Team Processes and Dynamics Demonstrated in Interdisciplinary BIM Teams

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Building Information Modeling (BIM) combines technology and methodology to integrate design and construction team members in order to optimize productivity and project outcomes. Inherent in cross-functional teams are members from multiple domains with divergent objectives and processes for a project. Educators in the architecture and construction disciplines face the challenge of preparing students to participate in this cross-functional team environment. This paper reports the results from a three year study of interdisciplinary teams working on multiple projects in an immersive classroom environment, focusing on team processes and team dynamics. Team processes included are goal setting, communication approaches, alternative analyses, decision making, and conflict management. Team dynamics included in this research are interpersonal relationships, trust, conflict, commitment, and cohesiveness. Teams demonstrated integrative strategies to optimize performance and project outcomes. In addition to the discussion about results from this research, recommendations are included about fostering an interdisciplinary learning environment focused on team processes and dynamics.

Key Words: Building Information Modeling, BIM, Interdisciplinary Teams, Team Processes, Team Dynamics

1. INTRODUCTION

The importance of cross-functional teams in the A/E/C industry is well documented in recent industry literature (IPD 2009; Smith & Tardf 2009; WBDG 2009). History has shown that the traditional linear approach for the design and construction process is inefficient and inundated with waste, in both material consumption and redundant work activities (Tiecholz 2004). Facility owners regularly experience project schedule and cost overruns attributed directly to the linear process and lack of collaboration among stakeholders (CURT 2004). The published reports cite the waste and inefficiencies in the industry and have motivated industry leaders to find a more integrated way of working together across disciplines. Building Information Modeling (BIM) has been identified as one of the means for improvement. When used as intended, a project BIM becomes a shared resource for information about a facility from which

decisions may be made during a facility's lifecycle. It is important to note that according to the National BIM Standard, a basic definition for BIM includes collaboration by different stakeholders at different phases of the life cycle of a facility (NIBS 2007). Design and construction activities in BIM are best accomplished with input from a team of cross-functional members with a goal to optimize project results. As the industry evolves toward more integrated projects, so does higher education for architecture and construction programs. Students graduating from professional programs should be better prepared to work in teams, equipped with skills that support a collaborative decision making process.

2. BACKGROUND

Factors that are important to manage in a team setting are 1) ensuring team goals are clearly defined with objectives and tasks, 2) the development of shared understanding through a common allegiance to a profession or organization, 3) frequent opportunities for interaction with team members, 4) well defined roles for each team member, and 5) established coordination norms with communication protocols about what gets communicated to whom, when, and how. Emphasis should be placed on managing these factors within the team.

Standards for team interactions, such as information exchange, should also be addressed and agreed upon. Standards for teams should be in place and serve to 1) establish and communicate expected performance to all team members, 2) establish and communicate roles within the exchange and each role's responsibility for information contribution in the exchange, 3) provide a point of reference for conflict resolution and/or reduce conflict, and 4) ensure a platform for team members to contribute technical competency (Malhotra, Majchrzak et al. 2001). It is evident from reviewing the small-group/team literature is that a team's success is contingent upon mutual goals, shared understandings, defined roles, established responsibilities, and technical expertise. (Gladstein 1984; Hoegl and Gemuenden 2001). These are all items related to the team process and how the team operates to accomplish assigned tasks.

The definition for collaboration used in the conceptual design of this study comes from the realm of business management. The literature defines collaboration as "a process of decision making among interdependent parties; it involves joint ownership of decisions and collective responsibility for outcomes" (Liedtka 1996). The fact the team takes ownership of the outcomes as a joint effort is the key to interdependence. Much of the foundation for the research in this study is drawn from the small group/team literature in the business domain (Lovelace, Shapiro, Weingart 2001; Gladstein 1984; Hoegl and Gemuenden 2001).

This paper focuses on identifying some of the characteristics present in effective interdisciplinary student teams that may influence the collaborative process. The objective is to provide some answers about the attributes associated with teams that approach problem solving as a collaboration of interdisciplinary perspectives. For the purpose of this paper an effective interdisciplinary team is defined as a team with a strategy for integrating differing ideas and solutions to improve project outcomes. An effective team is project centric and is successful at integrating ideas for the good of the project. Team process and team dynamics were the two categories selected for organizing team attributes in this research.

3. RESEARCH DESIGN

The research design focused this study on three elements identified in the literature that are considered important attributes of successful teams. The goal is to identify the primary element(s) that most influences interdisciplinary teams to adopt an integrative strategy for

problem solving. The research focuses on team process, team dynamics, and experience with teamwork, both as individual influences and as a set of influences on teams that adopt an integrative strategy for problem solving. Components of the construct team process include goal setting, communication approach, alternative analyses, decision making, and conflict management. Essentially these are the mechanics of the team and how it operates as a team. Questionnaires were designed to measure a team member's perception of the team process. For instance, "The conflict experienced inhibited group communication" is an example of an item from the team process category on the survey. In contrast, the team dynamics construct included interpersonal relationships, trust, conflict, commitment, and cohesiveness as items of the construct. These items are related to the social aspects and human interactions of a team. Following is an example of a survey question about team dynamics in this study "The differences experienced by the group were task related." An example of a question about strategy is "Group members examined the basis for disagreements, and attempted to ensure that all criteria were met.

The trend in architecture and construction education is toward experiential project based learning that introduces students to more interdisciplinary team experiences. The idea is that these types of experiences in education prepare students for the future. Emerging technology, complexity of design, greater demands for building performance and more integrated project delivery methods are the future for students.

4. RESEARCH METHODS

The research designed as an exploratory study focused on team process, team dynamics, and experience with teamwork as influences on interdisciplinary student teams. The research occurred during an intersession course offered in three consecutive calendar years. Enrollment in the course for each of the three years was capped at 10, limiting the sample for this study to 30 students. Data was collected using questionnaires, administered once in the pre-session (prior to any tasks) and then again after completion of each of the three tasks in the course. Questionnaires were anonymous and the students were given time to complete them in class.

Teams were established by the students through self selection after each student provided a brief background about him/herself, including industry work experience. Each architecture student was required to team with a construction student. Students were then required to complete 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. Teams were collocated and required to sit at adjacent work spaces throughout the remainder of the course.

Two modes were used to perform assigned tasks in the course. First students were required to use a traditional mode in task 1. They were then required to use a BIM system to complete task 2 and task 3. The traditional mode used conventional design, estimating, and scheduling tools to complete the assigned task. Tools in the traditional mode included paper based design studies,

CAD drawings, manual quantity take-offs, historical database reference printed materials, and electronic spreadsheet files. The BIM mode required the use of an integrated system to complete the designing, estimating, and scheduling tasks on two separate design assignments. Assignments with task requirements and deadlines were distributed over the course of seven six-hour class sessions distributed across nine calendar days.

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 point that would frame the students' experience going forward. The second task required students to transfer the previous task from the traditional mode to a BIM system. The first and second task program limited the structure to 1,600 square foot and required the team to work together to create a design concept and cost estimate for the new construction. For the third task students were given a 35,000 square foot prototype model of a core and shell 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. 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 a strategy for teams to solve the ill-structured problem that is integrative or run the risk of conflict or alienation of the other team member (Stumpf, Zand et al. 1979). Teams are further challenged because conflict is more likely to occur in cross-functional teams than in discipline silos as work toward an integrative solution begins (Lovelace, Shapiro et al. 2001).

The team building exercises previously mentioned occurred during the first session of the course. Software training and task assignments occurred in the remaining class sessions. The course was taught by a team of one professor from Construction Science and one professor from Architecture. The course design and content is a collaboration of the two professors. 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). The class is an elective in the curriculum for both architecture and construction students.

5. RESULTS AND DISCUSSION

This section reports the results from the analysis of data collected in the classroom during the course offered during the 2007, 2008, and 2009 intersession. Data was collected using a pre-session questionnaire and three post-session questionnaires in each year of the study, creating a data set of 264 post-session cases from a sample of 30 students. SPSS was used to analyze the data through descriptive statistics, Pearson correlation coefficients, and a multiple linear regression model. The data was entered into SPSS for each pre-session questionnaire and for each task specific post-session questionnaire. The data was organized by task and year. The

independent variables in this study were experience with teamwork (teamexp), team process (process), and team dynamics (dynamics). Experience with team work was measured using a 5-point scale, with 1 being 'very often', 2 'often', and 5 'rarely'. A 7-point Likert scale was used for team process and team dynamics - with 1 being 'never', 3 'rarely', 4 'sometimes', 5 'often', 7 'always' . The items for team process measured the team's approach to problem solving associated with a process established by the team. Items for team dynamics measured the interactions between team members considered positive in the team's work for a solution. Items for integrative strategy were how often the team resolved divergent task ideas and/or interpersonal issues by integrating ideas of both members.

Descriptive statistics were run first by task for each year in the study. The results for each task were then compiled by year. For example, the descriptives from task 1 for year 2007, 2008, and 2009 were input for a composite analysis of task 1. The same steps were performed for task 2, task 3, and the pre-session questionnaires. The results from each were then compiled and are represented in Table 1. Cases missing data were excluded from the study and are the reason for the variation of N in the variables.

Variable	**N**	**Mean**	**Standard Deviation**
Experience	89	2.2	.991
Process	88	3.5	.866
Dynamics	88	3.1	.607
Integrative Strategy	87	4.9	1.49

Table 1 Three Year Aggregate Descriptive Statistics

An analysis of the relationship between all variables in the study was computed using the Pearson correlation method with $\alpha = .05$ to identify if there was a relationship between the variables and if so, the size of the effect of the relationship. This section reports the results about the correlations between variables and about the effect size of each variable. Evaluating the effect of each variable provided information about the magnitude of relationship among variables and was determined based on the Cohen's index for effect size. Results revealed a positive relationship between all the variables in the study. In addition to having a positive relationship, the correlation between process, dynamics, experience, and strategy were statistically significant. The effect of process in the correlation with strategy was large (.59), whereas the effect of dynamics (.23) and experience (.28) were small. The correlation between experience and process was positive but it was not statistically significant and the effect was classified as medium (.18). Similar to the previous two variables, the correlation between experience and dynamics had a positive correlation but it was small (.06) and it was not statistically significant. Analysis of the correlation between process and dynamics revealed a large (.61) effect along with a positive and statistically significant correlation between the two variables. In summary, the findings revealed that the greatest relationship between independent variables is between process and dynamics. The results also indicated that process is the independent variable with the greatest effect on strategy. The scatter plot in Figure 1 provides a visual of the correlations computed in the analysis.

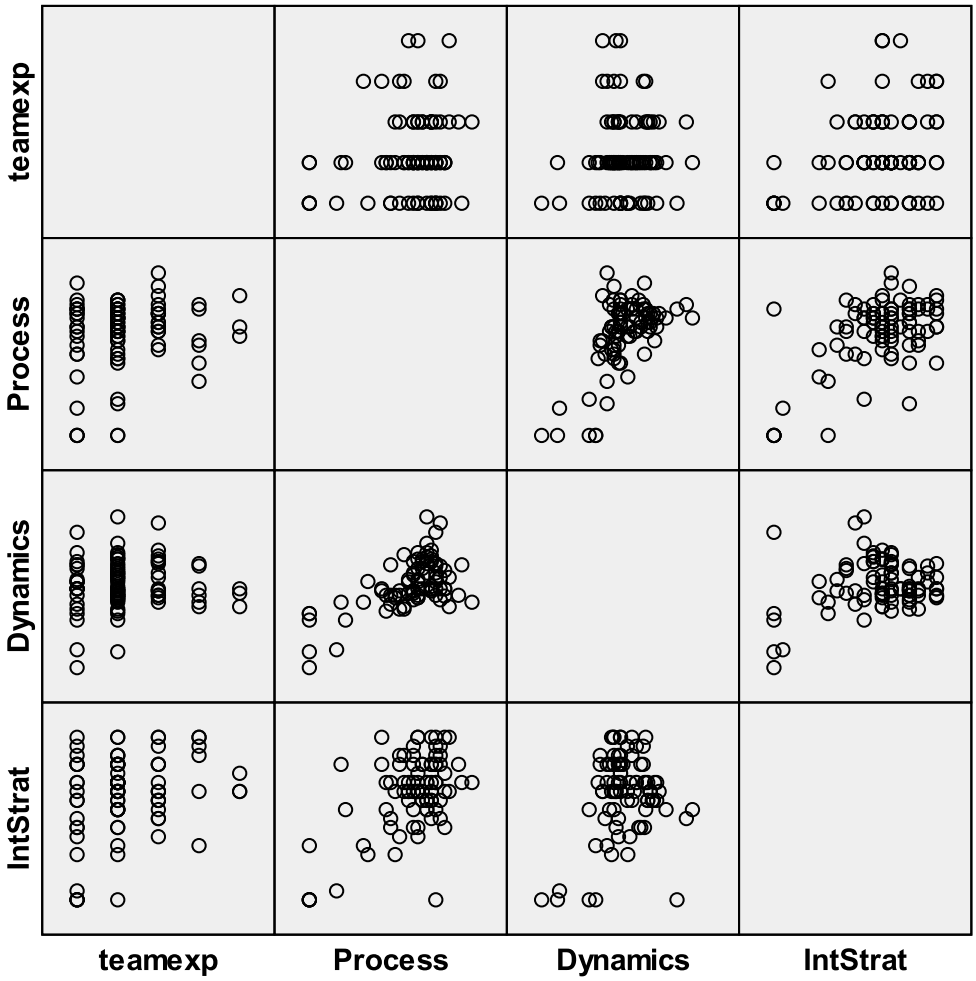

Figure 1 Correlation of Variables

Based on the results from the analysis of correlations, a question emerged regarding the independent variables and their influence on a team's strategy for solving ill-structured problems. The researchers agreed to pursue this question and perform an analysis of the independent variables as a set of predictors for integrative team strategy. The independent variables were assembled as a set with the objective being to determine if the set might be used to design curriculum for team experiences that are integrative in their approach to problem solving. The idea being that the goal of teams would be to integrate ideas for task related problems in a collaborative effort to optimize results.

A multiple regression analysis was conducted to predict the impact of an established team process, positive team dynamics, and prior experience with teamwork on teams with an integrative strategy for problem solving. The analysis was carried out at a 5 percent level of significance. Multiple regression analysis was selected because it is designed to test multiple independent variables (predictors) and the contribution of each variable on the dependent variable (criterion). The results from the regression model revealed that process, dynamics, and experience, as a set of predictors, account for 41% ($R^2 = .41$) of the total variance in strategy. Furthermore the 41% of variance in strategy explained by the set of predictors is statistically significant $F(3,83) = 18.86$, $p < .05$.

The regression coefficients from the model provided information about each independent variable after controlling for the other two independent variables. From the output of a regression model, conclusions may be made about the predicted change in the raw score for strategy with every raw score unit change in each of the three independent variables. Results revealed that for every 1 z-score unit increase on team process score there is a predicted .67 z-score unit increase in the score on the integrative strategy variable. The results for team dynamics indicated that for every 1 z-score unit decrease on the score for dynamics there is a .18 decrease in the score for integrative strategy. Team experience has a predicted increase of .18 in the strategy score for every 1 z-score unit increase on the score for experience.

Correlations within the model were computed for specific information about the contribution of each independent variable to the total explained variation of 41% in the dependent variable. The results revealed that team process had the greatest unique contribution to the variance in strategy, accounting for 27.5% of the variance. Team dynamics uniquely accounted for 2% and experience accounted for 3% of the variance in strategy. In sum the variation accounted for by combining the unique predictor scores of 27.5%, 2%, and 3% is 32.5%. The remaining 8.5% of the 41% variance in strategy cannot be identified because of the overlapping variance in the unique independent variables.

Based on the results from the multiple regression analysis it appears that there are relationships between each of the independent variables and the dependent variable. While overall the results only explain 41% of the variance in strategy, within the results there is interesting information about the set of variables as predictors of elements present in teams that adopt an integrative strategy for problem solving. Of particular interest are the findings about the experience variable. For instance, the fact that although a student's experience with team work had a positive relationship with the team process and team dynamics, the relationship was not statistically significant. However experience did have a positive and statistically significant correlation with integrative strategy. More research is needed to better understand the influence of experience and its relationship to strategy. Team process appears to have the greatest effect as a predictor in the model given the finding that with every 1 unit increase in process there is a predicted .67 z-score unit increase on to teams utilizing an integrative strategy. Based on this it is probable that improvements in team strategy may be accomplished by implementing a new process or by improving a process already in place. Further investigation is needed to explain the remaining 59% variance in integrative strategy as it is not associated with the set of predictors in this model.

The results provide a framework for designing activities that provide students with opportunity to learn ways of improving their work in teams so that it they are effective in their approach to solving task related problems. One limitation to the study is the small sample size of unique respondents. Another limitation is the team size and limited discipline diversity on the team. The results are limited to student experiences in one course form one institution and may not be generalizable to the entire population of interdisciplinary course work. However the study does provide tangible results that may be considered as a foundation for designing activities dedicated to improving team work skills.

6. CONCLUSIONS

While this study does not fully identify all the attributes associated with collaborative teams that practice an integrative strategy for decision making, the study does provide some answers about team process, team dynamics, and team experience. Team process clearly had the greatest

influence on teams that demonstrated an integrative approach. It is important to note that the phrase "demonstrated an integrative approach" is referring to the study participants' response to items on the questionnaire and is not a judgment of the end product in terms of academic evaluation by the instructors.

Activities to prepare students for a collaborative team experience should be included in course work prior to the start of a project. Time spent on addressing the factors to manage and on establishing team standards for interactions will be time well spent in preparing students for success. Activities should go beyond discussion about the concepts to include the mechanics of team process. Knowledge about how a team process works is important to developing team skills. Dedicated instruction regarding the key elements of the teaming process with some methods and measures for each element will provide students with a basis for establishing their team process. Key elements to include in the instruction are: goal setting, communication approach, alternative analyses, decision making, and conflict management. Requiring students to define and develop a team process consumes valuable project time, in the end however it may prove to actually reduce unproductive time and improve project outcomes.

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