Environmental Factors on Concept Maps Design

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Abstract. Building Information Modeling (BIM) environments have a lot of potential to facilitate communication and support collective work, speeding construction times and increasing the overall quality of the project. A few ontologies creation efforts have been made by both academia and practitioners to foster the transmission of knowledge in BIM environments. This paper aims to add to the discussion by analyzing the notes of users of concept maps, knowledge structures similar to ontologies, and comparing them to BIM environment researchers'.

Keywords: BIM·Concept Maps·Knowledge Management·Knowledge Transmission·Knowledge Construction·Ontologies

1 Introduction

Building Information Modeling (BIM) environments are excellent candidates for the implementation of Knowledge Management (KM) techniques and tools. As Dalkir [13] points out, one of the problems KM can help solve in projects being object to BIM is the need for professionals in different disciplines to "speak the same language". It seems that while technical interoperability surrounding BIM has been addressed by the development of standards and long-term use of BIM tools [22], business interoperability is yet to be fully supported in order to expand collaboration [33]. The multidisciplinary perspectives the same object can take in Architecture/Engineering/Construction (AEC) and the lack of tools that can support them seem to be in cause [30].

A bibliographic study of BIM literature has shown that in recent years ontologies have been considered as a means to foster collaboration in AEC environments exchanging BIM, but very few studies addressed different context or environmental elements in the interpretation process of ontologies [48]. This bibliographic investiga-

tion has justified Cerovsek's [5] perception that little attention was being paid to the semiotics of communication in AEC. In other words, the AEC field lacks studies on BIM projects and the different meanings and interpretations the same object or object characteristics may take.

Variance of meaning, or semiotics, is a natural element of human communication. As people have different backgrounds, beliefs and experience, it is natural that they accord different meanings to the same words and symbols. While semiotics account for the cultural richness in society, in a performance-intensive environment, such as construction, it can be a source of misunderstandings, frustrations, and barriers to collective work.

2 Concept Maps and Ontologies

Concept maps are knowledge structures that codify objects and their relation to each other. Several perspectives are used to depict the various dimensions of a relationship between two objects. In educational settings, the process of creating a concept map helps students relate different concepts of the domain explored [14]. Once the concept map is ready, it serves as a tangible representation of the domain and helps the student recall the propositions of the domain [28]. In knowledge management, concept maps are used to produce "visual representations of complex knowledge domains that meet social scientists' standards for rigor and reliability, while being easily interpretable to practitioners" [40]. The collaborative design process of the concept map is itself a team-building activity and involves a lot of articulation and negotiation skills [18, 51]. Concept maps' capacity to promote the construction of shared meaning assured the tool the recognition as a feminist research method [3]. Concept maps are the first step for the creation of ontologies [2, 4, 50, 60]. Concept maps that conform to a specific format and are machine-readable are called Ontologies.

Ontologies have been developed and implemented in BIM projects to help increase knowledge flow and business interoperability. The Information Delivery Manuals (IDM), guiding BIM implementations, represent the effort to connect and describe the context [25]. They are intended to provide directives to represent what is the place of a process, what is its relevance, the actors around the information represented, the information itself and how it should be supported by applications [59]. However, as Eastman, one of the most prominent scholars studying BIM [61], argues, the use of IDM is only a first step towards answering the need for full interoperability in BIM tools [15].

3 Environmental factors in KM and Education

In November 2017, I (Daniela) felt the urge to reflect on the influence and power imbalances surrounding the creation of concept maps. I have engaged myself in an exercise of critical reflection [10] on my own experiences facilitating concept maps creation in Knowledge management (KM) and education settings for the past five years. The production and treatment of the content followed Trochim's [53] method

adapted to one single participant and low-volume data. Fifty-nine statements related to environmental factors around the creation of concept maps were produced. These statements were regrouped in fourteen categories, which were then named. Similarities between the labels of categories motivated a subsequent fusion and reorganization of categories, resulting in the eleven main elements that motivated this study.

Previous research had already suggested that contextual factors may be responsible for mixed findings in concept maps studies [1]. In the preliminary phase of this study, validation in the literature was sought for these elements emerging from practice. These elements may have considerable impact on concept maps and, as a consequence, in ontologies creation and use. They have been divided into four categories, explained as follows.

3.1 People involved

Who creates the tool. Different people might produce different concept maps on the same subject [44].

In educational settings, concept maps may be created by the instructor or by the student [1], by a group of students having an instructor as a mediator and by a group of students working conjointly with an instructor. The number of participants representing knowledge influences the outcome of this representation [29]

In KM settings, concept maps may be designed by an information professional only, to express the results of document analysis, or in design sessions. Participants of design sessions tend to be admitted by invitation only [53]. The selection of participants usually takes into account their category [58] (external or internal client, subject matter expert, management level, for example); their potential to interact with other participants - power imbalances may be considered; their availability and their added value to the project. When conceiving how the concept map should be designed, the information professional considers what kind and level of endorsement would be most beneficial to the knowledge representation. The same participants may not take place in every step of the concept map production [31, 53].

The perception of the creators' authority in the field may represent a bias for the concept maps users, as would the creators' reputation and the support from senior management they are perceived to enjoy.

Importance of participants' knowledge and scope. How concept maps users and facilitators see the importance of the knowledge of the participants involved in the design of the concept map is likely to vary. In educational settings, students are less credited of understanding of the knowledge domain than are instructors. Students' knowledge representation in concept maps is perceived as the expression of their knowledge, rather than a representation tailored to meet users' needs. This common perception has to be taken into account by the facilitator when choosing intervention techniques.

In situations where instructors have authored the concept map, the general perception is that a didactic reduction was made to adapt to novices' understanding, leaving important knowledge of the field unrepresented in the concept map.

In KM settings, the knowledge articulated either by participants or by the information professional alone is seen as the important knowledge in the field. The common perception is that a selection of the important concepts was made – and what was left out is not as important.

Who uses the tool. In educational settings, any student – being the concept map's author or not – may use concept maps produced by instructors or by students working with an instructor. Concept maps produced by one single student are usually only used by that single student.

The relationship between authors and users may create different user experiences. For instance, as mentioned, concept maps may perform the role of an individual's memory guide if they are both the sole author and user but will take the role of an exploration path if the author is the instructor and the user, a novice.

In KM settings, the number of users can largely outnumber the group of creators. Concept maps may be used by employees, clients, suppliers and government for regulation purposes, even if they have been authored by one single person. Concept maps authored by one single person may be used by a sole other person, for example, when expressing the reasoning used behind an algorithm or technical solution.

The target user population will certainly have its influence in the authoring process. Facilitators should take authors' view of the target population into account when planning for concept maps design sessions.

3.2 Trends

Purpose. In educational settings, concept maps may be used to portray a knowledge field to be explored, to serve as a guide to one's knowledge and to assess learning. The purpose of the concept map will certainly have an impact on how it is produced. A concept map created as a guide to the author's understanding and memory of the field will not be the same as one created to display the author's understanding of the field.

In KM settings, concept maps may be created to help specify the conceptual frameworks of programs [45, 54], to help attribute meaning to sets of data [23], to determine technological solutions requirements [17], or as an aid to navigate internal documents or content published on the organization's website [27], among other uses. When coupled with other tools, they may also be used to assess relevance of documents over time. The purpose for which the concept map was created suggests the point of evolution of the knowledge represented, or how much agreement exists in the field at that moment. In other words, the concept map portrays, in some way, the collective endorsement of the knowledge represented.

Evaluation criteria. The purpose of the concept map may be attached to an evaluation strategy. Among other uses, evaluation strategies aim to assess the suitability of the concept map for the task it is intended to support or the coverage of its scope. Although there is still no acclaimed method for testing concept maps [57], it is reasonable to expect that evaluation criteria to be applied in a concept map influences the facilitator's choices of intervention techniques.

3.3 The impact of time

Number of workshops over time. Concept maps are usually produced in one session in educational settings, although they may be incremented over time. In KM settings, concept maps usually take one to five sessions to be considered final [53].

Momentum of production. As the concept map portrays the author's vision of the knowledge field at a specific point in time, a concept map produced in the beginning of a course or a project will be drastically different from one produced by the end of a course or project. The momentum of production may affect participant's motivation and user's perception of reliability of the tool.

Time of tool consumption. Concept maps are used in educational settings while the user considers the knowledge important and the tool useful, which could mean for the duration of a course or an educational program. In KM settings, concept maps may be used long time after production, especially when they serve as guides for navigating documents or content [27].

3.4 Collaboration issues

Facilitators and authors of concept maps will try to compensate for any perceived inadequacies regarding the preceding elements. For example, a facilitator conducting a concept design session in the beginning of a project for a concept map intended to hold a good level of maturity in concepts will stimulate participants to perform divergent thinking and will try to diversify interventions to achieve the desired level of maturity in concepts; a student might use shorter terms and clearer relationships when being evaluated through a concept map.

Variety. Focus groups, workshops, input from interviews [53] and document analysis [42], are some of the methods used to gather ideas for concept maps.

Collaboration. When concept maps are to be authored through collaboration, greater attention is given to staffing [31, 53]. That may include stimuli for different learning styles [55] and assuring representativeness of all participants in the end product.

Techniques for animation. Different techniques might be used to assure accurate representativeness of the participants in the end product. The idea is to have participants exploring different points of view and relationships [43] and being able to name concepts, ideas [19] and, more rarely but also importantly, emotions [7].

Table 1 summarizes the design process differences and the different factors involved.

Table 1. Main aspects and factors related to concept maps use in KM and Education

Main aspect	Factor
People	Who creates the information; importance of participants' knowledge; who uses the information; individual endorsement
Trends	Purpose - why was the information codified; evaluation criteria - how is the information expected to be evaluated; collective endorsement
Time	Frequency of information generation; point in the process generating information; point in the process where information is consumed
Collaboration	Criteria for selection of people to be involved; how interactive was the creation process; how did people interact when generating the information

4 Ontologies perspectives in AEC

Three very different perspectives in representing context were identified in the AEC. For Lee and Jeong [30], the people involved and the purpose of the information are the key elements to identify context in BIM projects. The authors describe a solution divided in a private and a public space. In the public space, the views of the objects depend on the qualification of the subject (e.g. an architect, a structural engineer and a mechanical engineer). For each object, the ontology would carry information describing the creator of the published data, the date of creation or modification, the qualifier of the relationships with other objects (e.g. a part of, a kind of) and "detailed description on reasons of creating or modifying the published data" [30].

The individual versus the shared space idea was originally explored by Cerovsek [5], who divides context description into various "standpoints". In the individual sphere, Resources, Process, Process result, BIM literacy and BIM tool would provide enough information for the evaluation of BIM support. In the shared space, the Reference Location, Time, Group, Teamwork, Business process, Information sharing, Application sharing and Communication channel would be the points helping evaluate BIM-enabled collaboration [5].

The framework conceived by Succar [52] identify fields, maturity and lenses / filters in a project. "Fields" relate to Technology, Process and Policy fields. "Maturity" aims to describe in much detail the point of the project where the object being described resides. "Lenses/Filters" present different views of the data. "Lenses" would

present all the information that answer a specific criterion, while "Filters" would present all the information that does not answer the criterion.

Up to the submission of this paper, to our knowledge, no attempt to integrate these three perspectives was made. Although concern about contextual or environmental factors is present in AEC literature, the level of discussion seems to be considerably still too low to inform approaches in practice.

5 Discussion

Even though not much have been said about communication in BIM projects and its relation to ontology use [5, 48], some of the environmental factors identified in concept maps production and use were already identified in AEC literature. Environmental factors involved in the representation of knowledge in KM, Education and AEC can be summarized as follows:

Table 2. Environmental factors of concept maps and their acknowledgement in AEC literature

Main aspect	Factor	KM/Education	In AEC
People	Who creates the information; importance of participants' knowledge; who uses the information; group; teamwork; individual endorsement	X	[30] [5]
Trends	Purpose - why was the information codified; evaluation criteria - how is the information expected to be evaluated; collective endorsement	X	
Time	Frequency of information generation; point in the process where information is generated; date of creation or modification; point in the process where information is consumed	X	[52], [30]
Collaboration	Criteria for selection of people to be involved; how interactive was the creation process; how did people interact when generating the information; information sharing; application sharing; communication channel	X	[5]

The identification of environmental factors of concept maps in AEC literature might indicate that research on the impact of these factors in ontology use would be welcomed in the AEC field. In practical terms, the correspondence suggests that there is a lot more to the process of knowledge building and consensus finding in BIM projects than the current ontology use supports. Therefore, BIM project managers and participants should be aware that BIM environments are not exempt from misconceptions and misunderstandings. Communication opportunities in a variety of channels should be encouraged to reduce conflicts having low positive impact in the construction process.

6 Conclusion

The creation of a concept map does not limit itself to the consignation of propositions into nodes and lines. A series of actions in design planning impact the actual design of the concept map and might influence how the concept map is perceived and put into use. If the same reasoning is applied to ontologies related to BIM, the information consigned in the ontology should not limit itself to the description of objects, but also the context in which those objects were created. Insight from the interaction between people and the knowledge representation in concept maps suggest that ontologies should also address the process of consensus building.

Similarities and differences between KM, Education and AEC in the description of context were identified. These preliminary findings suggest the usefulness of a larger and empirical research study on the context of objects represented in BIM tools.

Limitations

As this study originated in a single practitioner's experience, it might not represent an exhaustive list of environmental factors impacting knowledge representation in ontologies. Empirical, multi-participant, larger studies on environmental factors are encouraged. The results from the equivalence of factors in KM and Education and in AEC literature have to be considered taking into account the scarcity of literature in the AEC field. Exploration of the topic by AEC is also encouraged.

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