Socially Responsible Collaborative Models for Green Building Design

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Abstract
In light of recent industry and societal developments, we submit that Boyer and Mitgang's critical challenge facing architecture programs be revised to *making connections with design curricula*. We believe that connecting design curricula will have a professional downstream impact on the built environment. These future practitioners will be better equipped to collaborate during the conceptualization phase in an effort to minimize a building's contribution to climate change. This paper describes the connections of twenty-three teams and nearly one hundred architecture and engineering students from the University of Nebraska-Lincoln, Montana State University, and the University of Wyoming. The students collaborated on a comprehensive architectural design problem for a Performing Arts Center. We performed a variant of the exploratory mixed methods research design to examine the nature of how students connected with other disciplines. The results indicate that groups either chose the more difficult and unknown journey of completing a single architectural design with their distance partners, or groups returned to their local comfort zones and developed separate design responses. This highlights the need for more collaborative experience in design programs. We articulate the collaborative attributes into hallmarks of best practice strategies to achieve higher levels of disciplinarity.

1. Introduction

Boyer and Mitgang (1996) proposed that, "Making the connections, both *within* the architecture curriculum and *between* architecture and other disciplines on campus, is, we believe, the single most important challenge confronting architectural programs." This challenge of making disciplinary connections should be revisited in light of recent industry and societal developments.

Rearticulating Boyer and Mitgang's Critical Challenge

Educational administration authors have evidenced that curriculum advancements should include the consideration of its constituents (Diamond 2002). Theall (2002) furnishes an atomic model of constituent engagement for academic programs. Peripheral industry and societal movements must pass through organizations and accreditation boards to influence academic programs. For the upcoming 2008 Conditions for Accreditation, the National Architectural Accrediting Board, Inc. (NAAB) solicited recommendations from its constituent organizations: American Collegiate Schools of Architecture (ACSA), National Council of Architectural Registration Boards

(NCARB), American Institute of Architects (AIA), and AIA Students (AIAS). The common emergent themes were integrated practice (IP) and sustainability with a responsibility to community and society.

We propose that design education rearticulate Boyer and Mitgang's critical challenge in light of IP and sustainability. If we first unveil IP, we discover that this is supported by the AIA's Integrated Project Delivery (IPD). A specific attribute inside of IPD is how the project stakeholders enter and participate in the design phase. IPD replaces the traditional design process with an integrated design process. This introduces the design consultants (other disciplines) earlier during the new conceptualization phase, formerly known as pre-design. The connection now occurs prior to the commencement of criteria design, the former schematic design phase (AIA CCA 2007). The result is a condition where other disciplines are acting as equal project stakeholders at an earlier juncture contributing to potential architectural design outcomes. IP reduces Boyer and Mitgang's "architecture curriculum and other disciplines" to *design curricula*. This new stakeholder partnership is facilitated by the deployment of Building Information Modeling (BIM). The National BIM Standard Project Committee defines BIM as, "A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle" (NBIMS n.d.). The shared opportunities in BIM allow other disciplines to be "*off* campus."

The BIM platform supports the second emergent theme of sustainability. Writer and architect Jerry Laiserin (2005) illustrates that the larger picture of sustainability is dependent on the parametric attributes of BIM, based upon "performance simulations – the ability to manage information about building materials and building processes." Currently, buildings account for almost 40% of the primary annual U.S. energy consumption where over 85% is supported by non-renewable, fossil fuel energy resources (Kibert 2008). Performance simulations not only measure the operational energy, they also support carbon neutral design and can close the loop on our ecological footprints. This observes the larger goal of minimizing a building's contribution to anthropogenic climate change. To achieve this goal while being responsible to community and society necessitates the preparation of future architects and other disciplines in the conceptualization and criteria design phases.

In light of recent industry and societal developments, we submit that the most important challenge facing architecture programs today is *making the connections with design curricula*. Its simplicity is deceptively complicated since the challenge involves the early engagement of other disciplines into the architecture curriculum with distance capabilities. We will demonstrate how two architecture programs and one engineering program responded to our new challenge.

Connecting Design Curricula

Successful collaboration is required for IP to flourish. We investigated the accreditation requirement for collaborative opportunities between architecture and engineering programs. The current architecture accreditation requirement for collaboration is housed in NAAB's 2004 Conditions for Accreditation, Criterion 7, Collaborative Skills which reads, "*Ability to* recognize the varied talent found in interdisciplinary design project teams in professional practice and work in collaboration with other students as members of a design team" (NAAB 2004). The ACSA recommendation for the 2008 Conditions for Accreditation introduces a more prescriptive language in terms of applying multidisciplinary collaborations. This implies that ACSA is suggesting that architecture students work directly with other disciplines. The multidisciplinary collaborations would parallel what is already required in the engineering accreditation standards prior to IP developments.

The Accrediting Board for Engineering and Technology, Inc. (ABET) standards for architectural engineering (AE) programs specifically address architectural design. The purpose of architectural design in an architectural engineering curriculum is for graduates to have an, "Understanding of an architectural design . . . that will permit communication, and interaction, with other design professionals in the execution of building projects" (ABET 2007). Furthermore, "The AAC [AEI (Architectural Engineering Institute) Academic Council] believes it is a professional responsibility for architectural engineers to have a basic understanding of the design process of the architects involved in the execution of building projects" (AAC 2007).

An academic fit exists for architecture and engineering programs to collaborate on a common comprehensive architectural design project while meeting their individual accreditation and course objectives. The architects will engage in multidisciplinary collaborations, while the engineers will learn the design process by working directly alongside the architects. This is a first stage collaboration. Subsequent stages include architects studying structures or building performance while working with the affiliated engineers, and then the architectural design studios partner with the engineering capstone courses. Our research project was a first stage collaboration.

Research for Practice (RFP) Project

In an effort to connect design curricula at the first stage, we joined two architecture courses and two architectural engineering courses via distance in the fall semester of 2008. The students in the architectural programs (architects) were all fourth-year seniors. They were enrolled in either a five-credit architectural design studio at the University of Nebraska-Lincoln (UNL) or a four-credit construction documents class at Montana State University (MSU). Each architecture course requires significant visual student outcomes. The students in the engineering program (engineers) were either third-year juniors or fourth-year seniors enrolled in the three-credit first (introductory) or second (terminal) architectural design studio, respectively, at the University of Wyoming (UW). The distance collaborations between UNL and MSU/UW included five teams in a traditional setting with more disciplinary specific roles, while the collaborations between MSU and UW included eighteen teams with architects and engineers collaborating during the conceptualization and design criteria phases.

The research purpose was to gain an understanding of the nature of student collaborations connected with other disciplines. In essence, we *made connections with design curricula*. Understanding collaboration is the foundation for bridging successful disciplinary connections. We believe that connecting design curricula will have a professional downstream impact on the built environment. These future practitioners will be better equipped to collaborate during the conceptualization and criteria design phases in an effort to minimize a building's contribution to climate change. To support this notion we established backdrop conditions of IP and sustainability where the students were encouraged to use BIM and pursue green design, respectively.

2. Procedures

To examine the nature of stage one student collaborations connected with design curricula, we deployed a variant of the exploratory mixed methods research design (Creswell 2005). First, qualitative data was collected to explore and identify collaborative themes, and then quantitative data was collected to explain and validate the relationships found in the qualitative data. Figure 1 illustrates the research process through the three sequential phases of solicitation (participant observation study), central study (phenomenological study), and validation (cross-sectional survey). The investigators followed conventional research protocols. The UW Institutional Review Board approved the research project under an expedited review, and deemed the research project as a study that would not involve more than minimal risk to participants.

2.1 Solicitation (Participant Observation Study)

The design problem is a 57,500 square foot (5,340 square meter) Performing Arts Center situated in Lincoln, Nebraska. The program was previously developed by Mark Hoistad, Assoc. Dean at the UNL College of Architecture. The program has a variety of spaces and needs from an 800 fixed seat auditorium, 200 flexible seating performance space, restaurant and food service to an administrative area. The comprehensive architectural project offers opportunities for long-span systems, two-story spaces, acoustical needs, assembly uses, etc. The program accommodates the integrated practice and sustainability backdrop conditions. The IP backdrop was established through the use of its facilitator technology, BIM. The primary BIM file was exchanged between schools through a secured file transfer protocol (ftp) website. The sustainability backdrop was addressed by the students' designing towards the U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) certified standards.

The distance collaborations occurred between 97 of the students (population) enrolled in the four courses. A majority of the students prepared and posted a biographical summary on the ftp that was available for all students to view prior to teammate selections. They distributed themselves into 23 teams. There were 11 teams composed of two architect (construction document [CD]) students and two (introductory design [ID]) engineer students (CD-ID teams). Seven teams were composed of one or two architect (construction document) students and two or three (terminal design [TD]) engineer students (CD-TD teams). Two teams included three architect (design studio [DS]) students and two (terminal design) engineer students (DS-TD teams). Two teams incorporated three architect (design studio) students and two architect (construction documents) students (DS-CD teams). One team housed three architect (design studio) students, one (terminal design) engineer student, and one architect (construction documents) student (DS-TD-CD). The formal participants (sampling frame or target population) were students that submitted an informed consent form. Seventy-six students were designated as participants with eight students from UNL, 38 students from UW, and 30 students from MSU. All of the architecture and engineering instructors carry architecture credentials through affiliated licensure or terminal degrees.

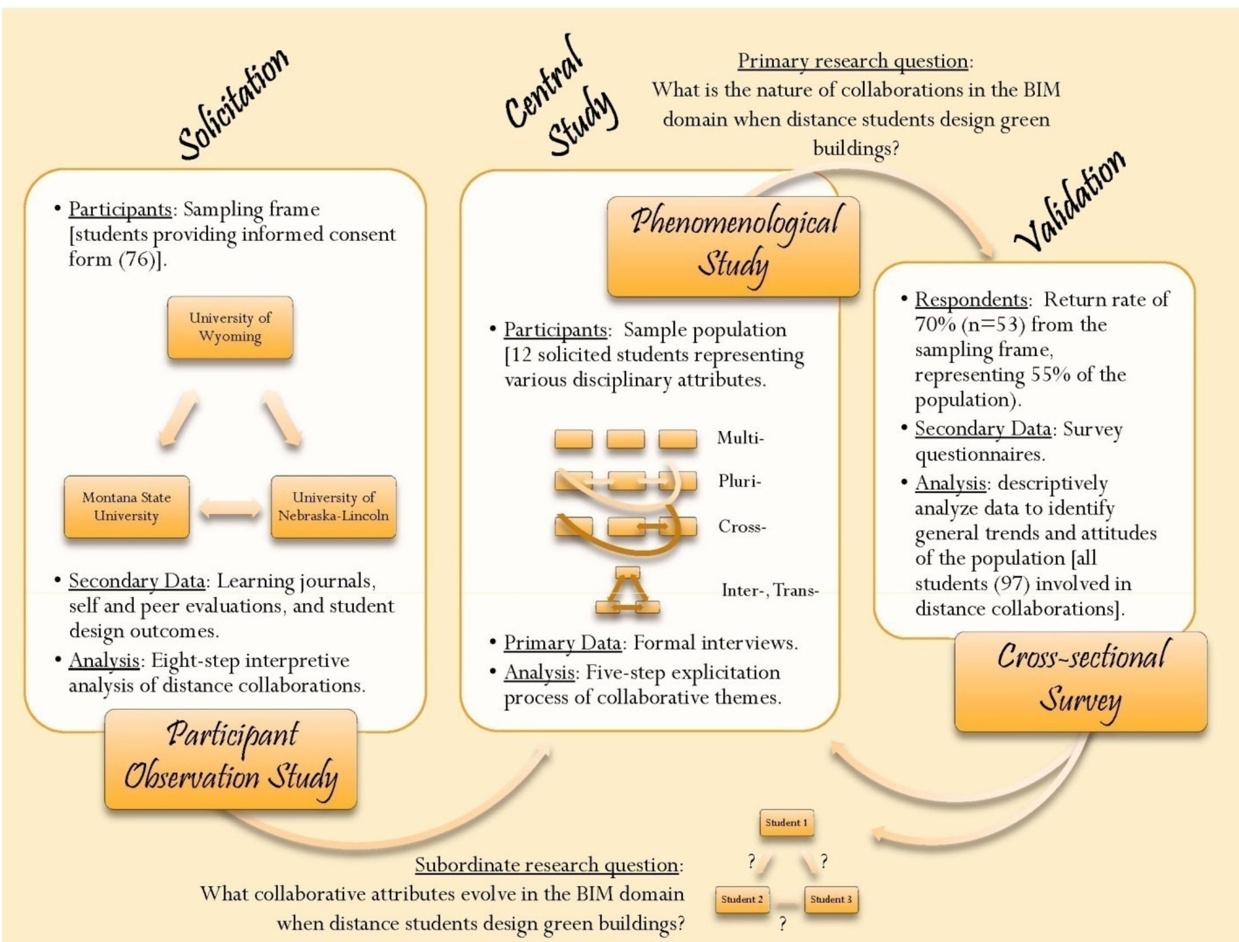


Figure 1: Three phase variant exploratory mixed methods research design.

The first qualitative study in the participant observation tradition evaluated the distance collaborations between the student teams to gauge the cooperation and coordination amongst the team members. The study included fieldwork methods such as artifact collection (learning journals, self and peer evaluations, and student design outcomes) and direct observations recorded in raw field notes. We identify this data as secondary since this study was supportive of the subsequent central study. The confidential journals were periodic student reflections regarding the backdrop conditions. The confidential self and peer evaluation forms portrayed each student's participation in the project and the team dynamics. These artifacts documented the student's roles and their perception of the quantity of work that they performed against the perceptions of their team members. The design outcomes are graphic evidence to document whether the individual contributions were incorporated in the team's collective design response. The data analysis was an eight-step interpretive analysis (Hatch 2002). Once the initial themes and trends of the collaborative attributes were identified, we solicited students for a more in-depth second qualitative study.

2.2 Central Study (Phenomenological Study)

The second research phase deployed a qualitative study in the phenomenological tradition with a constructivist approach. The intent was to capture the students' lived experiences of connecting with other disciplines, and to construct a portrait through their eyes. Each participant is a co-constructor of multiple realities along with the observers and researchers. The multiple realities are the mechanisms for understanding the defining attributes of collaboration, the cooperation and coordination among team members.

The primary data is in-depth interviews with a flexible structure. Twelve of the 76 students were solicited to participate (three telephone at UNL, three personal at MSU, and six personal interviews at UW). This meets the recommendation of Creswell (1998) who suggests ten participants for a phenomenological study. Of the 12 interviewees, ten were from five teams, where we chose one architect and one engineer from each team to better construct the team's disciplinary and distance experiences. The interviewees (sample population) were solicited to elicit a representative sampling built upon Jantsch's (1972) successive steps of disciplinarity through the team's cooperation and coordination attributes. In essence, construct portraits of successful and unsuccessful occurrences of collaboration. The interview protocol had multiple lines of questioning with various probes and follow-up questions. The questions were refined based on the participant observation study. In addition, the participants placed the interviewer inside their journey at their own discretion in the open-ended format. The overall intent was to explore student collaborations connecting with other disciplines. Each interview was audio recorded, transcribed, and member checked. Groenewald (2004) argued that data analysis is not an appropriate terminology for phenomenological research. We applied his five-step variation of Hycner's (1999) explicitation process which concludes by extracting general and unique themes and making a composite summary.

2.3 Validation (Cross-sectional Survey)

The third research phase shifts away from the qualitative studies and deploys a quantitative study. The information garnered in the phenomenological study allowed us to design a survey questionnaire instrument. This was used to validate the relationships and trends found in the participant observation and the phenomenological studies. This additional step may not have been necessary, but the intent was to close any research gaps between the sample and the population and between the sampling frame and the population. The population is students on distance teams in the four courses (n = 97). The sampling frame is students that provided the informed consent form (n = 76), while the sample population is the solicited students (n = 12). The survey response rate was 70 percent of the sampling frame or 55 percent of the population.

The survey is cross-sectional data collected at one point in time. The intent is to examine the collaborative attributes of students and the backdrop conditions. The survey is a written questionnaire delivered by the instructor to the students at the three research sites. The questionnaire was composed of primarily close-ended questions. The questionnaire was pilot tested by MSU and UW students. The data analysis procedures followed conventional statistical measures.

3. Findings

The findings represent the interpretations of the relationships inside the distance (and their associated local) collaborations across institutions. We found that groups either chose the more difficult and unknown journey of completing a single architectural design with their distance partners, or groups returned to their local comfort zones and developed separate design responses. The findings are organized thematically by teams in a light-hearted nickname approach to support of the two aforementioned paths.

3.1 Collaborative Journeys to the Center of the Earth

This section constructs a portrait of the representative teams that maintained their design relationships throughout most of the semester regardless of their differences or where the journey led. The most common themes evolved around managing the knowledge gap (mutual respect, single point of contact, and mentor-protégé relationships), establishing identities (casting calls and in BIM we trust), and negotiating design ideas (*Finding Nemo* and vision quest). We italicized some of the notable reasons that contributed to a team's perseverance.

Single Point of Contact

The architects on this CD-ID team noted that they were not initially aware that engineering programs taught architectural design. As a result, this group chose to list and exchange their individual strengths and weaknesses. This activity fostered a *mutual respect* across disciplines. The respect supported the development of roles or areas of expertise necessary for the students to solve the common design problem. The clarity of roles, or *casting call*, garnered more integrated work across institutions. One architect student mentioned that the, "General form, and all ideas" were integrated. This willingness to negotiate and explain design ideas demonstrated a high respect level of their engineer partners. The same architect stated that they, "Didn't want to do things without consent." This implies that the architects viewed the engineers as equal stakeholders as the conceptual design ideas were mutually integrated. His engineer partner said that we are, "Not really that different." The engineer thought that the disciplinary boundaries between architect and engineer remained inside their traditional structure. He was still an engineer, but was learning about architecture from the architect. The architect thought that the disciplinary boundaries evaporated as they worked towards a common goal. This implies that although the engineer still thinks of himself as an engineer, the architect perceives that the engineer was contributing to architectural design. Figure 2 illustrates how students interpreted others valuing their contributions. The students were confronted with the question, "My teammates treated me as an equal project stakeholder regardless of my role?" The introductory design engineers observed the largest receipt of respect, while the terminal design students felt the least amount. The teams were more likely to finish the project as a group when mutual respect was observed.

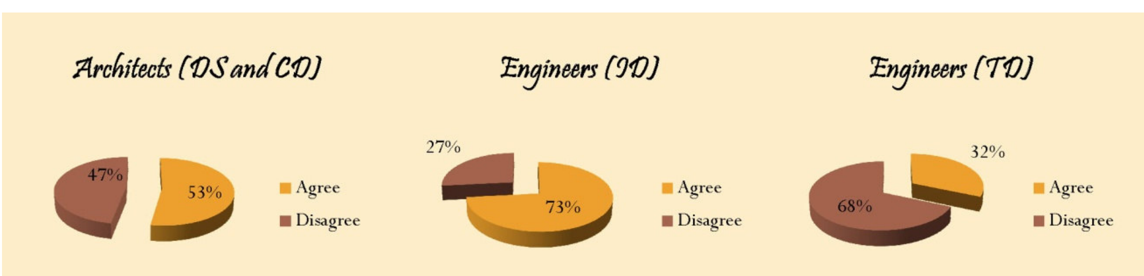


Figure 2: Survey data: "My distance teammates treated my as an equal project stakeholder regardless of my role?"

Nearly half of the architects felt that they were not treated as equal project stakeholders. This highlights the notion that architect students may interpret the design process as their currency. When strangers upset the design process, they begin to feel that their ideas are not being respected. In general, teams that were able to transcend the design process issues looked for ways to collaborate and established roles within the team. The architect student wrote that these consisted of, "Open-mindedness, professionalism and good work ethic during the process." The architect student controlled the design process and thought it was successful. He was also perceived as the team leader. The conclusion drawn is the importance of team structure with regard to the roles that everyone plays.

The students in this team ranked their cooperation and coordination as good or better. When the engineer was directly asked, "What led to this level of collaboration?" he responded with the chain of communication. Multiple times during the interview, he specifically referenced that each team had one representative, a *single point of contact*. This was an interesting finding as the communication follows the more traditional design approaches where lower-level coordination and cooperation amongst team members does not occur across disciplines. Higher-order disciplinarity requires that the lower-levels collaborate between themselves. This is contrary to industry where communications must follow the contractual chain. This team also expressed a *Finding Nemo* sensibility where they were able to agree on a conceptual design rather readily. Each team independently arrived at very similar conceptual ideas. This *vision quest* only occurred in a minority of the teams, but always contributed to their ability to arrive at a single architectural design.

Mentor-Protégé Relationships

Another CD-ID team had an engineer with an opposite opinion than the aforementioned engineer regarding his identity. He stated the disciplinary boundaries dissolved for the engineer in the beginning as the engineers were contributing in the conceptualization phase. He perceived his activities as those of an architect. His architect partner had the same perception as he stated that the, "Structural engineering hasn't shown up yet." This group developed their roles while actively engaged in the design process. The engineer student mentioned that the architects assumed the engineers' block diagrams were actually floor plans. The architects underestimated the engineer's ability to realize spatial relations on a basic level and thereby fully designed the floor plans for the engineers. When the engineers articulated these floor plans into three-dimensional forms in BIM, the architect perceived that the design knowledge gap diminished. The architect said that there, "Was not much of a gap as the [engineering] student had similar interests in design." The architects and engineers were envisioning similar 3D forms which closed the distance. Regardless of whether the engineers perceived themselves as architects or engineers, a *mentor-protégé relationship* evolved from circulating the design process between the schools. This was prompted by common interests in green design. One engineer student said with regard to green design that, "It makes economic sense . . . and it's the 'hip way' to design." His architect counterpart initiated discussions on precedent firms by providing information on Morphosis. Although they could not agree on the pronunciation, they all appreciated Morphosis' notions on sustainability. This led to deeper involvement in conceptualization and good cooperation.

The CD instructor observed that, in general, the architect teams approached the project from two opinions: apprehension about collaboration, or with an open mind. The intermediary minority opinion was one of indifference as the students meet the course objectives regardless. The local architect teams that approached the project with an open mind were generally interested in the opportunities to increase their knowledge base by working with engineering students. They believe the engineers could provide technical expertise with regard to structure and other building systems. The architects viewed the collaborative relationship where they would essentially teach design process and learn from their engineering teammates. This attitude is a fundamental building block of the *mentor-protégé relationship*. Please note that these first two teams were at the extreme ends of the knowledge gap where the introductory studio (ID) partnered with senior architects (CD). Each team also commented towards an initial open-mindedness. These groups were more likely to complete a single design solution.

The scheduling aided the coordination among some teams. The introductory studio was held on Monday and Wednesday afternoons and the construction documents course was held on Tuesday and Thursday mornings. This team chose to exchange the BIM model on a daily basis in concert with the class schedule and rotate on weekends as needed. Sharing the BIM model required an atmosphere of trust since they did not create BIM worksets to partition and protect their individual roles. The ftp website was used as a file sharing systems between this team (and most teams). The data was too large to share through e-mail exchanges although some teams initially attempted this as a document sharing scheme. In addition, the ftp provided secured team file folders for the students to individually manage. Teams exhibiting *in BIM we trust* were most likely to have an overall positive collaborative experience and complete a single design. When asked, "I intend to use Revit [BIM software] on future architectural design projects even if it is not required?" a vast majority indicated that they would (see Figure 3). In support of the BIM exchange, this team chose to communicate by telephone four times per week.

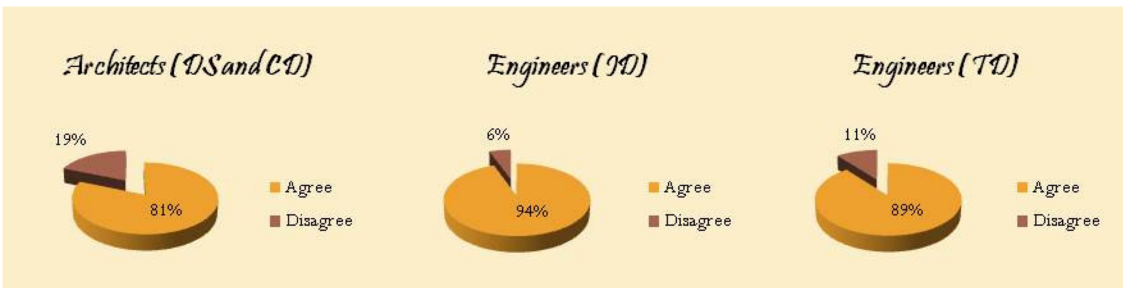
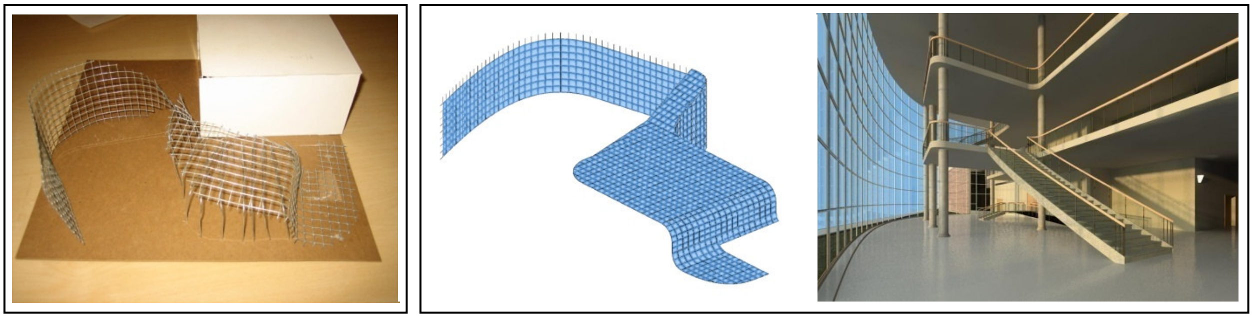


Figure 3: Survey data: "I intend to use Revit on future architectural design projects even if it is not required?"

In BIM We Trust

This DS-TD team struggled to understand their identities and how they could all participate in architectural design. The introductory studio students have a tendency to view themselves as engineers, while the terminal students are more uncertain as they have been exposed to the architectural vocabulary. The design studio group followed a more prescriptive path towards design, and was also paired with local construction management students (outside the scope of this study). The engineer students had to become more assertive if they wanted to have a design phase voice. Once during a conference call, one engineer let it be known that they were taking an architectural design class and she wrote, "So I am asking you to include us as much as possible so that we can learn from you and from each other. We have heard from him [architect] almost everyday since and I really enjoy how much our group seems to get along and be mutually excited about the project." This tactful approach facilitated improved communications and participation. In addition, they inherently followed the ABET interpretation of how to approach architectural design from an engineer's perspective.

One architect said that this DS team did not use BIM. The architects expressed their design ideas in CAD and conveyed them to the engineers. The engineers noted that it was extremely difficult to understand the architectural design exchanges when they were not accompanied by a written or verbal explanation. The engineers eventually overcame the challenge of communicating visual imagery via distance. The architects were comfortable that their design ideas were being exhibited in the BIM model created by the engineers. This was evidence of *in BIM we trust* theme. One architect stated that both the cooperation and coordination was very good with their distance partners. An engineer wrote, "The ideas conveyed both ways were great, but final design ideas were different on both sides." Figure 4 illustrates the design integration. One engineer noted that the BIM massing for the ribbon was one of the more significant engineering contributions. The engineer instructor observed that there was evidence of *mutual respect*, and in the end the engineer students felt a relatively strong sense of contribution to the architectural design.



(a) (b)

Figure 4: Design integration: (a) architect's concept; (b) engineer's BIM ribbon; and interior rendering.

3.2 Designing for the Final Destination

The section describes the representative teams that prematurely ended their collaborative relationships. The most common themes evolved around academic performance (*The Little Engine That Could* and lost in translation), mismanaging the knowledge gap (he said, she said and where have you been?), establishing identities (too many cooks in the kitchen, on the outside looking in, and mistaken identity), and negotiating design ideas (Where's Waldo?). We italicized some of the notable reasons that contributed to a team's separation.

Where Have You Been?

On some occasions, the students openly discussed the knowledge gap across institutions, particularly since the engineers are enrolled in architectural design courses. The teams had opportunities to delineate their individual strengths and weaknesses to negotiate tasks. When this did not occur, the gap was used as an excuse for underachieving or as an effort to assume control. This CD-TD team wrestled through the knowledge gap and arrived at an unexpected outcome. One engineer noted that an architect reinforced the knowledge gap with, "We had eight courses in design." The terminal studio students felt the effects of the knowledge gap more that the introductory studio students. This may be due to the introductory studio students entering the project with a clean (or empty) slate of architectural knowledge, while the terminal studio students are more cognizant of the differences. The surprising twist was that the engineers took ownership of the design. The architect provided analysis for the engineers, but noted that the engineers were, "Not really open to criticism." The engineers have had only one previous design course and their exposure to design critiques is limited. Their opportunities to develop a thick skin and an appropriate response mechanism have not been fully realized. Therefore, these engineers became more protective and sensitive of their design ideas. The architect stated that the design was, "Not worth arguing over to improve." An underlying problem is the currency of the architect's way of thinking.

The studio culture reinforces architects to establish a design process or method of how they consider architectural design. This is a very personal endeavor. The architect students believe that this intimacy will essentially create a design identity and separate them from their fellow students. We believe that this is a fundamental tenet that should be passed from the architects to the engineers to illustrate the inherent passion of architectural design. This training was brought forth by the CD teams to the engineer students with mixed results. This way of thinking was unsuccessfully attempted inside this team. One architect noted, "They [the engineers] won't listen to any of our techniques or methods." This was further outlined by his teammate, "We have tried to dictate, or lead, the design process for the UW students, but they seem to think that they already know how to design the best way, so in terms of process, they don't want any advice or guidance at all." These groups thought that they would contribute design expertise to the project and when that way of thinking was rejected the students generally felt that their projects would be compromised.

The engineer students had a contradictory experience. The CD-TD teams had their courses on the same day. This schedule did not allow for a convenient daily rotation of the BIM model. This team chose to bisect the week where each team would have the model for three-and-one-half days. A lack of productivity was perceived by the engineers when the BIM model was being uploaded by the architects without any changes. This suggests a *where have you been?* impression on the part of the engineers. Eventually, performance led to the teams developing two separate designs as cooperation weakened. This is asymmetrical to *in BIM we trust*. This may illustrate a potential disparity in prerequisite BIM knowledge between the schools. In addition, there were more engineers (three) than architects (two) which may have created a greater need to accomplish more in a shorter period of time. The engineer team employed the use of BIM worksets for real-time simultaneous collaboration thereby accelerating their productivity. This condition was facilitated by having the BIM model for longer periods of time.

Although the team did not continue together to the end, they valiantly found creative ways of communicating. They and a majority of the students found e-mail as an unreliable means of communicating via distance. This was deemed by one student as "*lost in translation*." E-mail allowed some students the convenience being unaccountable through delaying communications by not responding, or openly describing one action and later performing another. The preferred method of communicating design ideas was face-to-face regardless of proximity or discipline. This was easily achieved with the local teammates, but more difficult to pursue in distance collaborations. The students deployed various tools to approach face-to-face for the distance communications. One of the unique challenges associated with exchanging design ideas is the sharing of visual imagery. The knowledge gap of the distance partners heightened the need for greater face-to-face opportunities. Some teams chose Skype which has visual and aural communications capabilities, but requires a computer and a camera. As *The Little Engine That Could (I Think I Can)*, the engineers discovered a program that video-gamers use called Ventrilo. This is surround sound voice communications software. One student wrote, "It allows all five of us to get online simultaneously and talk to each other through computer microphones." The students would have the design imagery open on their computers where they could see the same images while they were verbally communicating. Telephone (then texting) was the most widely used communications tool amongst distance teammates, but may not have the proximity to imagery as Skype or Ventrilo.

Too Many Cooks in the Kitchen

Although we had only one team that was a DS-TD-CD composition, we found that having five students participate in the design phase reached a critical mass. They just had *too many cooks in the kitchen* to collectively participate in the traditional design phase activities. We found impediments to achieving forward design progress: uneven distribution of institutional representation, BIM prerequisite knowledge, and asymmetrical interpretations of schedules and roles. Of the five students, three were affiliated with the DS group, one with TD, and one with CD. The TD engineer and CD architect were *on the outside looking in*. If the combination was balanced with one student from each institution then one may speculate that the outcomes might have been different. The engineer mentioned that the CD student had superior BIM capabilities. This inequitable prerequisite BIM knowledge could not be overcome by the group. The DS team chose not to use BIM as two architects performed their design process tasks in CAD and the third architect used Google Sketch Up. This was similar to the *in BIM we trust* team, but with a different outcome as those BIM users were on a local team rather than being at different institutions (TD-CD). The engineer student did say that the DS architects were, "Hard workers." His perception of the process was that the effort existed, but was misdirected. This is a testament to the potentially decreased productivity due to overlapping activities when a common platform is not used by each team member.

The scheduling of each course was different. The DS was held every Monday, Wednesday, and Friday afternoon, the TD course occurred every Tuesday and Thursday afternoon, while the CD course was in the mornings on the days when the TD course was held. Since the teams were not using a common BIM file, this did not pose difficulties in the file sharing. In fact, this gave an opportunity for continuous work on the project. The scheduling was more of a challenge based on the asymmetrical needs of different student outcomes from the instructors. This was a common challenge as each course had to meet their objective.

Maintaining their identities in the design process was a challenge. The CD student wanted to have more influence in the conceptual design. She observed a sense of design ownership from the DS group. Interestingly, this paralleled the CD-TD (two-three) *where have you been?* combination. This was a source of frustration for her, but in the end the engineer stated that her, "Ideas made it in and the instructor was impressed." Due to *mistaken identity*, this group missed opportunities at performance simulations. The DS-TD-CD team was one of the few teams with a mechanical engineer option track student. He assumed the traditional role of a mechanical engineer after attempts of earlier conceptualization phase feedback were unsuccessful. The architect noted that the engineer had LEED knowledge that contributed to the architectural design. This is an interesting observation as LEED familiarity may create common ground between disciplines. The engineer did not concur and would have made different design choices based on performance. Although the project requirements stated that each team should design to LEED-certified standards, we found a noticeable variability in the outcomes with regard to green design. Some of the variability can be attributed to differential prior education and experience, and dissimilar priorities between the instructors. Moreover, some of the students who had not applied the LEED system before were surprised to discover that many of the credits are not determined by architectural design, and an un-built project cannot be accurately scored. The complexity of the architectural program also may have caused some students to defer examining green strategies. One student noted that, "The program was too large to pursue quality green alternatives." To some extent, teams could be classified as to whether they interpreted green design as an intrinsic concern in the design process, or whether they treated it as an attached requirement. Some teams pursued green strategies which required engagement early in the design process, such as daylighting and optimal building orientation. Other teams tended to emphasize green notions such as local materials and rainwater collection, because these decisions could be made and represented later in the process.

When the engineer was asked to discuss the overall coordination, he distinctly made a separation between the CD student and the DS students. This was a common attribute with teams that did not have good collaboration. What was unique is that this occurred in the only DS-TD-CD combination. The engineer did not make a local versus distance distinction. He considered this from a distance versus distance point of view. He favored the relationship with the individual CD student that had BIM familiarity. The DS architect rated the group collectively as opposed to institutionally. This has a leadership sensibility, but ultimately the team was not able to complete the project together. The TD instructor observed that the engineer collaborated with the CD student and created his own architectural, mechanical, and structural renderings independent of the DS group (see Figure 5). This team developed separate designs as the CD architect partnered with the distance TD engineer to create a new team.

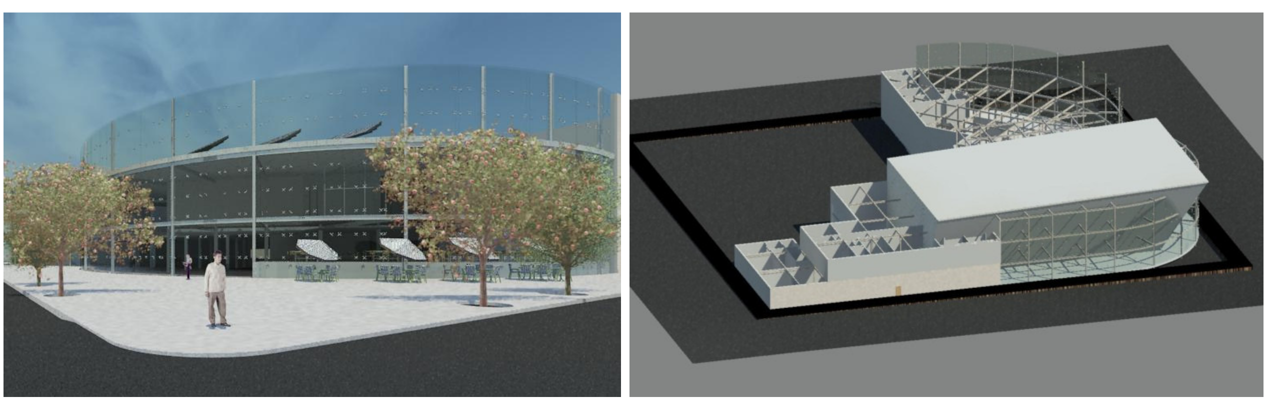


Figure 5: Renderings: (a) architectural; and (b) structural.

He Said, She Said

The local components of this CD-TD team would communicate one thing to the group, and then do something totally different. This was a *He Said, She Said* effect. The effect led the group to complete two separate designs throughout the semester. Although the architects and engineers found common ground for the conceptual theme of a continuous experience, the engineer student noted the design knowledge gap as problematic for their collaborative process. The engineer's felt their contribution was too elementary. The engineers perceived that they were not looked upon as equal stakeholders in any role of the design process (see Figure 2). The knowledge gap was coupled with He Said She Said dialogue exchanges. The architect would say, "great job, next time we'll do that," but that never happened. Negotiating and compromising on design objectives never realized. Rather than *Finding Nemo*, it was *Where's Waldo*? This leads to a larger issue of the motivation or inspiration of architects to collaborate with engineers.

From the architect's perspective, nearly half of the architects felt that they were not treated as equal project stakeholders (from Figure 2). This highlights the notion that architect students interpret the design process as their currency. When others intervene in the design process, they begin to feel that their ideas are not being respected. In general, teams that were able to transcend the design process issues looked for ways to collaborate and established roles within the team. The architect student wrote that these consisted of, "Open-mindedness, professionalism and good work ethic during the process." We found that the perceived team leader who controlled the design process viewed the project as successful. One conclusion drawn is that the team structure is important with regard to the roles that everyone plays alluding to the fact that you can have *too many cooks in the kitchen*. This was asymmetric with the survey data indicating that nearly three-quarters of the architects preferred to collaborate on architectural projects (see Figure 6). This goes against the grain of their training and indicates a gap between wanting to and having the ability to collaborate. It can be generally stated that architectural training is not geared towards collaboration. Students are quickly indoctrinated into a system that promotes the development of individual thinking and celebrates the architects of the modern era that sought to create the image of the master designer including Le Corbusier, Louis Kahn, Frank Lloyd Wright and others. Architecture students, as part of a studio culture, are taught to follow, and eventually establish, a design process or method of how they think about architectural design. This is a very personal endeavor and one that the architectural students are taught and believe will separate them from their fellow students, essentially creating a design identity for themselves. This training is how some of the architectural teams chose to negotiate within the collaborative environment, sometimes successfully but other times not.

When asked about the overall collaboration, the team followed a parallel path as that of too *many cooks in the kitchen*. The engineer segregated the overall collaboration into local and distance partners, while the architect thought of the group as a whole. This is a positive leadership attribute of the architect, but must be followed up with action to become successful. The engineer rated both the overall cooperation and coordination as good or better, while the engineer rated the distance group as fair or worse for each.

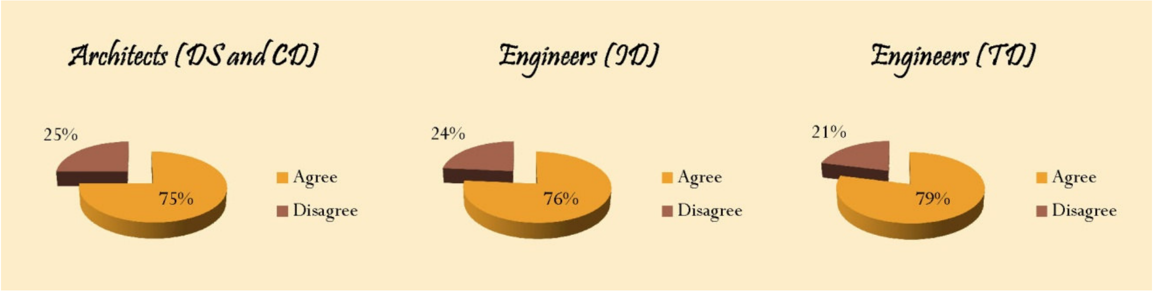


Figure 6: Survey data: "I prefer working collectively in teams to solve an architectural design problem?"

4. Discussion

The purpose of the study was to gain an understanding of the nature of student collaborations connected with other disciplines. This was a stage one application where architect students were paired with engineer students in the setting of the architectural design. Therefore, the engineer outcomes were of a visual sensibility. We believe that connecting design curricula is critical in having a professional downstream impact on the built environment. The primary research question asked, “What is the nature of distance collaborations in the BIM domain when students design green buildings?” We found that four primary themes evolved from the collaborations that led to hallmarks for best practice strategies that may increase the disciplinarity.

4.1 Major Findings

The four primary themes of academic performance, managing the knowledge gap, establishing identities, and negotiating the design idea are illustrated in Figure 7. These were supported by the fifteen subordinate themes: mutual respect, mentor-protégé relationships, he said she said, where have you been?, in BIM we trust, casting call, on the outside looking in, too many cooks in the kitchen, *Finding Nemo*, where’s waldo?, vision quest, single point of contact, and mistaken identity. The primary and subordinate themes are contributing elements defining the collaborative attributes between disciplines. Jantsch (1972) describes the successive steps approach to collaboration based on the cooperation and coordination between disciplines. Cooperation and coordination are interpreted as the action of working together for the same purpose or the same task, and the harmonious functioning together of different interrelated parts, respectively. Our primary themes are not exclusive to either cooperation or coordination. Therefore, we uncoupled the primary themes from Jantsch’s disciplinarity levels and matriculated the subordinate themes into the primary themes (see Figure 7).

Jantsch identifies the disciplinary levels in an education / innovation systems from lowest to highest (with attributes in parentheses): multidisciplinarity (no cooperation); pluridisciplinarity (cooperation and no coordination); crossdisciplinarity (rigid polarization towards a specific disciplinary goal); interdisciplinarity (coordination by higher level concept); and transdisciplinarity (coordination of the whole system toward a common goal). Developing a matrix becomes too unwieldy for illustrating all the combinations we found for each disciplinary category. Conceptually, the team with the largest number of weaknesses without offsetting strengths will fall into the lowest disciplinary category, while the team with the most net strengths may advance towards transdisciplinarity. In our study, we observed a range of naturally evolving orders of disciplinarity from multidisciplinarity up to interdisciplinarity. The teams that prematurely ended their collaborative relationships and completed independent projects were the lower-levels of disciplinarity. The teams with the greatest likelihood of a continuous relationship were at the higher ends of disciplinarity. For these cases, we did not witness many lower-level communications across the groups except when the single point of contact was out of class with an illness. For transdisciplinarity to occur, the lower-level communications must be a sustained activity. Ironically, this is contradictory to contractual communications in professional practice. We feel that the team disciplinarity will evolve in its own unique way.

Responsibility to community and society has an undercurrent of transdisciplinary research. Basarab Nicolescu, founder and president of the International Center for Transdisciplinary Research and Studies (CIRET), recognized the confusion between the different disciplinary models and offered this distinction, “Transdisciplinary is nevertheless radically distinct from multidisciplinarity and interdisciplinarity because of its goal, the understanding of the present world, which cannot be accomplished in the framework of disciplinary research. The goal of multidisciplinarity and interdisciplinarity always remains in the framework of disciplinary research” (n.d.). Nicolescu is describing the dissolution of the disciplinary boundaries at this higher level. Educator Sue McGregor portrayed transdisciplinary activities as being between, across and beyond disciplines, “Far beyond the academy, the synergy created at the interface between the academy (disciplines) and civil society is woven together to create new kinds of shared knowledge that shed light on the complex problems of humanity” (2007). This elevates the notion of transdisciplinary as a potential framework for accreditation as the design profession becomes more accountable to civil society. Moving forward, we need to explore of lower-level distance communications in support of this notion. We propose the following hallmarks for best practice strategies to engage higher levels of disciplinarity based on the primary and subordinate themes.

Figure 7: Collaborative themes.

Academic Performance

All student team members must adequately contribute to the final design outcome. Instructors must shorten the geographic distance and make the students more accountable to their teammates. It remains unsaid that the students must communicate on a consistent basis, but the challenge is for the team to have serious design dialogues regarding the exchanges of visual imagery. This may be facilitated by

- Approaching face-to-face communications strategies through aural and visual media
- Having a dedicated conference room for private exchanges
- Providing consistent schedules and outcomes across disciplines

Managing the Knowledge Gap

The stage one setting connects architecture students with engineering students studying design. The knowledge gap is more detrimental to collaborations when it converges. We suggest that students confront the gap by

- Developing a chain of communications similar to professional practice
- Having the students describe their individual strengths and weaknesses
- Having architecture students try and teach and circulate the design process in their group

Establishing Identities

Both the architectural and engineering students may not have an understanding of why engineering programs include architectural design courses. This may initially confuse the students as to what their identities may be inside a collaborative setting. We recommend that

- Each institution have an equitable representation within each team
- Instructors create an awareness of why engineering programs require architectural design courses
- Each institution participate inside the BIM model on a rotated or simultaneous basis
- Students have comparable previous collaborative experiences and BIM training

Negotiating Design Ideas

A majority of our groups were teams of four. The likelihood of having a student's design idea accepted for the final design is one-in-four. The challenge in architectural design collaboration is the release and sharing of the design ownership within the group. To facilitate negotiating the design ideas, we suggest that

- The students create individual design ideas that will not be holistically accepted by the group to foster the negotiation process
- The students converge on a conceptual design idea by a specified date

4.2 Comparison of Findings with Existing Studies

The architecture and engineering programs at Penn State University (PSU) received a joint grant in 2008 from Autodesk, Inc. and the ACSA to cross disciplinary boundaries. The two programs connected architectural design studios with engineering courses via the BIM software platform (ACSA 2008). This study made the connection with design curricula in a local manner. Our premise was to build upon the PSU work from the distance perspective. Not all institutions have the appropriate connecting disciplines. For example, UW is one of many engineering programs that do not have an architecture program and we must deploy out-of-state activities to engage architect students. In addition, higher education is becoming more remotely available to students across the world.

4.3 Implications of Future Research

Future research should include attempts at connecting design curricula (via distance) at the second and third stages. The second stage specifically addresses the architects collaborating with engineers on topics of structures and building performance. The third stage follows with the formal disciplinary collaboration between architectural design studios and engineering design capstone courses. One may seek to jump into the stage three application on the first attempt. If this occurs there must be sufficient prerequisite knowledge across the board, not only of the topical studies, but preceding BIM and collaboration activities. Our hope is that this study can be used as a springboard to encourage performance simulations during the conceptualization and criteria design phases.

4.4 Overall Significance of the Study

Making connections with design curricula is an important and necessary step in support of the future collaborations between disciplines. Our hallmarks were designed to help facilitate the earliest design phase communications across disciplines to build a common design vocabulary. We believe that early academic collaboration will lead towards downstream professional performance simulations as one of the conceptual design strategies for entries into the built environment. These future practitioners will be better equipped to collaborate during the conceptualization and criteria design phases in an effort to minimize a building's contribution to climate change. Design professionals must engage our responsibility to community and society and this begins with education.

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