Universities playing in the construction field: how the universities can facilitate collaboration for systemic process innovation

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Implementing Building Information Modeling (BIM) in the construction industry is expected to ease designing and planning, decrease costs and enable customer involvement. In order to meet the expectations, BIM has to be seen as a tool for process innovation that enhances collaboration in a project network. Developing new processes for inter-organizational interaction necessitates mutual understanding, collaboration and coordination. The task is especially challenging in the fragmented construction industry. In this paper, we examine, to what extend academic research using action research methods can facilitate knowledge creation in an inter-organizational network in order to support the development and implementation of a new systemic innovation. The empirical data is collected in a project network, in which nine firms and two academic research institutes were collaborating to develop BIM-based processes. The data is analysed using the knowledge creation framework originally formulated by Nonaka and Takeuchi (1995). The findings imply that active participation of an academic researcher supports mutual trust between different organizations, increase the involvement of the practitioners and enhance the relevance of the results from the view point of practice.

Keywords: knowledge creation, collaboration, building information modelling (BIM), systemic innovation, action research.

1. Introduction

Building Information Modelling (BIM) is claimed to be the catalyst of the paradigmatic shift in construction industry reducing complexity and fragmentation providing ICT tools to process information and collaborate across a project network in a cost-effective way (Succar, 2009). BIM refers to the software and processes which are used to make a 3D digital representation of the physical and functional features of a facility. As defined by National Institute of Building Science in the USA, Building Information Model forms a shared knowledge resource for the stakeholders in the project organization. (A Council of the National Institute of Building Sciences, 2012; Eastman, et al., 2009)

Besides being a huge opportunity, BIM seems to be a huge challenge. The full deployment of BIM has been hindered by practical and political problems, established work processes and business models, and attitudes in the industry. As noted by Harty (2005, pp. 517, 521) BIM

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as a “single Model Environment (SME)” integrating all information and elements and providing the ultimate tool for collaboration and information sharing within a project organization, is at the present only as an official vision. According to Harty’s research, firms are adopting BIM-based practices remarkably slower than its predecessor tools for two-dimensional (2D) computer aided design (CAD). Empirical research has suggested that slowness of the construction industry to implement BIM originates from the networked and complex nature of the project-based production within the industry. The construction industry seems to have no specific problems implementing and diffusing incremental innovations (Taylor & Levitt, 2004; Dubois & Gadde, 2002), unfortunately the fragmentation of the industry makes almost all innovations systemic (Gann & Salter, 2000; Winch, 2003). 2D CAD changed working practices inside an organization, but BIM necessitates coordinated change across the whole project network (Taylor & Levitt, 2007, p. 24; Taylor & Bernstein, 2009, p 70; Harty, 2005, p. 521).

In this paper, we define BIM as systemic process innovation using the division between process and product innovation suggested by Edquist: Product innovations are new or better material goods or intangible services. Process innovations, technological or organizational, are new ways to product goods and services. (Edquist, 2005, p. 182.) BIM as a systemic process innovation is not a new bundle of software to make design in 3D, but a bundle of ICT-tools and processes used to coordinate disparate parts of the construction. In order to meet the expectations, new BIM-based procedures have to be collaboratively developed and coordinated implemented in a fragmented, inter-organizational project network context. In order to ensure the viability of a systemic innovation, the coordination of different parts of the value network is required. In contrast to an autonomous innovation, coordination is needed not only with the suppliers and customers, but also with the producers of complementary products and competitors. (Maula, et al. 2006.)

In order to create a systemic process innovation, different pieces of knowledge from several professionals need to be integrated. However, the pieces of knowledge related to organizational innovation are often tacit or scattered (Egbu, 2004). In order to implement a systemic process innovation in a network, coordination and collaboration is needed. But systemic innovations are typically too complex and required changes are too large that no single integrated firm has enough financial resources or technological and market capabilities to implement a systemic innovation alone. (de Laat, 1999; Maula, et al., 2006.)

Since Gibbon et al. (1994) coined the term “mode 2” to describe locations, practices and principles of contemporary knowledge production that are more heterogeneous than what they used to be, various authors have participated in the discussion, what is the role of universities in the knowledge production (Godin & Gingras, 2000; Hessels & van Lente, 2008). Gibbons et al. (1994, 85) predicted, that universities are going to comprise only a minor part in knowledge production. In this paper, we focus on the role of university research when implementing a systemic innovation. We are not asking, whether or not the main role of universities in the knowledge creation is diminishing, but how the academic research could assist in the problem solving in collaboration with practitioners.

We investigate, to what extend an action research project can participate in integrating knowledge for developing a systemic process innovation in the construction industry and creating a mutual understanding to support the coordination in a network. We have analysed thoroughly a case in which an academic research unit and industry actors have collaborated within an open innovation network in order to develop BIM-based procedures. Earlier studies have shown empirical evidence that research pursuing active interaction with practitioners while planning the study, interpreting results, suggesting implications and testing findings may increase the relevance and usefulness of the research and interest of practitioners (Rynes, 2007; Rynes, et al., 2001). Because learning is a socially constructed process (Nicolini & Meznar, 1995), practitioners and academic researchers, coming from different backgrounds, create divergent possibilities for creating new knowledge.

2. Literature review

2.1 The challenges in creating systemic innovations in construction industry

Research has shown that implementing a systemic innovation in the construction industry is a challenging task. Many researchers agree that the challenges embedded in innovation activities in the construction industry are connected to the project-based production, the complexity of the end product, and the fragmentation of the industry. (Winch, 2003; Taylor & Levitt, 2004; Kadefors, 1995). Harty (2005, p. 513) mentions also how crucial the role of inter-organizational communication and collaboration, and dispersed distribution of power are in innovation activities.

Taylor and Levitt (2004, p. 6) define systemic innovations as “innovations that reinforce the existing product but necessitate a change in the process that requires multiple firms to change their practices. Systemic innovations typically enable significant increases in overall productivity over the long term. But these may create switching or start-up costs for some participants and reduce or eliminate the role of others.” The definition highlights the key challenges of the systemic innovation implementation in a project-based industry.

First of the key challenges is related to the need for coordinated changes among multiple stakeholders. Process innovation typically requires reorganization in the existing system. In the case of a systemic innovation, processes span over organizational boundaries. Because of the fragmentation of the construction industry and complexity of the end product, the construction processes involve multiple task interdependences making the coordination especially challenging (Dubois & Gadde 2002).

Second is the tension between (inevitable) short term costs and (possible) long-time benefits. The systemic character of innovation decreases the ability of a firm to control the benefits and increase the dependency on others. The context in which BIM has to be implemented, is characterized by “multiple inter-organizational relations, complex interdependencies between firms and the lack of a single authoritative driving force that can see through implementation across a whole project” (Harty 2005, 514). According to Maula et al. (2006), optimizing the use of resources within a company may lead to suboptimal situation when the target is to create a systemic innovation.

Third challenge is to achieve changes, not only in the function of the system, but also in the relations of the components in the systems. The actors of the systemic change need to balance between developing the new procedures and maintaining their existing business base (Maula, et al., 2006). The construction industry is an established industry characterized with strong institutions and practises. Researchers have noted that the institutions, which are created in order to manage complexity and decrease uncertainty as well as the costs of transactions may support the established order and hinder the transformation of the industry (Dubois & Gadde 2002, 629; Kadefors, 1995).

Forth challenge is the inter-organizational knowledge creation in project organizations. Researchers have noted that temporary project organizations do not promote cumulative learning and knowledge transfer between projects (Dubois & Gadde, 2002; Taylor & Levitt, 2007). Production based on temporary, unique project organizations is commonly remarked as a feature that is hindering the implementation of systemic innovations in the construction industry (Taylor & Levitt, 2004; Kadefors, 1995; Harty, 2005).

The features of the construction industry turn the attention to the dynamics in a network: How to get the stakeholders of the construction industry from yesterday to collaborate and to pool their pieces of knowledge in order to develop the new procedures for the construction industry tomorrow, when the traditional control mechanism based on hierarchy or integration is not an option.

2.2 Knowledge creation in the relation between the university and practitioners

Basically, innovation is knowledge about how to do things better than the existing state-of-the-art (Teece, 1986, p. 288). Thus, the questions how and where the knowledge is produced and which kind of knowledge benefits innovating activities are relevant for innovation studies.

In their highly influential book “The new production of Knowledge” Gibbons et al. (1994) distinguished a new mode of knowledge creation, “Mode 2”. According to Gibbons et al. (1994), the Mode 2 consists of five constitutive claims describing together the transformation at the research system. First, the knowledge is produced in the context of application. The process of problem solving is organized around a particular application, not inside a particular discipline. Second, the knowledge is produced by transdisciplinary collaboration. The transdisciplinarity principle defines a framework for problem solving, in which the solutions have both theoretical and empirical components and solely arise as an application of the existing knowledge, but require contributions from diverse ranged specialists. The knowledge is also diffused through participants, instead of using institutional channels. Third attribute is the heterogeneity and organizational diversity of knowledge production suggesting that numerous sites, other than scientific universities, take actively part to the knowledge production. Forth feature, social accountability and reflexivity of the knowledge production, refers to the growing sensitivity to the impact of the results. Various interest groups participate actively in defining the research problems and setting priorities. Fifth, as a contrast to mode 1, in which the quality of the knowledge produced is determined through the peer reviewed publications, the quality control at the mode 2 is more broadly based. The quality of the science outcomes is not determined by disciplinary peers, but also political, social and economic interests are taken into considerations.

The main argument made by Gibbons et al. (1994) is that universities role as the principal locus of knowledge production would diminish while locations, practices, values and principles of knowledge production become more heterogeneous. However, Godin and Gingras (2000, 277) argue that universities using collaborative methods are able to stay at the centre of knowledge production.

The knowledge diffusion between universities and industry is often rigid. Especially broad the gap between research results and deployment of results is in the field of organizational sciences, where the creation and commercialization process of an organizational innovation is more complicated than in the physical sciences (Rynes, et al., 2001; Ramsted, 2009). According to Powell and Owen-Smith (1998), a strong network with university researchers enhances the position of the corporation to solve problems hindering further progress. However, it also requires a strong capacity for identifying and evaluating the results of scientific research and new techniques of disseminating especially organizational innovations for companies. (Ramsted, 2009, p. 547)

Rynes et al. (2001) have discussed strategies how organizational scientists and practitioners might develop the pace and quality of knowledge creation and dissemination through collaborative efforts. They use the framework of knowledge creation developed by Nonaka and his colleagues (E.g Nonaka & Takeuchi 1995) to explain the gap between scientific research and practice. Nonaka`s model of knowledge creation is based on an idea that there are basically two kinds of knowledge. Tacit knowledge is often intuitive, unarticulated and undocumented, context-specific and difficult to communicate. It includes cognitive patterns as well as technical knowledge. Explicit knowledge is documented and structured and it can be transmitted in formal, systemic language. According to Nonaka and Takeuchi (1995), knowledge creation is a cyclical process comprising four phases of knowledge conversion: Socialization (from tacit knowledge to tacit knowledge), externalization (tacit to explicit), combination (explicit to explicit) and internalization (explicit to tacit).

In socialization, tacit knowledge is exchanged through joint activities such as individuals learning together in order to create shared understanding or a mental model. Successful socialization is difficult to achieve without face to face experience. In externalization, tacit knowledge is converted into tangible forms such as metaphors, hypotheses and models. In combination, pieces of explicit knowledge from different sources are analysed in order to produce a new synthesis. Combinations of explicit knowledge comprise the majority of scientific contributions published in journals. Explicit information is also transmitted from scientific researchers to practitioners through books and practice oriented publications. In internalization, explicit knowledge is converted into tacit knowledge through learning by doing. (Nonaka & Takeuchi 1995; Rynes et al. 1995.)

Rynes et al. (2001) argue that organizational science is focused excessively on making explicit knowledge explicit through the new combinations of theories. There are three kinds of implications. First, researchers fail in the mobilization and conversion of tacit knowledge that should be fundamental in knowledge creation according to Nonaka and Takeuchi (1995). Second, also the majority of the publications aimed at practitioners fail in integrating practitioners and academic perspectives and are only either combining explicit scientific theories or translating them to the presumed practitioners' language and format. Third, without a successful socialization of the new knowledge, attempts to transfer explicit knowledge across organizational boundaries are likely to fail.

Rynes et al. (2001) propose that collaborative methods, such as action research, provide both researchers and practitioners an opportunity to increase tacit knowledge. Transdisciplinary collaboration within diverse set of people with different interests and backgrounds are vulnerable to conflicts. There are also evidences (Rynes et al. 2001 346-347) suggesting that certain "creative tensions" springing from interactive dialogue between different disciplines, between different types of knowledge and between theories would enhance the quality and rate of knowledge creation. Rynes et al. encourage researchers to seek tensions between academic-practitioner interactions instead of trying to avoid them (Rynes et al. 2001 pp. 346-349).

3. Methodology

The central phenomenon, knowledge creation between a university and practitioners for a systemic innovation, was approached here with a case study. The other researcher participated in a research project where companies were involved and at the same time, she collected the data with qualitative methods. The authors of this paper are working in Aalto University within a research consortium developing the construction industryThe case can be seen as an action research project because of the contribution to solve a practical problem and the research are made in joint collaboration between practitioners and researchers (Rapoport 1970, p. 499).

The action research method utilized in the case project is called SimLab™ process simulation method (Smeds, et al., 2006). During the action research project, researchers prepare and implement a social process simulation in collaboration with the case stakeholders usinga visual process map. The primary data consists of the observations, notes and video recordings of the meetings between researchers and case companies and the simulation day. The secondary data includes documents, interviews and the feedback questionnaire answered by the participants of the simulation day. The data was gathered during the first half of 2011. We use Nonaka's framework of knowledge creation circle to capture relevant moments from the perspective of knowledge creation in the interaction between researchers and practitioners during the case project and to analyse to what extend academic scientists deploying action research methods may meet the challenges originated from the features of construction industry, facilitate knowledge creation in a network, and support BIM implementation.

4. Case description

The research project case is conducted as a part of a larger research project, which is initiated, supervised and mostly financed by Finnish government. The research project forms a consortium which is composed of nine firms and two research institutes. Industry shareholders compose the majority and research units the minority, which characterize the network as industry-driven. The common objective of the research consortium is to study and develop a new business model and new practices based on BIM for the Finnish construction industry. The studied case is a part of a larger three year research project.

The target of the case project was to create common understanding how BIM is used in Finland in inter-organisational processes during the design and construction of a building and what are the main challenges and bottlenecks in the inter-organisational collaboration and coordination. The case project was based on a real construction project where a school was designed and built in eastern Finland utilizing building information modelling.

The method consists of seven steps. First, the common objectives of the simulation project are formulated together. For that reason, a face to face meeting was organized with case companies and researchers. Second, the first rough process model is made by researchers based on tentative analysis of the case. In the case project, the tentative process model was formulated in a meeting, where two focal actors in the construction process with the help of researchers formulated the first version of the process model. Third, all the key actors are interviewed and the process model is refined based on the interviews. In the case project, altogether 18 semi-structured individual or group interviews were conducted in order to achieve holistic perspective on the process. During the interviews, the first version of the process model was validated and improved.

The culmination of the simulation project was the simulation day, when all the key stakeholders were gathered in one room to develop the process together. In the case project, 47 incumbents of the project or members of the research consortia participated in the simulation day. The researchers acted as facilitators of the simulation during which representatives of every key actor of the process explained the process from their own perspective. The visual process model was used as a boundary object. The discussion on simulation day was focused on the key challenges on the process. On the second half of the day, the participants were split up into smaller groups. Each group had a specific question or theme, which were selected based on the propositions made by participants. After the simulation day, the data gathered during the interviews and simulation day was analysed and results were published in a report that was shared with the participants.

Findings

4.1 Knowledge creation

The result of a successful **socialization** is a shared understanding that can be used as a foundation for the further knowledge creation. Because it requires participants to understand and accept the perspectives and beliefs of the others, it is difficult to achieve without close interaction. In the case project, the attempts of socialization were found at two levels: 1) between practitioners and researchers and 2) between different specialists and practitioners across the construction project network. Face-to-face meetings between case companies and researchers were used to define the objectives and targets of the research project.

Involvement of practitioners to the research project design increased the commitment of the case companies and assisted the researchers to focus on questions that had practical relevance. The role of researchers enhancing knowledge socialization within a construction project network was first to provide a shared place and time, and organise and facilitate the discussion between practitioners.

In **externalization**, tacit knowledge is made explicit. In this action research project, researchers facilitated the externalization of the tacit knowledge gathered from practitioners. In this case, 1) one tool used to transform the tacit knowledge into a concrete and tangible format was the visual process model. It was found as a practical way to express the complex construction project in a simple manner, so that the participants could get the picture of the process as a whole and understand the reciprocal interdependences between the tasks, eventually promoting mutual understanding. During the simulation day, the process model was used to identify and communicate the focal interaction point of the inter-organisational interaction. 2) Another tool was the final case report, where the identified best practices and specific challenges were linked to the process model to assist companies design their own processes. 3) The researchers also facilitated the externalization of tacit knowledge during the interaction between case companies and researches by gathering, articulating, formulating and documenting the common targets and boundaries of the project.

In **combination**, external knowledge is combined with external knowledge from different sources in order to create new knowledge through synthesis. 1) In this action research project, the focus was on combining different perspectives and pieces of knowledge gathered from the practitioners within the value network. 2) From the perspective of the researchers, the main function of the action research project was to collect empirical data. The combination between scientific theory and practitioners' tacit knowledge was a subject for further studies. 3) According to feedback from industry incumbents, a focal benefit of the action research methods applied in the case project was their ability to combine perspectives and information from all of the key organizations in the project network at several levels. For example, the software developer did not know that certain modeling programs were used at the construction site.

In **internalization**, the created explicit knowledge is transformed to tacit knowledge. 1) At the level of research consortium the knowledge achieved during the first simulation project was used as a shared experience further in the case project. 2) At the level of practice, the kn knowledge created during the simulation day was diffused through participants. As a part of final report the list of identified best practices and summary of the project results were used to ease the internalization process.

4.2 Creative tensions

As suggested by Rynes et al. (2001), we paid attention also to the tensions appearing in the data. 1) During the discussion during simulation day, focal tensions stemming from the BIM implementation were related to the allocation of resources used and compensation received during the development of the new procedures. For example, if the BIM use at the construction site or in the maintenance will require more exact and time-consuming modeling from designers, who should be responsible for paying for it.

2) Another tension emerged between the different attitudes to changes and schedules of different designers. From the perspective of the architect, the creative design phase characterized iteration and changes should go on as long as possible. From the viewpoint of the structural engineers, the central structures of the building should be determined as early as possible. Solving this kind of fundamental tensions between practitioners in the project network was beyond the scope of the case project. But identifying the sources of the contradictions, making them explicit through visualisation, and increasing mutual understanding within the network, the use of action research prepared the network to compromise.

3) Most tensions between the researchers and practitioners stemmed from the different opinions concerning the format of the results. Based on the feedback gathered from the participants, the practitioners were generally pleased with the results of the action research project, but more concrete, detailed and short list of suggestions based on the project results would have been appreciated.

5. Conclusion

In this paper, we have examined how academic research using action research methods can facilitate the knowledge creation in order to support the development and implementation of a systemic process innovation such as BIM implementation in the construction industry. According to our findings, action research methods may facilitate the knowledge creation within the construction industry. The case project also reflected the elements of mode 2 knowledge production as defined by Gibbons et al. (1994) and thus participates in discussion about the universities role in innovation processes.

In the case project, the socialization of the tacit knowledge was promoted in face-to-face meetings and facilitated the discussion. The research project was able to integrate representatives from all of the key organizations in the project network that helped participants to create an overall picture of the whole construction process. The understanding of the overall process can be seen to form a shared mental model that can be used as a framework when moving further in the knowledge creation process. Achieving mutual understanding of the impact of BIM implementation seemed to be especially beneficial in the construction industry, which is characterized with complex end products and the fragmentation of the production network involving several different specialists. As the case project increased the researchers` understanding about the phenomenon and produced quality and rich data to use for scientific study, the interactive action research methods may also have enhanced the quality of the academic research and the relevance of the results, as suggested by Rynes et al. (2001).

In the case project, the most important tools for converting tacit knowledge into a tangible format were a visual process map and the final report. The visual process map was used to integrate the different perspectives of the different organizations and represent the complex interdependencies of the individual tasks in a simple manner. The accurate presentation of the complex interaction point can also be used to coordinate change that was identified as a crucial challenge during BIM implementation based on the literature. For example, the visualization helps to identify, which problems can be solved by developing software and what can be solved through education and instructions. In the final report, the key challenges were gathered and best practices were identified from the project. In the project-based industry such as the construction industry, documenting the lessons from a project in such a detailed manner may facilitate the knowledge transfer between projects and thus enable diffusion of BIM practices.

The knowledge combined during this case project was mostly practical. Combining the theoretical knowledge with practical knowledge gathered during the case was left beyond the scope of this case study, however the empirical data gathered during the project also is a part of academic research. The combination of the different perspectives across the project organization facilitated inter-organisational learning. Most organizations were well aware of their own processes, but did not know how they were affecting the function of the other organisations within the network. Combining different attitudes, in a manner of speaking, opened the interfaces of individual organizations to be used in inter-organisational process development. The role of researchers as a neutral facilitator was seen to be beneficial to balance power distribution and thus relieving tensions in the project network and facilitated the collaborative knowledge creation. The internalization of the knowledge produced during the case project was mostly left for the companies. Most of the results of the research project were not ready to be implemented as such, but required development and application. That created minor tensions, because some of the participants would have like to get more ready, consulting-style answers to their practical problems.

Elements of Mode 2 knowledge production can be identified. The most evident element is the knowledge production in the context of application: The knowledge produced during the case project was intended to have direct practical relevance. The quality of the scientific publications is determined by disciplinary peer review judgements but the benefits of the action research project in general are evaluated more broadly, as in Mode 2. The transdisciplinarity in the case project stemmed not from the collaboration of scientists utilizing methods and theories from different disciplines, but from the collaboration of diverse set of specialists with different academic or practical background. In addition, the results were diffused in the first instance by the participants and only in the second instance through institutional channels reporting results in professional journals. In regard to heterogeneity and organizational diversity of knowledge production, academic research in the action research case project did not have a monopoly of knowledge production, but it still had a crucial role.

To conclude, action research methods seems to be a way to bridge the gap between practice and theory. The organization researchers have much to achieve, if they come down from the theoretical ivory tower. It seems that the action research methods used in the case increased the involvement and interests of the practitioners and enhanced the relevance and applicability of the results of the project. We are not urging researchers to abandon theoretical studies. Theoretically focused research could be seen as a link to the knowledge generated by other researchers on the other part of the world. For the practitioners in construction industry, scientific research may be the way to get rid of the grass root perspective and achieve a radical paradigmatic shift. Theoretical ivory towers are advantageous if they are used to get higher and to look further.

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