The Effect of Building Information Modeling on Conflict and Conflict Management in Interdisciplinary Teams

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Building Information Modeling (BIM) is an emerging phenomenon in the building design and construction industry requiring change from traditional functional silos to collaboration across multiple disciplines and stakeholders in a facility's life cycle. Construction educators face the challenge of preparing students for this evolving environment in which the focus is on interdisciplinary teams working together much earlier in the life cycle of a project. Industry professionals face a similar challenge and are looking to understand more about interdisciplinary team interactions and management. Conflict is typical in these types of diverse teams due to the various backgrounds and perspectives between team members. Collaboration and productivity from conflict requires teams utilize an integrative strategy for conflict resolution. This paper tests several hypotheses related to different types of conflict, conflict management strategies, and the productivity of conflict related to problem solving. The results reported are from an immersive classroom environment in which interdisciplinary teams first used traditional methods and processes for a creative task, then used BIM to complete two subsequent tasks. In addition to a discussion about the results from this research, there are recommendations about fostering an environment in which the inevitable conflict leads to productive solutions and improves team dynamics.

Key Words: Building Information Modeling, Interdisciplinary Teams, Conflict, Conflict Management

Introduction

The building design and construction industry is experiencing pressures to improve productivity and reduce excessive waste. The industry is in the middle of a crisis due to shortages of material resources and an urgent need to reduce energy consumption. There are widespread inefficiencies which are a direct correlation to years of wasteful practices and processes. This has in turn increased spending by facility owners on design and construction activities (National Institute of Building Sciences, 2007). Inefficiency within the design and construction process begins early in a project with the redundancy in information creation and lack of information exchange. Building Information Modeling (BIM) is an emerging collaborative technology that is designed to facilitate the input of information from an interdisciplinary team of stakeholders to improve efficiencies across a facility's lifecycle. According to the General Buildings Information Handover Guide (National Institute of Standards and Technology, 2007), early adopters have found that BIM:

- Speeds informed design decision-making
- Facilitates rapid iteration of simulations of building performance and construction sequencing
- Streamlines information flow and reduces time-to-complete in certain supply chains
- Substantially reduces field problems and material waste during construction
- Makes off-site fabrication feasible for a large percentage of the building components and assemblies
- Reduces on-site construction activities and material staging, leading to a less crowded and safer site

A major concept in BIM is the transition from functional silos of expertise, such as architecture, engineering, and construction, to an interdisciplinary (cross-functional) team collaborating from the earliest phases of a project (AIA, 2007). In contrast to this idea of BIM as a collaborative technology to improve efficiency, there exists prior literature about information technology suggesting problem solving and task completion are not necessarily faster in an electronic format but often occur quicker in more traditional exchanges and processes (DeSanctis and Monge 1999). In addition, within the BIM environment the opportunity for conflict is prevalent as teams are often assembled for a single project in which they have zero history in working together. Conflict management requires time and effort expenditures by all team members and can impede progress, which may slow a team's problem solving and task completion. The problem of conflict and conflict management within the BIM environment is the purpose of this study. The objective of this study is to provide a better understanding of conflict in interdisciplinary teams using BIM by measuring the amount of conflict, the type of conflict, and strategies for conflict management. It is important that both educators and industry professionals address each of these issues related to interdisciplinary team conflict in the BIM environment if BIM is to contribute to improved productivity.

Study Background

Several definitions of 'conflict' exist in the literature. K.W. Thomas (1992) provides a general definition of 'conflict' that includes higher level events, such as perceptions, occurring prior to conflict-handling modes. Thomas' definition begins upstream and includes more variables in its consideration. The Thomas definition differs from the more popular use of the term 'conflict' which focuses instead on conflict due to individual competitive intentions. Atreyi and Bernard's (2007) definition is particularly relevant for this paper because they defined 'conflict' as a disagreement among team members that implies incompatible goals or interests. Diverse teams should have shared goals with an understanding of the team's objectives, therefore included in this study were two team building exercises aimed at facilitating these items (Jarvenpaa, Shaw et al. 2004). Conflict can be classified into two types - issue based and interpersonal. Issue based conflict is related to task and is rooted in differences in viewpoints related to the team's task. Issue based conflict may be demonstrated with intense discussions and individual excitement, but it is devoid of affect and negative emotions associated with interpersonal conflict. Interpersonal conflict is relational based and typically manifests itself in tension and annoyance between team members (Atreyi, Bernard et al. 2007). The purpose of this paper is to report the results from a study about conflict experienced in interdisciplinary teams, the strategies used for conflict management, and the impact of conflict on the team's productivity. Previous research on diverse teams working on project based problems indicates both types of conflict often exist (Carte and Chidambaram, 2004). However, effective conflict management can contribute to a group's success. Research also exists that supports training in conflict management as it leads to more productive conflict management (Poole, Holmes et al. 1991).

Research Hypotheses and Design

Research Hypotheses

Hypotheses Related to the Amount of Conflict

Issue-based conflict has been found to be beneficial to team performance as it contributes to a critical review of alternatives and increases the accountability of group members, while its absence can lead to negative consequences such as groupthink. Task based, or issue-based, conflict is often referred to as constructive conflict in that it helps prevent domination and stagnation, seeks solutions for questions, and underlies creative thinking (Carte and Chidambarum, 2004). In contrast, interpersonal conflict is typically detrimental to team performance as it involves mutual dislike and personality clashes (Atreyi, Bernard et al. 2007). Carte and Chidambarum (2004) refer to interpersonal conflict as 'destructive' conflict. Diverse teams may experience both types of conflict as both exist in team environments regardless of the mode of technology utilized.
H1.1: Interdisciplinary teams will experience issue-based conflict on tasks regardless of technology.
H1.2: Interdisciplinary teams will experience interpersonal conflict on tasks regardless of technology.

Hypotheses Related to Conflict Management Strategies

The Poole et al. (1991) study on conflict management in a computer-supported meeting environment studied the effect of technology on team conflict and its relationship to team productivity. Additional research supports the concept that different types of behavior may be demonstrated in dealing with team conflict. Conflict management strategies reflect three distinct types of conflict behavior. The first is 'integrative' and is a behavior in which team

members attempt to work with all other team members to find a solution that benefits the interests of all. Integrative behavior is open to other viewpoints and the interests of all team members are clear. Its emphasis is on problem solving. Another type of behavior is 'distributive' in which team members pursue their own interest without regard for other team members. In addition, team members may conceal information and be competitive while displaying a closed attitude to alternative solutions. 'Avoidance' behavior manifests in team members seeking to flee from the group or smooth over the conflict. Avoidance behavior does not confront or attempt to resolve conflict. This type of management strategy demonstrates a low concern for the outcomes of the team (Miranda and Bostrom 1993). Regardless if it is task based or relational, conflict that is not appropriately managed will lead to poor performance and poor problem solving. Building Information Modeling is a collaborative technology and a basic premise of BIM is collaboration by different stakeholders (National Institute of Building Sciences, 2007). Within this context of collaboration the integrative conflict management strategy is best suited.
H2.1: Teams will use more integrative conflict management strategy when using BIM.
H2.2: Teams will use less distributive conflict management than integrative conflict management when using BIM.
H2.3: Teams will use less avoidance conflict management than integrative conflict management when using BIM.

Hypotheses Related to Productive Conflict Management

Research has examined the impact of technology use on conflict levels, conflict management strategies used, and the resulting productivity of conflict. Previous studies operationalized productive conflict as evidence of the following behaviors: exploration of alternatives, clarification of roles and procedures, use of voting, focus on personal relations, equal participation, reliance on written media, and expression of affect. (Poole, Holmes et al. 1991; Lovelace, Shapiro et al. 2001; Atreyi, Bernard et al. 2007). Evidence from this prior literature reveals challenges facing cross-functional teams in multiple disciplines. Interdisciplinary design and construction teams are no different and face similar challenges in achieving productive conflict behaviors. These challenges are directly related to the difference in educational backgrounds; difference in measures of success; and the difference in each discipline's purpose for using BIM.
H3: Groups will perceive conflict as more productive when using BIM than in traditional mode for task completion.

Research Design and Methods

This research is exploratory and focuses on the group processes for conflict and conflict management within interdisciplinary student teams during architecture design and preconstruction problem solving tasks. Two modes were used to perform the tasks. Students were required to use a traditional mode for the first task. They were then required to use a BIM system to complete the second and third tasks. The traditional mode used conventional design, estimating, and scheduling tools and processes for completion of the assigned task. Tools in the traditional mode included paper based design studies, unintelligent CAD drawings, manual quantity take-offs, historical database reference printed materials, and electronic spreadsheet files. The BIM mode required the use of integrated Building Information Modeling tools and processes for completion of the design, estimating, and scheduling tasks on two assignments. The BIM system tools included Autodesk Revit, WinEstimator DesignEst Pro, and Primavera P6 linked together through application programming interfaces (API). The APIs facilitate direct information exchange from Revit to DesignEst Pro to P6. Students used Revit to create data rich graphical representation of the design. DesignEst Pro was used for the cost estimating function and received material assembly information and quantities from Revit through the API. RSMeans 2007 Building Construction Cost Data was used for the electronic pricing database. Within DesignEst Pro information about location and work breakdown structure was created and then exported to Primavera P6 for the scheduling and project management functions. Assignments with task requirements and deadlines were distributed over the course of seven six-hour class sessions distributed across nine calendar days. The research design is summarized in figure 1.

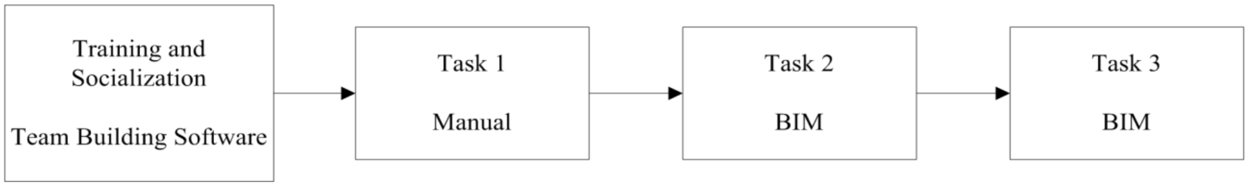

Figure 1. **Research Design**

The three tasks for this research represented two types of design problems typical in architecture and construction education. The first task was a design problem for new construction of a small office building on a given site within the Main Street district of the town in which the university is located. The mode for this task was traditional and intended to establish a reference and frame the students' experience going forward. The second task required students transfer the previous task from the traditional methods to a BIM system. The first and second task program limited the structure to 1,600 square foot and required the team work together to create a design concept and cost estimate for new construction. For the third task students were given a 35,000 square foot prototype model of a core and shell for a retail facility located in a designated commercial development within the town in which the university is located. The third task did not require teams create a design concept for the building but rather teams focus on the building performance criteria and achieving the specified Leadership in Energy and Environmental Design (LEED) rating. A couple of teams chose to redesign the entire structure in addition to meeting the LEED Silver requirements. Each task assignment included a design program and building performance criteria for a LEED rating. Students were motivated with an incentive for the team with the most LEED points for the least initial costs. Life cycle analyses were presented for costs whose payback exceeded five calendar years. Deliverables for each task were defined and a deadline for presentation by each student team established. This type of task requires groups make decisions that inherently foster conflict (Stumpf, Zand et al. 1979). In addition, conflict is more likely to occur in cross-functional teams than in discipline silos typical of the architecture and construction industry (Lovelace, Shapiro et al. 2001).

An initial class session included class orientation, team selection, team socialization, and team building exercises, all of which were delivered in one six-hour class session. There was a gap of thirteen days between this initial session and the subsequent seven sessions. Software training and tasks assignments occurred in the seven class sessions after the break. The gap in time between sessions was a result of official holidays and institutional time requirements for instructional delivery. Within the first session students self selected teams and performed two previously developed socialization exercises, which were designed as a tool to help team members understand and discuss each other's differences and to establish a mutual understanding of team goals and objectives (Jarvenpaa, Shaw et al. 2004). Team exercise #1 required that each member share personal information, core technical skills, and perceived challenges about working in a cross-functional team using new technology. This exercise is useful in establishing an interpersonal relationship and a basis for team expectations. The second team exercise outlined nine factors previously established by Miranda and Bostrom (1993) as important to ensuring a successful cross-functional team experience. Teams were required to discuss each of the nine factors and submit a written plan for ensuring each of the factors would happen for success in working together on projects.

The research occurred in a classroom setting for an elective course offered to senior and graduate level construction and architecture students. Enrollment management was instituted to ensure an even distribution of architecture and construction students, in addition to posing a limit on the total number of students so to ensure effective instruction. Final enrollment consisted of five construction students and five architecture students. A team of one professor from Construction Science and one professor from Architecture designed and taught the class. The class was designed and developed to utilize the charrette as a tool for learning in an immersive time constrained environment. The term charrette originated during the 19th century in Paris and the Beaux Arts period. The charrette concept is derived from the events of furious cart rides (charrettes) down cobbled streets during this time in Paris. Reports are that the combination of speed and rough going knocked loose more than a few mind blocks and gave rise to the vast array of creative solutions produced during this historic time (National Charrette Institute, 2008).

Students in the class included five graduate students from the Construction Science Division and five undergraduate students from Architecture. There were five female and five male students. Average age was 28 years old. All of the construction students had industry experience while none of the architecture students reported industry experience.

In the pre-session survey, 90% of the students indicated that they were comfortable participating in group discussions and 80% actually enjoy team discussion for problem solving. The class was not required as part of either discipline's curriculum and given the intense time schedule typical of a charrette, it seemed appropriate to conclude that students enrolled because they wanted the advantage of learning the technology or believed in some way it would benefit their career. However, the pre-session survey revealed that 30% of the students did not feel that BIM is a necessary tool in current educational or professional settings.

Each team consisted of one construction and one architecture student. Teams were collocated and required to set at adjacent work spaces. Before the first task, students were asked to complete a pre-session questionnaire to gather demographic information and student attitudes toward team work and with regards to BIM. The students were then asked to complete questionnaires after each task was completed and the solution presented. The questionnaires were designed to measure team member perceptions about the amount of conflict focusing on the type of conflict experienced, the team's conflict management strategy, and the productivity of the conflict related to their team's solution to each task. The instrument used for this study was previously designed by S. Miranda and used to measure conflict for team task completion in both manual and technology mode for problem solving (Miranda and Bostrom 1993). The design and reliability of the instrument was the basis for its selection and its durability over time in studies on conflict and conflict management provides a strong foundation for this exploratory study. Students responded to items in the questionnaire on seven-point Likert scales. Reliability for the instrument had been established by the instrument's creator and determined most items met Nunally's (1978) criteria of 0.70 for exploratory research. Reuse of this instrument seemed appropriate for this study. Table 1 presents a summary of scales used for this research. Table 1 list the six constructs from which the instrument was created. The number of items column indicates how many questions related to each construct occurred within the instrument. An example of a question from the instrument is provided in the sample item column of Table 1 below.

Table 1

Summary of Scales

Construct	Number of items	Sample item	Reliability (Cronbach's α)
Issue-based conflict	8	The conflict experienced by the team was directly related to the task	0.84
Interpersonal conflict	6	Altercations between group members were based on personality differences	0.81
Integrative conflict management	4	Group members examined the basis for disagreements and attempted to ensure that all criteria were met.	0.75
Distributive conflict management	4	In conflict situations some of the parties involved yielded to the other even though they didn't agree with the outcome.	0.63
Avoidance	5	Group members attempted to avoid confronting each other even when they disagreed with someone's opinion.	0.72
Productivity of conflict	8	Future group interactions are likely to improve because of the conflict experienced by the group today.	0.79

Results

Amount of Conflict

Issue Based Conflict

In support of hypothesis 1.1, the interdisciplinary teams experienced issue based conflict regardless of the mode used for problem solving. Students reported 20% more task related conflict in Task 1 - manual mode, than in Task 2 – BIM mode. These results were in response to a measure of the frequency of issue based conflict. No difference in the frequency of issue based conflict was reported between Task 2 and Task 3. Issue based conflict did exist in Task 2 and in Task 3 however there was no measurable difference in the amount of conflict. Results indicate a significant decrease (30%) in teams advocating different points of view across the three tasks, with increases in teams disagreeing over the criteria for evaluating solutions and disagreement over alternative solutions. These findings provide support for this hypothesis.

Interpersonal Conflict

Interpersonal conflict persisted throughout the teams and across tasks. Results indicate minimal ridicule, confrontation, or negative remarks about team members, with only 10% of the students reporting these instances. A slight increase in altercations between members based on personality was reported between Task 1 and Task 2. However, findings show a decrease in the expressed conflict targeted at other team members. The results discussed above provide support for hypothesis 1.2.

Conflict Management Strategies

Integrative Strategy

The findings in this research support hypothesis 2.1. Teams reported a 20% increase from Task 1 to Task 2 and a 30% increase from Task 1 to Task 3 in the integration of objectives of all members in conflict resolution. This despite teams reporting a 10% decline in the satisfaction level of all team members in the conflict resolution, in addition to the same overall decline in teams identifying the basis for disagreement for examination and resolution. Overall teams utilized integrative behaviors in their tasks using BIM compared to the task using conventional processes and methods.

Distributive Strategy

Findings indicate that during performance of the tasks and in conflict resolution, there was no change in the amount of the distributive conflict management strategy used with no report of change between each task or across the two modes of operations. These results indicate that while distributive conflict management may have been present it was at a constant measure and when compared to the increase in integrative conflict management strategy supports hypothesis 2.2.

Avoidance Strategy

Findings from this study support hypothesis 2.3. Student teams reported on average only a 10% occurrence of avoiding conflict with other team members. An overwhelming majority reported that 90% of the time team members confronted conflict openly and did not avoid confronting others 100% of the time (Task 3). In addition, students reported ignoring another team member’s differing view only 30% of the time in Tasks 1 and 2, and only 20% of the time in Task 3. A clear indication that teams did not avoid conflict in their interactions.

Productivity of Conflict Management

A majority of students, 70%, reported that they perceived the overall manner in which their team handled conflict as being productive and only a minority indicated that they believed the conflict experienced had a negative effect on the team's solution to the assigned task. There was a significant increase between Task 1 and Task 2, from 40% to 80% respectively, in the perception that conflict was likely to improve future team interactions. In addition, this study found that the conflict experienced actually improved team communication. Improved communication is evident between the two modes of task completion. In Task 1, traditional mode, only 50% of students believe that the conflict experienced improved communication, whereas in Task 2 and Task 3 this number increases to 70% of the time students believe that the conflict improved communication when using BIM for task completion. In addition, results do not indicate that the level of confusion between team members or that the conflict would deteriorate future team interaction.

Discussion

The objective of this research was to explore variables of conflict that exist in interdisciplinary teams, identify management strategies utilized, and determine if conflict can have an effect on productivity within the context of Building Information Modeling. The limitations of this study are the small sample size and the unique student demographics of unequally distributed industry experience. However, these same limitations are also true of the strengths of this study. The small sample size was best suited for the pedagogic format and delivery method. In addition, while the students' industry experience was limited to a single discipline (construction) it provided valuable to the richness of the team experience.

Two of the three tasks included in the research design, Task 1 and Task 2, were identical in the problem but required a change in the mode of completion. The problem was designed to act as a context for teams to experience the different modes while holding the problem constant. This approach allows teams to experience any measurable differences in the solutions that may occur between tasks. Differences in the project solutions between the two tasks may be attributable to familiarity with the project. However it is interesting to note that in this study the design solutions did not vary in concept between the two tasks, but rather students displayed more detail, information exchange, and mutual knowledge about the project within the team. From this observation it is possible to speculate that the teams were moving from a superficial display of the project to a more substantive understanding of the design and construction input in arriving at a solution. This is important in an interdisciplinary team of architecture and construction students working in BIM to develop for a comprehensive understanding problem solving. It is unclear if the improved solution is a result of the sequencing of tasks or an improvement in relational factors between team members. During the class sessions teams were encouraged to reflect on their project plan and attitudes expressed in the Team Building Exercise #2.

Although this research utilized previously identified constructs, instrument, and scale, it is unique in the context of construction education focused on interdisciplinary teams working in BIM. The findings are relevant and are useful as a means to inform Architecture/Engineering/Construction educators about conflict and its correlation with teams using BIM. This study may help to inform educators designing interdisciplinary team projects using BIM on ways to optimize the technology within this environment and understand the effect of BIM on conflict and conflict management. Furthermore, the research findings in this paper are useful for identifying obstacles and understanding concepts for application to frameworks in the theory of interdisciplinary team design, development, and operations within the context of the Building Information Modeling (BIM) phenomenon.

Conclusion and Recommendations for Future Research

This paper presents results that should be useful for pedagogical purposes in the design and development of interdisciplinary team projects requiring judgmental tasks in BIM. This paper also informs industry of team dynamics when diversity may lead to conflict and behaviors that exhibit various strategy. The goal should not be to eliminate conflict, but rather to educate teams about conflict, its benefits, and productive management strategies. Future research on the role team processes and dynamics play in strategies used for conflict management by interdisciplinary teams working in the building design and construction industry would be informative to both educators and industry professionals. In addition, future research should be dedicated to the development of a tool to measure team performance as it relates to productive conflict. One caveat to this measure is holding conflict as a constant in the measurement. This would be useful to assess team progress in its effectiveness and efficiency. While there is much to be discovered about BIM the technology, it is important that equal emphasis be placed on understanding how diverse teams interact and work toward more productive solutions in BIM. We should not neglect the complexity of team dynamics and its significant impact on conflict in interdisciplinary teams. This study has shown that the effect of BIM on conflict and conflict management is most beneficial in an integrative strategy that facilitates a productive outcome from team conflict.

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