BUILT ENVIRONMENT EPISTEMOLOGY: KNOWLEDGE EXCHANGE THROUGH UNIVERSITY-INDUSTRY COMMUNITIES OF PRACTICE

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ABSTRACT: This paper explores the nature of knowledge through a history of knowledge production in society. It emphasizes the modes of knowledge including explicit and tacit and argues for knowledge management and knowledge transfer as strategies to both codify explicit knowledge and extract and transfer tacit knowledge. One method that has been identified to encourage tacit knowledge transfer is communities of practice (CoPs). Further, the paper argues for ways in which the university as an institution and network of institutions may serve as a CoP knowledge hub in specific regions to foster new modes of knowledge transfer beyond traditional scientific means. The paper concludes with a preliminary proposal for this type of CoP in the Built Environment Exchange (beX) as a model for international university – industry knowledge transfer in the construction sector.

KEYWORDS: epistemology, knowledge exchange, knowledge production, construction knowledge

INTRODUCTION

Construction in large measure, and multi-national global companies notwithstanding, is regionally specific – material, labor, and climate (Rhodes, 2015; McIntyre & Strischek, 2005). Although there is much explicit knowledge codified in codes, publications, and now video online, the majority of knowledge regarding construction is tacit or implicit, embedded within people and organizations (Chimay et al, 2007; Bigliardi, 2014). Therefore, the best practices in construction business, design & manufacture, and skills, to name a few, and its associated knowledge are held by individuals within universities, companies, governments and associations in discrete regions. This is perhaps one of the reasons why productivity continues to decline and presents a barrier to the advancement and innovation in the construction sector (CII, 1996; Latham, 1994; DTI, 1998; Barker, 2004; MMC Cross Industry Group, 2006; HM Government, 2025).

This study of knowledge in construction has been conducted through a robust literature review in order to: 1) identify the knowledge barriers in construction; and 2) create pathways to overcome these knowledge barriers. This literature review includes an epistemological analysis of construction and emphasizes types of knowledge including explicit and tacit. It argues for knowledge management and knowledge exchange through communities of practice (CoP) as strategies to both codify explicit knowledge and extract and transfer tacit knowledge in the construction sector.

1.0 KNOWLEDGE EXCHANGE

There are two primary types of knowledge. Explicit knowledge is representative, able to be codified and communicated. It is data, records, and documents. In academia, explicit knowledge may be journal publications, databases, books, websites and videos. Conversely, tacit knowledge is difficult to transfer by means of writing or speaking. It is embedded in people, organizations, societies and cultures (Lam, 2000). It is based on experience, thinking, competence and commitment (Polanyi, 1966). In academia, tacit knowledge is found in conference discussions, workshops, internships, and exchanges. Explicit knowledge, knowing that, what and why, constitutes an estimated 10% of our knowledge repository as humans, while tacit knowledge, knowing who and how, makes up 90% of our total knowledge base (Fig. 1) (Wah, 1999; Bonner, 2000; Lee, 2000).

Knowledge exchange is sometimes referred to as knowledge management, the process of creating, sharing, using, and managing the knowledge and information of an organization (Girard & Girard, 2015). Tacit knowledge is key to overall quality of knowledge exchange (Quinn et al., 1996, Wah, 1999; Goffee and Jones, 2000). Effective transfer of tacit knowledge generally requires extensive personal contact, regular interaction, and trust (Goffin & Koners, 2011). Researchers indicate that tacit knowledge is revealed through practice in a particular context and transmitted through social networks (Schmidt & Hunter, 1993). Therefore, tacit knowledge is exchanged through a network of individuals, organizations in a community of practice (Goffin & Koners, 2011). It relies on experience and without it, tacit knowledge is not able to be transferred effectively (Lam, 2000).

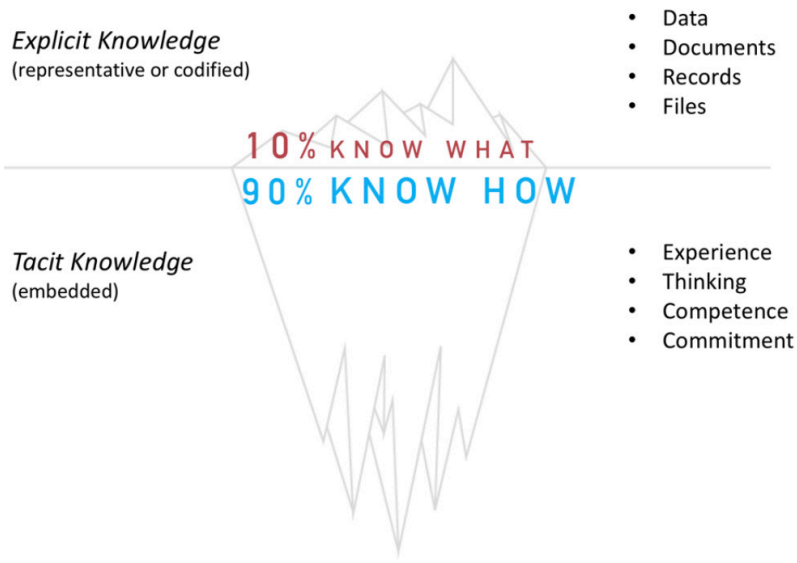

Figure 1. Types of knowledge – explicit and tacit knowledge

Explicit and tacit knowledge are often presented as divergent types. This is not the case however. Explicit and tacit are not separate modes of knowledge but in fact a continuum (Nonaha & von Krogh, 2009). Therefore, it is necessary to explore the concept of knowledge conversion, sometimes referred to as knowledge transfer, whereby knowledge is exchanged from one type to another.

Explicit knowledge may be transferred to another explicit form. This transfer is called combination. An example is academic archival research whereby texts are compared, synthesized and new explicit knowledge is developed, not unlike the function of this paper. Explicit knowledge to tacit conversion is called internalization. Knowledge is a human function; therefore, people internalize the knowledge making it part of their subconscious activity. An example of this transfer might include reading instructions to assemble furniture and then internalizing the operations after repeated activity. Tacit to explicit transfer is termed externalization, making that which is not easily explained or documented into a written or spoken form that is easy to communicate and disseminate. This transfer is the opposite of internalization. A worker for instance may have knowledge of how to assemble furniture, and then is asked to codify this knowledge in a training manual. Finally, tacit to tacit forms of transfer is called socialization. This transfer tends to be informal and often seen in apprenticeships. It is experienced in the very act of doing (Table 1).

Table 1. Knowledge conversion scenarios and terms

CONVERSION SCENARIOS	TERMS *(Nonaha et al 2002)*
EXPLICIT → EXPLICIT	*Combination*
EXPLICIT → TACIT	*Internalization*
TACIT → EXPLICIT	*Externalization*
TACIT → TACIT	*Socialization*

2.0 KNOWLEDGE IN CONSTRUCTION

Knowledge management is a growing field not just because it explains how knowledge is produced and transferred, but also because it performs. A growing number of organizations are now implementing knowledge management in their planning because the results include business process efficiencies, better organization, and higher motivation

among personnel and stakeholders (Nonaka & Takeuchi, 1995; Rezgui et al, 2010). The existing literature on knowledge exchange in construction is based on knowledge within specific architecture, engineering and construction firms, or project knowledge management and exchange between project stakeholders. It tends to focus on IT solutions for knowledge management whereby firms may codify explicit knowledge and exchange it across the firm and multiple office locations (Alvai & Leidner, 2001; Huysman & Wulf, 2006).

There are few references that cite the nature of construction knowledge more generally and theoretically. Of these sources, Patrirage et al (2007) claim that construction is tacit knowledge intensive, relying on experiential legacy knowledge embedded in people and organizations. In their research, the authors reveal that in construction valuable knowledge is wasted unless organizations make better use of tacit knowledge. Similarly, Woo et al (2004) explain that although construction firms are proficient at collecting and storing explicit information, they are poor at knowledge retrieval and exchange. The authors state that construction professionals find it difficult to reuse core experts' knowledge for highly knowledge-intensive AEC activities. Therefore, there is an argument for a method of disseminating tacit knowledge from experts' subconscious in the construction industry.

Further, Javernick-Will and Harmann (2011) point out that knowledge exchange in construction is a challenge because it is context specific. The authors explain that each region and country has unique explicit building code regulations, material and building system preferences, and labor skills availability. The authors utilize the theory of learning organizations – a concept coined by Garvin (1993) that refers to an organization whose personnel continuously increase in capability personally and collectively - and apply it to the field of construction. The basis for learning organizations includes proactive plans to engage people to gain new knowledge and exchange that knowledge through collaborative arrangements and networks (Kululanga et al, 1999).

3.0 KNOWLEDGE PRODUCTION

3.1 Mode 2

Gibbons et al (1994) in their seminal work The New Production of Knowledge, take the epistemological theory of two types of knowledge, explicit and tacit, further in proposing a new model for knowledge creation. The authors explain that historically traditional knowledge creation, called Mode 1, is the Newtonian model of inquiry that follows sound principles of scientific method. In this mode, the cognitive and social norms determine what counts as a significant problem and who is allowed to practice the solving of such problems (i.e. universities). Mode 1 is historically created and developed by and for the sciences. The method has now been adopted by the arts and humanities, architecture and engineering, law, business and seemingly every academic unit on campus by virtue of university massification in society. The authors point out at that these disciplines perhaps were never intended to be scientific in principle.

By contrast, Mode 2 knowledge production is created in the context of application. While Mode 1 is disciplinary and homogeneous, Mode 2 is transdisciplinary and heterogeneous. Organizationally, Mode 1 is hierarchical and self-preserving, while Mode 2 is flexible and transient. Mode 1 employs peer review based on standards of practice. On the other hand, Mode 2 is socially accountable and reflexive. It employs a temporary set of actors, collaborating on a problem defined in a specific context (Gibbons et al, 1994:1-16). Mode 1 excels in explicit knowledge exchange while Mode 2 thrives in tacit knowledge arenas (Gibbons et al, 1994:17,19,24-26,168).

Mode 2 is diffusing, characterized by closer interaction of scientific, technological and industrial modes of knowledge production (Gibbons et al, 1994:2-5). Mode 2 weakens the disciplinary and institutional boundaries through transient clusters of experts. It encourages market differentiation and international competition that is a result of Post WWII diffusion of mass production technologies based on economies of scale. Specific knowledge bases are localized and contingent on regional industry knowledge (Gibbons et al, 1994:68) (Table 2).

Table 2. Dimensions of knowledge production and attributes of knowledge production modes

DIMENSION	MODE 1 ATTRIBUTES	MODE 2 ATTRIBUTES
Knowledge focus	Produced considering interest of academia	Produced considering the context of application
Mode of knowledge production	Expert-centred	Network of diverse stakeholders
Characteristics	Disciplinary and hierarchical	Transdisciplinary and horizontal
Relevance	Relevant to academics	Relevant to society

Dissemination	Through indexed journals	Diverse channels reaching a wider audience
Quality assurance	Peer reviewed publication	Quality review process and research uptake/impact

3.2 Knowledge Hub

Youtie and Shapira (2008) present an argument for the evolution and transformation of the role of universities to advance technological innovation and economic development. The authors document the transition of the university as a knowledge factory into a knowledge hub. Prior to the 19th century, the university was primarily a storehouse of knowledge. These medieval institutions, including Oxford and Cambridge, is where scholars housed in colleges lived and learned cloistered from the general craft producing public. Universities expanded beyond Europe during the late 19th and early 20th century. Shortly thereafter, WWII initiated government and industry funded research at universities expanding global R&D efforts. The university in this period through the end of the 20th century was a supplier of inputs and outputs, a technology developer, and a knowledge factory for research, training and commercialization.

In the later part of the 20th century until today Youtie and Shapira argue that the university is seeing another identity change. It continues to serve as a knowledge storehouse and a supplier to the economy. However, the university is also now a knowledge hub. In this new role, it seeks to animate indigenous development, new capabilities, and innovation, especially within its region (Shapira and Youtie, 2004; Newlands 2003) (Table 3). In this function, the university spans between industry, government and society. It is integrated in an intelligent region and promotes indigenous development and new capabilities. Youtie and Shapira (2008:1190) conjecture that "in an increasingly knowledge based environment, high-performing institutions are those which have capability not only to develop, acquire and use codified knowledge, but also to effectively advance, distribute, and recombine tacit knowledge".

Table 3. Transformation of the university role in society.

MODE	TIMEFRAME	CONTEXT	ROLE	PERSONA
Traditional	Prior to 19th C.	Craft production	Storehouse of existing historic knowledge	Elitist above society
Supplier	19th C – Late 20th C.	Industrial mass production	Knowledge factory for research, training and commercialization	Supplier of inputs and outputs, a technology developer
Hub	Late 20th C - present	Post-industrial knowledge economy	Integrated institution in intelligent region, promotes indigenous development and new capabilities	Spanning entity between industry, government and society

4.0 COMMUNITY OF PRACTICE

A community of practice (CoP) is group participation in an activity for which the participants share understandings that what they are doing means something in their lives and those for which they serve (Lave & Wenger, 1991:98). It is a set of relations among persons, activity, and world over time and in relations with other topically overlapping CoP groups. The critical element in CoP theory outlined by Lane and Wenger is that it is an intrinsic condition for the existence of knowledge (1991:98).

Rezgui & Miles (2011) outline a process of leveraging social capital in knowledge exchange via CoPs in the construction industry. In this way, communities are developing across organizational and project specific lines that share a common concern or have similar problems. Knowledge is shared through physical or virtual means synchronous and asynchronous on a continual basis (Rezgui & Miles, 2011:16; Wegner et al, 2002). The authors illustrate how these types of communities foster innovation in a particular sector or interest area (i.e. sustainability, building performance, lean construction, offsite construction, etc.) This has given way to additional organizations whose role is to provide a community of practice such as trade associations or advocacy institutes on behalf of these interests (i.e. National Institute of Building Sciences, American Institute of Architects, Modular Building Institute, etc.).

Li et al (2009) explain that CoPs require that the group exist for a duration of time amongst a changing participant

pool in order to develop its own culture and communication methods. The community learns as individuals observe and model one another. Bandura (1977) states that observing behavior allows for a more efficient way of acquiring tacit complex knowledge by way of skills than through personal trial and error. A learning community therefore must develop a high level of trust among its participants in order to be functional (Kling & Coutright, 2004). They can be located discretely or dispersed, but are linked by common interests and goals. Virtual learning communities are growing each year and offer many advantages to traditional communities. Learning communities must be monitored for effectiveness because they are susceptible to favoring sustaining relationships over learning (Wenger et al, 2002). In this way, there is a real risk of group-think (Turner & Pratkanis, 1998), and/or becoming dormant and dysfunctional (Leconi, 2002).

CoPs borrow from education, sociology and social theory with a focus on socialization and learning of the individual (Li et al, 2009). Wegner described CoPs as a group contained by three dimensions: mutual engagement, joint enterprise, and a shared repertoire. Mutual engagement represents the interaction between individuals; joint enterprise is the process in which people are engaged; and shared repertoire is the common resources members use to accomplish their work.

Wenger suggests that CoPs not only emerge spontaneously, but can also be intentionally fostered, structured, and created to cultivate the qualities of a CoP and thereby enhance their competitiveness and effectiveness (Wenger, 2002; Saint-Onge & Wallace, 2003). In this more mature approach to CoPs, the authors revised the 3 dimensions of mutual engagement, joint enterprise, and a shared repertoire and named them domain, community and practice (Wenger et al, 2002; Wenger, 2000). The domain is a common ground of minimal competence that differentiates members from non-members. Community is the social structure that facilitates learning through tacit interactions and relationships. And practice refers to shared repertories of resources that include explicit documentation (Li et al, 2009).

Wegner and colleagues claim that CoPs can optimize the creation and dissemination of knowledge when these three dimensions are present (Table 4). Li et al suggest two additional dimensions in order to realize a mature CoP. The first is a leader/champion, a person well respected in the organization who is responsible for spreading the word, recruiting, and providing resources for the group. The second is a facilitator that is responsible for the day-to-day activities of the CoP. It is suggested that this person understand the overall mission of the organization and is well connected with members (Li et al, 2009). In CoP studies, the facilitator role has been deemed the critical link, the absence of which or if the facilitator fatigues, most often leads to CoP failures (Lathelean & May, 2002; Gabby et al, 2003; Ardichivili et al, 2002; Pereles et al, 2002). Sometimes the leader is the facilitator, while in other cases they are separate roles (Pereles et al, 2002; Chua, 2006). This decision is based on a number of factors including the size of the group, the geographical location of the members, the topic, and overarching goals of the CoP.

Table 4. Community of practice domains. (Wenger et al, 2002)

COP Dimensions	
Domain	Common ground of minimal competence differentiates members from non-members
Community	Social structure that facilitates learning through tacit interactions and relationships
Practice	Shared repertories of resources that include explicit documentation
Leader/Champion	Person or group that will advocate for the community and champion is vitality
Facilitator	Individual that facilitates the community interaction and structures the knowledge exchange

5.0 BUILT ENVIRONMENT EXCHANGE

The authors of this paper have created an international CoP focused on the topic of offsite construction called the Built Environment Exchange (beX). This progresses the concept of the university as a knowledge hub to the university as a CoP, working at the intersection of industry, government, and society. Instead of operating at a regional scale however, the beX CoP works at a global scale, exchanging knowledge across international contexts. This integrated institution is an intelligent global network that promotes international knowledge exchange in off-site construction. While many disciplines are represented in off-site construction (i.e. architecture, engineering, manufacturing, development, construction, etc.) the topic is unique and requires a particular knowledge base and knowledge growth to ensure the

effective implementation of off-site and realize its potential is meeting the demand of the construction market broadly. The proposed beX is being tested for effectiveness and refined so that it is generalizable to other topics in construction and potentially provides a model that is replicable by disciplines outside of construction. The beX is a co-evolved, co-developed international research exchange program led by university champions (faculty) at the following 6 institutions that will initiative the pilot test of the start-up CoP: Edinburgh Napier University - UK, University of Utah - U.S., Lulea University – Sweden, University of Alberta – Canada, Hong Kong Polytechnic University, China, and University of Sydney - Australia. The beX is a partnership of researcher and students at the engaged universities and industry personnel to develop future skills and talent to modernize the construction sector and increase productivity. The aim is to create opportunities for graduates, employees and construction companies to design and collaborate on innovative projects, supervised by research leaders, with access to international partnerships and entrepreneurial training. The beX provides a pipeline of future talent for industry and academic partners (Table 5).

Table 5. Goals of the Built Environment Exchange (beX)

GOAL	DESCRIPTION
Off-site Construction Business Development	To develop the future technical and business leaders who will modernize the built environment sector and spearhead the drive for sustainability and efficiency, enabling the sector to deliver the sustainable communities of tomorrow.
Workforce Development	To provide companies and industry lead organisations with opportunities to engage talented graduates on innovation and development projects.
Student Development	To provide opportunities for graduates and talent in the built environment to develop higher-level technical and business/ entrepreneurship skills, and to gain international experience.
Faculty Development	To develop academic practitioners who will integrate with industry to direct future research and deliver long-term skills development.
Internationalization of Off-site Construction	To internationalize research collaborations and increase global industry impact.

The beX provides unique opportunities for companies and graduates to grow and develop together through tacit exchange. The transfer of new knowledge and skills is enabled by:

1. *Sponsored Project*: sponsored by construction industry companies, student scholars are matched with companies to research and commercial activities via the host university partner, to work on paid projects delivering sector-defined innovation requirements while developing their enterprise skills. Students can work at the university, embedded within the company or from another location altogether, supported by faculty researchers and access to facilities at the partnering university institution.

2. *Entrepreneurship Training*: student scholars engage in a workshop series provided by the entrepreneurship training at respective university partnering institutions to hone business and enterprise skills oriented at the construction sector and the industry partner through the employability project. Entrepreneurship sessions include the industry partner(s) and faculty as appropriate to envision new products and processes aimed to transform and propel the construction sector into the future.

3. *International Exchange*: an internship available to penultimate year undergrad and graduate students from diverse disciplines. Scholars engage in an 8-10 week industry led research based project, supervised by academia and mentored by industry, with the opportunity for an international placement facilitated by the partnering universities.

CONCLUSION

Knowledge in the built environment is primarily tacit or embedded within individuals and organizations. Tacit knowledge represents up to 90% of the total knowledge repository in society and the disciplines of construction. As such it is imperative that the field of construction find ways to convert tacit knowledge to explicit knowledge through codification and dissemination, and transfer tacit to tacit knowledge through individual and organizational sharing. This research suggests that tacit knowledge production and management can best be fostered by means of communities of practice at the nexus of universities, government, industry and society. Further, value of the university serving as a knowledge hub and facilitator of a community of practice has been found in other disciplinary field outside of architecture, engineering and construction. We suggest that the built environment academic units may lead in a new mode of knowledge production that builds upon scientific method toward applied learning. Whereas this is not the traditional role of academia, in this way the university serves as a facilitator of emerging modes of learning, knowledge production and knowledge exchange. A specific international knowledge exchange program has been developed by the authors, called the built environment exchange. The model is based on this literature review and theoretical construct. Student researchers exchange internationally during the summer weeks, sponsored by industry companies, to engage in applied scholarship, then return to share this knowledge with their home context. BeX, concerned with off-site construction as a topic, is being piloted in the summer of 2017 and the results will be published at a later date for replicability by other topical CoPs in the built environment as well as disciplines outside of the construction sector.

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