2016

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Shaurette, Mark, "Use of Concept Maps to Illustrate Barriers to Construction Industry Inter-Organizational Communication: a Comparative View from Students and Professionals" (2016). *School of Construction Managment Technology Faculty Publications.* Paper 2.
http://dx.doi.org/10.1080/15578771.2016.1226214

Use of Concept Maps to Illustrate Barriers to Construction Industry Inter-Organizational Communication: a Comparative View from Students and Professionals

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Because of the fragmented nature of construction industry inter-organizational communication, construction industry stakeholders must rely on information exchanges in order to produce new information and directives for the process. This communication process does not always happen smoothly due to possible barriers during the information flow. The purpose of this study is to understand these potential information flow barriers and to use concept maps to engage students in discussions about communication within the construction industry. Concept map activities performed with industry professionals and senior construction management students in separate phases are described. To complement the concept map findings, interviews with key professional stakeholders provide further depth on reasons for potential communication barriers in the construction industry. Findings from this study indicate that students' lack a thorough understanding of the holistic communication process and information flow that is critical to many construction project stakeholders. Guidelines are suggested for the use of concept maps as an educational activity that is engaging to students and will enhance their knowledge of information flows in the construction process.

Keywords: concept maps; inter-organizational communication; construction management

Introduction

Knowledge management (KM) in construction can be difficult due to the industry's fragmented nature. In addition, the construction industry is known to heavily rely on tacit knowledge, with a strong emphasis on experience. This is often a result of the one-off nature of projects (Dave & Koskela, 2009, Dubois & Gadde, 2002; Nesan, 2012; Woo et al. 2004). These characteristics affect how information flows between stakeholders in the process, making it difficult for novice as well as seasoned professionals to understand the entirety of the process.

Barriers to effective communication in the architectural, engineering and construction (AEC) industry result in a halt or reduction in the flow of information exchange because of miscommunications and/or misunderstandings. These miscommunications and/or misunderstandings could be influenced by "…communication skills of individuals, existing incentive systems, different representational formats, rapid change, local jargon, breakdown of information capture (i.e., overwhelming amounts of information), and cultural mores and norms for individual behavior." (p. 282, Sonnenwald, 1996). Although the construction industry's fragmented nature is well known and stresses the importance of effective transfer of information and knowledge between parties, Cheung, Yiu, and Lam (2013) indicate that "communication study is under-researched in construction engineering and management" (p. 947).

The need for effective communication skills in construction is reflected in the requirements for undergraduate education. The American Council for Construction Education lists three required learning outcomes – written communications, oral communications, and multidisciplinary teamwork skills – out of the total 20 accreditation standards for construction that are directly related to the ability of graduates to communicate effectively (American Council for Construction Education, 2016). Effective communication and collaboration is not only desired for construction graduates, but is also seen as part of the 21st century skills which are considered necessary for achieving success in the work place as well as in life (Larson & Miller, 2011). Based on these considerations, the research questions for this study are:

RQ1: What are common communication barriers in the information flow process identified by experienced construction stakeholders?
RQ2: How do concept maps of construction communication flow produced by experienced construction stakeholders compare to those of senior CM students and how can the use of concept maps in a CM classroom environment help provide students with knowledge of barriers to construction communication?

Some specific issues that lead to communication barriers in construction have been discussed in previous papers (Cheung, Yiu, & Lam, 2013; Olander & Landin, 2005). However none of them has taken a general approach of summarizing multiple possible communication barriers. This study seeks to not only provide a more systems' view of communication barriers in the AEC industry, but also to understand how aware construction management students and professionals are of common communications barriers. Through comparison of industry's and students' concept maps, researchers begin to understand the gap of knowledge between those two populations regarding a holistic view of information flow within industry. Further, the comparison demonstrates areas where construction educators can utilize concept maps to assist students in conceptualizing and discussing challenges to the flow of information in the construction industry.

Literature Review

In this paper, the concept of knowledge is closely related to that of applied expertise, and KM involves processes of creation and especially transfer of knowledge (Alavi & Leidner, 2001; Lin, Wang, & Tserng, 2006). In addition, research indicates that knowledge management is critical in the context of collaborative networks within different organizations (Gann & Salter, 2000; Mircea, 2005). Knowledge sharing in this context presents challenges, which can be related to "...the security of the communication channel, the organizational culture of the participants and their roles, the nature of knowledge (tacit and explicit; formal and informal), the organizational structure, and the support offered by the information and communications technology (ICT)" (Mircea, 2015, p. 58). This type of knowledge can also be costly and contain imbedded risk while depending on stakeholders to work around a shared meaning in order to facilitate communication (Ngai, Jin, & Liang, 2008).

The AEC industry relies heavily on tacit knowledge because of its fragmented nature and the uniqueness present in each project (Dave & Koskela, 2009; Dubois & Gadde, 2002; Lin, Wang, & Tserng, 2006; Woo et al., 2004). Knowledge management is different for tacit or explicit knowledge. Explicit knowledge is related to formalized and generalized knowledge (Alavi & Leidner, 2001; Lin, Wang, & Tserng, 2006; Mircea, 2015). Examples of this type of knowledge are best practices manuals, procedures, and formalized company standards. On the other hand, tacit knowledge is that which is not formalized. It is individual, based on one's experience, values, and depends on a specific context (Alavi & Leidner, 2001; Lin, Wang, & Tserng, 2006; Mircea, 2015). Examples of tacit knowledge are a carpenter's cutting and assembling skills, or other personal skills developed by experience. In general, this type of knowledge "...is difficult to express, represent and communicate" (Lin, Wang, & Tserng, 2006, p. 695). New knowledge created within each AEC industry project increases the expertise of team members, but it is not necessarily shared or transferred to others within the same organization due to the project-base nature of construction endeavors (Dave & Koskela, 2009). This explains the high value of expertise in the AEC industry. As Lin, Wang, and Tserng (2006) indicate, "the know-how and experience of construction engineers and experts are the most valuable because its accumulation depends not only on manpower but also on money and time" (p. 694).

Recent efforts to improve knowledge sharing and to transform tacit knowledge into explicit knowledge in the construction industry are constant and valuable. However, the construction industry is known for its slow rate of change and technology adoption (Dave & Koskela, 2009; Mahapatra & Gustavson, 2008; McCoy, Koebel, Sanderford, Franck, & Keefe, 2015). This is also linked to several unique characteristics of this industry. The AEC industry may be considered a complex system industry, and as such, they create complex products, which are usually customized, with highly interconnected parts, and in which innovation requires high user involvement. Any small change in a complex product may affect the rest of the system, and therefore must be analyzed carefully before implementation (Winch, 1998).

The chain of information flow necessary to achieve change in a component within a complex system is also part of the industry-specific communications context and an important aspect for understanding KM within AEC industry. Much knowledge developed during the design conception and construction process is transmitted through a long supply chain between different firms and companies. Designers, constructors, suppliers and manufacturers who work collaboratively on a project may hold different interests and responsibilities within the building process (Harty, 2005; Mahapatra & Gustavson, 2008; Olander & Landin, 2005). For example, contractors are responsible for product installation, but not necessarily for product design, or product manufacturing (McCoy et al., 2015). Specific installation responsibility that has a low influence on design and manufacturing results in a tendency by the contractor to avoid risk and innovation in order to avoid increased liability. Several other issues also influence risk allocation and technology adoption in the AEC industry, such as the one-off and on-site nature of projects, the long-life span of buildings, the uncertainty of future work demand, the large number of small contractors, and the separation between design, construction, and maintenance. All of these issues generate what is referred to as path dependency, in which factors and systems in place make it difficult for innovations to occur within the construction industry (Mahapatra & Gustavson, 2008).

In order to improve information flow between the different stakeholders in project based organizations and complex system industries, such as construction, specific people act as knowledge brokers or systems integrators. These professionals act as a link between stakeholders, spanning their company's boundaries (Holzmann, 2013; Winch, 1998). They also are responsible for knowing about user-specific requirements and industry's practices. Pemsel and Wiewiora (2013) indicate that "effective knowledge brokers have to be capable of translating, coordinating and aligning different perspectives" (p. 33) in order to secure information and knowledge flow in the process. These professionals are also responsible for managing firm-based knowledge, as well as project-based knowledge to produce competitive companies (Gann & Salter, 2000).

Therefore effective communication is extremely important for transferring knowledge through the different stakeholders in the process. However, communication and efficient collaboration are often poorly performed in construction (Harty, 2005), which may result in future problems. Dave and Koskela (2009) note that "...many construction projects run into problems such as contractual disputes, cost and time overrun, and rework as a result of miscommunication or lack of communication" (p. 897). Also, researchers have indicated a link between trust and effective communication between construction project stakeholders is essential to the project's success (Cheung, Yiu, & Lam, 2013; Harty, 2005), as well as for product and process innovation to occur (McCoy et al., 2015). Effective communication and knowledge brokering is not an easy task in a fragmented industry in which different disciplines might have conflicting interests (Olander & Landin, 2005). However, researchers indicate that "effective management of information flow can minimize project risk and mitigate project delays as well as uneconomical decisions such that potential disputes can be identified and solved more quickly" (Cheung, Yiu, & Lam, 2013, p. 947). In order to improve knowledge sharing and brokering activities that facilitate construction problem solving activities and project success, there is a current need to evaluate construction communication flows and barriers.

Concept Maps

Concept mapping is a technique used to illustrate a person's or group of people's internal thought process towards a concept through the use of visuals (Novak & Gowin, 1984). It is unique to a person's own experiences (Kinchin, Hay, & Adams, 2001). It links concepts through the use of words, which are connected by lines and arrows. Once the internal thought process is captured graphically, it can be shared, compared, and analyzed (Cañas, Leake, & Wilson, 1999). Also, structural differences between novices and experts can be captured through the use of concept maps (Walker & King, 2002).

Yang (2007) indicates that knowledge mapping, of which concept maps are a part, "…plays important roles in implementing knowledge management" (p. 808). This concept has been used in some KM research within the construction industry, especially those related to tacit knowledge (Lin, Wang, & Tserng, 2006; Yang, 2007). However, few studies have been performed on the use of concept maps for construction management instruction, even though the interest in using concept maps for instruction within engineering education has been growing since the early 2000's. This can is represented by the increasing number of papers which deal with concept maps in the American Society of Engineering Education (ASEE), from nine in the 2000 annual conference, to 44 in the 2016 conference.

The use of concept mapping in instruction has two main purposes. The first is that the maps help instructors assess misconceptions towards concepts. They also help establish how students connect concepts to construct new knowledge (McAleese, 1998; Novak & Gowin, 1984; Walker & King, 2002). This approach was used by Clevenger and Ozbek (2013) to evaluate knowledge acquired by learners for a service learning course in construction management. As learners draw their maps, they are externalizing how they think about a concept. In addition to the ability to assess knowledge, concept maps can also be used as a learning tool (Walker & King, 2002). This happens because concept maps are not static, but dynamic representations of knowledge. During the process of drawing concept maps, the learner engages in a process of self-reflection to organize concepts and knowledge through the use of associations. Walker and King (2002) used concept maps as an instructional activity during a biomedical engineering class with positive feedback from learners: "students expressed enthusiasm for the technique not only as a means to seeing their own intellectual growth but also as an instructional tool that 'hooks things up'." (p. 7.332.13). This is consistent with another researcher's claim that concept mapping can be used as an aid to learning, which helps "…the learner interpret and organize personal knowledge." (McAleese, 1998, p. 260).

Concept maps can be multifunctioning aids to instruction. They can be used as an assessment tool, but also as a way to engage students in critical thinking during the process of externalizing knowledge (McAleese, 1998; Walker & King, 2002). They can become good points of discussion to be used to engage student learning, as suggested by Walker and King (2002):

> One could easily envision instructors giving students a brief orientation to the technique, and then asking them to construct maps (either individually or in pairs) at multiple time points during the semester. Students could then critique one another's concept maps or compare their maps to a criterion map created by the instructor. Used in such a way, concept mapping exemplifies classroom instruction that promotes active engagement in learning. (p. 7.322.14)

Methodology

This qualitative study was conducted in three phases as depicted in Figure 1. Phase one consisted of creation of concept maps by individual participants to reveal their understanding of how information flows in the ACE industry. Phase two was a collective brainstorming activity which allowed participants, as a group, to identify points of information breakdowns on a concept map provided by the researchers using existing literature. Finally, phase three included interviews with one owner's representative, one architect, and one construction manager for a general contractor, who were all currently working on the same project. The different data collection methods and research design phases contributed to triangulation of data and provided richness and trustworthiness while answering the research questions.

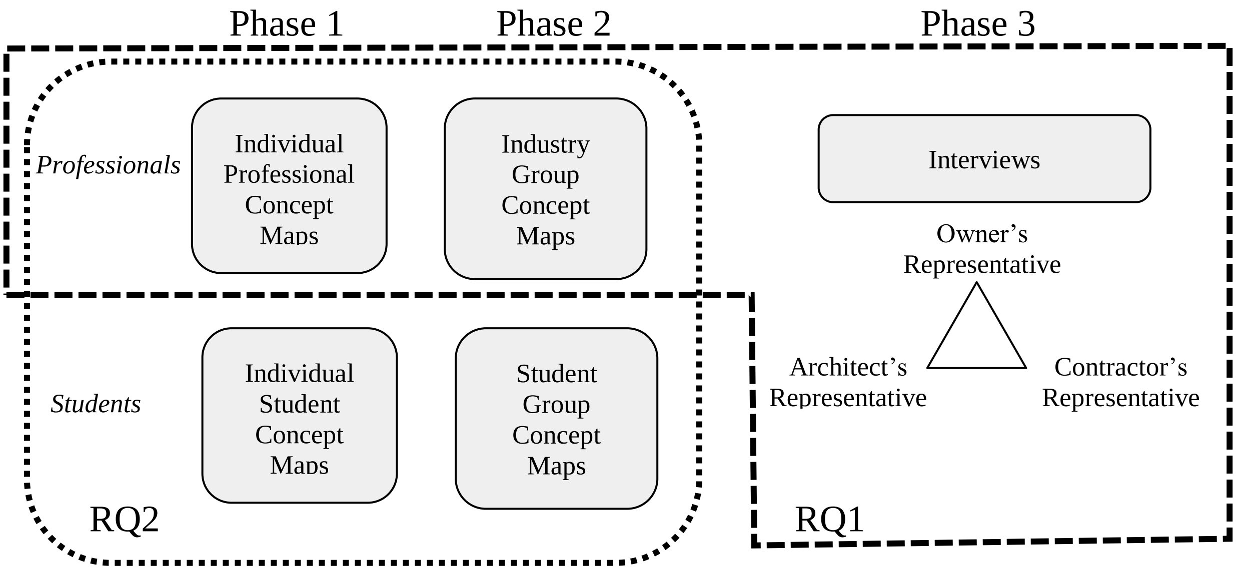

Figure 1: Conceptual Framework.

The sampling strategy for selecting industry professionals as participants for phases one and two was one of convenience by voluntary participation of individuals from the Construction Advisory Council (CAC) for a large Midwestern university CM program during their bi-annual meeting. Industry professionals at the CAC meeting self-select during a break-out session to participate in one of several available discussion groups. These break-out sessions vary in size, depending on the interests and backgrounds of the industry professionals attending the meeting. Fourteen industry professionals chose to participate in the break-out session during which this research took place. Of these, eleven chose to submit their concept maps to the researchers. The professionals who participated in the study during the Advisory Council's Fall 2015 meeting represent a sample of construction professionals from all regions of the United States and a variety of general and specialty contracting organizations.

The sampling strategy for student participants was using senior students in the capstone course for the Construction Management program of the same university. It is important to note that at this university, students are required to obtain 800 hours of industry experience in order to graduate. The capstone course, during which the concept map activity was performed, is a project based course where students respond to a request for proposal (RFQ) in a design-build context. Lectures given during this course support this process. The goal for the day of the research was to discuss communications within the construction industry. Students who did not wish to participate in the research activity were asked simply to not turn in their concept maps, and to either observe the discussion or ask the researchers to remove their comments from the impressions gathered by the researcher present. At the day of data collection, twenty-nine students were present and all students decided to participate in the research by submitting their concept maps to the researcher. Prior to the start of the activity, students were also made aware that this activity was not graded and that participation was voluntary.

Convenience sampling was used for both students and professionals during phases one and two. The advantage of access to a diverse population in a single setting for both groups outweighed the limitations this sampling procedure implies. In all likelihood, a more rigorous sampling method would not have guaranteed a sample that could provide a more generalizable outcome considering the fact that (1) the regular meeting of professionals with such as wide range of industry practice and interest in industry context education was available, and (2) the students provided the opportunity to utilize a new technique as proposed by Walker and King (2002) to enrich course discussions around the importance of communication.

Interviewees for research phase three were obtained by reaching out to a facilities management office of the same regional state university and their project collaborators in industry. After a positive response from the state institution, the researchers used snowball sampling to ask the participant to forward the invitation to other members of the project team. With this method, the researchers recruited one architect, one construction manager and one owner / client institution's representative. Each interviewee had between 16 to 40 years of professional experience. Interviews for this phase were all conducted by the same researcher and lasted from fifty three minutes for the shortest, to one hour and forty-five minutes for longest.

For phase one, students and professionals were asked to provide a concept map of all stakeholders involved and how information flowed between them, given a specific construction scenario. This individual activity lasted 15 minutes. Participants were first given a ten-minute introduction to the use of concept maps using examples of concept maps in various disciplines. Then, the following case was presented verbally to the each group of participants:

> Prompt: You are a general contractor. You have just signed the contract (lump sum) with a big Midwestern University for building a new dorm. Please identify all stakeholders in the process who will be required to participate in the construction process. Develop a concept map of how information flows from the time when you have executed the contract with all stakeholders in the process until full completion of the building. This building is expected to be silver LEED certified.

Individual concept maps were analyzed by two researchers independently for main themes. These themes were then reviewed and discussed collectively in order to reach consensus between the two researchers about which themes would best represent differences and similarities between students and professionals. Based on this discussion, the main themes which were used as a basis of comparison for this phase, were determined. The identified themes were: (1) organization of stakeholders; (2) organization of information flow; (3) detail level; (4) and visual organization.

Phase one was initiated to assure that all participants were comfortable using a concept map to conceptualize information flow and that each had considered details of the communication process as well as potential communication barriers prior to the group discussion (phase 2). During phase two, participants were invited for a group discussion around a previously developed concept map created by the researchers using previous literature and the same case as used in phase 1. This meant a group of fourteen industry participants, and a group of twenty-nine students, not including the researchers. The base map for phase 2 was printed in a 24 x 36 inches poster, which was attached to a moving partition (in the case of professionals) and to the board (in the case of students). This concept map was not visible to participants during phase 1.

As a group, participants were encouraged to comment on communication barriers using the printed concept maps as the base. This discussion lasted for 20 minutes. Prompt questions regarding map accuracy, communication barriers, possible solutions and areas to improve were provided to stimulate discussion and one researcher made notes of the responses as they were given by participants. All participants were allowed to have their individual maps with them during this phase. Both maps were analyzed, first independently by two researchers, who then discussed the concept maps together with the goal of finding similarities and differences between notations on the maps.

In the final phase 3, based on the initial findings from the concept map exercise and previous literature, interview questions were developed. The interview questions were designed using four reasons identified in the literature that lead to communication barriers in the AEC industry: (1) changes in the environment, (2) individual characteristics of the stakeholders, (3) characteristics of the communication (such as quality, style, length, channel, and frequency), and (4) knowledge/incentive systems. The goal of these interviews was to validate findings from previous phases, as well as provide readers with a better grasp of common circumstances that affect information flow in the construction industry, especially those that may result in a barrier to effective communication. These interviews were transcribed and a thematic analysis was used to identify key themes. A first pass on the interview data was performed by two researchers individually, who then analyzed the main points together in order to reach consensus. The findings from all three research phases, grouped by research questions, and the emerging themes are discussed in the following sections.

Results

Results are presented by phase in the following sections by research question. Research question one is answered using data from industry participants during phases 1, 2, and 3. Research question two is answered using findings from phases 1 and 2 obtained from both students and industry professionals.

Common Communication Barriers Identified by Experienced Construction Stakeholders

Eleven professionals submitted their individual concept maps for phase 1. Of these, five clearly indicated communication barriers in their concept maps, five did not clearly identified them, and one indicated issues (such as "incomplete design; MEP not coordinated leads to Arch [sic] impacts") and possibilities ("prefabrication; increased quality control"). The location of communication barriers on the concept maps varied greatly, however frequent issues were identified between pairs of three stakeholders - owner, designer, and contractor - in three of the five maps that had clearly marked communication barriers. One of the maps was conceptualized from a specialty contractor's point of view, and included communication issues between designers and contractors as well as designers and subcontractors, especially during a lump-sum contract. Two mentioned a communication barrier between the LEED consultant and other stakeholders, and one mentioned a communication barrier between suppliers and engineers (in this case, specifically the lack of communication between both).

During the group discussion a concept map prepared by one of the authors prior to the meeting was used. The group was prompted by specific questions in order to discuss communication barriers within the AEC industry and notes were made on the concept map to reflect the major discussion points. Industry professionals indicated communication barriers between and among the three major process stakeholders: the owner, the architect, and the general contractor. Other communication barriers were identified as well: between government agencies, contractors and architects. Other points mentioned by participants were the reduced ability for subcontractors to make suggestions in the design phase. Several reasons given for the exclusion of the subcontractor during design were cultural disparities or norms, lack of knowledge, and risk avoidance.

Analysis of industry concept maps created in phases 1 and 2 identified factors that may influence the communication flow between stakeholders including: (1) change management, such as changes initiated by client, or government agencies; (2) cultural norms within construction; (3) experience within the field; and (4) risk management. These factors along with those identified in previously described literature were used to prepare interview questions that could develop a deeper understanding of the communication barriers within the AEC industry. Interviews were obtained with three project representatives for the same project to provide more in-depth information about each of the identified reasons for communications breakdown. Table 1 provides a short summary based on each stakeholder's interview responses about reasons for communication barriers within the industry. These summaries are grouped in four major reasons for the communication barriers.

Table 1

Summarized findings for interviews with main project stakeholders

Reasons for Communication Barriers	**Project Representative**		
	Owner	**General Contractor**	**Architect**
Changes in the environment	Changes originated by client are most disruptive and require that owner's rep gets involved to mitigate impact of changes.	Changes originated by client are frequent. However, if something is urgent, a call from owner's or architect's' rep. will alert for the issue.	Changes initiated by the client are influenced by how much knowledge client and architect have about construction process to assess the impact it will cause.
Individual characteristics of stakeholders	Type of education can result in breakdown. However, a mediator (usually the project representative) may reduce impact by using conflict resolution techniques. Education in construction comes from experience.	Experience is the factor that affects most communication. Experience is extremely important to information flow. Underestimating and overestimating people may affect information flow and time you spend on an issue.	Combination of education and experience is essential. Formal education gets professionals to a starting point from where leadership skills are built. Leadership is important to help lay owner and team members.

Communication	Too much or too little is problematic. Email lacks accountability when trying to assign responsibility, and might get overused. Communication must be clear in order to get the answer to the correct question and not result in breakdown. Experience affects these issues.	Overload and piecemealed information may lead to breakdowns. Emails tend to get overused and lead to an unproductive conversation. Experience mitigates problems. Being clear on communications, setting clear expectations, and understanding the stakeholder diversity are important.	Have the experience to ask the right question, to the right person and state clear expectations. Being clear but also thorough in communications also helps to obtain meaningful answers.
Knowledge incentive systems	Informal communications to reduce tensions and increase trust are beneficial. Trust is also built by acknowledging mistakes and praising good performance.	Lack of transparency and availability to the right information may result in misunderstandings due to not having the full set of information. This is related to trust and experience level of participants.	Lack of transparency may lead to breakdown. This can affect trust in a relationship. Also mentioned was professional experience as a means to mitigate liability issues.

Table 1 lists a variety of different types, reasons, and consequences of information flow breakdown in the AEC industry. Findings indicate that change management in construction is important and requires active participation and communication between stakeholders, which is also consistent with previous literature (Winch, 1998). Another important aspect mentioned by interviewees are trust and risk management in construction. Lack of goal alignment between stakeholders was identified by interviewees as a critical reason for communication breakdowns. Interviewees also agreed that both trust and transparency are important to reduce communication barriers and to improve information flow, as mentioned by previous research (Cheung, Yiu, & Lam, 2013; Harty, 2005).

In addition to the issue of trust, the results presented in table 1 also reflect the importance of tacit knowledge nature within the industry. This importance is represented by the emphasis given to experience in the field of construction. Lack of experience was seen by interviewees as one of the reasons for communication breakdown in the AEC industry. Lack of experience can also influence all other types and reasons for lack of effective communication. Several researchers (Dave & Koskela, 2009; Dubois & Gadde, 2002; Lin, Wang, & Tserng, 2006; Woo et al., 2004) also mention the importance of taking the tacit nature of construction knowledge into consideration in order to understand barriers to information flow. All three interviewees recognized the importance of knowledge brokering activity, or the extent to which stakeholders understand how, which, and when information and knowledge needs to be exchanged in the process (Holzmann, 2013). In the present study, interviewees indicated that knowledge brokering activity is performed mainly by project representatives.

Concept Maps as a Classroom Discussion Activity about AEC Industry Communication

The concept map activity for industry professionals and senior students both consisted of first drawing individual maps around a given case (phase 1), and then discussing as a group communication barriers at various points in a previously developed concept map (phase 2). Participants were able to keep their individual maps for reference during the group discussion. For the individually built concept maps, the key observation made by the researchers was that there was diversity of thought among all the concept maps. Table 2 presents the summarized comparative findings for the individual concept maps using the parameters: (1) organization of stakeholders; (2) organization of information flow; (3) detail level; and (4) visual organization.

Table 2

Summarized findings for individual concept maps

Parameter	Students (n=29)	Professionals (n=11)	General Comments
Organization of stakeholders	26 maps were stakeholder-oriented, 1 map was process-oriented, 2 maps were mixed (stakeholders and processes)	4 maps were stakeholder-oriented, 5 maps focused on processes, 2 were mixed	Examples of processes indicated on maps included: site development, bidding, initial proposal, and budget
	11 students' maps mentioned local governments as a stakeholder. Other 2 students indicated local governments as important stakeholders (more connections and greater in size than other stakeholders)	No industry participants clearly indicated local government in their maps	Participants' indication of local government in concept map as an important stakeholder.
Organization of information flow	23 maps had a clustered distribution, 4 maps were cyclical, and 1 had no explicit connections between stakeholders	5 industry participants with cyclical structure, 3 were linear, and 3 were clustered	Organization in clusters, linear, or cyclical information flow
	1 had no links between stakeholders, 2 had links, but only some directional arrows, 7 students' maps had no directional arrows	Only 1 industry participant did not indicate directional arrow	Differences on the usage of directional arrows
	3 students chose to use colors	2 professionals chose to use colors	Use of colors might be limited to the materials available to participants
Detail level	5 students maps were complex	1 industry map was simplistic	Complexity is characterized by more stakeholders, connections between stakeholders and concepts

Visual organization	12 maps focused on general contractor, 10 on owner or building, 5 focused on combination of architect, owner, and contractor, 2 had no centrality	3 maps containing a clear centrality (one in design, one in general contractor, one in owner). 7 had no clear centrality	Centrality of maps may have been affected by many industry respondents focusing on processes

It was evident from the students' concept maps that there were misconceptions towards building project development. Four students did not include the LEED consultant as a stakeholder, even though the case specifically asked for that type of detailed knowledge. Of the students who did identify the consultant, three of them indicated the consultant as connected only to the general contractor, and only two students connected the consultant to the general contractor and the owner or owner's representative. Others varied between connecting the consultant with the owner or owner's representative, architect, and general contractor, or architect and general contractor, or only the architect.

Another issue observed in the students' concept maps was the placement and connections of the owner's representative with other stakeholders. Only eight students recognized the owner's representative as a stakeholder. However, two of those indicated the owner's representative as only connecting to the owner, thus lacking an understanding of the owner's representative's complete role. The other six connected the owner's representative and owners to other stakeholders, again indicating a lack of clarity on their roles in the industry.

Fifteen students have categorized design in sub-disciplines, with a majority (twelve) focusing only on architecture, and engineering or structural engineering. Only three students identified the need for mechanical, electrical, and plumbing systems design, or other designers in the AEC industry information flow. The student concept maps lacked a diversity of disciplines and an adequate level of depth in the stakeholders they identified. In contrast, the concept maps from the professionals were very detail oriented and had diversity, depth and a holistic view of the AEC industry information flows and information choke points.

Students were engaged during the concept map drawing process, however some students even after the introduction on concept maps, had questions for the researcher about how to draw concept maps. The researcher answered individual questions and also placed an example concept map (not related to the AEC industry) on a projector in front of the class. After explanations were made, all students present completed this activity within the 15 minutes given. Professionals also were handed copies of the same example concept map which was shown to the students, however they did not pose any questions about the activity or about concept mapping during their 15 minutes of drafting their individual maps.

After the individual activity, students and industry professionals (meeting in separate gatherings) were invited to participate in a group discussion around a concept map previously created by one of the authors. As they were prompted with questions regarding map accuracy and points of potential communication breakdown, students and professionals developed the marked-up concept maps in Figure 2 and 3. This activity allowed for the researcher to verify possible differences between professionals and students concept maps as well as better understand the knowledge gap between the two groups. Concept maps are a way to identify possible differences between experts and novices (Walker & King, 2002), and to assess knowledge connections and misconceptions about a concept. A similar approach to evaluate students' knowledge was used by Clevenger and Ozbek (2013). As proposed by Walker and King (2002), the discussion around the concept map produced by participants stimulated discussion around the theme of communication barriers within the AEC industry. Students by the end of phase 2 were engaged in discussing not only themes proposed by the concept map, but also other issues about communication barriers that they considered important.

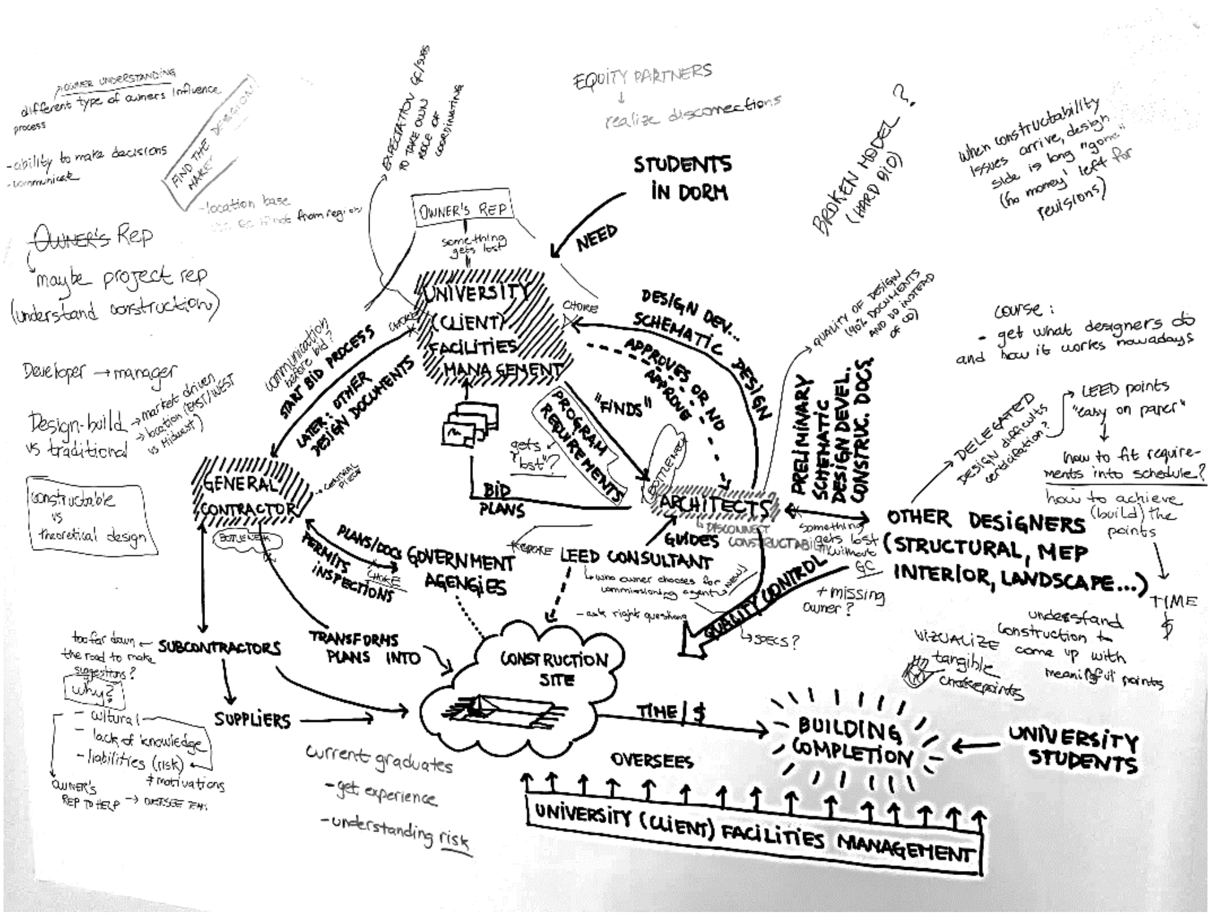

Figure 2: Industry group concept map

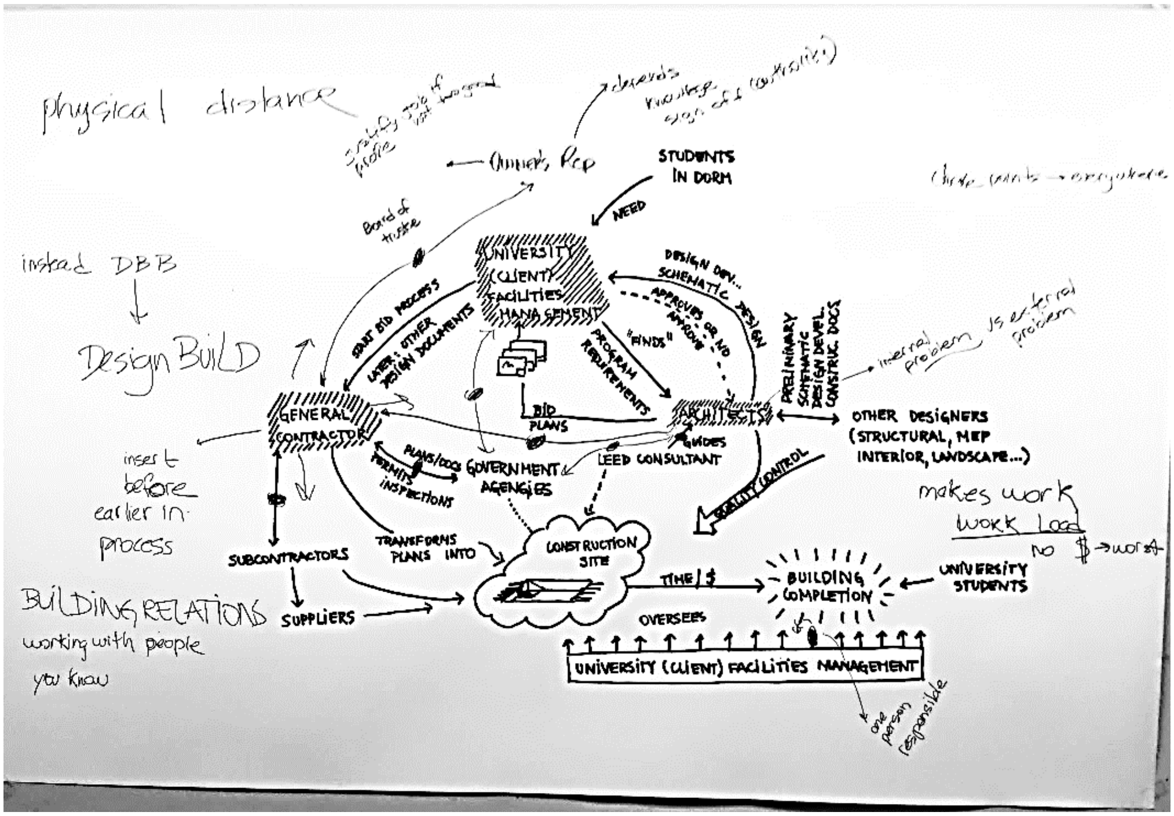

Figure 3: Student group concept map

Similarities noted in the group discussions were that both students and industry participants indicated the need for inclusion of the owner's representative as a stakeholder. They agreed that this stakeholder's contribution depends on how much authority they have, and how familiar this stakeholder is with the construction process. Both groups also indicated that the design-bid-build model is less efficient for communication between stakeholders than the design-build model in which construction companies can actively participate during design development.

Some differences that emerged are that, given the same amount of discussion time, the professionals' concept map identified and examined more issues regarding information breakdowns compared to the students' map. Industry professionals were more participative in the discussion from the beginning, which was expected because this activity was performed during a bi-annual meeting with the intent of holding discussions around the CM program curriculum. Students were reluctant to provide comments during the first five minutes of the discussion. The use of prompt questions helped to engage the students in the discussion and by the end of the twenty-minute task, students were engaged in providing feedback and generating new discussions, such as one regarding design-bid-build, and the importance of building professional relations within the industry. Students acknowledged the importance of all stakeholders understanding industry practices as the industry participants had done. They mentioned that owner's representatives need knowledge of the construction processes, but did not make the connection with risk management as the industry representatives had done in their discussion. Also, students mentioned the need for a LEED consultant, but did not expand the discussion around this stakeholder. Industry professionals, on the other hand, noted that LEED consultants who are not familiar with the construction processes impact information flow to the general contractors during the construction phase.

The concept map activity used in the present study allowed the identification of possible differences between experts and novices as well as the use of concept maps to verify knowledge connections and misconceptions towards a concept. Previous research indicates this type of comparison and analysis as a possible uses for concept maps (Clevenger & Ozbek; Walker & King, 2002). The discussion activity around concept maps was based on a proposal by Walker and King (2002). Even though the depth of the student discussion was not comparable to that of the industry group, and the students took longer to engage, by the end of phase 2, students were discussing not only themes proposed by the map, but also other issues about barriers to communication barrier that they considered important, such as building working relations as part of the AEC industry's communication process.

Discussion

The first research question sought to identify barriers to effective communication within the construction process that are well-known to experienced construction stakeholders. The second research question for this study sought to ascertain how the concept maps for information flow in the construction industry produced by CM students and experienced construction professionals relate to each other, and how concept maps can be incorporated in the CM classroom. The variability in the industry participant concept maps produced in phase one was evident in the findings and can be attributed to the fragmented and project based nature of AEC industry (Bresnen et al. 2003; Dave & Koskela, 2009; Holzmann, 2013; Lin, Wang, & Tserng, 2006; Woo et al., 2004). In this section, the authors present the major emerging themes from the findings. Knowledge gaps between students and professionals are considered with regard to points of information breakdown in the AEC industry and how the use of concept maps can be utilized to illustrate AEC communication barriers in CM education.

Holistic understanding of the information flow processes in the ACE industry:
A majority of students and professionals' concept maps were drawn using process models rather than a stakeholders' model. However, professionals had a deeper and richer understanding of the roles and responsibilities of different stakeholders compared to students. This illustrates clear differences between novice and expert concept maps. The possibility to assess differences of expertise is one use for concept maps (Walker & King, 2002). It was also evident that since the students were from a construction management program, their focus was on the construction management stakeholders such as the general contractor. Students also lacked understanding about how information flows to and from other stakeholders, such as the owner's representative, architect, etc. Results and background literature regarding knowledge management in the AEC industry reaffirm that this 'big picture' view is more present in industry professionals and that students lacked knowledge about the 'whole' process. The difference between professionals and students could be due to the accumulation of tacit knowledge during professional experience, because much of knowledge in construction is experienced based (Dave & Koskela, 2009; Lin, Wang, & Tserng, 2006). This holistic view of the construction process is also important within a

complex systems industry, in which various interconnected parts require stakeholders to have a systemic view and to analyze changes carefully (Winch, 1998).

Importance of tacit knowledge, risk management, and industry experience:
During the discussion and interviews, industry professionals stressed the need for graduates from construction management programs to acquire industry experience, and also to understand risk management in construction. Industry experience includes the know-how in construction as well as the tacit knowledge that formal education and training does not necessarily encompass. Previous research relates risk management in the AEC industry to effective communication, industry experience, and decision making (Cheung, Yiu, & Lam, 2013; Dave and Koskela, 2009; Mahapatra & Gustavson, 2008). However, these conclusions do not include suggestions for how to include these topics in the CM curriculum.

Building relationships among different AEC industry stakeholders:
The industry professionals echoed repeatedly in all three phases of research the role of trust and transparency among the different stakeholders in the industry, and how the lack of these critical elements lead to the majority of communication barriers. The AEC industry relies on a long and fragmented supply chain. In this process, multiple stakeholders participate, often with different goals (Harty, 2005; Mahapatra & Gustavson, 2008; Olander & Landin, 2005), which stimulates distrust and hidden agendas within the industry. Interview participants suggested the use of triads (representatives from the architect, owner, and contractor organization) to act as mediators in conflicting situations. The importance of conflict resolution skills and understanding goal alignment may be found in previous AEC research. These previous research mention trust as the foundation for these relationships, leading to transparency and communication of the required information at the required time. Lack of trust leads to misalignment of goals and expectations among different stakeholders, which is another key reason for information breakdown (Olander & Landin, 2005; Pemsel & Wiewiora, 2013).

Concept Maps as an Activity to Discuss Construction Industry Communication Barriers

The comparison of concept maps created by industry and senior students helped to illuminate some misconceptions by students and differences between novices and experts (Walker & King, 2002), as well as to understand how students connect concepts (Cañas, Leake, & Wilson, 1999). Industry professionals were engaged and provided important feedback to improve the teaching of industry communication to students. Students had more difficulties understanding the idea of concept mapping and needed more help and prompts through the discussion process. However, their engagement in the activity is similar to that cited by Walker and King (2002). Even though participation was voluntary and the activity was not graded for any course, all students developed and surrendered their concept maps to the researchers. The group discussion for students also started with less participation than industry, but as students were being prompt with questions they started to become more comfortable sharing and proposing new thoughts that were then added by the researcher into the baseline concept map. As Walker and King (2002) proposed, concept maps can be used not only for evaluating knowledge, but also as a learning aid for critical thinking and peer discussions.

The results provided by comparing students and professionals' concept maps (both individual and group results), show possible deficiencies in CM education regarding communication skills. As mentioned previously, effective communication is an important skill for CM graduates (American Council for Construction Education, 2016), and improvements in construction specific understanding of effective communication skills is important to the flow of information within a complex systems industry. Some of the emerging themes discussed previously indicate a gap in knowledge between professionals and students in the following areas: (1) holistic understanding of the information flow; (2) understanding the tacit nature of AEC industry knowledge; (3) understanding risk management within the industry; and finally (4) the importance of building relations within the industry. The latter was mentioned by students, however the discussion did not encompass the importance it was given by professionals. All of these concepts should be considered in order to provide students with a better understanding of information flow and the consequences of ineffective communication in the construction industry.

Conclusion and Further Research

This study sought to understand communication barriers within AEC industry communication, and how the use of a concept map activity can foster discussion around this topic when used by students in a senior CM capstone course. Competence in effective communication is expected in graduates of construction programs (American Council for Construction Education, 2016; Cheung, Yiu, & Lam, 2013), as well as for construction professionals in general (Larson & Miller, 2011). Results obtained during individual and group concept map activities as well as from in-depth interviews identified the following main themes: (1) a lack of holistic understanding by CM students of AEC industry information flow; (2) the importance of tacit knowledge and risk management for the construction communication process; (3) the need for building relationships among stakeholders to improve trust and reduce conflicts, and (4) usefulness of concept map creation as an aid to discussion of construction industry communication barriers. Based on their experience of using concept maps, the authors suggest the following guidelines for other CM educators who consider this tool for use in the classroom:

- A brief introduction should be given to what concept maps are, including connectors and directional arrows. Visual examples are also helpful for students to understand the goal of the activity. The authors suggest using a non-construction related example concept maps in order to avoid influencing participants. Students should be made aware that the aesthetics of the map are not as important as the informational content it carries.
- The activity could be performed as an integration activity for the whole curriculum during a senior level course, or as integration of concepts for a single course.
- Students should developed their individual concept map before advancing to the group discussion. Fifteen to twenty minutes for the activity reported in this paper was sufficient for this individual phase,
- In a group discussion, the authors suggest having broad prompt questions such as "Is any information missing?" or "Do you disagree with what is in the map?" prepared prior to the discussion for use as appropriate to help engage students in the initial stage of

discussion without leading them to any specific response. After engaging students, educators should focus on more focused questions regarding the concept being discussed.

- The authors suggest using a moderator with industry experience, to impart expert knowledge and lead concept map discussions if possible. This moderator should provide a basic concept map of AEC industry information flow for students to discuss after students have spent time individually creating a concept map of their own. The industry professional's map can be used to confirm or oppose students' understanding of information flow. This approach can enrich the discussion, while adding knowledge and helping to clarify misconceptions.

Limitations to this study are its narrow sample, and the use of a convenience sample for phases one and two. Nevertheless, through the use of this limited sample and the supplemental interview data, the researchers were able to explore communication barriers within construction to identify possible knowledge gaps in a prominent CM education program. In addition, a preliminary test of concept maps as an educational tool with the potential to minimize the knowledge gap identified was completed.

This qualitative study suggests the need for further research in understanding: (1) the effectiveness of the proposed guidelines for use of concept maps in CM education both as a formative as well as a summative educational experience; (2) how internships affect the evolution of student knowledge through the use of concept map development and discussion; (3) how concept maps can be used to discuss other topics within construction management education; (4) how experience refines industry professional's and students' knowledge of information flow in the process of construction over time; and (5) how professional industry experience can be utilized in the undergraduate curriculum to reduce students' misconceptions and to broaden their understanding of information flow in construction.

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