IMPACT OF CONSTRUCTION TECHNOLOGIES ON EDUCATION IN DENMARK

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ABSTRACT

At the Technical University of Denmark the training in how to adopt BIM tools in the design and construction processes has increased due to a request made by companies in the Danish construction industry. The growing interest in BIM is partly due to the fact that Danish state clients were forced to require BIM models in IFC-format from consultants since 2007. As a consequence of the demand most Bachelor of Sciences and Master of Sciences students in Denmark have been taught interoperability and BIM tools since then.

At the Technical University of Denmark a multidisciplinary course in "Advanced Building Design" at MSc. level has been developed. Through project work the goal of the course is to provide training in interdisciplinary skills and teamwork as well as using building information models at the final stage of the engineering education. In addition to preparing drawings according to the present requirements which are valid in all ordinary projects, the students should hand in BIM models in IFC format and document results from the use of clash detection tools.

A number of experiences have been gained from the course. The students underestimate the effort it takes to integrate components from different disciplines in a BIM model. The student evaluations of the course have been very ambiguous, since some have seen this as a good opportunity to simulate real building construction projects and learn how to use BIM tools in a multidisciplinary team, while others are very sceptical about working in multidisciplinary teams. Universities should be aware of their role in influencing students, since the students are very loyal to the software tools that have been taught in at the university when they are selecting software products in their projects.

Keywords: MSc. education, BIM, mandatory use of BIM, choice of tools

1. INTRODUCTION

In general the adoption of 3D CAD and BIM tools in the industry has been slower than expected from a purely technological perspective, despite the fact that a variety of companies in the AECO industries today claim that they are able to benefit from the technology. The slow uptake can be explained by many different reasons such as lack of competence, return on investment, traditions, need for new contracts, redefinition of processes etc. The Danish government decided to stimulate the uptake of 3D CAD and BIM tools in the industry by making ICT requirements mandatory for state clients. These requirements have been mandatory since January 2007.

The governmental initiative has increased the awareness of 3D CAD and BIM tools at the educational institutes. Most, if not all, colleges, architectural schools and universities have been providing training in the use of BIM tools as a part of their educational programs since 2007.

In the dialogue with representatives from the Danish construction industry and Technical University of Denmark (DTU) it has been identified that the companies expect that newly graduated students have an up-to-date knowledge in ICT and are trained in collaboration. It was therefore decided to combine the need for training students in applying BIM in a course with a multidisciplinary project that has to be solved by a teamwork effort.

2. METHODOLOGY

The paper is primarily based on observations by the author of the paper and questionnaires that were distributed to students during the course “Advanced Building Design” at DTU in 2008/2009 and 2009/2010.

The overview of the BIM tools used by the students in the course is based on the ICT agreements that the students submitted as a result of their work. bips, a non-profit member organisation with 550 member companies made a survey in 2008 among its members. This survey (bips 2008) will be used as a snapshot for the situation in 2008 regarding the adoption of ICT in the construction industry.

Input from seminars (Technical University of Denmark 2005), (Technical University of Denmark 2007) and (Technical University of Denmark 2009) where representatives from the industry have expressed their views on the requirements to the students' competences has been used in the paper.

Finally observations from an EU funded ICT implementation at DTU (BIMlab 2009) is used to compare the different needs for training among students and people working in the industry.

3. DIGITAL CONSTRUCTION PROGRAM

In 2002 the Danish government (The Ministry of Economic and Business Affairs, 2002) tried to improve the quality and productivity in the construction industry by an increased use of ICT. In a joined program called the Digital Construction (Digital Construction, 2010) between state, a strategic foundation and the industry, ten ICT requirements, a 3D-working method, a new classification system and a production card were developed. The ten requirements became mandatory in state projects and four of these requirements are directly related to 3D. Most of the other requirements are somehow related to 3D tools or BIM in order to make quantity takeoff etc.

In 2008 the Danish Enterprise and Construction Authority signed a public statement (U.S. General Services 2008) that supports the use of IFC (www.buildingsmart.com) in state projects together with four other state clients.

An EU founded implementation program with support from the professional associations has been active between 2007 and 2010 in order to stimulate implementation of the concepts from the Digital Construction program in the industry and education. Due to this all engineer students today are introduced to BIM and several other groups of students are trained in the use of BIM. Especially the constructing architects have been trained in how to use the BIM tools in real world projects.

Unfortunately, from a diversity point of view, there has been a standardization at a number of educational institutes to more or less the same product family from one vendor, which on one hand will lead to a common practice but also to the situation that Denmark will not gain from the international competition on the software market. Furthermore the industry will not benefit from the freedom of choosing their preferred tool that comes from the IFC based data exchange.

4. STUDENTS AT DTU

4.1 Population and semesters

Students at DTU can graduate with degrees at Bachelor of Engineering (BEng), Bachelor of Sciences (BSc.) and Master of Science MSc. and Doctor of Philosophy (Ph.D.) levels within many different engineering disciplines. About 6,500 students are studying at the university, 10% of which are international exchange students. Within the building and civil engineering area there are about 120 students at MSc. level per semester studying different engineering and architectural engineering courses.

4.2 BIM training

Since 2007 BSc. students at DTU have been introduced to building information modelling and model based data exchange. Previously the students were taught in a more traditional CAD oriented practice based on the use of file based systems such as Architectural Desktop from Autodesk and parametric modelling in ProEngineer from

Parametric Technology Corporation. In the basic BIM course students today are mainly trained in Revit and ProEngineer, but will also gain experiences with Solibri Model Checker from Solibri and tools for analysis such as Autodesk Robot. Besides the ability to use the tools the students are given a general introduction to the BIM concept and neutral data exchange by the use of IFC.

Some MSc. students have an advanced course in BIM where they are taught to make Families in Revit, modify Rule sets in Solibri Model Checker and understand the 3D working method (bips 2007) developed as part of the Digital Construction Program.

BEng. students have been taught in the use of AutoCAD and some in visualization tools as well. Most BEng. students will have used the tools actively during the study in project work. Today BEng. students are also trained in Revit.

5. COURSE IN ADVANCED BUILDING DESIGN

5.1 Background

Although students at DTU are used to working in teams it was a specific request made by representations from employers (Technical University of Denmark 2005) that the skill set could be developed further. The representatives (Technical University of Denmark 2009) also expected graduated students to have an up-to-date knowledge on ICT. As the requirements from the state have been mandatory since the beginning of 2007 it was decided to include BIM in the design course as a mandatory element.

The Advanced Building Design course is based on 5 ECTS modules in the autumn followed by a fulltime 5 ECTS module in January. It was decided to make the course mandatory for MSc. students in 2008/2009, while students could avoid having the course in 2009/2010. In 2008/2009 the students got a specific grade whereas in 2009/2010 the students passed and or failed the course, but they also participated in competitions for the best integrated project and the best ICT projects.

By adding a BIM component in the course it became possible to train the students in using BIM tools as an active element in the design process as well as making it visible for the students when there is inconsistency in the aggregated BIM model. Another aspect of including BIM in a multidisciplinary course is the possibility that the BIM based working method can be spread to other courses that the professors are active in.

5.2 Assignment

The course is based on solving a design task. In 2008/2009 the students should replace an existing 20,000 m^2 office building with a building complex with the same requirements to space program etc. In 2009/2010 material from an architectural competition for a 65,000 m^2 building complex in Copenhagen formed the background for the project. The site was located at the waterfront and included a bridge 65 m above sea level. In both cases it was mandatory to make the design of the building according to fulfilling the Energy Class 1 (Maximum 50kW/m^2/year).

More than 60 students participated in the course in 2008/2009 and about 100 students followed the course in 2009/2010. The students were divided into teams of approximately 6 by the course coordinator based on a response to a questionnaire on the student's competence in the following subjects: Building Design, Structural Engineering, Building Services, Geotechnical, Facility and Construction Management, Project Management and ICT coordination. Each team was formed to include some knowledge from all six subjects and had a mixture of Danish and foreign students.

Each team should make their own project proposal of the building. All students with the same subject discussed common issues in so-called Subject Groups that had one or more professors associated to the subject groups as consultants.

In 2008/2009 the students were to present their proposals in the first part of the course and hand in a report by the end the of the 13 week period together with BIM models in native and IFC format. Finally by the end of the 3

week period they should hand in the final project including reports, calculations, drawings and BIM models. A poster was presented by the end of the course.

In 2009/2010 the students followed the same schedule as the previous year but the poster presentation was transformed into an oral presentation of the project based on the poster and made part of the evaluation of the project.

5.3 BIM tools and working method

The students have had the freedom to choose the BIM tools they preferred as long as they were able to export the BIM models to IFC2x3 format. The students' choice of BIM tools are shown in table 1.

Table 1: BIM tools used by teams in the course "Advanced Building Design" at DTU.

BIM tools\semester	2008/2009	2009/2010
ArchiCAD	11%	13%
AutoCAD Architecture	11%	0%
MagiCAD	100%	93%
Revit	77%	87%
Solibri Model Checker	100%	100%
Tekla	44%	0%

Most students used Autodesk Revit, but some students used ArchiCAD or AutoCAD Architecture for Architectural work. In 2008/2009 many students used Tekla Structures despite the fact that the students had not been trained in this product. The reason was probably that a few of the students were used to using Tekla in their student jobs in private companies. For building services MagiCAD from Progman has been the preferred program. Simple models of the foundation were made in Revit. Solibri Model Checker from Solibri has been used for checking and combining domain specific BIM models in IFC format. Students at DTU are provided with training in Revit, MagiCAD and Solibri Model Checker. Despite the fact that the students had the opportunity to select the BIM tools that they wanted as long it is possible to export models in IFC format, they are using the tools that they have used before or in which training is provided. 12% of the structural students in 2009/2010 stated in their reports that they would have preferred to have used Tekla if they should decide again which tool to use for structural BIM models. Since the students are very loyal to the tools that they have been taught the university should be aware of its role as influencing the students future selection of software tools.

bips made a survey (bips 2008) in 2008 in which 115 companies answered which tools they were using and 62 answered which tools they expected to use in the future. Results from the survey are shown in table 2. The survey is based on the number of responses from companies which do not necessarily give the same profile as licenses in the industry.

Table 2: CAD tools used or expectation of changing to in Denmark according to a survey made by bips (bips 2008)

CAD tools	Using in 2008	Expect changing to
AutoCAD ADT/ACA/MEP	69%	5%
Revit incl. applications	28%	76%
AutoCAD without applications	17%	
MagiCAD	10%	5%
ArchiCAD	9%	
Bentley	8%	2%
3D studio	8%	2%
Tekla	7%	2%

SketchUp	3%	2%
Navisworks	2%	
Rhino	2%	2%
Solibri (Model Checker)	2%	
(Autodesk) Civil 3D	2%	
Other	2%	5%

From the tables it can be seen that more students are using database based CAD/BIM tools than the companies in the industry in 2008.

Students have been trained in the 3D working method (bips 2007) developed by bips during the Digital construction program. The method is based on each discipline having its own model(s). This method fits very well with the existing roles and responsibilities in the construction industry, but is not exploring the full potential of BIM. So far BIM model servers have not been introduced in the course, despite the fact that they have the potential for a more true collaboration than what has been developed in the 3D working method.

5.4 Submitted BIM models

In 2008/2009 most students handed in both native format and IFC as required at the end of the 13 week and 3 week periods. The level of detail was limited as only the main building elements and the air condition system for one storey was modelled.

In 2009/2010 37% of the teams failed to hand in IFC models at the end of the 13 week period. A mistake that was fixed by the end of the 3 week period as only one team did not submit an IFC model by the end of the course.

Architectural models contained roof, wall, slabs, columns, windows, doors and spaces. It has been necessary to encourage the students to remember to include spaces in the models. Seen from a BIM perspective spaces are very relevant for many different purposes like cost estimation, thermal calculations, structural load, cleaning etc.

In 2008/2009 a number of separate structural models were made, mainly in Tekla, whereas in 2009/2010 architectural and structural models have been combined into one model. The structural models have only contained the main structural elements like slabs, columns, beams and walls while connections have not been detailed.

Is has only been mandatory to model the air condition system in the building services area. As MagiCAD works with product specific component the elements in the model contain a number of properties.

In general the students have concentrated on making the geometrical description of the building elements and building services elements. The students were instructed to identifying which properties would be beneficial to have in order to making query, extractions, input to analytical programs etc. All students failed to fulfil this task.

Although some students claimed the use of 3D models was not necessary and beneficial it was clear that the models contained serious problems regarding coordination e.g. collisions between the main load bearing structure and the air condition system and even situations where the air condition system simply went through the roof.

5.5 Students' views on the course

The students' views on the course are very diverse. Some describe the course as really bad while others are pleased to try to work with a realistic assignment in a project specific team. Detailed information about the collaboration is described in a conference paper (Dederichs 2010).

Table 3: Feedback from students in course "Advanced Building Design" at DTU.

Questionnaire	2008/2009	2009/2010
Participation in evaluation	66%	60%
5 points is equivalent to 9 hrs./week (45 hrs./week in the three-week period). I think my performance during the course is	Much less 0% 8% 33% 35%	Much less 2% 5% 52% 17%

	Much more 24%	Much more 24%
In general, I think this is a good course	Strongly agree 3% 13% 37% 29% Strongly disagree 18%	Strongly agree 5% 14% 12% 35% Strongly disagree 34%
What went well – and why?	Learning process - collaboration is time-consuming The idea of different experts is good The basic idea of the course is good Some of the professors are enthusiastic Interesting to learn about other subjects Solve multidisciplinary problems	Tried to work with Revit and Solibri. Work in a team with new people. Tried to apply knowledge from other courses in a construction project. Contact to industry. The potential in the course is great since the industry is moving in this direction This is first course at the university where I felt that I am studying at a university
What did not go so well – and why?	Waste of time Too many meetings Lack of coordination Idea of using BIM is fine, but students should have skills in using the tools before they start. Lack of understanding among the professors that BIM is an important part of the course Problem to be assigned to a task without having enough knowledge	No lectures – just guidelines Collaboration in the team did not work well The architectural role became too strong for engineering students Too demanding level of details regarding the outcome of the course Too open ended problem Pass/not pass is not motivating to put a lot of effort into the course
What changes would you suggest for the next time the course is offered?	Do not expect that student can do the course based on existing knowledge Better course material	Small project Better coordination among the professors Make the objectives for the course more visible Focus more on ICT in the beginning of the course.

As it can been seen in table 3 some of the students found it hard to learn BIM tools at the same time as they had to develop the design of the building. Students that recently have had a CAD/BIM course during their BSc. had been trained in BIM tools while foreign students and older students have only been trained in using 2D drafting tools.

Despite the fact that BIM played a role in the course most of the comments are related to other areas. After reviewing the feedback from the students is has been concluded that the challenge for the students has been too big, since they have to establish a method for working in a team, act as architects without having the skills, not used to producing ordinary design documents, use BIM tools in a large design project. It has therefore been decided to allow the students to make their proposal based on projects from the official architectural competition.

In the final report several students documented that they realized that an early use of the BIM tools would have benefited them at a later stage. An earlier adoption of the tools would have improved coordination between the different subjects and made integration to other tools easier. Like companies in the industry that are using BIM tools in processes parallel to traditional 2D-drawing based design processes teams will only have limited

benefits from using BIM tools. In a situation like that most of the teams will not gain much from using BIM since they have to learn how to use the tools, make the models in addition to making the traditional models and probably not use extractions from the model like drawings, reports, input to analytic tools etc. None of the students have claimed that the BIM requirement was wrong, which is in contraction to the statements that were made at the beginning of the course where some students claimed that BIM modelling was an irrelevant task for engineers. About 25% of the teams document in their reports that BIM should have been used more actively in the process of developing the design.

5.6 Professors' views on BIM

During the development and beginning of the course most of the professors did not pay too much attention to the use of BIM, but there has been an increasing interest among the participating professors, and especially the architects, to both increase the use if BIM in general and to encourage the students in the Advanced Design Course to adopt the use of BIM as early as possible, in order to get as many as possible to be active in modelling the different elements of the building.

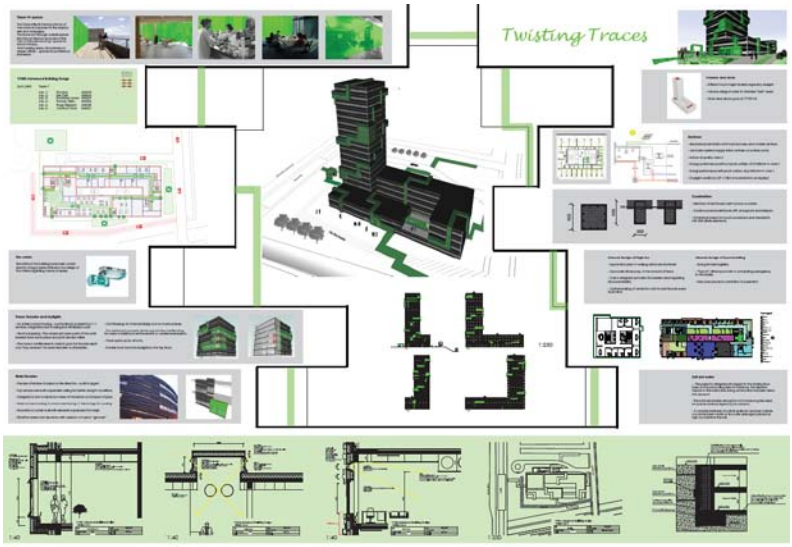

Figure 1: Poster from 2008/2009 Advanced Building Design

6. OWN OBSERVATIONS

The students seemed to divide themselves into two groups. One group of students could see the benefits of using BIM tools, while the other group did not seem to see the benefits in using BIM - at least in the beginning of the course.

In 2008/2009 most teams concentrated all the modelling work to a few students despite the intention being e.g. the ICT coordinator should be to coordinate the development of the models and check the consistency of the aggregated model. In some teams the ICT coordinator was simply seen as a draftsman, while the intention from the professors had been to use the BIM tools interactively in the process of finding the most appropriate solution, and not just use the BIM tools to document solutions. An exception was the students that had the role as structural engineers since some of the students were used to Tekla activity in the design process.

In 2009/2010 more students got involved in the modelling probably because the professors' team had a more united view on the modelling task. It should be divided between the members of the team and not be concentrated on one student.

Most of the foreign students have not been trained in using BIM tools and may only have heard about the concept. This easily lead to a situation where modelling was delegated to a specific student who then did all the modelling and learned how to use the tools. In such a situation the group may have been able to summit the

required models, but missed the opportunity of using the tools and the working method to help them to find the best solution in their design.

Another effect from introducing the BIM tools at a late stage is that in some cases the use of BIM only became a burden, since the students made drawings in e.g. AutoCAD and then had to redo everything in BIM instead of using the BIM model as the background for drawing production, quantity take-off, transfer of information to analytical tools, etc. Unfortunately this is a situation which can also be seen in many companies.

Sadly there are still serious problems in reusing model data from one application in another application and keep a very high semantic level.

It is obvious that the students in general have not been trained in bringing tools together. Sometimes even basic requirements such as the IFC model having to include spaces caused problems for the students probably because the students miss the point about reusing the information from the BIM model.

There may, however, be a tendency that Architectural Engineering students were more positive using the BIM than the Civil Engineering students.

Professors that have been involved in the course are generally positive towards an active usage of BIM at the university while there is still a large group of the professors who see BIM tools as something related to production of drawings and something that is mostly relevant for the industry. Others think that it is something that should be taken care of by other professions.

It may be useful to refer to Little BIM as Jernigan, F. (Jernigan, F. 2007) to the isolated existing BIM tools and Big BIM to a more overall integrated system where data representing many different aspects are coordinated and stored. The background for many of the existing BIM tools can be found in drafting systems or are sold by the same vendors that have focused on making drawing production more efficient. This is causing problems in order to adopt the Big BIM concept, because professions such as architects and engineers only see the BIM as tools to produce drawings. The attitude towards BIM is varying from irrelevant at university level to those who have adopted the BIM concept. The first point of view is mainly held by professors with an analytic view and the latter is held by professors looking into early stage design or sustainability issues.

Implementing BIM is not just about knowing how to use the tools but will lead to people, over time, re-evaluating their business processes, services etc. but also to be more specific about which information that should be exchanged. buildingSMART has formalized how to document and implement the required data and functionality in a software product by the IDM (ISO 29481-1:2010), MVD (Model View Definition, 2010) and certification processes although this will not in itself guarantee implementation in the industry. Bringing methods to specify needs and how they can be implemented into the education of engineers would lead to a better understanding of the complexity in the flow of information in the AECO industries.

It is anticipated that outcome of the course can be improved be using the principles of the Constructive Alignment methodology (Biggs, J and Tang C., 2007), where the professors are focusing on identifying learning objects that the students should understand and be tested in. This method will be used in the semester of 2010/2011 to get a better integration of the BIM tools and the design process.

7. FUTURE ACTIVITIES

7.1 Future activities at DTU

As mentioned earlier most students are introduced to BIM tools at DTU, several students are making special courses in BIM related issues and a number of PhD projects and research on BIM are ongoing. Despite the progress there are still several areas and courses where the BIM concept could be linked to the domain specific content e.g. life cycle analysis, acoustics, indoor climate etc. An further adoption of BIM is mainly depending on professors having an interest in making this happen and it is therefore highly dependent on each professor's willingness to adopt the paradigm.

Another option to increase the use of BIM would be a full commitment from the management to change the attitude towards BIM and force the professors to adopt BIM. This is not a common approach at a university but not unlikely to take place.

7.2 Future activities in Denmark

Although the use of BIM has been mandatory in state projects since 2007 the implementation at the university and the industry is not completed. Due to a very good financial situation most companies have had the freedom to choose whether they would work for the state clients or not. Another effect during the period with a good financial situation has been that the state clients have only had a very limited level of activities. On the other hand some companies have seen and benefitted from using BIM tools in their daily work regardless of there being an external pressure or not.

Since the recession started in 2009 the state has initiated more projects and the magnitude of private projects has diminished and therefore the interest in public projects has increased. Therefore there is an increasing need of people with the ability to handle the BIM concept in the industry.

In order to finalize the concepts and a classification system that was developed during the Digital Construction program, the Danish Enterprise and Construction Authorities made a €6 million call for an ICT knowledge centre. In addition to the development the ICT knowledge centre should also make research and stimulate the implementation of ICT tools in the construction industry.

At the operational level training in BIM at educational institutes will continue and initiatives like BIM Camp (BIM-Camp 2010) in Ebeltoft and "De digitale dage" (Digital days, 2010) in Aalborg where students with different backgrounds meet, and create a digital mock-up within a few days. At DTU a number of companies have used the opportunity to receive free training in principles of BIM and test tools at the BIM laboratory (BIMlab 2009)

It is the observation of the author that the existing view that the BIM could be used within the existing paradigm has to be replaced by an acceptance of the fact that in order to get all the benefits from BIM, the industry has to move to a new paradigm.

8. CONCLUSION

Adoption of BIM at DTU is in a process where more and more professors see how BIM can be integrated and used as a value adding component in education and research. On the other hand BIM is not a relevant component in all research areas.

Training in BIM tools and working methods have increased at DTU and most of the students have been trained in BIM tools since 2007. In the Advanced Building Design course BIM is a relevant component. It has forced the students to be specific, and it helps them to indentify issues that they have to look into. Although not all members of the teams have been using the tools actively a progression is seen.

Despite the fact that there are still many challenges to work in a truly integrated way with BIM tools it is possible to bring models together, but the tools still need to improve their ability to interoperate. By training the students more on how needs for information can be specified by using concepts from the buildingSMART, the students will be more aware of the possibilities and ready to play an active role in influencing the development of the tools and working methods in the future.

The governmental initiative has stimulated the adoption of modern ICT tools, like BIM, in the industry and has lead to a demand for additional training in BIM tools and 3D based working methods at the educational institutes in Denmark. It cannot be verified to which extent the demands are directly driven by the government but it is likely that the focus on ICT has increased the awareness in the industry. Private companies and public authorities have encouraged DTU to increase its focus on collaboration and ICT which had lead to the development of a new course.

ACKNOWLEDGMENTS

Projects samples are made by students of the Advanced Building Design course in 2008/2009 and 2009/2010.

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