Simulating real world collaboration
through interdisciplinary student projects using BIM

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INTRODUCTION

The construction industry is evolving as a reaction to modifications of the legislation for public tenders, higher performance requirements as well as awareness of quality problems and an often inefficient production process. For this evolution to take place, a fundamental change in the global building process is necessary. This implies also the need for corresponding changes in the curricula of all construction related disciplines.

In the traditionally building process the programming and the sketch design phase involve mainly the building owner and the architect, neglecting possibly important contributions from other actors to deal with increased complexity and avoid late and costly changes of the initial design. Also at project delivery an important part of relevant information from the construction phase is not transferred to the owner or facility manager. This often causes unnecessary additional cost and discomfort.

An alternative approach is to gather all involved parties early on, by forming so-called "*Building teams*", where owner, architects, engineers, contractors and other consultants are grouped to join forces. As a consequence, the different tasks and responsibilities within the building team have to be clearly defined and indicated in chronological order together with specifications for the corresponding information flow. To ensure the correct information flow, making agreements and describing the flow becomes a logical step and serves as a base for a proper choice of software tools and their use. Earlier research projects have studied how the building process can be organized in a more efficient way.

Introducing this knowledge into the education of the different engineering disciplines is the main goal of the present research project: "*Communication and management of digital building information in a multidisciplinary team during the construction process*" (COM.BI, OOF-project 2011/24, [1]). This is achieved by implementing collaboration in building teams and introducing innovative software tools. Since all building-related disciplines are represented within the KU Leuven Association, there is an opportunity to form multi-disciplinary student teams and to share knowledge from different fields of research and professional experience.

In this project students and lecturers from KAHO Sint-Lieven, Master of Science in Industrial Engineering: Civil Engineering, Professional Bachelor in Construction and Electromechanics, LUCA, Sint-Lucas Architecture: Master of Science in the Architecture, KU Leuven: Master of Engineering Science: Civil Engineering, Architecture and Energy closely collaborate.

1 THE BUILDING INDUSTRY PERSPECTIVE

To provide a background for a better understanding of the chosen didactic approach of the COM.BI-project, this section gives a short summary of the most relevant developments in the construction sector.

1.1 Higher performance requirements

Local governments as well as European authorities are steadily increasing the performance requirements for buildings. Examples are the recast of the Energy Performance of Buildings Directive requiring new buildings to be nearly zero-energy by 2020, increased requirements for building acoustics and environmental noise, accessibility, safety and many others.

Rating systems such as LEED [2] and *BREEAM* [3], assess environmental performance of new or existing buildings. Since January 2013 a *life cycle assessment* (LCA) needs to be added to building permit applications in the Netherlands. Zero impact on ecology, energy, water, materials, internal environment etc., will become a criterion for future buildings to receive a building permit. To meet these high requirements it is necessary to work in a team of experts where everyone contributes his knowledge and all relevant aspects are taken into account during all stages of the process.

1.2 Performance criteria in public tenders and new contract types for public buildings

The traditional procedure for a public tender, where an open price based competition is a basic principle, makes it impossible for the contractor to participate in the design process during the early design phase. As a result, the contractor cannot be a member of a building team, which is disadvantageous because the contractor offers a different perspective on the building process. Integrating his knowledge already in the design phase can reduce cost of failure and can avoid conflicts such as delay in construction due to faulty planning.

Today, more and more building companies work together on building projects. Cooperation contracts or temporary joint ventures, such as *PPS* (public private cooperation) or *DBFMO* (Design Build Finance Maintain and Operate), connect construction partners contractually. These contracts imply a closer link between the different building phases (design-implementation-management) and contain more explicit performance requirements for each phase of the process. This advances aspects such as sustainability and quality control since they are part of the contract. Through this contract an interdisciplinary building team is formed and controlled information exchange becomes essential.

1.3 Identifying reasons for quality problems and improve the production process

Changes in the current organization of construction processes will improve the quality of work. For instance, due to insufficient knowledge of the contractors, airtightness of the building is often not guaranteed [4]. The presence of the contractor in the early stage of the construction process will help to prevent defects in the building envelop by pointing them out early. Such critical aspects need to be considered / recognised in the design phase, where adjustments have the biggest impact on lowering the overall building cost.

An integrated approach of the project, where concept and construction are not separated from each other, enables a more clear definition of the responsibilities of each actor: risks are contractually shared and parties work towards a common objective.

1.4 Inefficient production process

The information flow between different actors is currently very inefficient as information must be entered repeatedly in many different software packages. It is far more effective and less error prone to directly transfer and adapt the relevant results from one task to the next using standardized interfaces and software tools. Building information models (BIM) can be used to manage, select and transmit the required information between different software packages via a neutral format [5], [6]. A formal description [7] of the requirements at different process stages and a well-defined version control can improve the reliability of the entire process.

2 THE DIDACTIC PERSPECTIVE

To anticipate on the above illustrated evolutions in building practice, students must learn to work in construction teams. Therefore it is necessary to simulate real world collaboration between different educational institutions. The different levels and specialisms of the Association KU Leuven make it possible to create the different roles in a building team.

Based on experiences during a previous educational research project (OOF 2007/24, [8]), it was concluded that communication and information management is a problem for students working in building teams. However, this is a required competence for future building professionals. Students have difficulties to formulate the correct questions to receive the required information and to transfer precise data. While students are familiar with a variety of communication tools and platforms, they often fail to apply them properly and effectively during collaboration. Students automatically fall back on platforms they are familiar with, such as Facebook, e-mail or text messages. It is therefore necessary to assist students in the cooperation.

Students often work in groups for particular assignments. Even though, as future building professionals, they need to collaborate on construction sites, they seldom collaborate with students from other disciplines during their studies. The different roles are commonly simulated by the tutor, acting as an architect, an engineer, the building owner or the general contractor. This is one reason why students fail to understand what their task and the task of the different actors in the design and construction process entails. Students seem to have also little understanding about the (organization of) the entire construction process. They often do not reflect on their role in the process (failing to analyse the process itself).

Within the COM.BI project, students have to learn to manage project information by using digital building information models; to experience and to reflect on the opportunities of communication and information management; to understand the synergy of a building team and their role in a building team by simulating a realistic collaboration between the different disciplines. To achieve these objectives, students are requested to fulfil an assignment in a building team.

3 ASPECTS OF THE USED METHODOLOGY

This project employs the methodology of *Building Information Modelling* (*BIM*). A building information model can provide a digital representation and shared knowledge resource of both physical (graphical – 3D) and functional (attributes and relations) characteristics of a building through its entire life-cycle.

There are two essential aspects: on one hand the available software tools and data models and on the other hand a formal description of the design and construction process.

This section discusses how practice and research on BIM and IDM are implemented in education. BIM and IDM are used to communicate and manage information in building teams.

3.1 BIM: The tools and the data

The building industry is migrating to BIM more and more, in order to improve the building process. Through the application of better processes and communication, productivity and efficiency increases and failure costs can be diminished. As such, BIM is currently changing the construction industry and education [9], although not without problems of adoption [10] or misuse [11].

A building model (or database) contains not only geometric data, but also information on material properties, construction and economic aspects. Each piece of information about the project should ideally be entered only once.

When used properly, it is not required to exchange the complete project between parties to be able to collaborate. This is in contrast with the notion of a *single, unified central model* that was deemed the ideal goal in the early years of BIM. Current best practices [12] suggest the use of several distinct *aspect models*; each set up to contain only the specific subset of model information as required in a specific collaboration stage. *Model viewers* allow the assembly of different sub-models and to receive a full overview of all models in a single view.

In addition, most documents, such as drawings, presentations and tabular listings, are derived directly from the model, ensuring synchronization between all project representations, which drastically lowers errors and ambiguities.

While not exclusive to BIM, working in 3D presents better opportunities for improved visualization of the design and to avoid misinterpretation of the design intent.

Building information models can be used for information management in collaboration in building teams.

To support interoperability between partners in building projects, an open, neutral exchange format was developed for building model data. *IFC* (*Industry Foundation Classes*) [6] allows the exchange of building information between different software packages.

3.2 IDM: describing the process

The non-profit organization *buildingSMART* supports an open approach to BIM (also termed *openBIM*) by implementing the *Information Delivery Manual* (*IDM*) methodology [13].

IDM describes which information has to be shared with whom and at what time. *Process Maps* (PM) display the tasks with the related information flow in chronological order. *Exchange Requirements* (ER) specify which information has to be shared between team members.

Based on the observed evolution in the construction sector and requirements from authorities in several countries [14], [15] and earlier research projects [16], new content and collaboration structures have been prepared during the project [1] and are gradually introduced into the curricula of the participating disciplines.

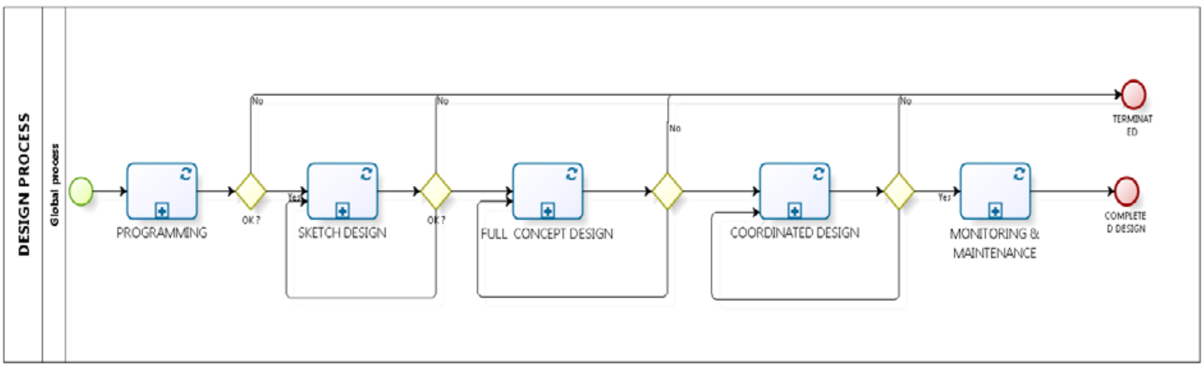

Fig. 1. Life-cycle stages of a building (first level)

To handle the complexity of a description of the entire building, the process maps are often organized in three different detail levels. The first level provides a global view containing all life-cycle stages as “tasks” (see figure 1). Each of these “tasks” represents a collapsed sub-process and links to a PM on the second level providing a more detailed view for each stage. Depending on the aim of the created PM's, there might be a need to further depict sub-processes for more complex "tasks" of

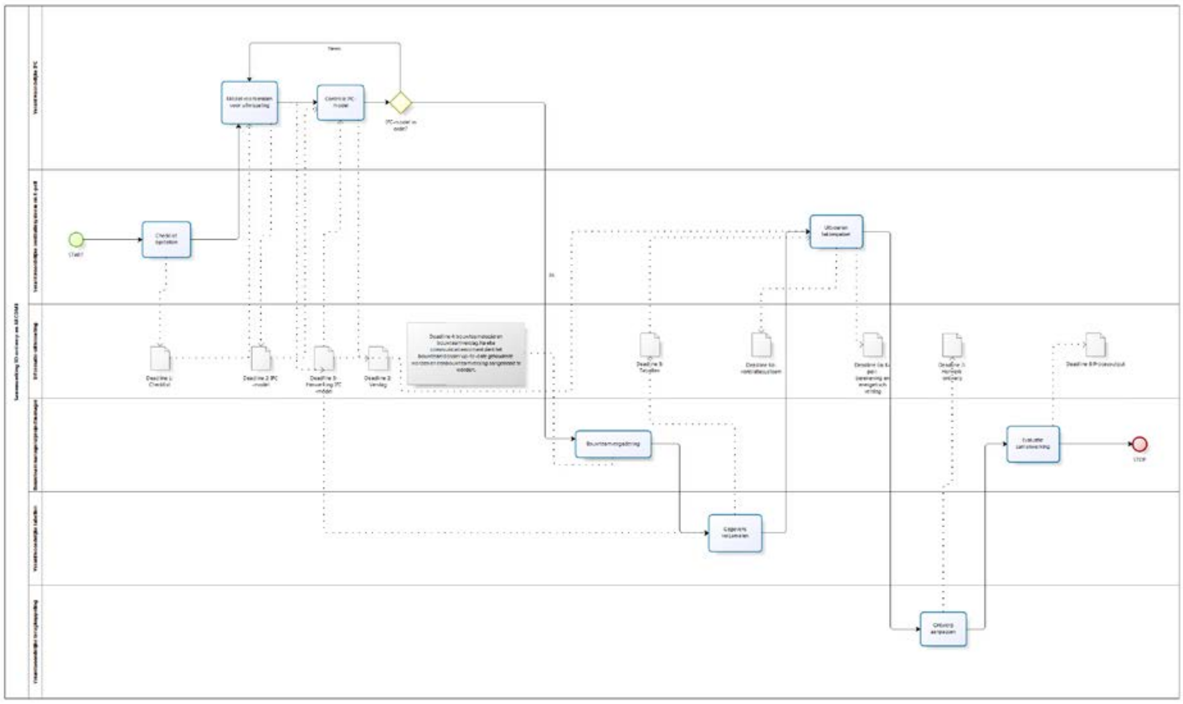

Fig. 2. Student building team, 2nd collaboration project: example of a process map

the second level, producing a third detail level.

To get a better view on interaction, communication and the exchanged data, tasks are attributed to different actors (or roles) and documents for ER's are added.

This hierarchy provides a good framework for the students to situate their own activity and understand dependencies and necessary iterations during the design process. Also the required input data and the produced output of their own task can be visualized with PM's and ER's (see figure 2).

The results from current activities [5] to extend and standardize the description of the communicated data (BIM and other linked data and documents) will help to improve the communication in real world building teams as well as in the simulated projects of the student building teams.

4 IMPLEMENTATION

This section describes in more detail, how groups of students from different curricula are collaborating in building teams, to exchange information and to communicate. Different elements of the aforementioned methodology are used, to be able to simulate a building project and to better manage the process.

4.1 Collaboration Projects

In the existing curricula of construction courses three collaborations in building teams were created. In these collaborations students learn to indicate in a process map their task and where communication and information exchange is needed, to formulate the required information for the next assignment, to define feedback and to organize the required adjustments to the model.

In a first collaboration project, master students in architecture and professional bachelor students in construction, both from a different education institution; design a zero impact building starting from the early sketch design and continuing until detailed construction plans. Students in construction check the practicality of the design and perform an additional cost analysis. Due to the integration of collaboration in the team assignment, students will not only observe these contradictions, they will be able to solve these problems together. To succeed in this assignment a lot of communication is required to avoid conflicts or to solve problems at an early stage. The choices for communication (responsibilities / initiative, type of communication, used tools…) are left to the students.

In a second collaboration project master students in engineering co-operate with bachelor students in architecture. The engineering students assess the energy performance of the design of the architecture students in the early design phase. In this collaboration, students discover the usefulness of an energy audit already in the early design stage, learn to formulate possible solutions and experience the key challenges in this stage. Besides the difference in maturity level and campus location, students also work with different, modelling software (Graphisoft ArchiCAD and Autodesk REVIT). The required model transfer is accomplished by an IFC-model. This requires that students learn to describe the process in terms of the methodology introduced by BuildingSMART, by formulating particular exchange requirements (ER's) and a simple process map (PM) for their collaboration.

A third collaboration involves a group of master students from different disciplines (architecture, engineering and energy) who are asked to execute energy performance simulations for buildings described by BIM-models. Master students in Architecture deliver BIM-models of existing buildings. Due to different calendar schedules, the communication in this collaboration is asynchronous, so students will not cooperate directly. To overcome possible conflicts and misinformation the data embedded in the BIM-models needs to be clearly specified. In each collaboration students experience the importance of their role, their tasks, responsibilities and the added value of the collaboration. They learn to detect problems in their method, to experience constraints in the process and software tools and to communicate through appropriate channels.

4.2 Building team organization and documentation

The collaboration, discussed in the earlier section is structured using a "*building team file*". This document follows the *Integrated Project Delivery Protocol* (IPDP) and is based on an example set up by a local BIM software vendor [17]. This document requests students to formulate arrangements (e.g. about versioning or software platforms), formulate the tasks and responsibilities of the different actors, compose a planning using a Gantt chart format and choose appropriate communication tools. In other words, this document is a representation of the methodology of IDM.

In addition, a "*building team report*", a "*final reflection report*" and a "*logbook*" are used to structure the process and, if deemed necessary, to make adjustments. Peer- and self-assessment questionnaires are used to reflect on the responsibilities and the participation of the different team members. By means of a final reflection report it was monitored whether the students recognize the added value of cooperation and their position and the position of the cooperating actor in a construction team. These reports are used in the OOF-project to refine the cooperation for the next years.

4.3 Sharing learning material

Within the OOF-project, existing and newly created learning contents from the different partners is shared on the public project site and through the *Toledo* learning platform [18], Online presentations[1], video tutorials for particular software applications, manuals and scripts are communicated and shared. They can be used to help other teachers or institutions with setting up a multidisciplinary collaboration. The course material is divided into several categories allowing teachers to use the desired material depending on the type of collaboration. On the one hand generic teaching material that deals with communication and project work was developed. On the other hand teaching materials which introduces new technology (BIM, IDM) in the curriculum of various courses is presented. In addition specific examples of collaboration are shared.

4.4 Public workshops

Throughout the project, two public workshops have been organized with a dual objective: to present the expected project outcomes and results, but also to gather feedback from the stakeholders. Educational Institutions and representatives of the construction sector, such as architects, engineers and software vendors, attended these discussions.

After the first project year a regional BIM workshop was held. At the workshop the first results from the pilot project were presented. These results were evaluated by the attendees. With the received feedback the cooperation between the various institutions and the didactic structure have been further refined. In addition, the status and the use of BIM in the Flemish and in a larger international context was presented and discussed. This permitted to determine if the right target was being achieved with the project. The received feedback ensured that the communication and information management aspects in the OOF project is in line with current innovative projects and recent methodologies in Flemish and international practice.

On the 10th of September 2013, the project organized a final seminar, presenting the final results, but also to foster the relevance of BIM for the Flemish construction industry, by gathering different regional stakeholders. More information concerning the seminar can be found on the COM.BI project site [19].

5 CONCLUSION

The COM.BI project implemented several improvements in the curricula of different construction-related disciplines within the KU Leuven Association. Several scenarios and documents have been developed that can be used to structure and follow project-based collaboration. Project conclusions and knowledge about these process have been shared on the public project website and also using the internal Toledo learning platform of the Association KU Leuven. These documents could form a starting point for new collaborations between other disciplines. Even though the BIM methodology is quite specific for the construction sector, the collaboration and communication processes and technologies are more widely applicable in other engineering contexts.

[1] General introduction to Building Information Modelling (http://prezi.com/ppmsvvw_el0a/presentatie-bim), presentation focusing on information exchange and communication methods (http://prezi.com/gxxttvqkmnwr/samenwerking), presentation that discusses performance simulation using a BIM: (http://prezi.com/6gqems1qkwov/simulatie-en-bim), presentation about structure the design process using the methodology of BuildingSMART (http://prezi.com/__hc1todkq9w/ontwerpproces-en-bim/)

Students from architecture, engineering, energy and building mechanics are being prepared for an increasingly complex and collaborative future construction industry. They have been exposed to several current innovations that are emerging in the building practice and these experiences have been examined and implemented in an educational context.

It remains a challenge to use good examples of collaboration and to create a supportive context that encourages students to gain insight in the design and construction process. The collaborations let them experience both the benefits and difficulties of multidisciplinary teamwork. As such, the students encounter the limits and shortcomings of their own working-process; they have an opportunity to learn to analyse their own processes and to systematically improve them. This can be supported by properly prepared teaching materials, such as questionnaires and peer assessments.

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