GENRES OF COMMUNICATION INTERFACES IN BIM-ENABLED ARCHITECTURAL PRACTICE

SHERIF ABDELMOHSEN
Ain Shams University, Egypt
Email address: sherif.morad@gmail.com

Abstract. This paper explores the interaction and different types of representations enacted in a BIM-enabled environment that involves interdisciplinary and intradisciplinary collaboration among teams of designers in an architectural praxis context. By means of an ethnographic study conducted over the course of an architectural project from schematic design to construction documents, including five disciplines and twenty subjects, genres of communication interfaces are identified between BIM-authoring tools, sketching interfaces and domain specific analysis tools, and explored within the realm of distributed cognition. Implications in architectural practice and education are then discussed.

1. External Representations as Socio-cognitive Glue

In the realm of distributed cognition (Hutchins, 1995), cognition is viewed as a property of an entire system performing some activity. This system extends beyond individuals as the unit of analysis to include both individuals and external representational artifacts. It follows that a given design process is perceived as a system that consists of a set of representations. These representations exist as both internal representations in designers' minds and external representations available in cognitive artifacts (Norman, 1991), where the design of the artifact affects both the cognitive abilities of the designer and the nature of the design task in hand.

Sketches, physical models, diagrams, mathematical equations and computer models are all examples of cognitive artifacts that maintain, display and operate upon information from designers in order to provide representational functions, while simultaneously affecting their cognitive performance. As these artifacts help enhance cognitive abilities of designers, it is significant to observe how the information processing roles played by the artifacts interact with the designer's information processing activities. Putting external representations at the heart of any design process emphasizes the role of representations as constituting and mediating a rich cognitive environment for task accomplishment, social interaction and collaboration (Norman, 1993).

In addition to the cognitive component, a key issue in the social sciences that affects any design environment, or any organizational context at large, is the debate over the dominance of *structure* or *agency*. This debate relates to whether socialization (where social existence and perceived agency of individuals are mostly explained by the overall structure of society) versus autonomy (where the emphasis is on the capacity of individual agents to construct and reconstruct their worlds) is predominant. Many social theorists, including Bourdieu, have attempted to find a balance between the two forces; viewing both structure and agency as complementary, where human behavior can change social structures and vice versa.

Social and cognitive scientists, such as Bruno Latour, extend the notion of social agency, where people are considered the primary determinants of their actions, but also pursuing entities that have characteristics of both structure and agency. Latour refers to objects or artifacts as “missing masses” that are socially ignored, especially in the fields of science and technology. Introducing artifacts and external representations as a kind of structure-agency *glue*, Latour points out the role of material objects in articulating, embodying, coordinating and authoring actions. To show that all actors only gain agency by belonging to specific networks of materials (or artifacts), Latour (1988) mentions that “we neither think nor reason. Rather, we work on fragile materials –texts, inscriptions, traces, or paints— with other people”. He adds that these materials are “associated or dissociated by courage and effort”, that they have “no meaning, value, or coherence outside the narrow network that holds them together for a time”. He further argues that this network can be extended by “recruiting other actors”, and that it can be reinforced by “enrolling more durable materials”.

It follows that design is enacted as much through artifacts and external representations than spaces and people. Actors or players thus come from each discipline with their own artifacts (or *play toys*). As Wittgenstein’s (1961) “the limits of my language mean the limits of my world” implies, the boundaries of a certain discipline or its line of philosophical thought can be identified through the study of the representations that are involved in that discipline. Representations that are situated in the practice of each discipline can be shared or unique, or can appear similar but in different ways. A dance choreographer for example works with both graphical communication and words, but uses more words. The richness of the context in this case stems from the fact that nothing is developed a priori, but groups of dancers rather play *together*, remember the words and use them afterwards.

This paper explores the interaction among teams of architects and consultants in the context of architectural practice enabled by building information modeling, or BIM (Eastman et al., 2008). As implied by the conceptual basis of BIM, it has multiple affordances including the virtual building and construction of designs, and the ability to test and simulate building performance. Practice however involves both interdisciplinary and intradisciplinary interactions of multiple actors with different concepts, methods, and tools or representations. The nature of interdisciplinary collaboration in the AEC industry is changing, where participants, practices, systems and business structures are integrated into a process that captures the skills and feedback of all its participants. In this process, the goal is to maximize efficiency throughout project lifecycle, expand value to the project owner, and optimize end results through the early collective contribution of expertise from different domains. The paper presents the results of a study that identifies genres of communication and ways in which the design process is operated and configured in this emerging type of intradisciplinarity and interdisciplinarity where the boundaries of specialization are becoming less and less distinct, read through the lens of the network of involved external representations and artifacts. The paper then sheds light on pedagogical implications based on the findings of the study.

2. External Representations in BIM

To claim that external representations in BIM-enabled practice, and consequently the patterns of interaction among its actors, are genuinely unique is rather debatable. On the one hand, the machine readable nature of its applications and methods of representing information has brought about a transformation in the epistemic culture of architectural practice and in methods of formulating, expressing and transferring design ideas. By focusing on information-rich representations rather than mere geometry or catchy presentations, mechanisms of information exchange and knowledge construction have been impacted widely, especially in collaborative and interdisciplinary contexts. This is achieved through interoperability, which describes the need to pass data between software applications to enable the contribution of different participants and applications to building model data.

On the other hand, design concepts and information were conventionally exchanged among different stakeholders and captured using notes, sketches and physical models, and were validated by means of client meetings and design brief development. Computers were used at late design phases for documentation purposes following the approval of clients for a selected design scheme. 2D CAD presented a method for drafting which replicated manual drawing techniques, such as plans, elevations, cross sections and perspectives, which had existed long before computers were invented. Introducing BIM began to impact the way architects approach their designs. Concerns became no longer how to present an idea using hand-drafted or computer-drafted perspectives. More concern was about the amount of completeness of embedded knowledge in a design and the degree of precision in representing every detail in the design beforehand.

With the introduction of BIM to the industry, new methods and processes were developed that might be affecting the nature of interdisciplinary collaboration. Integrated project delivery (AIA California Council, 2007) emerged as one of these methods. By contrast with CAD, the claim with communication in BIM-enabled practice is that it is designed to take place at the model level, where the information in a 3D BIM model becomes available and ready for exchange to all participants.

However, in AEC practices, collaboration typically involves the communication and coordination between multiple professionals and specialists, including architects and engineers from different disciplines to execute a certain project. Challenges to interdisciplinarity traditionally emerged due to specialization, where each discipline working on the same project employed its own array of practices, concepts, methods and tools. Workflows and tools in traditional CAD practices represented only a replacement of the existing trend, which focused on the exchange of drawings to describe design intent. In terms of collaboration, architects and engineers rarely relied on using each other's work directly. Only basic information from CAD drawings was exchanged, and this information was used for reference only.

In order to examine the nature of external representations exploited by participants in the AEC industry, and particularly in a BIM-enabled environment, it was necessary to conduct an ethnographic study in situ, or in the workplace. The study involved a long-term observation of the practices and interactions of teams of architects and consultants in the context of an architectural project (Abdelmohsen, 2011). The goal was to identify genres of communication interfaces through day-to-day interactions that take place among and across the AEC teams residing in different *communities of practice* (Wenger, 1998) and using a shared BIM model in the workplace.

The study focused on a detailed observation of a single architectural project: a three storey 80000 square foot technical college medical technology building. It included lecture spaces such as auditoriums and classrooms, laboratory spaces, public circulation and lobby spaces, and service spaces. The main participants in the study included an architectural firm, a structural engineering firm, an MEP firm, a civil and landscape firm, and an A/V (audiovisual) firm, in addition to two cost estimation teams and one sustainability analysis team. The study was conducted over the course of 8 months, starting from the schematic design (SD) phase and going through design development (DD) and construction documents (CD). The author became a participant observer of most of the day-to-day practices in each of the firms, especially the architectural firm where most of the decision making took place and where design meetings sessions were held with the consultants.

3. Communication Genres Unpacked

The context of naturalistic inquiry (Lincoln and Guba, 1985) in this study comprised two main modes of interaction: 1) interaction related to exchanging data among AEC design teams by means of a shared BIM model, and 2) socio-cognitive interaction related to exchanging views and arguments among and across teams by means of a shared design problem. To capture these two modes of interaction in BIM-enabled practice, the study adopted ethnographic field observation and interviewing as a strategic data collection methodology. The unit of inquiry in this case was the participant, or the *persona* (Cooper, 1999), seen through interactions with other participants and with artifacts, including digital and physical representations, in the context of practice involving disciplinary participants. Grounded theory coding and analysis (Strauss and Corbin, 1998) was used as a basis for analytic induction to arrive at emergent phenomena, including identifying genres of communication interfaces in BIM-enabled practice. These are described in the following sections.

3.1. MULTIPLE BIM-AUTHORING TOOLS

In this communication genre (figure 1), the primary representation used in the interaction between the designers is the BIM platform. This includes two or more architects working on a BIM-authoring tool such as Autodesk Revit Architecture or ArchiCAD and exchanging versions of the BIM model, or an architect and an MEP engineer working on BIM tools belonging to the same platform, such as Revit Architecture and Revit MEP. This level of communication is presumably the most accurate and complete in terms of geometrical representation and coordination of information, as it involves the BIM modeling platform as the main shared external representation. From the study, it was found that as the teams started using the BIM tools to exchange information about the project, peripheral communication external to the BIM model was needed. Designers had to use email, or verbal communication if collocated, to check for consistency and confirm aspects related to the original intent of the designer so that they would have a clearer interpretation of the exchanged information.

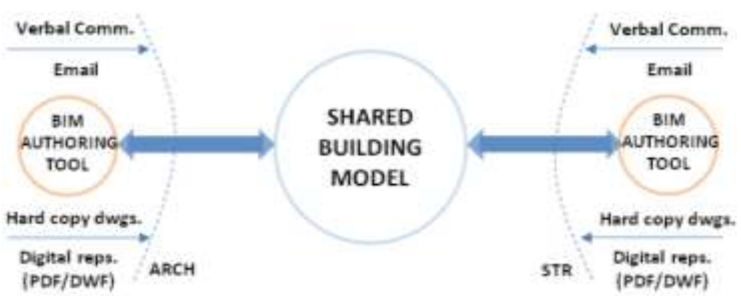

Figure 1. Communication interface between two BIM-authoring tools

3.2. SKETCHING AND BIM-AUTHORING TOOL

In this communication genre (figure 2), the representations used in the interaction between the designers include the BIM platform in addition to freehand sketching. This includes one designer working in both representations simultaneously, or multiple designers exchanging sketches and BIM models, especially during conceptualization phases of the design. This communication often involves a conflict between the quick and flexible nature of sketches and renderings and the rigid nature of BIM models. Each representation has different affordances and limitations; while sketches are relatively well suited for externalization and reflection of design ideas, BIM models are more information rich representations with a higher degree of precision. Interdisciplinary and intradisciplinary interactions among designers revealed a continuous need and urging effort to represent and translate the ambiguity in sketches and quick renderings into the BIM model, since it was the main repository of information among different disciplines. At the same time, most designers could not work with the BIM model alone; they needed representations such as freehand sketches, physical models and graphic renderings to fully describe their designs and externalize their ideas. The dullness and rigidity of the BIM model representation resulted in an insufficient and incomplete expression of design ideas and intent while exchanging the BIM models among the teams and individuals. The accumulated process of switching and translation from one representation to the other often results in an output that is apparently richer in content but that may not necessarily reflect the full capacity of the design thinking process.

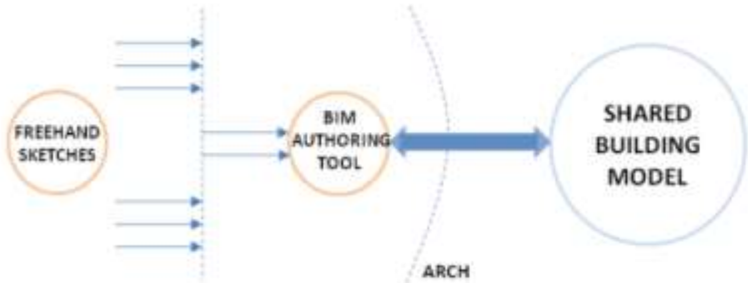

Figure 2. Communication interface between sketching and a BIM-authoring tool

3.3. BIM-AUTHORING TOOL AND ANALYSIS TOOL

In this communication genre (figure 3), the primary representations used in the interaction between the designers are BIM-authoring tools and domain-specific analysis tools. This includes for example an architect developing a design using a BIM-authoring tool such as Revit Architecture and an analysis tool such as Ecotect for early energy analysis and feedback, or an architect and a structural engineer exchanging models, where the architect is using Revit Architecture and the engineer is using a domain specific analysis tool such as RAM Structural Analysis. Issues in this communication genre include incompatibility among different modeling and analysis tools, where a set of translators or mapping operations are required to align those tools together and provide consistent and reliable results. This is usually due to the fact that each participant comes with a suite of background related methods and tools, and the discrepancies between these tools are exposed upon interdisciplinary and intradisciplinary interactions across and among teams. In the process of resolving tool incompatibilities, some of the exchanged information is not transferred smoothly or automatically, often requiring that participants input data from scratch in their domain-specific analysis tools rather than dealing with unreliable data.

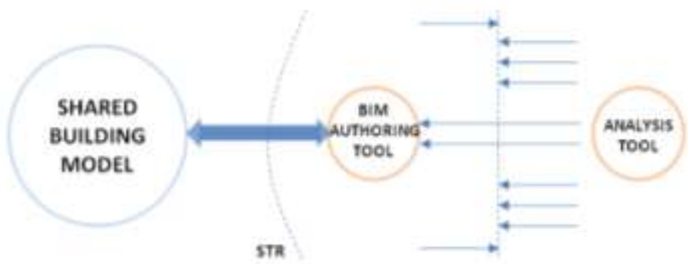

Figure 3. Communication interface between BIM-authoring tool and domain specific analysis tool

In some cases, designers do not fully understand the needs of analysts or other participants. This may lead to missing data or an inaccurate representation of data in the BIM-authoring tool. In the study for example, members of the architectural team lacked an understanding of the basic needs of the cost estimator. At the same time, the estimator did not have a clear understanding of the modeling mechanisms in the BIM-authoring tool. The estimator often had to start estimates from scratch instead of relying on data from the BIM model, or had to revise all the parameters manually to establish a reliable estimate. With the intervention of other participants in the firm, a mapping scheme was developed to align the information requirements of both parties. In other cases, it was observed that some engineers use analysis tools for domain-specific purposes, but use CAD modeling tools (such as AutoCAD) instead of BIM-authoring tools due to certain contractual agreements or restrictions, in spite of their capability to use BIM related software. In this case, the information-rich base in BIM-authoring tools is not exploited and is replaced by 2D data. This *unused* data could lead to misrepresented information or deficit in the process of informing significant design decisions for all stakeholders.

3.4. CAD MODELING TOOL AND ANALYSIS TOOL

In this communication genre (figure 4), the primary representations used in the interaction between the designers are CAD modeling tools and domain-specific analysis tools. This includes a landscape architect for example developing a terrain model in an analysis tool such as Civil 3D while working with the base project model in a modeling tool such as AutoCAD. A potential loss in 3D geometrical data takes place from the analysis tool to the CAD modeling tool. In the larger interdisciplinary context, 3D information from the BIM-authoring tool coming from the architect is indirectly translated to the analysis tool. Issues of inaccuracy and misrepresentation of 3D geometry are at stake in this type of indirect communication, which often requires the designer or analyst to input data manually in each of the modeling or analysis tools.

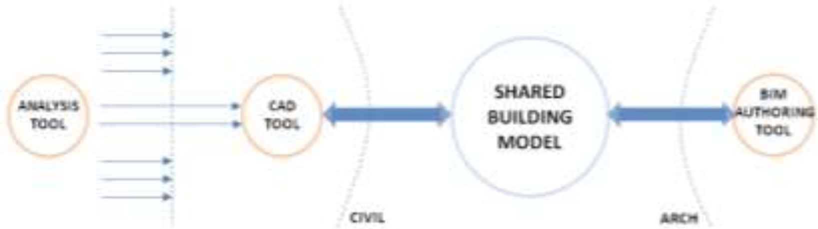

Figure 4. Communication interface between CAD tool and domain specific analysis tool

3.5. MULTIPLE ANALYSIS TOOLS

In this communication genre (figure 5), the primary representations used in the interaction between the designers are domain-specific analysis tools. This includes for example an architect or sustainability analyst developing an energy model in a tool such as E-Quest, and an MEP engineer developing that model using Carrier HAP for HVAC systems. It was observed in the study that tool incompatibility and interface limitations between both analysis tools could lead the MEP engineer to develop a more accurate model based on domain-specific assumptions and calculations rather than relying on presumably flawed or misrepresented geometrical data from the architect.

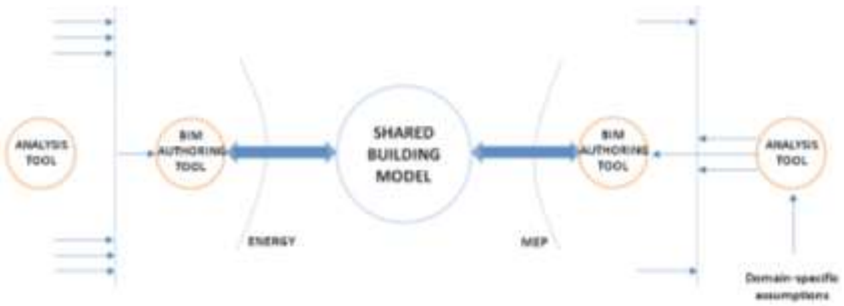

Figure 5. Communication interface between multiple analysis tools

4. Implications

From the above mentioned genres, it is apparent that a plethora of external representations are exploited by architects and consultants, and are used interchangeably through different types of interaction; mainly interdisciplinary and intradisciplinary interactions. The notion of the BIM model as the sole central repository of information for all participants is revisited, where it is assumed that the model encompasses all the parameters, attributes and rules required and comprehended by all AEC consultants sharing it and that it communicates their goals, needs, motivations and intentions, besides communicating design information. Not only is the BIM model shown to undergo several states and constraints, but also other representations, such as sketches, CAD models, analysis tools and other representations external to the model come into play with different affordances and interactions with this central repository of information.

It is also apparent that the BIM model acts in some way as a primary socio-cognitive *glue*. As an external representation, it was at the center of the interaction and forced participants to use it as a thinking tool and an execution tool but with varying levels. Expert tool users used BIM authoring tools as a design thinking tool, while others who were in a learning process relied on auxiliary representations for conceptualization and reflection, and used BIM-authoring tools as tools for execution of their thought process. On the other hand, the BIM model was not the only factor in the process. Other representations acted as socio-cognitive glue among smaller groups of participants in the periphery, such as freehand sketches between architects and landscape architects, and analysis tools between sustainability analysts and MEP engineers.

At the same time, although BIM-authoring tools had their limitations in terms of incompatibility and data exchange problems, they still allowed for new communities to emerge and for new mechanisms of social interaction to take place. The lack of understanding between architects and the cost estimator for example, which was caused primarily by discrepancies in the representations they used (the BIM model and the cost estimating software), forced them to at least come together and discuss the issues of concern. Furthermore, it allowed other participants who were not primarily in the scene such as the BIM manager and the project manager to intervene and make extra effort in order to align their perspectives, whether through additional meetings or by developing software that encompassed the needs of both participants.

In terms of pedagogical implications, interdisciplinary and intradisciplinary interactions are considered a key aspect to keep in mind from this study. The interaction between the different external representations in BIM-enabled practice and the resulting genres of communication interfaces was highly influenced by the type of interaction. This has its effect on the design of architectural curricula and educational programs in the AEC domain in general. The studio should be expanded to meet both interdisciplinary and intradisciplinary dimensions. In order to develop a “BIM curriculum”, both dimensions should be addressed. A BIM curriculum in this case should focus on teaching domain-specific core concepts (physics, math, cost analysis, simulation, etc.) rather than digital design tools, abstract modeling and drawing procedures, or BIM tools and functionalities per se (e.g. Autodesk Revit, Ecotect), together with focused studios that incorporate ideas from integrated practice, collaborative and collective design, and problem solving. These focused studios should incorporate ideas from the identified genres of communication interfaces. Three main themes could be integrated in the curriculum: a team-based theme (that employs ideas pertaining to interdisciplinary, intradisciplinary or web-based communication, crowdsourcing, and designing through social media and other collective rather than collaborative means of communication); a domain-based theme (that encompasses different domains, such as building technology, interior design, landscape design, etc.); and a design problem-based theme (that takes into consideration an overarching design problem as the overarching theme, such as analysis and evaluation, building retrofit, new design and construction, etc.). The integration of these themes should allow for early involvement and immersion in integrated practice and a better understanding of other disciplinary requirements. Specializations or concentrations can be achieved through a mix-and-match of core courses and studio themes. Core concepts and studio themes can also be extensible (e.g. studios can be extended to include building type-based, function-based, architectural form-based, etc.).

5. Conclusion

This study looked closely at two aspects of BIM-enabled architectural practice: (1) the abstract information exchange mechanisms brought about by BIM-authoring tools and analysis tools to facilitate collaboration and interaction, and (2) the nature of social interaction, and mechanisms of knowledge construction and negotiation within and across AEC teams, as communities of practice. By analyzing these two aspects in the context of an architectural project in the workplace, five main genres of communication interfaces were identified in BIM-enabled practice involving multiple disciplinary teams: a) interface between multiple BIM-authoring tools, b) interface between sketching and BIM-authoring tools, c) interface between BIM-authoring tools and domain-specific analysis tools, d) interface between CAD modeling tools and domain-specific analysis tools, and e) interface between multiple domain-specific analysis tools.

A key observation in the study is that the concept of the BIM shared model – as a sole repository of information – has to be revisited. Although the shared model is claimed to bring together teams, together with their tools, concept and methods, throughout the design process rather than their participation at distinct phases in a linear process, it was shown that a lot of representations and communication channels external to the model are still required *upon interaction* to achieve effective communication among teams. Consequently, proposing more intuitive interfaces, translators and automated data exchange mechanisms, and integrating these representations and communication channels within BIM-enabled practice would provide more effective communication, enable social interaction among and across teams, and reduce the cognitive burden upon design teams. Horizontal Glue (2011) and BCF (2010) are two web-based initiatives that extend workflow communication to include social interaction, virtual discussion and remote and real-time collaboration among actors in BIM-enabled practice. More efforts are needed to address the specific genres identified in this study.

References

ABDELMOHSEN, S., 2011. *An Ethnographically Informed Analysis of Design Intent Communication in BIM-Enabled Architectural Practice*, Unpublished PhD thesis, Georgia Institute of Technology, Atlanta, GA, USA.

AIA CALIFORNIA COUNCIL, 2007. *Integrated Project Delivery – a Working Definition*.

http://www.haskell.com/upload/NewsLibrary/WhitePapers/IntegratedProjectDelivery.pdf. (Website accessed January, 2012).

BCF, 2010. *BIM Collaboration Format, building SMART* Online Document.

http://iug.buildingsmart.com/resources/abu-dhabi-iug-meeting/IDMC_017_1.pdf.

(Website accessed January, 2012).

COOPER, A., 1999. *The Inmates are Running the Asylum*, New York, Macmillan.

EASTMAN, C., TIECHOLZ, P., SACKS, R., LISTON, K., 2008. *Building Information Modeling Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, Wiley.

HORIZONTAL GLUE, 2012. *Horizontal Glue, Horizontal Systems Inc*.

http://www.horizontalsystems.com (Website accessed January, 2012).

HUTCHINS, E., 1995. *Cognition in the Wild.* MIT Press.

LATOUR, B., 1987. *Science in Action: How to Follow Scientists and Engineers through Society*, Harvard University Press.

LATOUR, B., 1988. *The Pasteurization of France*, Harvard University Press.

LINCOLN, Y., GUBA, E. 1985. *Naturalistic Inquiry,* Sage Publications Inc.

NORMAN, D.A., 1991. *Cognitive artifacts*. In: J.M. CARROLL, Designing Interaction: Psychology at the Human-Computer Interface. Cambridge University Press.

NORMAN, D.A., 1993. T*hings that Make Us Smart: Defending Human Attributes in the Age of the Machine*, Addison-Wesley, New York.

STRAUSS, A., CORBIN, J., 1998. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory,* Second Edition, Sage Publications.

WENGER, E., 1998. *Communities of Practice: Learning, meaning, and identity,* Cambridge University Press.

WITTGENSTEIN, L., 1961. *Tractatus Logico-Philosophicus*. Translated by D.F. Pears and B.F. McGuinness. Routledge and Kegan Paul, London.