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PROCESS AND STRUCTURE: PERFORMANCE IMPACTS ON COLLABORATIVE INTERDISCIPLINARY TEAM EXPERIENCES

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SUMMARY: *Does a team's process or its structure have a greater impact on its performance? In a recent study investigating interdisciplinary student teams assembled for a design-build charette, results indicated that both process and structure influence team dynamics and by extension the end product. Teams with no prior experience working together were given two weeks to complete a proposal for the addition to an elementary school. Team members represented both the design and construction disciplines and were in their final semester of undergraduate studies. A Request for Proposal (RFP) was issued for the project requiring each team to submit a building information model as part of their proposal that was then presented to the owner. Students developed their proposals within a charette context, contributing their discipline specific knowledge and expertise early in the project. Working in a charette environment requires teams to form quickly and establish roles, responsibilities, and workflow if the team is to be successful. The findings reported in this paper indicate that students perceive team process to be slightly more important than team structure and thus agree that protocol, information sharing and standards impact collaboration. The results also indicate that the students neither agreed nor disagreed that information exchange has an impact on collaboration. The goals of the project were to improve student understanding of both team structure and process and how, when integrated early in the project, each could affect the final outcomes. The results reported in this paper indicate that students perceive team process to be slightly more important than team structure and thus agree that protocol, information sharing and standards impact collaboration. The results also indicate that the students neither agreed nor disagreed that information exchange has an impact on collaboration. Discussion about the importance of establishing a framework to support the team's structure is included as a link between process and structure. Results from this study can be used to inform future curriculum development that supports student success in the 21st century as more design and construction programs seek to integrate collaborative interdisciplinary team experiences utilizing BIM.*

KEYWORDS: *interdisciplinary teams, BIM, design-build, charrette*

REFERENCE: *Tamera McCuen, Elizabeth Pober (2016). Process and structure: performance impacts on collaborative interdisciplinary team experiences. Journal of Information Technology in Construction (ITcon), Special issue: 9th AiC BIM Academic Symposium & Job Task Analysis Review Conference, Vol. 21, pg. 177-187, http://www.itcon.org/2016/12*

1. INTRODUCTION

C5 is an interdisciplinary design-build project designed as a collaboration between architecture, interior design, and construction supported by the use of building information modeling. The name C5 derives itself from a mantra developed to define the project containing 5 "C's: Collaborate, Create, Construct, Capstone Charette. Guiding the development of C5 is the premise that BIM enhances collaboration in the design-build process and that collaboration depends on five key principles applied to all team members: 1) interactive communication, 2) full involvement, 3) mutual trust, 4) shared risks and rewards, and 5) teamwork (Design-Build Institute of America [DBIA], 2012).

1.2 Literature Review

Collaboration is the norm for how academic, business, and creative ventures should be executed in the 21st century. Although the definition for collaboration may vary across domains in the balance of function and social inputs, the essence of collaboration depends on the ability of a team to interact for the purpose of successfully accomplishing the team's goal. One definition from the business management literature describes collaboration as a process of decision making among interdependent parties that involves joint ownership of decisions and collective responsibility for outcomes (Liedtka 1996). Collaboration facilitates a shared understanding about the purpose of the team and its reason for existence to work on a common goal toward task accomplishment. Additionally, it is important that the organization of a team's members provide a structure to facilitate a process that supports collaboration. The process by which teams accomplish their goals and the structure within the process occurs have been the basis for team research and frequent topics in the literature of teamwork. In her early work related to team building and collaboration, Gladstein (1984) presented a model of team effectiveness in which a team's process was determined to be the antecedent for team effectiveness.

For this study, the distinction between team process and team structure provided a baseline for better understanding about the aspects that contribute to effectiveness within a team environment. According to Gladstein (1984), a team's process 1) defines specific modes of interaction between its team members at specific points in time, and 2) is influenced by the team's structure. Additionally, Gladstein (1984) identified the factors of team process as: open communication, supportiveness, conflict, discussion of strategy, weighting individual inputs, and boundary management. According to Marks, Mathieu, & Zaccaro (2001), a team's process can be categorized into three dimensions - transition, action, and interpersonal. It is during the transition phase that a team's process includes strategy formulation and planning about how team members will achieve their tasks, exchange task-related information, prioritization of goals, and communication of plans to all team members (Marks et al., 2001). Action processes occur during task performance and focus on coordination and monitoring activities directly related to the accomplishment of objectives, whereas the interpersonal processes focus on managing interpersonal relationships and are continuous (Marks et al., 2001). The four factors identified by this study as influencing team process were based on the previous work of Gladstein (1984) and Marks et al. (2001).

Team structure has an impact on team process and can have both a direct and indirect influence on group effectiveness. The indirect link to effectiveness is achieved through the influence of group structure on group process (Gladstein, 1984). Team structure refers to the arrangement among people based on roles and responsibilities, clarity of goals, work norms, task control, size, and formal leadership. A team's structure is driven by its tasks, or purpose for forming. The concept of a taskwork network by Crawford and Lepine (2013) proposed to account for how team taskwork ties emerge either from explicit task assignments based on tasks inherent to members' positions, or through the team's decisions on how to allocate taskwork. Fundamentally it involves the interactions team members experience with tasks, tools, machines, and systems. For this study, Gladstein's (1984) definition of team structure combined with the research by Crawford and Lepine (2013) about taskwork network, guided the identification of factors influencing team structure.

An understanding about the relationship between technology, structure, and communication to encourage an effective communication process can contribute to improving team interactions and performance. Team management factors facilitate standards for team interactions, such as information exchange. Standards for the team serve to 1) establish and communicate expected performance to all team members, 2) establish and communicate roles 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 in a normative manner that fits within the team's understanding of roles and responsibilities (Malhotra, Majchrzak et al., 2001).

It is important that teams working in a collaborative project delivery method, such as design-build, exchange information at many different levels and stages from early design through construction. A variety of BIM tools support the mechanics of exchanging information utilizing a common language (IFC) or with the use of proprietary plug-ins; however even with the technology support, gaps in information exchange still exist. It may appear that data and information are interchangeable but there is a distinct difference between them. Data is defined as a collection of empirical observations or facts. In contrast, information is a collection of facts or observations for use in making decisions or drawing conclusions (Smith, 2009). According to the National BIM Standard (NBIMS), information exchange is a process in which a project team establishes what information will be exchanged and the format for exchange between team members (National Institute of Building Sciences [NIBS], 2012). The Project Execution Planning Guide (Computer Integrated Construction Research Program [CIC], 2010) includes the act of defining information exchanges as one of four steps to be completed by project teams in creating and implementing a BIM Project Execution Plan. To be effective the information exchanges should be created early in the team planning process and establish a mutual agreement about 1) the model elements to include by discipline, 2) the level of development for each model element, 3) any additional information or attributes important to the project, and 4) discipline specific deliverables (CIC, 2010). The team process of defining information exchanges is a critical step for teams to collaborate and have success in meeting the project goals.

Information sharing is closely related to information exchange; however, sharing information is considered a principle necessary for success in a design-build (DB) or integrated project delivery (IPD) project, whereas information exchange is a process established to share information. Project delivery methods with less integration between disciplines typically stifle information sharing as individual entities hold separate contracts for design and construction services. Sharing information is a DB principle that facilitates the alignment of design and construction professionals and reduces redundant work resulting in time savings (DBIA, 2012; NIBS, 2012).

With the team committed to information sharing and the information exchanges established, teams should define a procedure for file transfer protocol and their communication protocol. Establishing protocols will support collaboration and define the team's document management process to include file folder structure, permissions and access, folder maintenance, folder notifications, and file naming convention (CIC, 2010; Eastman, Teicholz, Sacks, & Liston, 2008). The Architecture/Engineering/Construction (AEC) National CAD Standard (NCS) and the NBIMS are standards adopted by the industry that set forth the expected content, format, and graphical representations in BIM models. Standards such as ISO, LEED, ADA and ASHRAE are just a few other industry standards utilized to guide the design and construction of the built environment.

1.2 Purposes

Research about collaboration among interdisciplinary student teams using BIM is an important topic for educators in the design and construction disciplines. As buildings become more complex, the ability for project team members to collaborate increases. As a consequence, efforts to educate tomorrow's AEC professionals are evolving to integrate interdisciplinary team experiences with instruction about interdisciplinary collaboration.

The current study focused on three elements identified in the literature as important attributes of successful teams. The research investigated the process and structure of a team, and how the two impact collaboration. Variables of the construct team process included information exchange, protocol, information sharing, and standards. Essentially these are the actions of the team and how it operates as a team. Questions were designed to measure a team member's perception about the team process. For example, "It is important that team members agree upon a format for the exchange of technical information." In contrast, the team structure construct included items that measured participant's perceptions about the roles, responsibilities, project knowledge, and technical expertise on a team. "Clearly defined responsibilities for each role is important to ensure positive team dynamics" was one of the items included about team structure. The current study sought to answer the following research questions:

1) Is there a difference in student perceptions about the importance of team process compared to team structure?

2) Which individual team process components do interdisciplinary teams identify as impacting collaboration?
3) Does a team's process or structure have a greater impact on its performance?

The results from this research would serve to inform the instructors in the AEC disciplines that are involved in teaching collaboration. In particular, the results would help determine if the current instructional model and strategies for teaching interdisciplinary collaboration are appropriate or sufficient to developing students' collaboration skills.

2. METHODS

2.1 Participants

An exploratory study was conducted with undergraduate students (15 female; 15 male) enrolled in either the senior level commercial construction, interior design, or architecture course in the College of Architecture at the University of Oklahoma. Students were recruited and volunteered to participate in an online survey. Participants included 11 Construction Science, 12 Interior Design, and 7 Architecture of which 24 students reported a grade point average of 3.0 or higher. Twenty-eight of the 30 study participants reported having at least one internship experience and all 30 participants reported having experience working in teams during their academic studies in the College of Architecture. No distinction was made between interdisciplinary or single discipline team experiences, but 26 of the 30 reported working in teams at least 4 times. Ten of the students reported working in teams more than 10 times in their course work.

The study was designed to investigate the relationship between team effectiveness, structure, and process utilizing a 44 question online survey administered after completion of an interdisciplinary course project. Students were provided with a web link to the survey and time to complete the survey in class. There was no pre-intervention survey to measure student attitudes about teams; however, student teams were required to complete a questionnaire about ten factors previously identified as impacting collaboration.

2.2 Context

The C5 interdisciplinary design-build project was organized for students in the final semester of their academic career. The composition of each typical student team was balanced with one student from each of the architecture, interior design, and construction programs. The planning and design of the project was also a collaborative team effort with one faculty member from each of the three represented disciplines.

The faculty team began their collaboration for C5 with each team member having a true understanding and respect for each discipline in the design and preconstruction process. The C5 project development began with an extensive planning phase executed by the participating faculty members. During the first step of the planning phase, the faculty had an open dialogue about collaboration from their discipline's perspective and shared their personal experiences with previous collaborative efforts. This open dialogue enabled a better understanding of each discipline and obstacles that could impact the effort. The faculty identified discipline specific learning outcomes first, and then vetted each until an agreement was reached about the project's learning outcomes from a collaborative team approach. The importance of this process was that only through first identifying the discipline specific outcomes could the faculty better understand each other's perspective and how to merge the siloed perspectives into an integrated perspective.

The primary intent of C5 was to provide architecture, interior design, and construction science students with the opportunity to apply their discipline specific knowledge in an interdisciplinary team environment to demonstrate their ability to collaborate for the purpose of creating a proposal that successfully responds to the owner's requirements for a given project. The learning outcomes identified by the faculty members included:

1) Given a real-world project students would create a proposal that met the project owner's requirements.
2) Students would demonstrate their ability to analyze project requirements and collaborate to establish and execute team goals for the project.
3) As a member of an interdisciplinary team students would apply their expertise as defined by the team's roles and responsibilities.
4) The team would demonstrate their ability to create an effective visual and oral communication of their team proposal for the project.

Three key components guided the faculty in the development of the C5 project. The first component was to situate the experience in the first two weeks of the capstone courses during the final semester of each team member's undergraduate program. The relevance of the project occurring in the last semester was that at this point, all the students would have completed their discipline's core technical course work. As a result of the their discipline knowledge from prior course work, the students would be better prepared to successfully collaborate and add substantive value as a team member than they would have at a point earlier in their education. Secondly, the students would work together within the context of a charette. The faculty members believed this format would provide a concurrent and multi-level process in which all team members would contribute their knowledge and expertise early in the project through openly shared information. The third key component was that each of the students would share the risk and reward for the success of their team's final project proposal with the same weighted project grade allocation in each of their respective capstone courses.

The faculty agreed that the best way to teach collaboration was by example; therefore, the decision was made to recruit industry partners with prior experience working together to actively participate in the project as experts to role model for the student teams. The faculty believed that through the industry partners sharing specific examples of successful collaborative experiences, including their typical structure and processes, students would gain a real-world perspective and valuable knowledge about best practices and lessons learned from an integrated project approach. It was expected this type of industry partner would demonstrate the principles of mutual respect and trust between the team members. The participating faculty members also taught collaboration by demonstrating an integrated team approach themselves during the charette. The faculty members agreed that the project outcomes would be evaluated as a faculty team and that the final score would be a team score weighted equally in the course work for each discipline. This approach to evaluation by the faculty, supported an environment of mutual benefit and reward for student teams

The goals of the C5 project were to improve student understanding about the integration between the disciplines of both team structure and process and how, when integrated early in the project, each could affect the final outcomes. For example, the faculty members viewed this as an opportunity to improve the architect and interior designer's understanding about the impact of design elements on a project's cost and schedule. The experience would also provide the constructors with an opportunity to better understand the impact of the holistic approach that the design team must utilize to meet the project programme and consider the surrounding context. It would also provide architecture students with an opportunity to better understand the environmental psychology and space use of the users. Interior design students would have an opportunity to better understand the integration of structural systems that architects are responsible for on the project. Constructors would gain experience during the iterative design approach in which they would have the opportunity to provide insight about the construction process. Ultimately, students would have an improved understanding about the roles and responsibilities of each discipline and, in turn, their overall team structure. The students also would understand where there were possible gaps and overlaps in their team's knowledge and skills, giving them a better opportunity to fully understand and implement a process for the team to follow.

A local community client with a real-word project was utilized. The Superintendent of Schools for a local school district agreed to fully participate in the project and act as the client throughout the duration of the project. A school from this district was identified for the project focus. Hillcrest Elementary is an early childhood center educating students in Pre-kindergarten and Kindergarten. The original school was constructed in 1952 with four additions being made since 1961. The RFP developed for C5 solicited proposals for an addition of five new classrooms, student bathrooms as needed to meet code for proposal addition, a new entry with secured vestibule, secured reception area, new administration offices, minor interior renovations to the existing facility to bring a somewhat cohesive aesthetic to the interior, a below grade safe room that would hold 600 people and site additions of 50 parking spaces and a new parent drop off lane. The client was available to answer questions and provide feedback throughout the charette.

2.3 Materials

The materials for the charette consisted of 1) a personality assessment, 2) two team building exercises, and 3) a written 48 page Request for Proposal (RFP). The personality assessment provided a quick interactive activity for students to complete based on four qualities that identified their interaction and leadership style. Team building exercise 1 required team members exchange personal information, along with their academic and professional goals. The second team building exercise required student teams to list 10 factors they identified as impacting collaboration. Students were asked to first discuss each of the factors and then develop a written plan describing how their team would address and manage each factor to optimize collaboration. The RFP provided an overview of the project including the project owner's requirements, and a detailed list of deliverables. Additionally the RFP included exhibits (or links to exhibits) of the existing building drawings, site survey, location map, estimate summary sheet, and geotechnical report. Digital photographs of existing building and site conditions were also provided. All deliverables were submitted electronically through the on-campus course management system. Students were required to have a personal laptop with Revit, SketchUp Pro, Assemble, Microsoft Project, Adobe Photoshop, and Microsoft Office.

2.4 Procedures

The first day of C5 was scheduled as an eight hour intense meeting with team building exercises, introduction of the project by the community client, industry partners' presentation and role playing demonstrations on team building and professional collaboration skills, release of the request for proposal (RFP), and time dedicated for the teams to work together and begin making decisions about the project. During the work time the faculty and industry partners had the opportunity to observe and advise the student teams through the beginning stages of their collaborative design efforts. The students not only had the opportunity to learn from both their professors and professional industry advisors, but began to learn from each other within the controlled collaborative environment. The faculty and industry partners worked with each team during the initial eight hours to define their goals and implement a process for the team to follow in order to better prepare themselves for an outstanding performance. Teams were also required to discuss individual expertise, identify each team member's roles and responsibilities. Additionally, the teams also determined a method for transparent and inclusive communication when all team members were not together, along with a method to share electronic files during the first session. Through industry partner participation, teams learned to manage and resolve conflict in a way that would support the team's goals for the project.

A second meeting between the faculty and students took place midway through the project to evaluate the students' progress and address any issues with team dynamics, structure or process. Within the two weeks of the project, the three faculty members maintained collaborative office hours where individual teams could meet with the faculty and discuss any issues or ask questions about the project. The client also made himself available to answer questions from the teams through email. Faculty members were copied on these emails in order to be fully aware of what was being communicated to both the client and teams.

The architecture and interior design students formed the design team and worked together in a collaborative teamwork approach. The design team's first responsibility involved translating the owner's programme during early design in an iterative manner between the two disciplines. With a common understanding of the space requirements, adjacencies, and project constraints the design team then discussed with the constructors the results from their pre-design activities, at which time, the constructors completed an analysis and provide recommendations for consideration by the project team. Based on the project team's agreement from the pre-design phase, the design team continued developing the project's schematic design. The architects and interior designers worked closely together to coordinate the structural system, building enclosure, and mechanical/electrical/plumbing (MEP) systems in a manner that provided spaces that would function for their intended use and provide a healthy environment for its occupants. The constructors provided ongoing design review and feedback about the project's constructability, costs, and risks. BIM was utilized throughout the project by all team members to facilitate interactive communication and decision making between team members.

During the final segment of the project, the student teams submitted and presented their project proposals to the clients, industry professionals and faculty members. The minimum deliverables required from each team included: precedent studies, programme analysis, concept development, code analysis, site plan, floor plans, interior and exterior perspectives and elevations, preliminary specifications, basis of estimate and schedule, constructability review, conceptual cost estimate, preliminary construction schedule, site logistics plan, risk analysis, and safety plan. All deliverables were organized in a proposal booklet and synthesized in digital presentation slides with an oral group presentation. Each team was required to handover a building information model (BIM) with the project proposal. Requirements for the model included complete and accurate model elements ranging between level of development (LOD) 200 and LOD 300.

2.5 Research Design

In the design of this study there were eight variables for the two constructs of team process and team structure. The team process variables included information exchange, protocol, information sharing, and standards. Roles, responsibilities, project knowledge, and technical expertise were the four variables for team structure. The research model for this study is shown in Fig. 1.

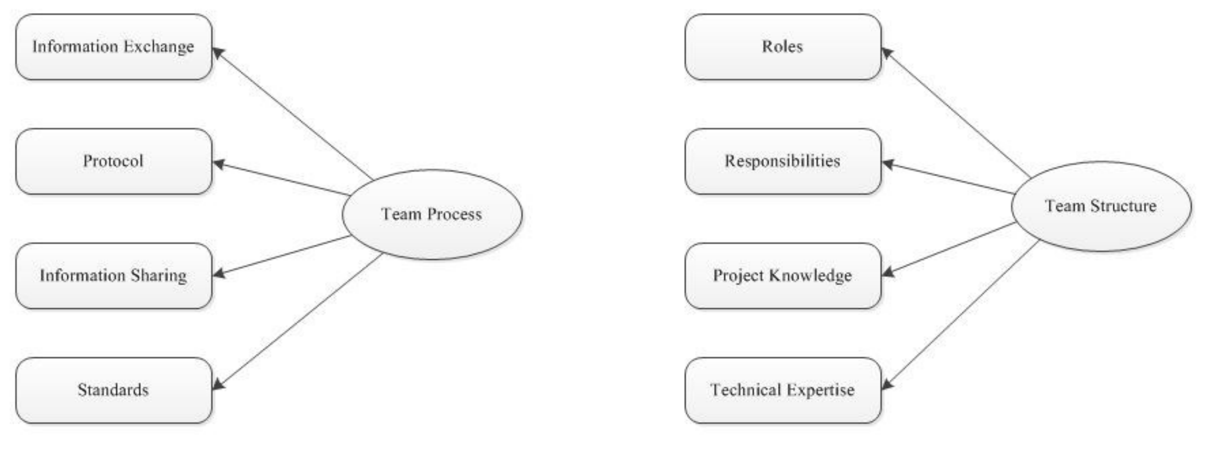

FIG. 1: Research Model

2.6 Instrument

An online survey with 44 Likert type questions was used to collect data. Participants were asked to complete the survey outside of the classroom. The survey included questions designed specifically for each variable. A scale of 1-5 was used with 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree. Within each group of questions about a variable there was one question designed with a reverse scale. In addition, five questions were included to collect demographic information. A total of 30 students participated from the 38 students recruited, resulting in a 79% response rate.

2.7 Data Analysis

Descriptive statistics and Pearson correlation analysis were used to answer the research questions. The co-researchers were domain experts and also taught two of the three courses involved in the project. Survey data was extracted from Qualtrics as an exported file and imported to SPSS for analysis. The eight reverse scale items were first transformed and recoded into same scale as the other items. Next, the results from the three questions about each construct were summed to compute an aggregate mean and standard deviation for each variable. The aggregate mean for each variable was then summed for an aggregate mean and standard deviation for the construct. Lastly, a correlation analysis of all eight variables was performed.

3. RESULTS

Table 1 displays the aggregate mean and standard deviation for each item measured by the survey, along with the summed aggregate mean and summed standard deviation of constructs.

3.1 Summary of Results

Based on the data in Table 1, the researchers were able to provide the answer to research question 1, which indicated that there is a slight difference in student perceptions about the importance of team process compared to team structure. The results revealed that the aggregate mean (4.0, SD = .698) for team process is slightly greater than the aggregate mean (3.93, SD = .842) for team structure in the current study. The team process results by variable displayed in Table 1 provided the researchers with additional data to answer research question 2 about which individual team process components interdisciplinary teams identify as impacting collaboration. Based on the results, students perceive information exchange as having the least impact on collaboration. The aggregate mean (3.76, SD = .963) for information exchange equates to students neither agreeing nor disagreeing (based on a scale of 1-5) that information exchange has an impact on collaboration. In contrast, the participants agreed that protocol, information sharing, and standards impact collaboration.

In addition to mean and standard deviation, correlation coefficients were computed between the eight variables. A p value of .01 was used for significance due to the small sample size. The results of the correlation analysis presented in Table 2 show that five of the correlations were statistically significant and were greater than .35, regardless of the direction of correlation. The correlations of standards with protocol; roles with information sharing; and roles with responsibilities were all high and significant compared to the other correlations between variables. The results reflect correlations within both groups of variables, along with a correlation between groups.

TABLE 1: Team process and team structure data

Variable	Aggregate Mean and Standard Deviation (by variable)	Aggregate Mean and Standard Deviation (by construct)
Team process		
Information exchange	3.76 (.963)	
Protocol	4.05 (.609)	4.0 (.698)
Information sharing	4.18 (.637)	
Standards	4.03 (.585)	
Team structure		
Roles	4.12 (.863)	
Responsibilities	4.19 (.809)	3.93 (.842)
Project knowledge	3.61 (.905)	
Technical expertise	3.79 (.791)	

TABLE 2: Correlation of variables

	1	2	3	4	5	6	7	8
Information Exchange	---							
Information Sharing	.16	---						
Responsibilities	.06	.17	---					
Technical Expert	.12	.48**	.21	---				
Protocol	-.16	.04	-.13	-.31	---			
Standards	.01	-.18	-.11	-.40	.59**	---		
Roles	.15	.58**	.60**	.40	.07	-.08		
Project Knowledge	.16	-.14	-.29	-.49**	.38	.30	-.21	---

Note. Variable 1 = Information Exchange; Variable 2 = Information Sharing; Variable 3 = Responsibilities; Variable 4 = Technical Expert; Variable 5 = Protocol; Variable 6 = Standards; Variable 7 = Roles; Variable 8 = Project Knowledge

**p < .01

The significant correlation of standards with protocol suggests a positive relationship exists between the two team process variables and may contribute to an answer for research question 2. The other two significant high correlations exist between group variables, roles with information sharing, and within the team structure group variables. The correlation between roles and information sharing suggests that certain aspects about team process and team structure interact and influence collaboration. In addition, relationships exists within the team structure group between roles and responsibilities. The researchers were unable to provide an answer to research question 3, investigating whether or not a team's process or structure has a greater impact on its performance, based on the data collected for the current study.

Fig. 2 is a proposed model representing the relationship between team process variables based on the results used to answer research question 1. Collaboration is at the top indicating the team's goal with industry standards providing the basis on which all other variables build. Although the results indicated a neutral attitude about information exchange, the participants perceive protocol as an important variable of collaboration therefore it is combined with information exchange in Fig. 2.

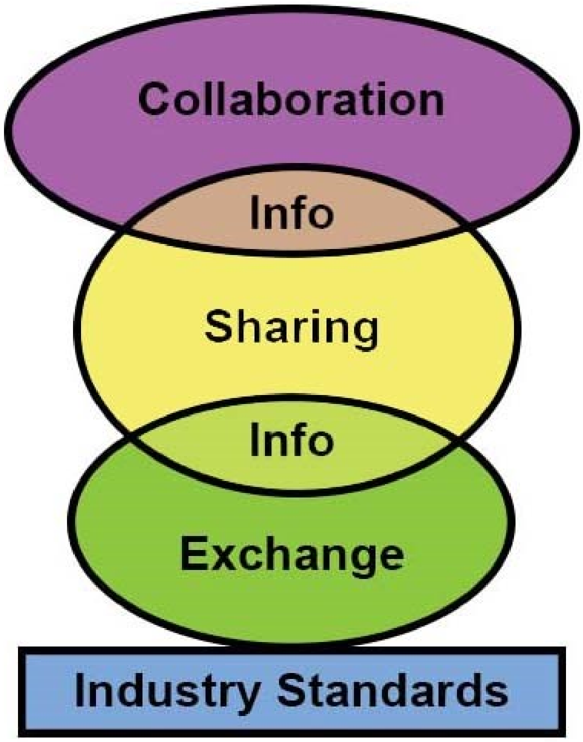

FIG. 2: Team process model of variables

4. DISCUSSION AND IMPLICATIONS

The distinction between the importance of team process and team structure are slight based on the current study results; however, the results initiated additional questions about each construct and the possibility of interdependence between variables and constructs. As reported in the study design section above, 28 of the 30 participants reported having real-world industry experience and all of the participants had previous experiences working in teams during their academic studies at the OU College of Architecture. A tentative conclusion may be made that because participants had experience with both industry and teams, the students understood the impact of team process on collaboration. Drawing the conclusion that previous experiences may have created an understanding about team process led to further questions about the quantity and quality of student experiences compared to the type of experience, whether industry or academic. Further research that discerns between type, quantity, and quality of student domain experiences relative to team performance would provide empirical evidence that could be used to evaluate the effectiveness of the current instructional model used by educators teaching students about design and construction team collaboration.

C5 is expected to continue annually as a project in the spring semester of students' senior year; therefore the researchers anticipate opportunities to study student experiences and their relationship to team process, structure, and performance. There is anecdotal evidence however that indicates gaps between the students' perceptions about team process and their approach to ensure a process in which the team utilized industry standards to establish protocols for information exchange. Based on observations during the charette and discussions with students post proposal submittal, the faculty believe there are opportunities to improve student team performance.

4.1 Study Limitations

Limitations of this study include its small sample size from a single institution, which may have influenced the results. Not only were the participants from a single institution, they were from a single college at one university. The participants' knowledge and experience with interdisciplinary collaboration may have influenced the results. Another limitation of this study was its restriction to senior level students only whose perceptions about collaboration may be influenced by the number of academic and professional experiences. Even with the limitations there are indicators that relationships exist between variables within groups and between variables across groups.

4.2 Instructional Implications

Interdisciplinary collaboration is gaining importance in the AEC industry and education. Therefore instruction is needed about collaborative methods and processes that will prepare students to participate in integrated project teams. Results from the current study indicate that team member roles are significant in their relationship to responsibilities and information sharing. Although the results are not generalizable, they do indicate that instruction about team member roles should be included in future courses to aid in improving team performance.

5. CONCLUSIONS

The results from this study revealed that the variable having the greatest impact on team process was information sharing, which aligns with the literature that information sharing reduces redundant work through the alignment of design and construction professionals (DBIA, 2012; NIBS, 2012). Fundamental to BIM are tools and processes which are designed to 1) reduce waste due to redundant work and 2) support team collaboration through information sharing (Smith & Tardiff, 2009). Establishing the team structure and its processes was the responsibility of each student team; however, all teams were required to use BIM for design and preconstruction activities. It is unclear as to the reason why participants identified information sharing as having the greatest impact on the team, but it is reasonable to conclude that the BIM-enabled information sharing influenced the results. It is also reasonable to conclude that the students who participated in the C5 project are better prepared to utilize BIM as members of a collaborative team in their future professional endeavors.

Based on the results related to team structure, the students' understanding about the impact the other disciplines' roles and responsibilities on their team improved. The hope is that the students moved into their professional careers with a better understanding of each profession's strengths and weaknesses, including their own, and have a greater respect for each discipline. In addition to the students' increased knowledge about collaboration, the C5 faculty members increased their knowledge about each discipline and are better prepared to teach in an interdisciplinary college and collaborative environment.

Additionally, students further developed their technical expertise and gained a better understanding about how BIM can enhance interdisciplinary team collaboration. Although traditional capstone projects are completed individually, C5 provided an added component that further reinforced the idea that a collaborative effort is required to successfully design and construct a building. Ultimately C5 provided students with an abbreviated simulation of what they can expect in their future professional roles as design-builders. The academic environment provided students with an opportunity to practice their professional roles with peers who represent the roles of future team members. Buildings are ultimately created by a diverse team of professionals, and better buildings can be created when the team members are able to escape their individual professional silos and collaboratively work together based on mutual understanding and respect.

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