
BUILDING INFORMATION MODELING IN ENGINEERING TEACHING - RETAINING THE CONTEXT OF ENGINEERING KNOWLEDGE AND SKILLS

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ABSTRACT

The application of Information and Communication Technology (ICT) in construction supports business as well as project processes by providing integrated systems for communication, administration, quantity takeoff, time scheduling, cost estimating, progress control among other things. The rapid technological development of ICT systems and the increased application of ICT in industry significantly influence the management and organisation of construction projects, and consequently, ICT has implications for the education of engineers and the preparation of students for their future professional careers. In engineering education there is an obvious aim to provide students with sufficient disciplinary knowledge in science and engineering principles. The implementation of ICT in engineering education requires, however, that valuable time and teaching efforts are spent on adequate software training needed to operate the ICT systems properly. This study takes on the challenge of using ICT in engineering education without diminishing the body of technical disciplinary knowledge and the understanding of the engineering context in which it is taught, practiced, and learned. The objective of the study is to describe and review an extensive role play simulation where students interact with real professional engineers. The role play simulation aims at providing a realistic learning context for the students in order to facilitate the learning objectives of the disciplinary knowledge of the course, which in this case is represented by adopting Building Information Modelling, BIM, for construction management purposes. Course evaluations, a questionnaire and discussions with students confirm a genuinely positive attitude towards the role-play simulation and interaction with industry professionals. The students engage in the role-play and express an increased understanding of the requirements and implicit rules of real-life engineering. The interaction between students and the professional engineers acts as a prime mover for the students to perform their best, which in turn strengthens the learning of the disciplinary subjects.

Keywords: BIM, engineering teaching, role play, simulation, industry participation.

1. INTRODUCTION

Engineering education fundamentally aims at preparing students to become professional engineers. This requires thorough and specific knowledge of science and engineering principles and a general understanding of the complex products, processes, and systems that constitute the society of today. Besides the disciplinary engineering knowledge needed, the practice of professional engineering requires among other things the ability to work in teams with people of different professional and cultural backgrounds, to communicate orally and in writing, to understand the basics of markets and business processes, to be creative and innovative, to conduct to professional ethics and social responsibilities. The continuous development of specialised technical knowledge is challenging engineering education programs, and engineering education has been criticised for being too biased in favour of the teaching of theory and technical disciplines while too little attention has been paid to the teaching of

personal, interpersonal, and professional skills (Sheppard et.al 2009). Further, engineering education must adapt to the continuous and rapid development and growing application of information and communication technology, ICT, which is vital to the preparation of students for their future professional careers. Thus, the application of ICT tools constitutes important elements with significant implications for engineering teaching (Batista and De Carvalho 2008). However, the implementation of additional skills as well as adoption of ICT tools in engineering teaching must be done without reducing the existing curriculum of technical disciplines and still allow for the continuous acquisition of new technical knowledge.

Different initiatives are developed and implemented in engineering education to meet this complexity. One is the CDIO initiative which constitutes a comprehensive pedagogical approach that has been designed to meet the current requirements for engineering education. According to CDIO, the need for engineering education is "to educate students to understand how to conceive – design – implement – operate complex value-added engineering products, processes, and systems in a modern, team-based environment." (Crawley et al. 2007). CDIO integrates the disciplinary technical knowledge and the personal, interpersonal, and professional engineering skills that are required of engineers. Besides, learning is dependent on the context, i.e. the situations and settings in which the learning takes place, which implies the general problem of transferring knowledge and skills from a university context to a professional context in industry (Lave and Wenger 1991). CDIO expresses the importance of providing a context for engineering teaching that corresponds to the context and work procedures of professional engineers and where the engineering teaching includes hands-on actions, integration of different subjects, and realistic teaching settings (Crawley et al. 2007). Thus, the CDIO approach corresponds to Dewey's (1938) ideas of activating the students in the learning process and Kolb's (1984) ideas that establishing a realistic and meaningful context is crucial. which altogether aim at generally enhanced learning. According to CDIO, teaching methods in engineering education that build on the principles of experiential learning can help to manage the complexity in developing engineering knowledge and competences.

1.1 Purpose and Objectives

This study is about adopting advanced Building Information Modelling, BIM, systems in an engineering course about construction management, where the challenge is to design the course with retained focus on the disciplinary subject field of construction management avoiding a too biased focus on software training. The course is designed as a role play simulation in which the students recurrently meet and interact with engineering professionals from the industry.

The purpose of the role play corresponds with the thoughts of Dewey (1938), Kolb (1984), and the concept of CDIO (Crawley et al. 2007), i.e. to activate the students in their learning process and to create a realistic and stimulating context for the teaching in order to gain enhanced learning of the disciplinary knowledge as well as of the supplementary knowledge and skills required to become a professional engineer. The objective of the study is to describe and review the design and results of the role play simulation and to report on the students' attitudes and experiences.

2. METHOD

The presentation and the review of the extensive role play simulation described in this context rest upon practical experiences from teaching at the Technical University of Denmark, Department of Management Engineering during the time period of 2009 and 2010. The subject field in question is construction management, the teaching is project based, the course is optional for students in their final year of education, the course credits correspond to about 30% of full-time studies for a semester, there is about 15 to 20 students from civil engineering and architectural engineering programs in the class, the students work in groups of about four to five students, the groups are formed by the teacher, and a number of different nationalities are typically represented in the course.

The review of the extended role play simulation rests upon course evaluations from 2009 and 2010 and a questionnaire survey carried out in 2010. The collected empirical data are reviewed in light of existing research and literature in the field.

3. THE TEACHING CONCEPT OF ROLE PLAY

Literature reports on a variety of different role playing procedures and concepts applied for educational purposes in many different sciences and subject fields, e.g. social sciences (Druckman and Ebner 2008), supply-chain management and marketing (Clements 2007), natural resource management (Krolikowska 2007, García-Barrios et al. 2008), and accounting (Umapathy 1985, Craig and Amernic 1994). Druckman and Ebner (2008) provide a thorough literature review on the experiences and evaluation of role play simulation in which they refer to Cherryholmes (1966) as one of the early originators in the field. Thus, the concept of role playing as a teaching method has a long tradition and has been widely used in higher education.

Role playing for teaching purposes is part of a wider group of teaching and learning methods known as simulation and gaming which provide a learning mechanism that involves and activates the participants embracing their roles, guided only by implicit rules and instructions (Druckman and Ebner 2008). Role play constitutes a case-based learning method in which the participants assume the roles of different characters and interact in the contextual settings of a given scenario.

Many cases describe various advantages of role plays. Maier et al. (1975) point out the values of role playing as a teaching method when it comes to developing personal and interpersonal skills by referring to how the students gained an improved understanding and control of emotions and feelings. They also improved their self-knowledge and understanding of their attitudes and of human interaction in social situations. Craig and Amernic (1994) describe role playing as “one particular type of simulation that focuses attention to the interaction of people with one another” and, consequently, they share the view that interpersonal skills are central to role playing.

The general purpose of role playing in teaching is for the participants to gain enhanced learning outcomes, but in wider perspective, role playing has turned out to embody many other distinctive merits. As always in research and scientific studies with human processes as the research object, criticism can be levelled against the validity of the research reviews of role playing as a teaching concept. Despite the criticism of how to evaluate the pros and cons of role play as a teaching method, the advantages of role playing seem to exceed the disadvantages. Literature studies and reviews of experiences with role play for teaching purposes are primarily positive when it comes to the way in which it helps the students to enhance and retain learning of the subject field. Besides, role playing also facilitates the important development of personal and interpersonal skills, e.g. the skills of communication, behaviour, decision-making, and the ability to manage diverse and unstructured problems (Craig and Amernic 1994). Thus, role play simulation retains the context of engineering knowledge and skill and provides an extended learning scope which includes professional skills as advertised by the CDIO-concept.

The teaching of professional skills concurrently with disciplinary knowledge is an important issue for any engineering education program. Understanding the role, expectations, culture and ethics as well as understanding the consequences of one's actions are important aspects of the development of the students' professional skills and their professional identity. The concept of professionalism requires knowledge, autonomy, and responsibility to be integrated and interrelated in practice (Bates 2008). A number of teaching and assessment methods used in engineering education such as Problem Based Learning, Case Based Method and Project Based Learning etc., have been developed to facilitate the learning of disciplinary knowledge in a realistic engineering context of practice, applying realistic problems and situations.

The experiences with role playing as an integrated part of teaching are very diverse. The pedagogical concept of role playing as described in this paper rests upon the principle argument of establishing a realistic context, i.e. a realistic learning environment for the students. This argument is supported by Pepper and Clements (2008) who identify and describe the need to prepare students for the ever-changing and dynamic environment of engineering work and, in order to facilitate the teaching and learning of professional skills, they introduce the approach of role playing as a way to establish a realistic learning environment.

The teaching method of role playing also supports the understanding of the underlying context, the functions of the different actors involved, and the complex dynamic nature of the given problem (García-Barrios et al. 2008). The establishment of realistic environments and scenarios for the role play encourages the participant to become involved in, and commit to, the learning process of disciplinary knowledge (van Ments 1989). Besides the immediate purpose of generally improved learning from role playing, the active involvement required in role play

simulation promotes an enhanced enthusiasm, motivation, and a positive attitude to the teaching subject (Umamathy 1985, Haskins and Crum 1985, Craig and Amernic 1994).

Even though role play has many documented advantages, literature also reports on challenges when using role playing as a teaching method, both from the participants' and the teachers' point of view. Craig and Amernic (1994) bring forward the risk that the roles played by the participants can emphasize stereotypes and maintain prevailing and inadequate behaviour and relations. On the other hand, to a certain extent the given roles to be played need to be of a stereotyped nature in order to be distinct and familiar to the participants (Loui 2009). The value of enhanced commitment and enthusiasm among the role play participants must also be balanced in order not to turn the role play into a too frivolous and giggly game where the learning process is neglected. If the value and the procedures of the role play concept are properly conveyed and perceived by the participants, the "constructive peer pressure seems likely to operate to prevent role play degenerating into play" (Craig and Amernic 1994). Participants with no previous experience from simulations might express an initial anxiety and apprehension about acting and performing in the role play situation (Loui 2009), and, as a consequence, they may adopt a cautious and non-committal attitude or even withdraw from the course (van Ments 1989).

From the teachers' point of view, role playing requires considerable efforts in the design and conceptualisation of relevant role play simulation and the establishment of a realistic environment that stimulates and activates the participants in their learning process (Druckman and Ebner 2008). Despite the efforts and determination of the teacher when designing and preparing for the role play, the teacher must allow the role play participants to act and perform within the context of the given scenario only with implicit rules and a minimum of guidance. As the role play situation provides a creative and less predictable process in which the participants are in focus, it will pose difficulties for the teacher to apprehend and assess what is learnt among the group of participants (van Ments 1989). To sum up the described experiences and studies from using role play as a teaching method in higher education, combined with the factors mentioned before, which can have a certain impact, for students developing professional skills the method seems to cover many important aspects of this professional training. Using this method, the learning is taking place in a realistic setting, there is social interaction, the students must actively use the disciplinary knowledge in the course, apply it on a case, and try it out acting as professional engineers. This addresses the context dependences of learning. In the cases described in this paper, the students interact with professional engineers from industry who also act as role models. It seems as if role play is a teaching method which can be useful fostering professional skills in higher education while at the same time supporting the learning of the disciplinary knowledge and working with the relevant tools used by engineers like ICT tools.

4. EXTENDED ROLE PLAY WITH INDUSTRY PARTICIPATION – THE CASE STUDY

The extensive role play simulation that is tested and evaluated in this study is applied in an advanced engineering course in which the basic learning objective is for the students to learn how to use Building Information Modelling as an integrated tool in the planning and management of construction projects. The pedagogic design of the course relies on three interactive processes described as the tutorial process, the project process, and the social process which run in parallel throughout the course, see figure 1. It is the project process that is designed as a role play simulation in which groups of students carry out a project assignment in the role of BIM-consultant, assigned by real clients represented by professional engineers from the industry. Each group of students has its own client. The project process and the role play provide the corner-stone of the course facilitated by input from the other two processes. The tutorial process includes traditional lectures and exercises in which relevant theories and methods regarding BIM-modeling and project management are introduced on the basis of the discussions and requests that arise from the role play between the students and their professional clients in the project process. Thus, when the clients introduce and discuss a new topic, problem or need to the group of students assigned to their project, they also create an interest, understanding, and a sense of "need to know" among the students for the subsequent lecture. Consequently, the project and teaching processes are synchronised throughout the course. The social process includes a conscious and formal assessment of the students own personal development and progression of personal and interpersonal skills, which also relates strongly to the role play of the project process (Andersson 2009). The basic argument for the social process rests upon the team-based working environment that

is typical for engineers in which knowledge and skills in teamwork, leadership, and communications are highly required.

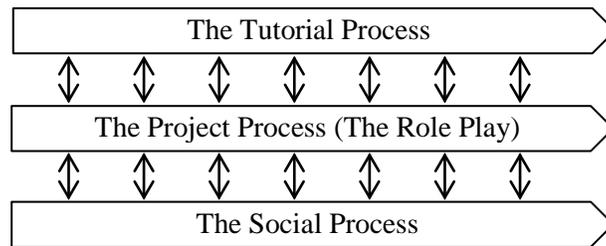


Figure 1: The Tutorial, the Project and the Social Processes of the Course

4.1 Establishing a Realistic Learning Context

The project process and the role play are initiated at the very beginning of the course. On day one, each group of students receives an invitation to a business meeting with its professional client. The students contact their client and arrange the time and place for their first meeting. The early introduction of the role play and the immediate need to prepare for the first meeting with the clients act as a strong motivator for the students to take on the role of BIM-consultants and to organise themselves as a fictitious consultancy company including a company name, a logo, and a business plan etc. Thus, the initial work prepares the students for their roles as engineering consultants, it gets them introduced to the general terms and conditions of the subject field of Building Information Modelling and, not least, it gets the teambuilding processes in the groups started.

The role of the client is played by a professional engineer typically employed at a consultancy firm or as a contractor. The meetings between the students and their clients take place at the office of the respective industry representatives in order to strongly contribute to the realistic context of the project assignments and the role play simulation. The students are responsible for setting up the meeting appointments with their respective client, to agree on when and where to meet, to prepare a meeting agenda, and to keep the minutes of the meeting. Four meetings are scheduled during the course period of 13 weeks.

4.2 The Clients Pull the Project and Teaching Processes Forward

The recurrent project meetings with the clients make up milestones during the course at which the students report, discuss, and get feedback on their intermediate results. The clients pull the project process forward in dialogue with the students as they successively introduce new requirements to the project. This, in turn, arouses interest and a need to gain new disciplinary knowledge among the students. Thus, when the students return to the teaching process of the course after a meeting with their client, they have an explicit urge to learn the disciplinary subjects in order to provide an answer and solution for their client at the next meeting. Besides, the recurrent meetings and part deliveries of the project assignment help balancing the workload distribution during the course.

The clients have been given a step-by-step guideline for the project assignment. The guideline provides a framework for the project assignment, defining its scope, principal contents, and the basic topics that are to be introduced consecutively during the course. The guideline has been developed in dialogue with the professional engineers in order to provide a common platform for each client and to make sure that the project assignment is realistic, relevant, and valid.

4.3 The Students' Attitudes towards the Role Play and the Realistic Learning Context

Regardless of the arguments and intensions of role play simulation with industry participation, it is of little value if the students do not respond and adapt to the pedagogic design. However, course evaluations, a questionnaire, and informal discussions with students in the course, confirm a genuinely positive attitude towards the realistic context of the course and the role play simulation with industry representatives. In the recent course evaluations from 2009 and 2010, the students were asked to - individually and at their own will - write down positive and negative aspects about the course. Subsequently, the notes of each student were passed around to all of the other

students in order for them to either agree or to disagree with the positive and negative remarks pointed out by the other students. Consequently, the results of the course evaluation include the students' own remarks and the share of students who agree to each of the remarks.

It is evident from the course evaluations from 2009 as well as 2010 that the realistic context of the course provided by the role play simulation with industry participation is very much appreciated by the students. Quotes from the evaluations, presented in the bullet list below, are examples of positive remarks from the students regarding the realistic learning context and the role play with industry representative. The shares of students who agree to the respective statements are put in brackets. There were a total of 14 and 20 students in the courses as well as in the evaluations from 2009 and 2010.

- Direct contact with the industry made it more interesting (100%)
- Real Case - makes it realistic, (100%)
- Real experience, (100%)
- The client contact/case, (100%)
- Real Clients, (100%)
- Working with an external client, (100%)
- The correspondence with a real firm, (100%)
- Getting real cases to work with did it exciting to solve, (93%)
- Very good with role play (real clients), (90%)

Besides the general, positive remarks about the role play in this case study, there are of course some difficulties identified as well. The list below presents the very few, but relevant, negative remarks about the role play and interaction with industry.

- Expectations from clients contra what we learn, (70%)
- Too much uncertainty in the very beginning of the course concerning meetings with the client, (60%)
- Expectations from clients really high", (7%)

These are relevant remarks as they point out the difficulties and importance of coordinating the project and the teaching process, i.e. the topics and discussions between the clients and students need to be coordinated with the input from the teaching process. From the teacher's point of view, it is emotionally difficult to leave part of the teaching in the hands of the professional clients. When involving external clients, who meet with their respective group of students at their offices, the academic teacher loses some of the control of the teaching process. Recurrent updates between the clients to the academic teacher are of vital importance for the teacher to keep informed about the results of the role play sessions in order to be able to address the subjects and questions from the role play in the teaching process. In the course evaluation from 2009, one of the students expressed the following concern: "- The workload is very much in the hands of the clients - can be good and bad". The opportunity of each client to highlight or add specific topics to the project on basis of their own personal interest, experience and specialised competences contributes to the dynamics and flexibility of the course. There is no reason why the role play and the project assignment should be exactly the same in all groups, but, of course, there must be a common framework for all clients in order to ensure that the learning objectives are covered. In this connection, it is worth mentioning that there is only a single student (7%) who claimed that the clients' expectations were really high. In order to keep the role play between students and clients in line with the scope of the course, its learning objectives, and the teaching process, a clients' guide was developed. Among other things, the guide outlined some common milestones in terms of subjects that should be considered in the role play. Thus, the guide provided a common framework for the role play in which the clients were free to act.

The remark about the uncertainty experienced in the very beginning of the course is an expression of nervousness as well as excitement about the interaction with professionals from the industry. The students express that they felt more pressured but also more motivated to deliver thoroughly worked-out results to their clients. Besides, only half of the students had any previous experience from role play simulations in their previous university studies at DTU or any other university.

The questionnaire survey from 2010, with a total of 20 respondents representing 100% of the students in the course, shows that there is a prevalent positive attitude towards the realistic learning context established by the role play simulation and the interaction with professional engineers. All students agreed to the statement that

"teaching of professional engineering skills is of importance in an engineering study programme" At the start of the course, 75 percent of the students rated their own current awareness and understanding of the context and conditions of professional engineering as being limited, and by the end of the course, 85 percent of the students claimed that they have gained a higher degree of knowledge and understanding of professional engineering. Only 3 students (15%) reported an unchanged level of professional skills after the course.

Personal comments were also registered in the questionnaire. The following bullet list presents some descriptive examples of positive comments (quotes) from the questionnaire.

- It has been very inspiring and learning
- I think it is a very important part of studies, which would help students to understand how it works in real life
- Engineering is not only reading books and solving problems in exams, but it's also being a responsible engineer in real life
- More realistic, more responsible
- Learning about real life industry. You have to communicate with persons with different interests
- I hope/expect that role play with real firm will improve professional skills and give experience
- You get the understanding of how engineers should act in real life
- It was a good experience that we had worked with a real client and we had seen what the expectations in the real world are. We learned a lot from this experience
- Real experience - some issues that never deal in university

There were also some examples of concern among the open comments from students in the questionnaire (quotes).

- Doubt that our presentation will live up to their requirements/standards
- It's a good idea but you are not necessarily a better engineer by learning in this way. Sometimes there is too much focus on learning to communicate instead of gaining other relevant engineering skills
- Role playing is still not real work
- Nervous on how it will go, but think it is a good idea

The remarks of concern presented in the questionnaire correspond to the comments in the course evaluation described above, i.e. the anxiety about meeting the requirements made by the professional engineers, the risk of overdoing the role play, and a risk of diminished learning of disciplinary knowledge due the emphasis placed on obtaining an authentic learning environment.

5. CONCLUSION

This study takes on the challenge of adopting advanced Building Information Modelling systems in an engineering course about construction management, with retained focus on the disciplinary subject field of construction management and avoiding a too biased focus on software training. The study describes and reviews a role play simulation with industry involvement with the purpose of creating a realistic and stimulating learning context that will facilitate the learning process. The role play simulation goes beyond the limitations of a discrete teaching exercise. Instead, the role play constitutes the principal foundation of the course design.

Course evaluations, a questionnaire and informal discussions with students, confirm a genuinely positive attitude towards the role-play simulation and the interaction with industry professionals. The students engaged in the role-play expressed an increased understanding of the requirements and implicit rules of real-life engineering as a consequence of the realistic context of the teaching provided. The recurrent interaction between students and the professional engineers acts as a prime mover for the students to become engaged and to perform their best, which in turn strengthens the learning of the disciplinary learning aspects. Besides, the students feel committed to the role play simulation and express an increased understanding of the requirements and implicit rules of real-life engineering, i.e. the realistic context provided by the role play enhances knowledge and understanding of professional engineering skills. One of the challenges identified concerning role play and industry participation is the diminished control of the learning progress from the academic teachers' point of view. Preparations before the

course and continuous updates between the academic teachers and the professional engineers must be made to ensure sufficient coordination between the role play and the teaching process of the course.

The study concludes that role play with industry participation creates the realistic and stimulating learning context which facilitates the learning of disciplinary knowledge, as well as professional skills, and consequently, it supports engineering students to become professional engineers ready to enter the industry.

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