different project life cycle stages and three respective domain tasks. During the course, students take the roles of different stakeholders by solving these domain specific tasks.

1. The *planning* phase (P) is represented by a structural analysis task.
2. From the *execution* phase (E), a construction management related task has to be carried out, e.g. quantity take-off from building models for cost and progress tracking.
3. As an example from the *operations* phase (O), a facility management task such as recording of maintenance cycles of technical equipment, is assigned to the students.

The domain specific tasks are carried out successively with the same project data. In between solving the tasks students exchange their building models. Using a BIM server, they hand over the solution to a fellow student in a different role, switch their own role and receive data from another fellow student. This concept of continuing exchange of preliminary results is inspired by a historical project in architectural education at ETH Zurich, where students worked on architectural designs. Over several cycles they provided their preliminary designs through a dedicated web site to their fellow students who had to choose a design other than their own to continue working on [10,11].

3 IMPLEMENTATION DETAILS

3.1 Project work

Fig. 1: Three stage cycle of a project task

Each task to be carried out during the project work is organized as a cycle of three week-long parts as shown in *Fig. 1*. During the first week the students clarify the requirements of the data needed for the specific task, they receive the data, import, verify and explore it. During the second week, they carry out a small given task. The third week is dedicated to prepare, export and hand the result over to the next student.

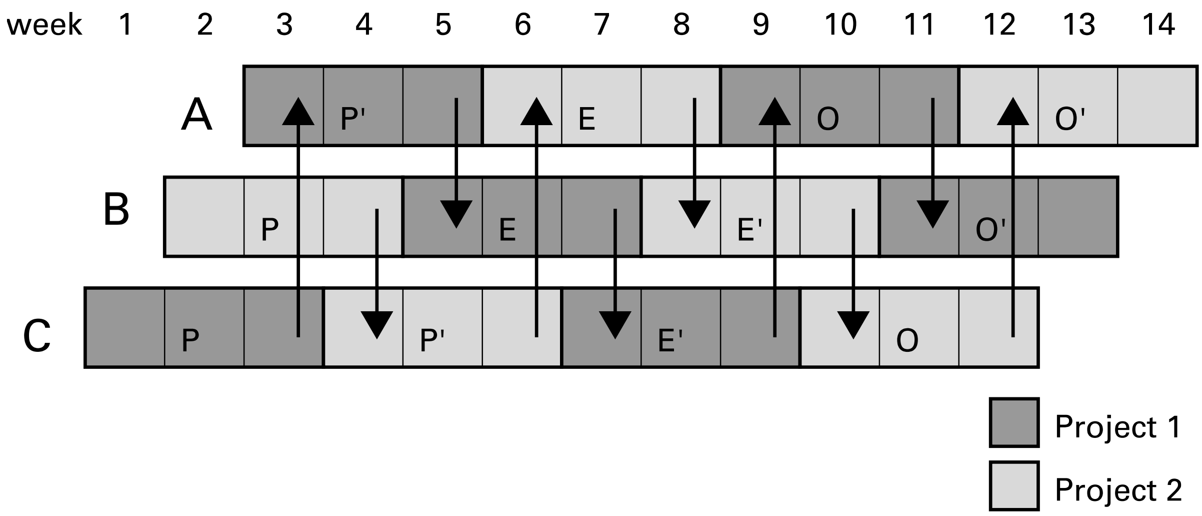

Fig. 2: Semester schedule of project task cycles in the planning (P), execution (E) and operation (O) phase with handover between three students groups A, B, and C

The project data comprise two or more different projects, such that the role changes occurring every three weeks are marked by a change of the project for every student.

Since the hand-over week involves two different students, the cycles have to overlap by one week. These week-long offsets result in three groups of students (A, B, and C) with different schedules. The semester schedule for the three groups is shown in *Fig. 2*. Note that the groups are not meant to function as teams, but serve only the purpose of organizing the schedule. Collaboration takes place between particular students of different groups in the hand-over phase, otherwise students work independently. In case students drop off the schedule, default intermediate project results are provided as a fall-back for the students taking over for the next task cycle.

Each project runs through the three phases of the life cycle with according tasks in a series of alternating hand-over and task weeks. For a project, each task occurs twice, first as initial task (P, E, O) and then as modification task (P', E', O'). While during the initial task additional information is created, during the modification task given information is analysed, compared, integrated or corrected.

Each student has to complete four cycles involving at least one task for each project stage. For each task new data for a different project is received, and to finish the result is handed over. *Table 1* shows an example of a semester schedule for a student of group B. Assuming that the groups consist of four or more students, it can be seen that this schedule contains exchange with seven different students (A1, A2, A3, A4 from group A, and C1, C2, C3 from group C).

Table 1: Exemplary semester schedule for an individual student of group B

Week	Task	Project and Phase
2	Receive initial model data from architect, check model contents, import in structural engineering software	Project 1 Planning (P)
3	Structural engineering task: check the bearing capacity, correct dimensioning of load-bearing walls	
4	Handover of the changed model to student C1	
5	Receive model data from student A1, check model content and validity	Project 2 Execution (E)
6	Management task: perform quantity take-off, complete a partial schedule based on the quantities, given effort and resource values	
7	Hand over the completed schedule to student C2	
8	Receive schedule data from student A2, check model content and validity	Project 1 Execution (E’)
9	Management task: compare given progress reports to the schedule, identify delays, identify places which were not built as planned, update the as-built model	
10	Hand over the updated as-built model to student C3	
11	Receive operations data for different disciplines from student A3 (elevators) and A4 (ventilation system)	Project 2 Operation (O’)
12	Operations task: merge operations data, create an integrated maintenance schedule	
13	Add the maintenance schedule to the repository	

3.2 Theoretical track

The theory lessons are offered in parallel to the practical tasks, and are accompanied by self-assessment sessions. Thus, after an introductory lesson, students can study at their own paces. Because of the cooperation focus in the practical part, the project work schedule is very restrictive – as in many real working environments. The theoretical track provides more freedom to the students, and thus accounts for the fact that the course has to be integrated into different foreign curricula as the students go abroad. The students are responsible for the respective adjustments themselves.

The self-study nature of the course facilitates further flexibility: different learning types regarding the relation of theory and practice will be supported. Corresponding to their preferences, students can either work on the theoretical lessons and then confirm it by practical experience. Alternatively, they can start with the practical project work, and then underpin that with theoretic explanations. Therefore, the theory and practice parts have to be largely decoupled. There will be few lessons of the theory part which are bound to the practical tasks, but the majority of the material can be studied independently. Bidirectional references between theoretical sections and practical tasks facilitate making the connection either way.

3.3 Communication, supervision and examination

E-learning courses substitute communication in face-to-face classes with remote communication. Blended learning concepts combine on-campus classes with online self-study elements. The shorter the phases of attendance are, the more communication options have to be provided online [12]. For an entire online course this means, that different communication channels (synchronous, asynchronous, moderated, informal) of the learning management system (LMS) have to be utilized, both for students to communicate among each other as well as for communication between students and the lecturer. Consultation times have to be anchored in the schedule.

To award credit points, the students' progress during the course has to be examined. The examination requirements consist of a documentation of the project work to be handed in at the end of the semester. Students will be urged to document in particular the success and failure during the handover phases and to combine the documentation with theoretic reflections.

4 DISCUSSION

By teaching the BIM method in the context of specific projects, the learning effect is twofold: Students can embed the theoretical foundations of BIM into practical application, and they are introduced to the complexity of cross-project workflows with various different stakeholders – a fragmentation which is characteristic of construction projects. From a pragmatic point of view the BIM method enables the students to work together across time zones and stay connected during the study period abroad.

For the students in the M.Sc. Facility Management program at the University of Kaiserslautern with a required study period abroad, the BIM online course is a mandatory part of the curriculum. For students of the M.Sc. Civil Engineering program the BIM e-learning course is an option to obtain credit points at any point of time during their studies. This option helps students to organize their studies independently and it opens up the possibility for work, travel and internships while still actively pursuing their studies.

As for every mandatory course at the University of Kaiserslautern a students' evaluation will take place at the end of the semester. It will allow the authors of this paper and developers of the BIM e-learning course to continuously check if the learning goal "understanding of Building Information Modelling" has been reached. As for a more long term evaluation it is necessary to stay in touch with former students during their first years of professional practice and see if the BIM course could effectively contribute to the learning goal "project team work in a globalised world". The feedback of young practitioners, i.e. project managers, civil engineers and facility managers will also help us to further develop the online course and to ensure that content and methods reflect today's business requirements.

To ensure the sustainability of the course we will have one designated research assistant at part time to communicate with students while they are working on project tasks and to keep software versions up to date. As much as it is possible within a two-years program we also seek to integrate students who have formerly taken the course as mentors for the classes of the following year.

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