Understanding BIM through a Simulation Game - Case study of Indian Students subjected to this course

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Design Hub India and Jade University of Applied Sciences conducted a simulation game in Bangalore, India to teach the networked and digital planning methodology Building Information Modelling (BIM). The teaching format was developed in Germany and has already been implemented and field-tested in teaching. At this event, the format was used in an international context for the first time. It was investigated in a one and a two-day course at Indian universities. The main focus was to give a playful and simple introduction to the new planning method BIM in order to minimize initial fears of contact and to guide an understanding of the digital planning standard for construction projects with a focus on collaboration. To convey the necessary expertise in a relatively simple way, so-called BIM Nuggets were developed as a self-learning tool. They are described in more detail in this article. Results of these events were outstanding design projects, with data structured and submitted according to given specifications. The results were motivated students who worked together on their projects far beyond the required workload, as well as satisfied teachers who enabled a large number of people to gain an introduction to a complex topic in a very short time. This event was a good test ground to check the performance of the teaching format on international level. This event motivates to further develop the training in a cross-cultural format where Indian and German students work together on one project.

Keywords – Information modelling techniques, Building Information Modelling; BIM; business game; international case study

1 Introduction

Introduction of new technologies and ideas are often met with opposition, as it is human nature to resist change. This lack of awareness and experience of Building Information Modelling (BIM) within the industry is hindering the extensive utilization of the technology. Therefore the education and training of people, while representing a substantial challenge, is essential. When faced with the task of introducing BIM people related issues have been largely overlooked. Issues such as culture, experience, support, education and training need to be addressed.

"BIM facilitates a new way of working: creating designs with intelligent objects. Regardless of how many times the design changes - or who changes it - the data remains consistent, coordinated, and more accurate across all stakeholders" [1]. Eastman defines BIM as "a modeling technology and an associated set of processes for creating, communicating, and analyzing building models."[2].
BIM allows for all key design decisions to be made digitally at the working drawing stage before actual construction starts, resulting in a higher degree of certainty in all aspects of the project, like quality, cost, scheduling, sustainability and targets. BIM will become the planning standard for construction projects all over the world. [3,4].

In India due to the high volume of construction activity both in the public and private sector, great emphasis is laid by the government to transform the construction industry to go digital. This has resulted in a high demand for professionals with good knowledge of Building Information Modelling among the various professionals like architects, structural engineers, MEP, HVAC consultants, etc. involved in the construction industry. Realizing the need for relevant training using new teaching and learning formats, not only at universities but also in the field of continuing education for working experts, Design Hub India [5] a pioneer in co-curricular learning in the field of Architecture invited Prof. Grunwald from Jade University of Applied Sciences, Oldenburg- Germany, to conduct workshop on learning BIM through a simulation Game, which he has devised.

Thus, it was decided to conduct two simulation game sessions in Bangalore – first one at BMS School of Architecture – which was purely for undergraduate students and a second one at the Impact School of Architecture in Bangalore for a mixed group of students and professionals to teach the networked and digital planning methodology BIM.

The teaching format as a "simulation Game" was developed at the Jade University of Applied Sciences two and a half years ago and has already been conducted several times with different groups of participants - both interdisciplinary and in mixed groups of students and professionals together. Reports on these first events are given in the references [3,5,6,7]. In Bangalore, the BIM game could now be tested internationally for the first time and was thus a test run for the course in English-speaking countries. Fifty students participated in a two-day workshop, the second event was reduced to one day and had even more participants: with eighty interested people from the university and the professional planning industry. The event was partly sponsored by Capricot Technologies Bangalore, a partner of Autodesk India, with the noble mission of popularizing the application of BIM in the construction industry. They invited industry experts for the concluding session where Prof. Grunwald presented the successful outcome of the Workshop under the topic of "BIM – Game Changer for Construction Professionals", in which, among other things, the results of the events were presented. [9]

2 BIM Simulation Game

The BIM game is primarily an architectural competition with an increased focus on the correct provision of information. In the game, participants are divided into working groups and assigned different roles. The participants are: the architect, the civil engineer, the visualiser and the BIM coordinator. The teachers act as clients and as coaches who supervise the students. The list of roles is expandable and can be adapted to the needs and teaching topics.

The aim of the group is to create a 3D model for a specific construction task and to practice working together on this model. For this purpose, the play time is divided into different work phases, each phase ending with the submission of certain deliverables as defined in the EIRs issued by the client. Figure 1 shows the basic structure of the workshop

Certain tasks are directly assigned to one of the roles, according to the project-specific role description. Each delivery item is checked, evaluated, an overall group score is created and puts the participants in a direct competitive situation with the other groups, who work out and process their own ideas in parallel. In this way,

the game creates a concentrated and intensive working atmosphere, also due to the limited processing time, in which effort initially remains secondary because the common goal of completing all deliverables motivates the groups.
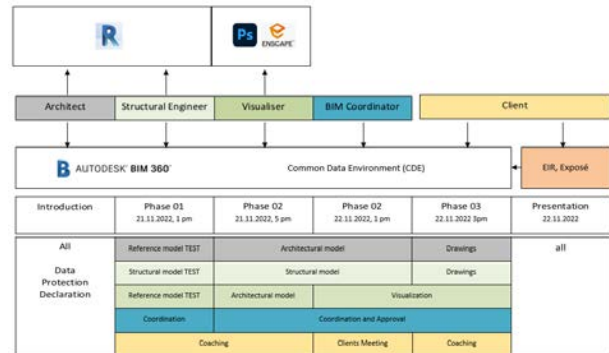

Figure 1: Structure of the workshop – Source: own figure

2.1 Record of progress

Both workshops were organized into similar work steps as described below.

Day 1, 8.30am – 10.30 am: resource persons in the venue, prepare their laptops and study materials and are ready to receive the students. Starting lecture for the students with general instruction in which the programme objective is highlighted time break ups for the next two days are defined and outcomes are defined.

10.30am – 1.00pm: Grouping of five students and role assigning within each group, software is downloaded on to each student's laptop through cloud computing. Nugget learning phase. – Students start working on their assignments while the resource persons go from group to group giving them advice and clearing their doubts. 2.00pm – 5.00pm: students fully engrossed in their works, the designing part of assignment completed, and they are now working on the 3D aspect of design, improving on their designs, integrating various service aspects, etc.

Day 2, 9.00 am – 2.00 pm: The students have solved their assignments going through all the phases of BIM, like integrating information, extracting the structural model, performing a clash detection, etc. They are ready with their 3D designs of the assignment.

2.30 - 4.00 pm: Each group is called over to the actual site within the campus where they were asked to locate the building. The resource persons feed their designs into the AR glasses which they have brought along with and each student is made to experience their final outcome on augmented Reality using the "Hololens". The students were mighty excited to see their buildings come alive and

felt a sense of achievement of having got an insight into BIM and its usefulness in the design process.

4.00 – 5.00 pm: The students were back in the studio, each group making its presentation and taking feedback from the resource persons.

The workshop ended with observations from the resource persons and distribution of certificates to the students.

2.2   Working material

The students receive the building task in the form of an exposé. This document contains all the boundary conditions for the design, such as the spatial programme, location, explanations on the use of the building, its urban context and others. The information requirements are summarised in an Employer Information Requirement (EIR). This document contains a project overview, the BIM-goals and use-cases, it highlights the specific BIM-goals of the project, explains the content provided to all participants and briefly describes the organization of the design contest. Most important chapter contains the digital delivery item definition. The document continues with the specification of roles and responsibilities, the strategy of cooperation and ends with handling instructions of the Common Data Environment (CDE), a cloud based data storage with further control and project management functions, described in chapter 2.3.

It is therefore the planners' specification of how information is to be prepared and delivered in the project [10]. The EIR is based on the model template from BIM Germany [11]. The usual response of the planners to the EIR in the form of a BIM execution plan (BEP) will be dispensed with in this event due to time constraints.

2.3   Modelling and information enrichment

When the game starts, the initial focus is on designing and modelling the spatial structure in a modelling software. Revit was used for the events in Bangalore. Considering the given boundary conditions from the exposé, rooms and utilisation units are created by joining individual building elements. They are designed with Revit's own build-in parameters in accordance with the Level of Information (LOI) defined in the EIR. In addition to these standard parameters, however, properties are defined specifically for the BIM Game. In this way the students should learn to define and upload their own parameters independently of the modelling software and to fill them with information. In summary the exercise focuses on enriching the geometry with semantic information.

For all further work steps and for communication with the other group members, the models are exported as Industry Foundation Class (IFC) files. The teachers subject these IFC files to a model check and can thus automatically examine the file for required information. The models are also reviewed for compliance with the modelling guidelines. The level of detail (LOD) of the model is compared to the specifications from the EIR and evaluated. More information on this automatic model check in chapter 2.4.1

2.4   Collaboration on the model

The collaborative teamwork takes place in a working platform, a Common Data Environment (CDE). At the events in India, Autodesk's BIM360 CDE was used [12,13]. It serves as a storage location for files and is a communication space for the participants. Various planning and coordination processes run on the CDE: The BIM coordinator performs a clash check to compare two 3D models previously created by the architect and civil engineer in Revit. This check trains the merging of different 3D models and the detection of clashes. The conflicts found are to be documented and sent back to the authors for revision as a direct task in the form of the BIM Collaboration Format (BCF). This is to practise generating a coherent coordination model. Communication about the model is also practised in this subtask. The clear protocol structure of the CDE enables the traceability of the performed task and thus simplifies the evaluation of the exercise by the game leaders. The participants are confronted with further planning challenges. Marking and commenting on the model is another function that students should get to know and actively integrate into their planning process. The students can collect points for this activity and positively influence the overall assessment. Furthermore, it is important to initiate an approval process. The architect and the civil engineer can ask the BIM coordinator via the CDE to approve the finished files. The coordinator must review the files and then either approve the file or reject the request and ask for improvements. Only approved files are allowed to be submitted in the competition. Likewise, the use of a standardised naming convention is prescribed. Incorrectly named documents are not considered in the evaluation. Here, too, the CDE with preceding convention helps to comply with the standard.

The data storage structure of the CDE is very simple, as can be seen in table 1. There is a folder with general information for all groups. Each group also has its own working area. Two folders with special properties are built in here. Each group receives a drop-off folder and a coordination folder for performing clash detections. Additional subfolders can be added as required.

Table 1 CDE Structure – source: own figure

Folder	Documents	Access
00_Information	Exposé	all
	EIR	
	Click Tutorial	
01_Work folder	---	group only
01.1_Submission	approved delivery items	
01.2_Coordination	IFC models for clash detection	
01.3 …	any	

2.5 BIM Nuggets

To convey the necessary expertise for the steps listed above in a relatively simple way, so-called BIM Nuggets are used to introduce participants to digital planning technology. A BIM Nugget is learning material reduced to one topic area and usually consists of a video tutorial, click tutorial, exercise, sample solution and a questionnaire. All material is available to students digitally for self-study and can be accessed at any time. The BIM Nuggets (schedule and structure are presented in Figure 2) are primarily designed for the preparation and qualification of the BIM Game, but they can also be used in the game for reference and as a reminder.
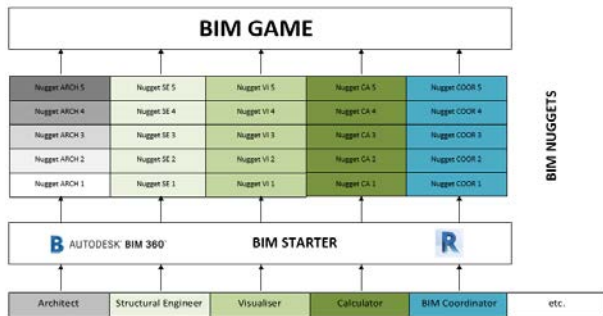

Figure 2. BIM Game Schedule and Structure – source: own figure

In general BIM Nuggets consist out of:

- the video tutorial, which introduces different BIM use cases, explains them and enriches the topic with further information, in order to finally demonstrate the implementation in the corresponding software application step by step. A schematically superimposed mouse records the clicks required for the application, and keyboard shortcuts are also displayed. The workflow is explained via voice recording. The video tutorials serve primarily as preparation for the BIM Game.

- a click tutorial, which provides the learners with a PDF-based reference work. Here, the required work steps are numbered and summarised. It is a condensed format that is particularly suitable as a reminder during the BIM Game.

- exercises and sample solutions which help learners to apply the knowledge they have learned in self-study and to test it before participating in the BIM Game. In this way, the participants learn how to use the most important applications.

- By means of quizzes, what has been learned is reflected upon and consolidated. In this respect, the quiz is an integral part of the nuggets and serves as a self-check.

2.5.1 Automation and Visualization

The self-learning character of BIM Nuggets is an important feature of the learning offer. Since the university curriculum rarely offers space for the study of digital planning methodology, and when it does, self-learning materials are usually the only way to learn this key technology. Self-study is simplified by automations and thus becomes an interesting feature in this teaching project. Some of the automations used in this simulation are summarised below with corresponding references to relevant publications on these topics.

BIMQ is a web-based database that was developed specifically for the requirements and quality management of BIM projects. With BIMQ, the assignment or understanding of LOD and LOI requirements in relation to planning phases, service profiles and use cases no longer takes place via data sheets, but in a database-oriented manner. With the help of BIMQ, comprehensive and well-structured information requirements for a project can be centrally defined, distributed and processed. [14, 15] With BIMQ, an automation technique is used in the BIM Game that allows to control the input of data and to create a consistent information request. BIMQ is used to generate the checking rules of the final BIM model to verify the students' IFC files with model checking software such as Solibri for rule compliance, content consistency and the properties specified and required in the EIR. This automation technology thus helps in checking the performance in terms of information enrichment of the models in the IFC file. Students can also do this independently as a self-test and thus check their work regarding the quality of the information. A further increase is achieved using process control tools within the BIM Game. Here the authors have experiences in the use and integration of a Bizagi work platform, which can be read in more detail in [6].

In addition to automation, visualisation is also an important and motivating factor in the BIM Game. For

visualising the IFC files of the students Microsoft's Power BI is used to graphically evaluate and display different aspects of information such as number of rooms, size and area of the design. For this purpose, the IFC file is extracted with Bimsheet from Simplebim [16] and exported to an Excel file in order to read it into Power BI and check the students' spatial results. Further information in [6].

The participants of the two-day workshop could also view their designs using Hololens glasses. The 3D model was loaded onto the glasses via the Trimble Connect Cloud and located at the planning site. The students were able to view their design on a scale of 1:1, embedded in the surrounding buildings, and thus had the opportunity to assess their design in terms of proportion, design, orientation and many other aspects. The realistic visualisation of their designs inspired the participants and was another highlight of the event. Figure 3 below shows the use of the AR glasses in the workshop.

Figure 3. AR glasses visualize the 3D model – source: own figure

2.5.2 Project Funding

The creation of the BIM Nuggets and their implementation in a new training structure is funded by the "Stiftung Innovation in der Hochschullehre" (see Figure 4). The aim of the foundation is to enable innovation in teaching and learning at universities. [17].

The funded project is called "AUFLADEN" in English "CHARGING" and is briefly summarised: The journey into the digital future of construction requires ideas, time, courage and energy. The education and training laboratory for digital planning and building is the place to charrge energy and knowledge in order to participate in the digital transformation. The aim of the project is to create a suitable training concept for teaching BIM, the didactic preparation of the learning content and the scientific evaluation of the new concept. The

knowledge gained from this should contribute to improving the courses offered at the university, to promoting the standardisation of the education offered and to providing impulses and suggestions across the university. The project is aimed at students of degree programmes along the entire value chain of the construction and real estate industry, especially prospective architects, civil engineers and specialist planners. The project serves to close the gap between beginners and advanced BIM users, to pick up students who are still seeking access to the topic and to involve everyone in the digital transformation.

Figure 4. Logo of the Foundation – source [17]

3 Observations

The aim of conducting this workshop was to test the teaching format in an international environment. Figure 5 and 6 at the end of the article show some final designs that were created in these workshops. Besides the architectural design quality a particular focus lies on the functionality of the BIM Nuggets. In addition the workshops were intended to show whether and to what extent the game-like approach of the business game successfully contributes to increasing the motivation of the participants. The next observation is the cultural aspect: the event should clarify to what extent the learning format can be transferred from Germany to Indian conditions and whether there are cultural differences that need to be taken into account. Final observations examine demographic aspects with regard to the age-structural composition of the two workshops.

3.1 Functionality

The developed format was successfully implemented both in the one-day and in the two-day workshop. The learning content could be conveyed quickly, thus creating a knowledge base for its application. The learning content is summarized in table 2 with a note on the training method used. The topics were either communicated via Nuggets, explained in the starting

lecture or explained in the personal support of the students.

Table 2 Result evaluation in percent

Tool	Criteria	Training Method	Evaluation
R	Access/ Handling	Coaching	90
R	Template Settings	Nugget	85
R	3D-Modelling guidelines	Lecture	45
R	Parameter Settings	Nugget	65
R	Creation of Views	Nugget	70
R	IFC Export	Nugget	60
R	Pset Export	Nugget	55
V	IFC Check	Coaching	75
V	Parameter Check	Coaching	90
B	CDE Access	Nugget	100
B	Handling Documents	Lecture	90
B	Drawing Sets	Nugget	85
B	Naming Convention	none	95
B	Issues (BCF)	none	55
B	Transfers	none	75
B	Marker	Lecture	80
B	Clash Detection	Nugget	70
B	Views	none	95

R=Revit / V=IFC-Viewer / B= BIM360 (CDE)

It should be noted that all topics that could be processed using a BIM Nugget achieved good to very good results. Here, the students knew how to solve the task. The instructions provided helped with the application on their own design. Some tasks were assigned without direct assistance. Their processing can be carried out relatively intuitively in the programs used. This was also confirmed in the evaluation of the results with exceptions in issue management and the use of the BCF data format. Further support is required here. A major challenge in the workshops was adhering to the modeling guidelines. this overwhelmed many students and, in many cases, could not be dealt sufficiently. Additional learning materials are required for this topic.

In addition, the very high number of participants (50/80 people) posed a particular challenge: However, it shows the advantage of the Nuggets as self-learning modules. Only with this help could a large number of students be taught and trained within a very short time with only two teachers as supporting coaches.

3.2   Gamification

The playful approach in the simulation game consists in the competitive situation that the participants are exposed to. Students work together as a team on a design in direct competition with other teams. For their processed Nuggets and completed tasks, they receive points (see table 2) that make their performance status visible at any time. This is motivation for the students to work intensively on the tasks set, with the aim of making progress and achieving good results. A final jury evaluates the works at the end of the workshop and selects the winners.

Another gamification accent is created by the distribution of roles in each of the groups. Participants may take on a task role in the workshop and should play this character Table 3 includes an overview of the role assignment. On the one hand, this limits the workload of each individual, creates identification with a discipline involved in the project and produce an understanding of the problems involved in the division of tasks. Topics such as coordination and communication become relevant, the cooperation between the individual disciplines is trained, the participants get to know the planning process from different perspectives

Table 3 Role Assignment – source: own figure

BIM role	Role assignment	Project-specific role description
Information author	ARCH, STRE	Building modelling and enrichment of the component objects with information, each for its own discipline.
Information user	ARCH	Use of geometric and alphanumeric building information for visualisations
BIM coordinator	COOR	Organisation of the LOIN and coordination of the data flow within the own discipline. Responsible for the composition of the internal coordination model, the collision check and the model-based coordination process.
Consulting	CONS	CONS empowers participants to work in a BIM-compliant manner, if support becomes necessary

ARCH= Architect/ STRE= Structural Engineer/ COOR= BIM Coordinator

3.3   Demographic Structure

In order to investigate the effects of different experience backgrounds and different ages of the participants, it was decided to follow a two-pronged strategy in selecting students for these workshops. Different age and ability groups were formed. Figure 4 shows a group of experienced practitioners.

Figure 4. Group of experienced practitioners – source: own figure

The first group is enrolled by undergraduate students of architecture who have just completed two semesters of study (in their third semester of the ten-semester course), who are yet to even achieve proficiency in computer drafting. The average age of the participants was 20 years. Their knowledge of CAD was very limited – almost nil. Since they have to be taught from scratch, we decided to have a two-day work-shop. This is henceforth described as workshop-1 (WS1).

The next case study for implementation of the Simulation Game was to have professional architects & engineers, who have varied years of experience in the field, but are yet to be introduced to BIM implementation. For these professionals we had a one day workshop as we presumed a certain degree of CAD knowledge and who are exposed to practical experience already handling building projects. For this group a one-day workshop was offered, wherein the entire process of the BIM Game was reduced to eight hours of intensive learning over one day. This is henceforth described as workshop-2 (WS2)

The two events conducted were an experience to examine the influence of age and previous knowledge on the learning curve of the participants. Conclude:

a) The older age group, used to working with CAD software such as AutoCad, showed lethargy when moving from CAD software to BIM – particularly Revit software, and were therefore slow to adapt to BIM processes. The results were similar to those of the novice group. This is surprising, since their lead in knowledge and experience would actually have led to expect a better result.

b) The students who were new to CAD, on the other hand, showed remarkable resilience in dealing with Revit and BIM 360 and were thus able to quickly grasp and apply the principles of the BIM process. No old and practiced application routines and ways of thinking stood in the way here. The fresh and unbiased handling of the matter promoted a quick grasp of the learning content and its implementation in the project.

3.4   Cultural Aspects

Both workshops focused primarily on the communication aspect. As the speakers were both from Germany, the organizers were worried about passing on their instructions to the Indian students. However, within the first hour, we could observe that the students and professionals responded to the resource people's instructions and were able to convey their points easily. This can also be attributed to the fact that the BIM Nuggets were easy to understand for the participants and, in addition to linguistic elements, are very much focused on visual information. The clear numbering of the application steps to be carried out is internationally understandable and a suitable instrument for explaining the operation of software.

in addition to the language barrier, the number of students was a challenge. previous experiences from the events in Germany are based on group sizes of around 20 participants. In India, far more people had to be integrated into the teaching format, which in no way harmed the play and the learning process.

4   Conclusion

The two events held were an intercultural experience for understanding BIM. The game format helped to successfully convey the new technology despite cultural differences and the very tight schedule. The evaluation results of the event in India are similar to the results of the workshops held in Germany.

To conclude: The BIM-simulation Game as a teaching aid has high potential irrespective of cultutral barriers as proved with the success of implementing the game for the first time outside Germany. The efficacy of BIM Nuggets to effectively instil interest in learning the finer points of BIM operations by using this learning modules over a wide age group has been proved to be successful.

The workshops has been successful in teaching the essence of BIM for beginner students of Architecture and has evoked their interest to further learn BIM process in detail over a period of time.

BIM - Simulation game works as an "Appetizer" and can be effectively used as a tool to increase the awareness of applying BIM process for building projects big or small. This could be an effective tool to communicate the advantages of introducing BIM process by various software companies catering to the building industry.

Figure 5. Student Café Design of a student group: Sumedha, Chethana, Bahuleya, Riya, Saakshi, Syed

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Figure 6. Student Café design of a group 1:
Shaik Ahmed Affan, Tanvi Prasad, Y Sai Sushanth, Arpitha Prasad, Ashita S., Murtaza Suterwala