

Experiencing BIM Collaboration in Education

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Abstract. In a context of a slow uptake of the Building Information Modeling (BIM) methodology in the Flemish region, we present the results of an educational research project, carried out over 4 semesters, in a multi-disciplinary, cross-campus collaboration. This project fosters an improved application of BIM, information management and communication, by organizing building teams involving students from different schools.

The project partners collaborated on a shared framework of supportive learning material, collaboration scenarios between teams of students and the integration of digital tools for communication, information management and collaboration in the curriculum.

This article, in particular, will elaborate on one of the collaborative exercises, involving architecture and engineering students, using BIM for modeling, information exchange and model evaluation.

Keywords. BIM; education; collaboration; interoperability; IFC.

Introduction and context

While the use of the *Building Information Modeling* (BIM) methodology is increasing worldwide, we notice a slow uptake in the Flemish region (Belgium). In contrast with surrounding countries, such as The Netherlands or the UK, there is no governmental incentive that promotes the use of BIM for building projects. We are far from the adoption rate as noted in the *McGraw-Gill SmartMarket* reports (Young Jr. et al., 2009; Bernstein and Jones, 2012), which mostly reflect the North-American industry BIM uptake. Eastman et al. (2011, chap.4) describe the value of BIM for building owners, but apart from a single initiative, the demand for BIM from building owners in our region is non-existing. Even architects, who are using BIM software more often, apply it only in their own, local context and still rely on traditional, drawing based collaboration with other building partners. Local software vendors seem to claim no more than 20 or 30% of their clients have licensed BIM software, while the effective use in projects is probably even lower. While the BIM concept is slowly gaining more attention, amongst professionals and educators, it is sometimes regarded as merely a software tool or an alternative method to make 3D models.

Too often, its usefulness is misunderstood, as it is not seen as part of the design process. As such, the added value and the potential productivity gains that are promised by BIM use are not experienced and might hinder BIM adoption. This is in line with the experiences mentioned by Holzer (2012): the resistance to process changes and the “*monodisciplinarity*” of BIM tools. Hartmann and Fischer (2008) note the lack of knowledgeable practitioners as one of the major bottlenecks for widespread BIM adoption. Lockley mentioned in the *NBS Building Information Report* (Anon, 2011, p.20+21) the important role for educational institutes in the unavoidable transition to BIM. Livingston (2008) argues that BIM manifests itself

both as a 3D-modeling tool (the software) and an information management system, which aids students for “a greater understanding of building systems integration”.

The authors of this article participate in the *COM.BI project: “Communication and management of digital building information in a multidisciplinary team during the construction process”* [1]. This two-year educational research project implements collaboration in building teams and introduces innovative software tools. Since all building-related disciplines are represented within the *KU Leuven Association* [2], there is an opportunity to form multi-disciplinary student teams and to share knowledge. Also the tutors can share their different fields of research and professional experience. The didactical approaches and methods have been elaborated in (Boeykens et al., 2013), whereas this article will focus on how the BIM methods and technologies are being applied in an educational context.

We deliberately want to foster the application of the BIM methodology in the architecture and engineering curriculum, by allowing students to experience the benefits of using BIM in a collaborative context, rather than as a mere modeling and documentation tool, as it happened before. Students will learn to work together, to exchange information using BIM models and to apply BIM as part of the design process. We want them to migrate from “*little*” BIM to “*BIG*” BIM (Jernigan, 2008), which includes model exchange and model evaluation.

Challenges

The first challenge is mostly a mentality problem. As witnessed by the authors, the majority of architectural design studio work still relies on traditional drawing based methods, where 2D CAD software, such as *AutoCAD* and *VectorWorks*, is used mostly for representational purposes or construction documentation. Ambrose (2012) discusses some of the pitfalls and how BIM could be applied in a design studio context. He mentions an underestimating of the way digital tools and methods change the “*way we make architecture*”. By defining BIM as a design methodology instead of a design tool, it “acts as *provocateur* to design education and the *how* and *what* of the academic design studio”. Many designers see BIM as a hindrance to the creativity during the design process. Morton (2012) expresses this concern in schools, where teachers often fail to see beyond the tool and how BIM can be “interfaced” with the design process. Even students who are being introduced to BIM, often fail to look beyond the 3D modeling aspects as mentioned by Weber and Hedges (2008). In that context, prior CAD knowledge proved both beneficial and discouraging at the same time. Beneficial, since drawing functionality is still provided to finish the drawings where the model is incomplete or lacks detail; discouraging because drawing a floor plan directly is usually quicker in 2D. “The simplest tasks proved to be a challenge.” Students and design studio teachers need to look beyond the effort inherent with BIM.

To avoid too much friction of introducing a BIM-based working method and enforcing it in the design studio, the project collaboration was taken out of the design studio assignment and hosted as part of a course where the authors were directly involved. There is the *Architectural Computing* course on the side of the architectural-engineering Bachelor program, during the fourth semester and the course on *3D-Design* on the side of the construction engineering students, which is an elective in the Master track. However, this directly implies a second challenge, as students with different maturity levels will need to work together. They have different background knowledge, do not possess the same technical expertise and speak a partially different language.

There are also multiple technical challenges. It was decided for this exercise to enforce the usage of BIM software and to apply it intensively as part of the collaboration. The different BIM applications that are used in the two schools are inherently incompatible, as they apply a proprietary data model and file format. In the architecture course, *Graphisoft ArchiCAD* was used, whereas the engineering course relied on *Autodesk Revit*. It was a deliberate choice not to avoid this challenge, as it is a good illustration of a real context of various players and tools. Even if everyone would use the same software, interoperability is not guaranteed. Version differences can make file exchange impossible: e.g. it is not possible to export Revit models to older releases. In addition, even when people would use the same software version, there are still many differences in model structure or applied model templates.

The evident solution was to rely on *ISO/PAS 16739 IFC (Industry Foundation Classes)* [3] to exchange building models between ArchiCAD and Revit. However, 100% complete information transfer cannot reasonably be expected due to implementation limitations. Rather than to complain about this, we decided that this represents a realistic context for collaboration, so the challenge was included as part of the exercise. This was motivated by the obtained successes in several case studies and reports (Bos, 2012; Mitchell et al., 2007; Hitchcock and Wong, 2011), which testified of the usability of IFC and how it can be implemented in construction projects, despite most authors acknowledging that the information transfer was seldom perfect. As long as project team members have means to assess the limitations and are willing to communicate constructively, this should not prevent collaboration. Moreover, deeper understanding of the usage of IFC in practical scenarios can help software developers to improve their BIM implementations.

In addition, there were several logistic challenges. Students had different timetables and were located in different cities, about 90 km apart. Moreover, the architectural students were more than 100, whereas the engineering students are part of an elective course, for which only six students registered this semester. Only some of the groups with architecture students could be linked to an engineering student. The assignments for all groups, however, had to be similar and present equal work.

Methodology and organization of project teams

Since design collaboration is an important driver for BIM adoption, we will focus on the collaborative aspects of BIM, by simulating a *Project Team*, containing different roles and disciplines, with students. Because it was not feasible to assign an external engineer to each project team, we had to make the distinction between internal, local collaboration (e.g. architects from the same office) and collaboration with an external office. The two types of collaboration provided a challenge of trying to balance the amount of work, as not to place an advantage on one or the other.

Figure 1 gives a schematic overview of the collaborations. We indicate different roles, the used software systems and document types and the information flow.

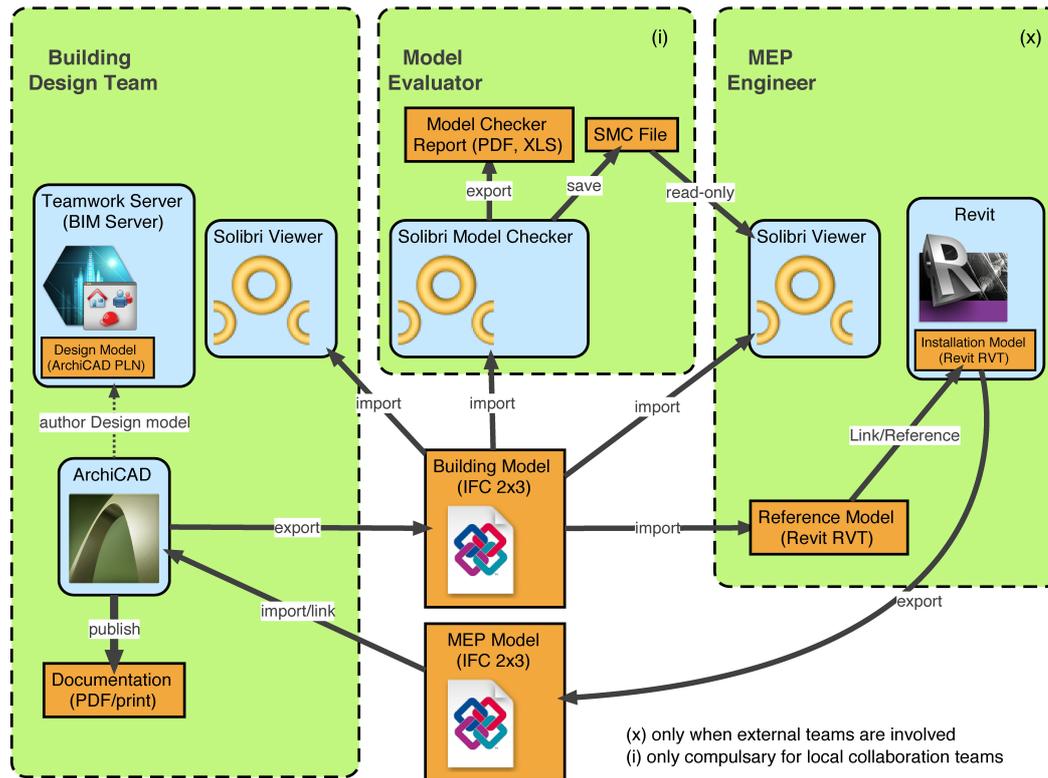


Figure 1:
Schematic overview of the collaboration.

As can be seen on the previous diagram, in the collaboration with an external engineer, the architectural team collaborates internally on the design model (e.g. using *ArchiCAD TeamWork* [4]), whereas the engineering student fulfilled a consultant role, focusing on heat-loss calculation and designing the ventilation system. In the internal collaboration, there is an additional role indicated, namely that of the model evaluator. It was decided to have the project team assign one group member with this role, as an equivalent consultant role. These students perform some qualitative and quantitative analyses of the design model, using model evaluation software (*Solibri Model Checker* [5]). This necessitates the usage of IFC as an exchange format.

Process and workflow organization

The design team prepares an architectural model that is transferred to the other disciplines, to provide feedback on how to improve building performance. To support this process, students are provided with basic guidelines and learning material, but they have to organize the actual collaboration independently, by specifying tasks and appointing responsibilities. The guidelines document is derived from a regional, localized *IPDP (Integrated Project Delivery Protocol)* document [6], in which the students need to formulate the different roles in their team, responsibilities, the information flow and the necessary collaboration activities (deadlines and meetings). We reformulated this document, which was oriented to professional practices, for an educational context, but kept a similar objective. Instead of formulating the document as a static checklist, it was written as a series of open questions, for which the students needed to define an answer within their group.

buildingSMART [7], an organization focusing on interoperability and building process improvements, defines *Exchange Requirements (ER)* and *Model View Definitions (MVD)*. To prepare the collaboration between design team and external consultant, the engineering students set up ER, including room areas, volumes or the façade area. This enforces them to specify required information precisely and unambiguously, including the correct way to measure certain quantities, e.g. gross or net values and inner or outer dimensions. Based on the ER, the architectural model is filtered to contain only the requested information, rather than transferring a full model. This is in line with the MVD concept. Before the filtered model is exported to IFC, it can be further optimized to improve model exchange, as will be described in the next section.

To accompany the exported model with quantitative results, the architects create additional table schedules. Engineering students who receive the IFC model follow a *reference model*-based approach, indicating that they will use the exported models for information exchange only and continue working in their native BIM environment. This is in line with current best practices for BIM application (Bos, 2012). Reference models help to clarify who is responsible for which part of the model. The imported model, after being further optimized, is then linked to a separate project file for the modeling of an HVAC installation, using a series of custom *Revit Family* objects, kindly provided by a regional engineering office. Ideally, the HVAC model is assembled again with the design model of the architects, but this was left as optional.

For the local collaborations, the exported IFC model is used to create a qualitative and quantitative assessment of the model, which is returned to inform the design team about possible model improvements. This includes clash detections (element overlaps), verification of model completeness, project validity and checking against a prepared building regulations rule set.

In both types of collaboration, we completed a full feedback-loop, in a model-based workflow. While such a workflow might be a bit simplified, compared to expected future professional exchange, students are learning several important characteristics of design collaboration: description of exchange requirements, preparing models for a particular goal, cross-checking the exported information and learning about means to improve the model preparation. By introducing students to such processes, they are being prepared for a future construction industry and might be able to introduce this knowledge in the offices they will join in a few years.

Experiences about the didactic and digital communication aspects of the collaborative work are elaborated by the authors in another conference paper (Boeykens et al., 2013). There we describe more in detail the importance of the different modes of communication, the different roles that members in a project team take on and the experiences learned from a related collaborative assignment on “*Zero Impact Building*” between students of architecture and students of construction management, which was also undertaken during the COM.BI project.

Technical description of the collaboration

The collaboration in the architectural team used the *ArchiCAD TeamWork* functionality, which allowed all group members to work synchronously on the same model hosted inside *Graphisoft BIM Server* [4].

To be able to access the *Solibri License Server* and to sign in to the BIM Server from outside the university computer room, a *Virtual Private Networking (VPN)* connection is required. While this is provided by the university ICT services, it posed certain restrictions on the computer systems. The connection would only succeed if

the operating system on the student laptops were up to date and equipped with a correctly configured virus scanner and *Java*-runtime. Unfortunately, some students were not able to establish the necessary VPN connection, due to technical problems. As a backup plan, the main computer classroom was fully configured and some teams needed to rely on this.

We encountered limitations when trying to keep the exported IFC model fully usable in the receiving BIM software. Since we cannot expect students to be aware of all peculiarities of particular IFC implementations in BIM software, possible problems are documented and, where possible, solutions are given that present better model exchange. The actual export requires additional configuration of the IFC writer settings, with direct impact on the usability of the model. This is also documented for students, to provide them with a usable starting point. It is very important that they experience the implication of the used configuration. In a *Coordination MVD*, the focus is on accurate geometry, enforcing the model to be exported using *Boundary Representation (BRep)* geometry. This has the disadvantage that the model will be completely static, preventing it from being further edited or corrected. Using *extruded* geometry on the other hand generates better editable objects, containing more IFC attribute values, but at the cost of a loss of certain model details. To assist this last step, students are obliged to perform a visual check using an IFC Model viewer.

During the preparation of the learning material, a series of recommendations and known problems were documented, giving the students pointers to problems they might encounter. At first, before the IFC model is exported, the design model in ArchiCAD can be altered to generate more usable output, as summarized in Table 1.

Problem Situation in Revit	Recommended Action in ArchiCAD
Objects lack properties Walls become “ <i>in-place</i> ” families, Window/Door vertically offset from opening Orientation of walls, doors and windows not available. Spaces do not contain category	Enforce attribute export in <i>IFC Translator</i> Simplify geometry, e.g. remove <i>Solid Element Operations</i> , reveals, casing. Add custom IFC tag or agree on ID naming convention. Add category name manually as added attribute using <i>PSet_SpaceCommon</i>
Walls do not connect to Sloped Roofs	Replace with legacy “ <i>crop</i> ” operation and convert multi-plane roofs to single-plane

Table 1
Overview of ArchiCAD model adjustments to improve IFC import into Revit.

Some aspects were not solvable within the design model, so in those cases, manual changes in Revit are required, as described in Table 2.

Problem Situation in Revit	Recommended Action in Revit
Door and Window voids do not protrude through the wall volume. Rooms get wrong height (= default value from template file). Identical windows and doors become separate Family objects. Door & Window height attribute not set	Edit family object and extend void to wall façade. List ArchiCAD Zone Height alongside Revit Room height and manually correct. Select and replace with appropriate family object (if desired). Check extended IFC attributes for exported value from ArchiCAD

Table 2
Overview of some Revit model adjustments to re-create the ArchiCAD design model.

Even then, certain information was inconsistent and some workarounds were still required. In those cases, students were free to use other means to communicate the missing information.

Didactical learning material and facilities

As part of the didactical vision on the *Architectural Computing* course, which also comprised other themes (visualization, freeform modeling, digital documentation), it was decided that as much classes as possible would be replaced with video-tutorials. After a general introduction seminar, students follow the provided lessons at their own pace. While the recording of this material was a serious effort, student reactions were mostly positive. They appreciated the freedom to watch the material, rewind where necessary or even skip parts that seem unneeded to them. As the computer skills vary considerably between students, this was a valuable alternative to classroom-based tuition, which has become more difficult over the last few years. After students were given time to assimilate the tutorials, guided consulting sessions were organized, where students were able to pose individual questions, based on their own work. This was accompanied with an online forum for questions. An added advantage of video-tutorials is that they can be easily shared. They not only serve our own classes, but also attract many other users worldwide, since they were openly hosted as *YouTube playlists* [8].

Is it worth the effort?

While some of these aspects might seem rather trivial, they do pose a serious technical challenge to properly set up and we have been lucky to have full collaboration of the system administrators throughout the whole project. It also required a serious additional management effort of the teaching staff to e.g. set up user accounts on the TeamWork server and to assist with the ICT aspects of the exercise. It should also be noted that, even with more than 100 users, the system appeared quite stable and reliable and only some minor interventions were required. We are aware that such additional efforts and support are more difficult to impose on design studio teachers, certainly if they are not accustomed to BIM software and all required network functionality.

We are convinced about the value of BIM in construction and the necessity of learning BIM as a methodology in education. However, to appreciate these values, students should not only learn the theoretical basis. They also need to experience the BIM methodology in a realistic collaboration scenario and learn to use the software tools in an efficient way.

As part of the first BIM assignment of the architecture students, the focus was on understanding the concept and applying it in a practical context. Most of the students testified that they understood the idea of BIM, but not all of them were convinced about the effectiveness. Many students still fall back on their approach of using *AutoCAD* for 2D drafting and *SketchUp* for quick 3D modeling. The underlying theme was that BIM was often regarded as a software tool for 3D modeling instead of a collaboration method through the building process. They specifically mentioned limitations in modeling freedom, due to the indirect nature of describing geometry with parametric entities in BIM software. However, teachers should also not overestimate student maturity and insight into the design process, especially at the Bachelor level. Instead of enforcing the use of BIM in the design studio, for which there is no general consensus, at least in our schools, our process-based introduction

will give students a more hands-on insight in how the BIM methodology could work, with obtainable objectives. The support with adequate learning material and sufficient technical facilities is essential.

Some people would argue that learning a specific BIM software tool is not the task of the university, but we have the experience that it is very valuable to at least learn the proper usage of one BIM software application in a practical context, which can be transferred to other software later on, if required.

Evaluation and Feedback

Students are asked at several points in the collaboration exercise to reflect on the process and the applied techniques, using questionnaires and a logbook. In addition, their own role in the simulated design team is also evaluated.

The project results in two types of guiding documents. The process and project based documents are oriented to be used by students. The process-based documents are formulated as open questions instead of a fixed checklist, as to foster reflection and discussion among team members. For a more detailed description of the different guiding documents that were set up, we refer back to (Boeykens et al., 2013). In addition, we summarize the didactic guidelines towards educators. They are categorized into BIM, construction-related and domain-neutral aspects, e.g. organizing student teams.

Student feedback is also necessary to gradually improve the collaborations. As it is the intention that the collaborations continue after the COM.BI project-funding timeframe, we take their remarks and considerations seriously. We list some comments in Table 3 and how they are improved.

Student comment	Afterthought
Assignments need to be clear and compact	Refine the assignment, limit requested documents/models/reports, be specific
Improve team coherence	Initial group meeting, esp. with external engineering students. Have them clarify their tasks to each other.
What should the model checker role do?	Add explanations about the rulesets.
Graphics in model checker look weird	Clarify software limitations. Model checker is not a visualisation environment. Focus on relevance in process.
Model geometry is not exact in model viewer/checker	Clarify that the purpose of a viewer/checker is different from a documentation tool.

*Table 3
Comments and recommendations from student feedback.*

Overall, students noted that the collaboration exercise did not take an enormous amount of time and many groups finished their assignment before the deadline. The main intention of the exercise – a first-hand experience of how BIM could be applied as part of the design process – was clearly specified, avoiding students to spend excessive time on solving detail-problems.

It should be noted that the building model was not a new design, but rather a retake of one of their earlier design studio projects, to avoid the overload of the full design process, with conceptual development and extensive teacher consults. It was explained that the architectural quality of the design would not be part of the grading criteria, because this was already done as part of the original design studio exercise.

The quality of the model however, taking the received feedback into account, and the reporting were effectively graded.

Conclusions and future outlook

All project partners are convinced that this is most valuable exercise, providing a huge experience for both students and educators. This approach illustrates BIM as a process, rather than as a tool. Students are stimulated to reflect on both the product (the design) and the process (the design collaboration in a Project Team). However, do not underestimate the need for continuous evaluation and the increased technical complexity to facilitate the collaboration. Luckily, the software tools, while not perfect, proved to be adequate and fairly stable. IFC support, while not perfect, due to implementation differences between software vendors, is gradually improving and is, indeed, “good enough” to be used at the core of the collaboration process.

It is very important to be clear about the expectations towards students, as the exercise should present them a positive experience with BIM and not blur this with an extensive assignment. The exercise attempts to capitalize on the virtues of BIM: synchronization of representations (all documents), extraction of information (schedules), model-based information exchange (IFC) and model evaluation (model checker). The formulation of the assignments and the final expectations need further refinement and valuable lessons were learned to improve the assignment for the next semester.

Several adjustments to the curriculum are initiated, to ensure a durable implementation of the collaboration beyond the period covered by project funding. All involved partners are enthusiastic to continue further, precisely as we seemingly are, in our Flemish region, at a turning point, where several professional, academic and commercial parties are increasingly moving towards BIM, which will form the basis for a regional knowledge network.

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