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Operational Knowledge for BIM Adoption and Implementation for Lean Efficiency Gains

Yusuf Arayıcı*, Paul Coates*

Abstract

BIM adoption entails substantial challenges such as the operational skills and knowledge for the users and it is required to understand the commands, protocols and standards of the environment in which they operate. Furthermore, different building types and applications or purpose of use of a BIM model add another layer of complexity in understanding the required protocols and standards. Thus, the acquisition of this operational knowledge and skills is fundamental impediment that restricts the adoption of BIM if it is not rigorously considered. Effective development of the aforementioned skills and knowledge to exploit the new BIM technologies for lean practices is not trivial problem. On the contrary, it requires conceptual and process knowledge to conform and create organisational, inter-organisational quality and requirements, which are likely to be a mixture of both organisation and project driven needs.

In this paper, the learning experience derived from a KTP (Knowledge Transfer Partnership) project of BIM adoption and Implementation between the University of Salford and John McCall Architects (JMA) in Liverpool, UK is reviewed and discussed. During the project, many of the challenges of training members of staff to use newly introduced BIM tools were addressed. How members of staff were educated in the use of BIM is considered and evaluated within this paper.

Keywords: Building Information Modelling, Knowledge Management, Operational Knowledge and Skills, Lean thinking, Architectural SME

* University of Salford Y.Arayici@salford.ac.uk, S.P.Coates@pgr.salford.ac.uk

1. INTRODUCTION

The construction industry in the UK is at a crossroads. As a result of national and international economic drivers, new expectations are being placed on the construction industry to produce more with less. By more, it means not only a greater quantity of buildings, but also buildings of a greater value to client. On the other hand, by less, it does not refer to cost only, but also buildings that emits less CO_2 in their creation and operation. These are the main challenges that face the construction industry today (Coates et al, 2010).

There is a danger in assuming that the type of knowledge that made an organization successful in the past will be the type of knowledge that will make it successful in the future. "*Paradigms shift*". In contrast, different approaches are required and new associations and understandings are necessary for success in the future. One possible approach is to look to other industries or countries and consider how similar transformations have been achieved.

A well documented approach to process improvement is Lean engineering: a methodology and strategy that emerged from car manufacturing at Toyota. Central to the Lean philosophy is focusing on what the customer wants and removing activities that do not add value from the customer perspective. In the Lean approach, non value adding activities are defined as wastes and an emphasis is made to remove these from the production process. This was the approach behind the changes implemented at John McCall Architects, which will be elaborated later in the paper. In addition, most successful manufacturing processes in advanced economies are neither fully manual nor fully automatic (Baudin. 2007).

In society, similar to the construction industry as a whole, architectural SMEs are also experiencing inefficient processes due to the lead times, fragmented nature of working style, repetitions, duplications,lack of collaboration and communication, and lack of information share and exchange. These drawbacks subsequently leads to time and and cost inefficiency as well as low quality design solutions causing serios problems and challenges later during the construction and post construction stages. It is witnessed that the rise of ubiquitous computing and computers already dominate the architec-

tural process. In many architectural practices, staff salaries account for over 65% of the expenses incurred in an architectural SME. In a symbiotic relationship between architects and technology, the potential machine automation needs to be utilized, as long as the practices are to remain competitive. In terms of the construction process, the drivers for automation embraced in BIM are: (Adapted from Tizani, 2007):

- To avoid repetitive manual re-entry of data and the move to an integrated practice
- To increase automation of the building process. A key element of this being machine readable data
- To accommodate design experimentation and awareness through virtual analysis
- To facilitate a more agile methodology
- To create data consistency across all forms of building representation over the building lifecycle
- To provide greater understanding particularly through visualization
- To create a more effective collaborative working environment
- To create a knowledge driven object orientated process

The question then is how these changes should be brought into architectural practice. In this paper, knowledge management is considered as the tool and how it can be used to develop the human element of the BIM technology adoption for automating the design process in an architectural SME. In Figure 1, these elements are shown as skills and process ability. BIM can be seen as an innovation that will allow organisations remain competitive. In this way, from an outcome-based perspective, organisations can manage innovative knowledge to create business value and generate a competitive advantage (Tiwana, 2000).

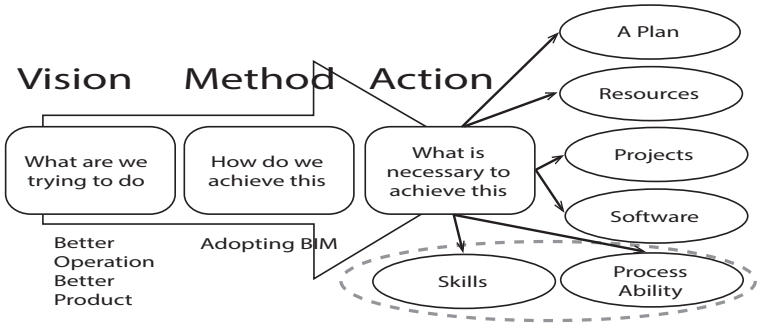

Figure 1: Vision Method Action

The basic vision at JMA was that BIM was being adopted to improve competitive position through an increase in employee productivity without altering the underlying management hierarchy of the company. It is also recognised that the training of staff is a critical part of BIM adoption. But this raises the questions when BIM training should take place, what form it should take, who should receive BIM training and what subjects should be covered in BIM training. Ultimately the aim was to create an active community of BIM learning and development within the company and to establish a facilitated learning path for new employees to the company.

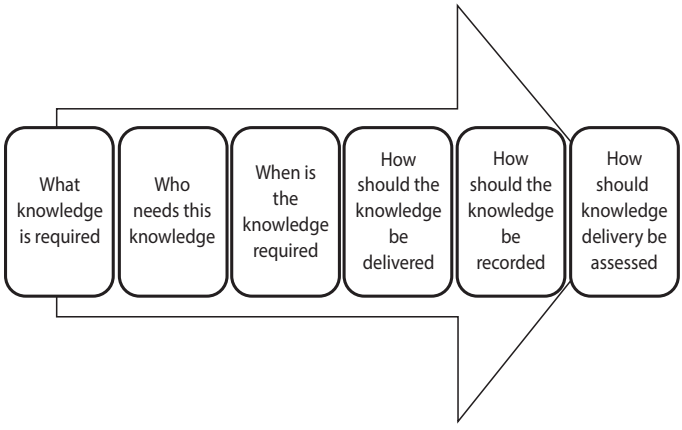

Figure 2: Application of knowledge to be delivered in a process of innovative change

The aim of the paper is to demonstrate a learning process and related knowledge transfer skills and capacity building in the overall BIM adoption process, which employed a socio-technical view of BIM implementation in that it not only considers the implementation of technology but also considers the socio-cultural environment that provides the context for its implementation

2. THE CASE STUDY COMPANY: JOHN MCCALL ARCHITECTS (JMA)

The company was established in 1991 in Liverpool in the UK, and has been involved in architecture and construction for more than 17 years designing buildings throughout Northwest England. Focusing primarily on social housing and regeneration, private housing and one off homes and large extensions, the company is known for good quality, economical, environmentally sustainable design. JMA works with many stakeholders from the design through to building construction process and the associated information is very fragmented. Projects in which JMA are involved are typically of 2½ years duration, involving many stakeholders and requiring considerable interoperability of documentation and dynamic information.

JMA operate within the architectural niche of social housing and as a forward thinking company, they approached the university to improve their design process and technical capabilities via BIM adoption and implementation in order to attain competitive sustainable advanatages in their market place. This effectively provides a greater focus for the knowledge required by the company and also a focus for how BIM tools should be used in the company.

Historically JMA used a 2D CAD tool for two decades. The company also has its own procedures and templates to optimize its practice. However, the current practice with this 2D CAD tool brings about some inefficiencies such as timescales, deadline pressures, duplications, lengthy lead times, lack of continuity in the supply chain, over processing, reworking, overproduction, distractive parallel tasks, lack of reliability of data and plan predictability, lack of rigorous design process, lack of effective design management

and communication. Hence, the company needs to improve its capacity for (Arayici et al, 2011):

- greater integration and collaboration with other disciplines in the production process;
- adopting technology change to provide a more effective business process;
- effective intelligent real time response; and
- moving into related building sectors.

At the strategic level, lean principles (Koskela, 2003), have been utilized and they formed the seven pillars of the BIM implementation strategy:

- eliminate waste;
- increase feedback;
- delay decision;
- deliver fast;
- build-in integrity;
- empower the team; and
- see the whole.

There was no practical understanding and awareness of BIM in the company at the beginning of the project. Yet, senior managers of the company had some visionary understanding of BIM for investment to attain competitive advantage and better position in market place and provide sustainable green design solutions in the future.

The next section explains the research methodology of the paper

3. RESEARCH METHODOLOGY OF THE PAPER

An action research oriented qualitative and quantitative approach for discovery, comparison, and experimentation has been employed in the re-

search. This is because, the knowledge transfer project (KTP) project with JMA also provided an environment for "learning by doing" (Boshyk and Dilworth, 2009). Further, action research provides dual commitments: to study a system, which is JMA's architectural practice; and concurrently to collaborate with the members of the system, which are JMA's staff, in changing the system towards a desirable direction. Accomplishing these twin goals requires the active collaboration of researchers and practitioners, and thus it stresses the importance of co-learning as a primary aspect of the action research process (O'Brien, 2001). Furthermore, primarily, its focus is on turning the people into researchers; people learn best and more willingly apply what they have learnt when they do it by themselves (Coghlan and Brannick, 2001). It also had a social dimension; the research takes place in real world situations and aims to solve real problems. In accordance with the action research philosophy, the BIM implementation process and subsequent action learning was carried out through the four stages (Arayici et al, 2011) as illustrated in Figure 3.

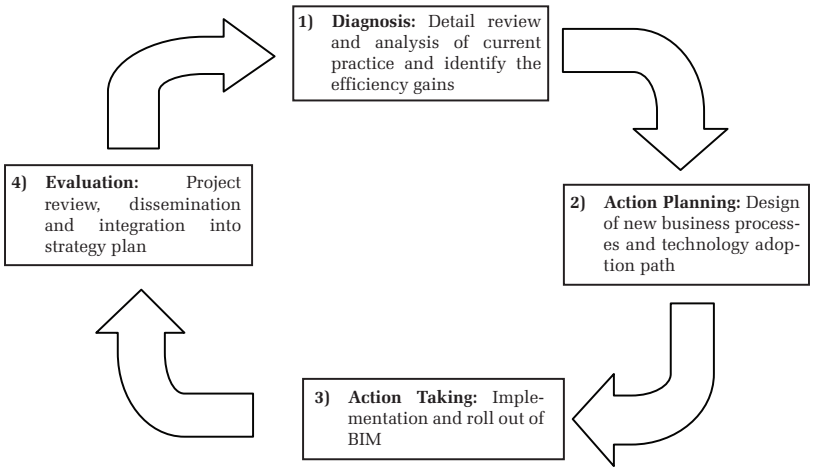

Figure 3: Action Research Oriented BIM Adoption Process (Arayici et al, 2011)

Details of the BIM adoption process can be found at Arayici (et al, 2011). The remainder of the paper elaborates the training activities for capacity building and knowledge transfer through those action learning stages and highlights the outcomes.

3.1 DIAGNOSIS STAGE

3.1.1 Establishing the Knowledge Requirement for BIM Implementation

Figure 4 shows the range of knowledge as part of the BIM implementation at John McCall Architects, which were required for successful adoption of BIM. This range of knowledge ideally should be possessed or acquired by the BIM Champion (the person leading the project). However, all of these areas of knowledge are not required by staff working within the BIM environment on a day-to- day basis.

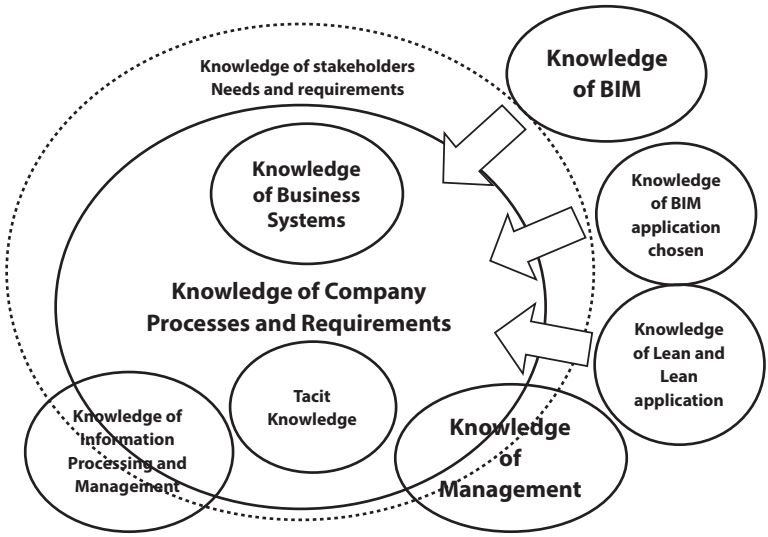

Figure 4: The knowledge required to implement BIM

When implementing BIM, it is desired that the staff development is achieved up to functional BIM user level (see figure 5). However, all the staff within the company should be reviewed and the level which they are to achieve and by what date should be established. But individuals at expert and specialist levels may also be required. On the other hand, providing the staff with inaccurate training or too much can lead to waste of time and resources. Furthermore, giving insufficient training can also result in disastrous consequences

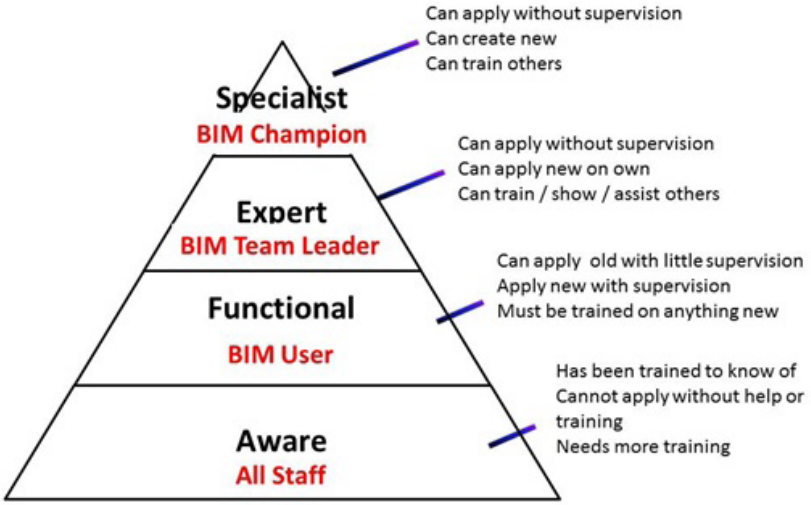

Figure 5: Different level of staff ability

3.1.2 Integrating Training in the Overall BIM Adoption Programme

Before the relevant knowledge is delivered to the company staff via the training programme, it can be reviewed and organised by an academic to ensure the systematic delivery and high level of intake by the staff. Besides, this systematic delivery can be carried out through the action research cycles during which knowledge acquisition and discovery can occur, leading to experiential learning for the staff . This is because knowledge without use in applications can quickly become obsolete and forgotten, thus information and knowledge should be shared and grown through applications, which can be also considered as project based learning.

If knowledge is not available at the time it is required this may lead to abortive work, waste and possible liability. The provision of knowledge can be divided into two types. These are just-in-time knowledge and just-in-case knowledge. Just-in-time knowledge is supplied before the knowledge is to be applied whereas just-in-case knowledge is knowledge is provided in case of need at some point later in time. Deciding into which category the knowledge should be allocated also to some extent determine its appropriate method of delivery.

3.2 ACTION PLANNING STAGE

3.2.1 Deciding in What Forms Training Should Take

The process of acquisition of knowledge occurs through abstraction, induction and conception. Due to the complexity of knowledge to be delivered for effective BIM operation, a simple brain-dump in recorded or presented form is not sufficient to fulfil the educational requirements. Recorded and presentational forms of knowledge transfer need to be integrated with action based and ideally collaborative learning based techniques. To decide the form of the training, the following issues were considered:

- How much time is available for training
- where and in what environment is the training to take place
- what equipment and software can be used as part of the training
- what is to be taught, what knowledge needs to be transferred
- what is the level of retention necessary
- when the lessons are to be taught
- how the training is to be delivered
- how many staff are to receive the training
- the cost of providing the training
- the skills of the educator
- what knowledge and concepts the staff already have (ideally training should be build on top of existing skills and concepts). Questionnaires and interviews can be used to document the skills that members of staff have.
- How much importance is given to the training by the staff and the company
- How well the training minimises anxiety associated with innovational change
- How complex is the knowledge to be transferred
- what is best learnt by individuals and what is best learnt by groups

- what is the training development of classifications and class inclusion
- whether or not internal trainers should be used or should external expertise to be used

Types of training can include:

- Lecture
- Programmed Instruction
- Computer assisted instruction
- Audiovisual techniques
- Business games

When it comes to what learning practices were developed at JMA to implement BIM: Staff training was supplied through a mixture of mediums and methods. Some of the training was provided by external experts but the majority of the training was provided by the BIM champion, who was the KTP associate employed by the university but located in the company throughout the duration of the BIM implementation project. A number of issues should be considered when capacity building. For example, staff may or may not be convinced with what they are told. Yet, active involvement of a senior staff in the BIM training program is a powerful motivator to encourage staff on their road to learning BIM.

The overall BIM training and learning experience in JMA also showed that the best way to learn for learners is to construct their own knowledge rather than someone constructing it for them. This experience also coincides with the Constructivist Learning Theory, which states that learning is an active process of creating meaning from different experiences. In other words, students or learners will learn best by trying to make sense of something on their own with the teacher as a guide to help them along the way.

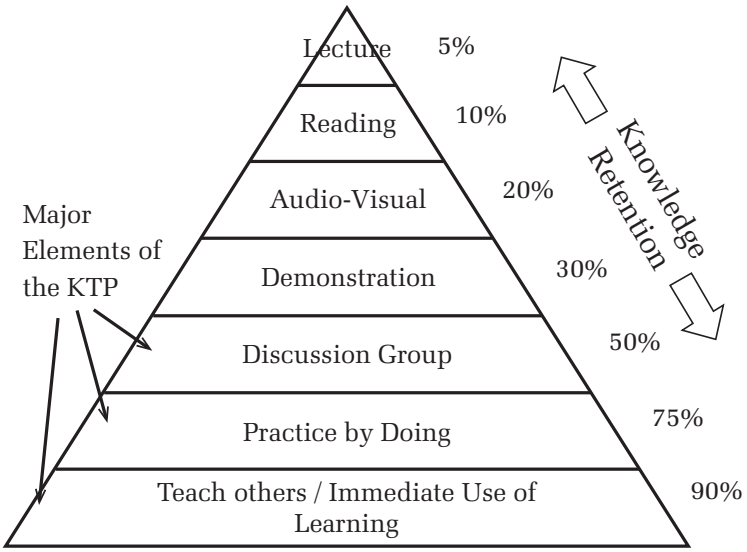

Figure 6: Analysis of best methods of knowledge acquisition (Adapted from Draper, 1996)

3.2.2 Building On Existing Knowledge at JMA

A considerable wealth exists in architectural practices associated with the knowledge of how existing processes are performed. This can also be embedded within the culture, language and customs in organisations. Tacit knowledge can be extracted through socialisation, externalization, facilitation, scenario mediation and semantic associations. These techniques were adopted at the outset of the BIM adoption process to acquire a deeper understanding of JMA's methods of operation. When adopting new technology, care must be taken that important knowledge is not amalgamated into obsolete processes.

In relation to the company specific strategy for effective knowledge transfer, the specific strategy adopted was dependent on the number of employees and the time scale during which BIM operation is delivered. In addition, different facets of BIM in relation to the various design and construc-

tion process stages should be also taken into consideration. For example, a model produced to facilitate environmental analysis is constructed differently from a model to be used for quantity-take off.

3.3 ACTION TAKING STAGE

3.3.1 Undertaking Training to Facilitate BIM Operation

An important part of knowledge maintenance is to ensure the knowledge is effectively collated. The collated knowledge can be existing knowledge or knowledge that has been cultivated or acquired.

Mentoring by senior staff to junior staff is highly important for successful knowledge transfer. However, it is also a fundamental challenge of knowledge management that the engagement of senior and experienced staff in the learning process with inexperience ones, who can easily attain knowledge with help from those who possess it. The immediate beneficiaries are often junior staff and trainees, while the senior staff are the main contributors in terms of both specialist knowledge and financial resources.

Table 1: List of One hour lecture based training sessions given at JMA

1 A14 Project Markup.pptx	1 ArchiCAD How to do roofs.ppx	1 ArchiCAD eco.pptx
1 ArchiCAD efficient models	1 ArchiCAD Libraries. pptx	1 ArchiCAD Stairs.pptx
1 ArchiCAD Things.pptx	A14 Add Ons.pptx	A14 Collaboration.pptx
A14 File Formats.pptx	A14 Layers.pptx	A14 Objects.pptx
A14 Template Files.pptx	A14 visual.pptx	A14 What's New.pptx
ArchiCAD 14 Guide Lines.pptx	ArchiCAD 14 Plot versus print.pptx	ArchiCAD Cusor Forms. pptx
ArchiCAD GDL Complex profiles.pptx	JMA Training.pptx	ArchiCAD Schedules. pptx
ArchiCAD Terrain Modelling.pptx	ArchiCAD Virtual Legends.pptx	ArchiCAD Wall Slab Junctions.pptx

Certain areas of knowledge must be continually acquired from outside the organisation. For example, new knowledge can be acquired by recruiting new staff with satisfactory technical knowledge. When employing new staff, it is important that their knowledge is effectively disseminated within the organisation. On the other hand, over the recent years, academic institutions have increased their role as knowledge providers to industry. In recognition of this, JMA used the knowledge transfer partnership to increase it knowledge in the area of lean agenda and BIM. In addition, an effective knowledge management strategy can also make it possible for knowledge acquisition via sharing at a variety of levels including such as;

- between individuals
- among a team
- among an entire organisation
- beholding brainstorming sessions
- organising training courses
- maintaining up-to-date documentation about processes and procedures
- between different organisations

3.3.2 Operators Manual

Developing a BIM manual provides a valuable learning tool, which can be used by the operators when help is not available from more experienced staff. Given the diversity in architectural practice, including the varying size and scope of projects, it is necessary for each firm to evaluate their project types, workflow and standards. For example, JMA works on several different types of projects. This includes extensions, single homes, housing estates, flats, old people's homes, interiors, single buildings, and unitised buildings. The question is whether these different building types should have their own separate template files or just be documented within the BIM manual, which requires inputs from multiple sources as illustrated in figure 7.

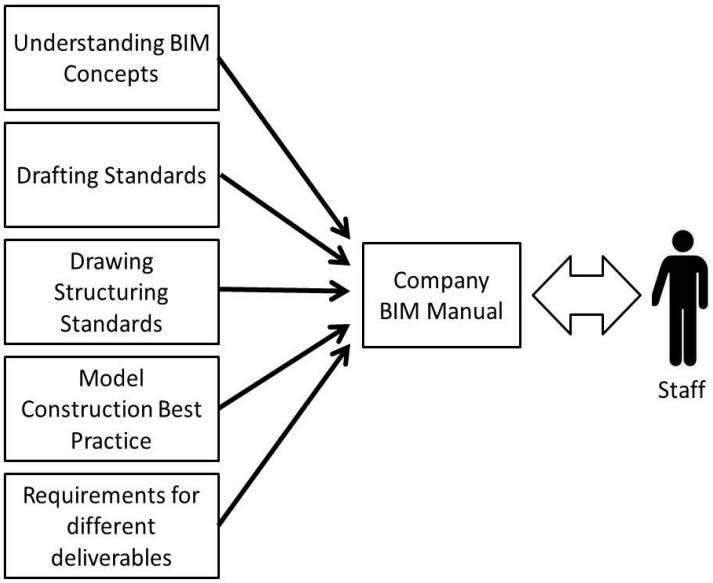

Figure 7: Inputs required for the BIM manual for JMA

The goal of the BIM manual was to standardize the process and procedures. It was developed during the time the piloting projects with BIM authoring tool were undertaken at JMA. As the manual was developed, it was presented to and reviewed by senior staff in the office. The BIM manual is seen very much as the legacy of the BIM implementation process providing a continual instrument and resource in the development of a BIM orientated approach. On the other hand, it is important that staff know how to use the knowledge resources available. Otherwise such resources will not be used.

As JMA predominantly undertake similar types of design projects, the lessons learnt on one project can be transferred to the next project they undertake. The goal is to ensure that the lessons learnt on one project are built into the next projects for continuous improvement in efficiency (cost and time) and effectiveness (quality and sustainability). Therefore, the artefacts produced in the architectural process, which are for the actual construction of the buildings are required for knowledge extraction and stored as companies knowledge asset, which can then formalized into the company's procedures and standards as illustrated in figure 8.

3.4 EVALUATION STAGE

It became obvious that many in the company was not clear about what really BIM means for them. It was observed that how the professionals are practicing really affects that how BIM can be implemented efficiently at organisational level and indeed that the limiting factor in BIM deployment was more often than not the skills, but competencies and knowledge and capacity of the people in the company. In order to teach and knowledge transfer in BIM effectively across the company, it was required to identify how it would affect the roles of the individuals in the company. It is believed that closer link and communications via the KTP between Salford Univesity and John McCall Architects played a key role in the capacity building in JMA.

Extensive training and lecture programmes were also conducted alongside the piloting projects and the real use of BIM on the JMA's current projects. Training and upskilling the staff via action research approach was very effective. For example, provision of instant reflection of theoretical knowledge into real practice in a safe environment with the support from the KTP team helped to ease the radical changes and process improvements in the company. This made the training process an unforgettable learning and working experience. The training covered a range of subjects from basic operational skills and JMA modelling standards to JMA's methodology for BIM use and working with others in a collaborative BIM environment (Coates and Arayici, 2012). The type of activities included in the training is shown in figure 9.

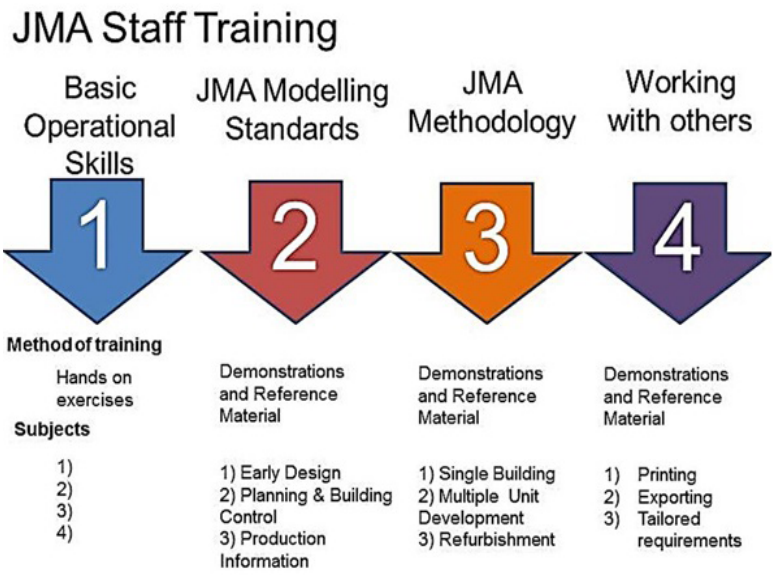

Figure 8: Areas of staff engagement for training and knowledge transfer for

While BIM was vaguely seen as technology by the staff at the earlier stages of the BIM adoption process, half way through the action learning process in the KTP, it was seen as much about people and process as it was about technology. The prototype projects from the past and current projects were used as the learning vehicle that required them to investigate information, assembling analysis of information, presenting responses, using the projects as means to demonstrate sense of inquiries, research and synthesise information in a meaningful way, thereby leading to developing understanding and knowledge by that means. This can be interpreted that the principles of BIM can be effectively taught by "learning by doing". In this sense BIM goes beyond being a subject area and becomes pedagogy as a way for training and knowledge transfer. Figure 10 below shows the BIM training exercise through the action learning in JMA, which represents evolutionary understanding of BIM training possibilities from a technology and topic towards more complex and in-depth possibilities of training and knowledge transfer such as approach and pedagogic stance in BIM training and knowledge transfer.

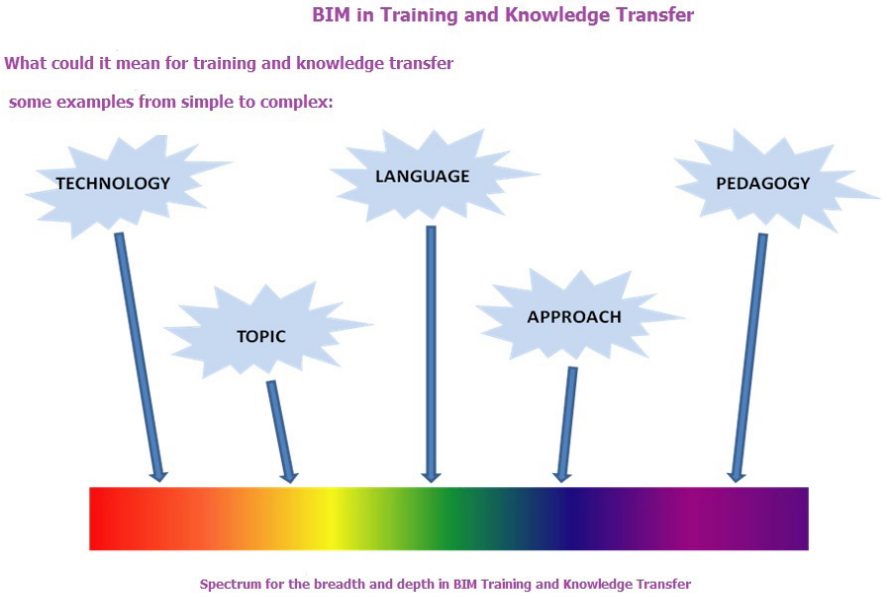

Figure 9: BIM means differently from simple (technology) to complex (pedagogy) in its adoption for training

In addition, from Higher Education perspective, developing educational opportunities in BIM is as much challenging as training and up skilling professionals in the construction sector. Further, developing educational material and designing and developing curriculums of BIM from scratch is a big barrier. This is because, most of the sources of materials are either from research studies, which are mainly released via publication only, or the vendor oriented material, which are biased towards proprietary BIM tools. In order to overcome this challenge and barrier in educational material development, one effective way is to undertake KTP (Knowledge Transfer Partnerships) projects between universities and companies through which academia share knowledge and assist the industry in BIM adoption and implementation. This sort of collaboration will also create an invaluable opportunity to develop high quality, accurate educational material for BIM courses at the universities in both undergraduate and postgraduate levels.

4. CONCLUSION

This paper demonsrated the knowledge gain and use of this knowledge in the upskilling staff as part of the BIM implementation for an architectural SME. Since there is no other similar systematic and in-depth BIM implementation within a real life context, this can be used by researchers and practitioners as a guide or systematic approach based on action research that considers not only the technical sides of the adoption but also takes into account the socio-cultural environment within which learners or trainees become active researchers.

In the adoption of BIM, education and training should be an ongoing exercise. Also the staff ability and the effectiveness of the training should be diagnosed and observed. BIM implementation aligned with an appropriate training strategy will lead to an enhanced productivity payback as seen from JMA BIM adoption case study project. Visible support and leadership by the senior management for innovative training programmes is important for the successful conduit of the BIM adoption and upksilling the company staff. Otherwise, it may lead to ad hoc implementation and subsequently diminished motivation and cultural resistance to change. Thus, paper also reflects how important effective leadership is for achievement of process improvement and capacity building for the targeted productivity.

Although up to a certain level, BIM knowledge and making sense of the technology can be acquired in a classroom setting learning by doing was a critical element of the learning strategy adopted at JMA, actual project based piloting through a intended lean process would also be essential for lessons learnt and capacity buildings towards a complex pedagogic level of training and knowledge transfer.

Finally, knowledge transfer provided the opportunity to realise which theoretical knowledge from academia is practical in operation and helped for what extent the theoretical knowledge can be measured in operation and facilitated to acquire implicit knowledge from the real practical context, which helped to improve the theoretical knowledge towards a more practical strategic vision for the systematic BIM implementation for architectural SMEs.

Acknowledgement

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