Enhancing Interdisciplinary Thinking, Teamwork and Collaboration across CM, Arch and CE Disciplines through a Design-Build Competition

Giovanni Migliaccio Ph.D., Ing., Carrie Sturts Dossick, Ph.D., P.E., and Elizabeth M. Golden, R.A.

University of Washington

To enhance interdisciplinary thinking and learn how to collaborate with other disciplines, design-build classes are often offered to a student audience that includes construction management students as well as students from design disciplines. The authors designed and delivered a design-build course with students from three programs: Construction Management (CM), Architecture (Arch) and Civil Engineering (CE). As part of this course, three teams of students at our university competed to submit a design-build proposal for the delivery of a computer lab facility to be built in Kenya by civil engineering students enrolled at a partner university jointly with the local community. The proposed approach aimed at achieving an enhancement of interdisciplinary thinking, teamwork and collaboration across CM, Arch and CE disciplines while delivering a set of design alternatives for our partner and client in Kenya. This paper describes how the instructors designed this pilot offering. Then, information on student learning outcomes as well as a set of instructors' lessons learned is provided. Last, a framework for developing an elective course around this pilot offering is presented to show that this approach for augmenting interdisciplinary studies could be replicated in different ways by other ASC programs.
Key Words: collaborative learning, interdisciplinary thinking, teamwork, lecture, studio.

Introduction

Across ASC programs, the education of undergraduate students follows different delivery paths in terms of program duration, interdisciplinary learning and course schedule. When investigating Design-Build curriculum, Jackson (2005) found that curricular restraints were the most frequently reported barrier to design-build course work. Some programs accept students after they have completed their general education requirements, and, therefore, concentrate construction topics in the last two years of undergraduate education (Chen et. al., 2012). Conversely, students in other programs are admitted early to their major and take construction topics along with their general education requirements. Sometimes, students are enrolled in five-year dual degree programs taking construction topics along with other courses. Programs are also different in how they approach interdisciplinary learning. Some programs allow students to take most or some of their required classes jointly with students in other programs whereas other programs rely on a homogeneous cohort of students. Last, some programs build their schedule around lecture courses while others integrate several studios in their curricula. Overall, a program's approach for delivering its curriculum strongly affects the course schedule and the flexibility of making changes to the curriculum itself.

To enhance interdisciplinary thinking and learn how to collaborate with other disciplines, design-build studio classes are often offered to a student audience that includes construction management students as well as students from design disciplines. This approach is easier to apply when students in the various programs follow a similar schedule. However, this is often not the case, so instructor's desire for pedagogical innovation often crashes against the complexity of fitting the new class in a fairly rigid program schedule.

The authors encountered these scheduling issues when the opportunity of delivering a joint course for construction management (CM), architecture (Arch) and civil engineering (CE) students suddenly presented itself. In 2012, a Leadership Fund grant was awarded by Hewlett Packard to faculty with the CM department. Under this grant, many concurrent educational activities were planned to initiate collaboration between our college, the Kenya's Masinde Muliro University of Science and Technology (MMUST), industry partners, selected K-12 schools in the Seattle area, and selected rural schools in Kenya. Relying on Experiential and Contextual Learning (ECL), this collaborative effort uses construction project-based themes to identify and deliver activities for innovating STEM+

Learning and Teaching. One of these activities was focused around a public service project for the delivery of a computer lab facility to be designed and planned by our students and built in Kenya by MMUST civil engineering students jointly with the local community. The proposed approach aimed at achieving an enhancement of interdisciplinary thinking, teamwork and collaboration across CM, Arch and CE disciplines while delivering a set of design alternatives for our partner/client in Kenya.

The nature of this project called for a design-build studio, but the instructors did not have space to fit a studio course into the busy schedule of construction management and civil engineering students on such a short notice. At our university, students in the construction management and civil engineering programs follow two separate curricula that are both built around a lecture-type schedule relying on the usual 3 to 4 contact hours per week. On the other hand, architecture students follow a schedule that is heavy on studio courses that rely on 6 to 12 contact hours per week. The main question for the instructors was “How to allow students in lecture-based curriculum programs to participate in studio-like courses where new ways of experiencing teamwork and interdisciplinary thinking may be investigated?” To respond to this challenge, the instructors piloted a new course model that relied on team-level independent studies to be concluded with a design-build competition. This paper describes how the instructors designed this pilot offering. Then, information on student learning outcomes as well as a set of instructors’ lessons learned is provided. Last, a framework for developing an elective course around the experience of the pilot offering is discussed to show that this approach for augmenting interdisciplinary studies could be replicated at other ASC programs in different ways.

The Pilot Project

With funding and support from the Hewlett Packard Leadership Fund, we had the opportunity to pilot a team-level independent study course providing collaboration experiences between architecture, engineering and construction management students. There have been several formal attempts to bring students from various disciplines together in project based settings (McCuen & Fithian 2010; Dossick & Pena 2010; Holland et al. 2010; Dib & Koch 2010; Gardzelewski et al. 2010; Salazar et al. 2010). Many of these are semester long courses where students work in architecture studio environments to develop a design proposal that include engineering analysis and construction planning (Dossick et. al. 2012). One challenge of the studio model is that studio classes usually require significant time commitment from faculty and students alike (12-15 hours per week). Few engineering and construction management programs are organized for this type of class load and are challenged to set up a joint studio activity. With this pilot project, we sought to develop a curriculum model for collaborative project based learning experiences without the faculty and student time commitments related to a typical studio course structure.

This pilot course work was in the form of a design competition, where students worked in teams under independent study credit, and faculty coached the students as they worked through the problem. Bigelow et. al (2013) found that positive effects of competitions (confidence, connecting all the dots, industry involvement, leadership, motivation, presentation skills, problem-solving, real world experience, teamwork, and time management) outweighed the negative effects of false expectations, resources, scoring methods, and time. There were two faculty members who committed 3-5 hours per week on the project. There was also a TA hired to organize and facilitate the class, and this TA spent between 5-10 hours per week. The faculty and TA time included planning presentations and invited guests, meeting and coaching the students, evaluating interim deliverables, and coordinating the communication with Kenya partners, industry guests, as well as the funding agency.

Course Description

The syllabus stated the learning objectives as follows:

- Proficiency in:
  - Organize work among team members
  - Roles and organization of the design-construction team
  - Design, engineering and construction planning for remote rural international setting
- Competency in:
  - The evaluation and selection of materials and systems for buildings
  - The production of written documents and the delivery of oral presentations supporting design and/or construction management decisions
  - The production of digital information models
- Awareness of:

  - Sustainability issues related to the built environment

Working in teams, students enrolled in this independent study course were expected to integrate their architectural, engineering, and construction management knowledge to design and plan construction of an educational facility. As part of the assignment, teams had to produce an electronic building information model that would result in a set of detailed documents, including building plans, sections, exterior wall details, and material selection, electronic three-dimensional model of the facility, quantity take off, and a project schedule.

Each team was comprised of 4-5 undergraduate and graduate students in architecture, construction management, and civil engineering. On each team, we had either a CM master student or an Arch/CM dual degree student. Each team also had a civil engineering student who focused on structural design. The other team members were juniors and seniors in the architecture and construction management programs.

Throughout the quarter, we met as a “class” once per week and CBE faculty and industry representatives provided short presentations on various topics. On weeks without presentations, instructors and guest industry coaches met with each team individually and provided coaching and feedback on their projects. Presentation topics included:

- How to successfully participate in a design-build competition;
- Challenges and lessons learned with international cooperation projects;
- Rural education in Kenya: challenges and needs; and,
- Availability of construction materials and methods in Kenya.

Since we were not meeting regularly throughout the week, to keep the teams on track we gave them interim deliverables as listed in Table 1.

Table 2

Design Definition Submittal Schedule

Due Date	Deliverable	Scale
April 12	Floor plans, and site layout	1:100
April 19	Floor plans, 2 building section, and elevations illustrating all sides of your building	1:50
April 26	Structural plans and sections	1:10

The final deliverables included a final notebook (i.e., digital pdf and TWO bound 11x17 color copies), a final presentation (i.e., digital pdf/ PowerPoint and (8) summary sheets for reviewers, as well as any other supporting documentation teams wished to provide, such as calculations and estimates). The final notebook was subdivided in sections and include at minimum the following information: Design, Conceptual Plan Sequence, Quantity Estimate, and Sustainability. We asked the students to emphasize the integration of the project across all of the dimensions and disciplines. See Figures 1, 2 and 3 for examples from the final notebooks.

The Project

The teams developed a design for an educational facility for the Hafumbure Secondary School in Kenya. This is a real classroom project in rural Kenya and this facility will host computers to allow local students to have access to virtual classes via a HP Catalyst Partner in Kenya. As design requirements, student teams were asked to think the facility as consisting of:

- A classroom that will host the laptops for the virtual classes, area 89 ± 5 m^2 (958 ± 54 ft^2);
- A collaboration space, area 55 ± 3 m^2 (592 ± 32 ft^2);
- A server/ storage room for the laptops, area 30 ± 3 m^2 (323 ± 32 ft^2); and,
- Passage area and lobby, area 74 ± 24 m^2 (796 ± 258 ft^2).

We further challenged the students to think about phasing, as financial resources for this project were scarce. While the classroom will be certainly built, the collaboration space, the passage area, and the lobby may not be built due to a shortage of resources. Thus, the teams designed the classroom as a self-standing structure while envisioning the whole facility as a phased project.

The course ended with a final competition event on Friday May 31, 2013 where the teams presented their proposals to a panel of judges from various Built Environment disciplines. This panel included an architect (who was a professor in Architecture), the president of a nonprofit organization that builds similar facilities in developing countries (Construction for Change), and a member of the CM industry advisory council. The instructors were not part of the panel, but they facilitated the panel discussion and captured jurors' comments and critics for student feedback. The panel of judges evaluated all projects. Furthermore, presentations were video-recorded and shared with HP Catalyst Initiative partners. A short documentary was produced as an innovative way to disseminate this initiative and to report to the project sponsor. This documentary will be presented at the conference.

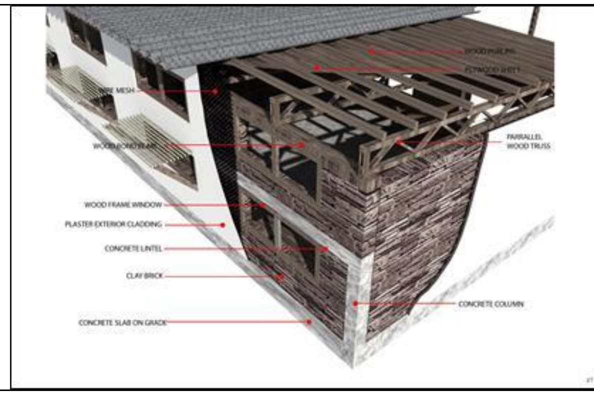

Figure 1: Overview of design concept and detail of wall construction by Team 1

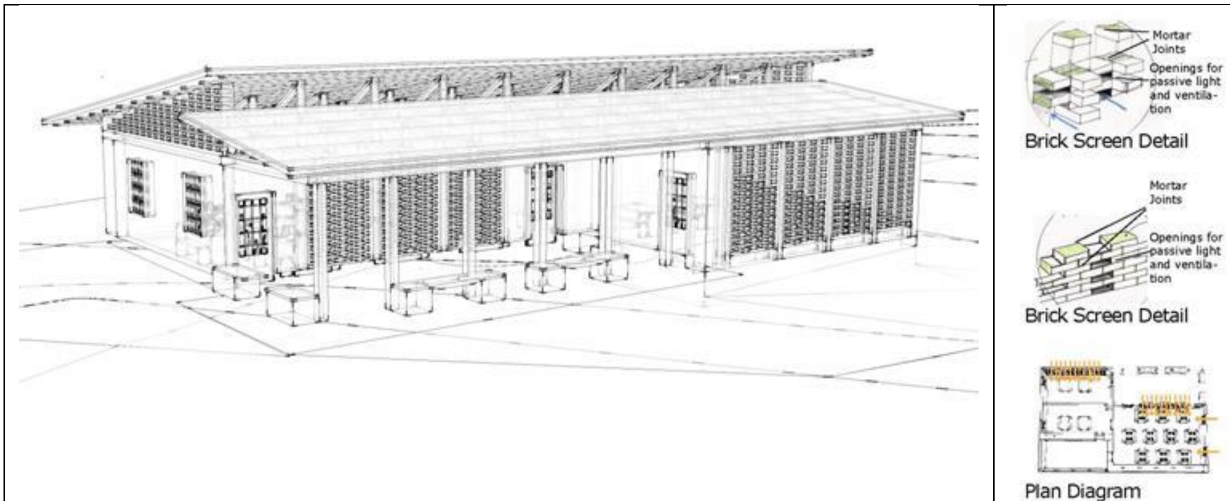

Figure 2: Schematic Overview of design concept by Team 2

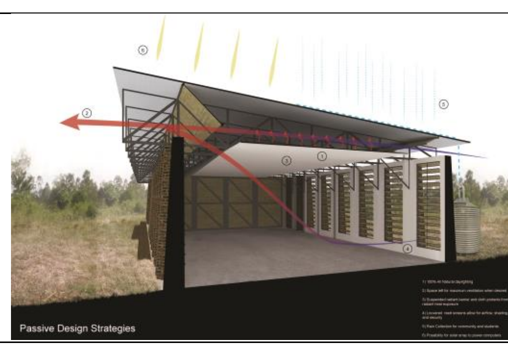

Figure 3: Overview of Design Concept and Passive Cooling Strategy by Team 3

Learning Outcomes

In general, the pilot offering was successful in many ways. First, the student engagement with this course was outstanding. The judges commented that they were "blown away" by the amount of work the students put into the projects. All three projects were very strong, and could actually be constructed with some modifications to the design. The students themselves reported that they enjoyed the class and relished the opportunity to work on such a unique design problem, as well as work with students from different departments. The civil engineering students, in particular, said that it was one of the best experiences they have had in their program because they applied their new found engineering skills to a real world project and learned a great deal about the other disciplines on the team.

Based on the final design and construction concepts, the course also enhanced interdisciplinary thinking. Students from the three disciplines had to negotiate some design and construction aspects to generate the most innovative and constructible concept. Figure 4 includes excerpts of student final deliverables that exemplify outcomes of interdisciplinary work.

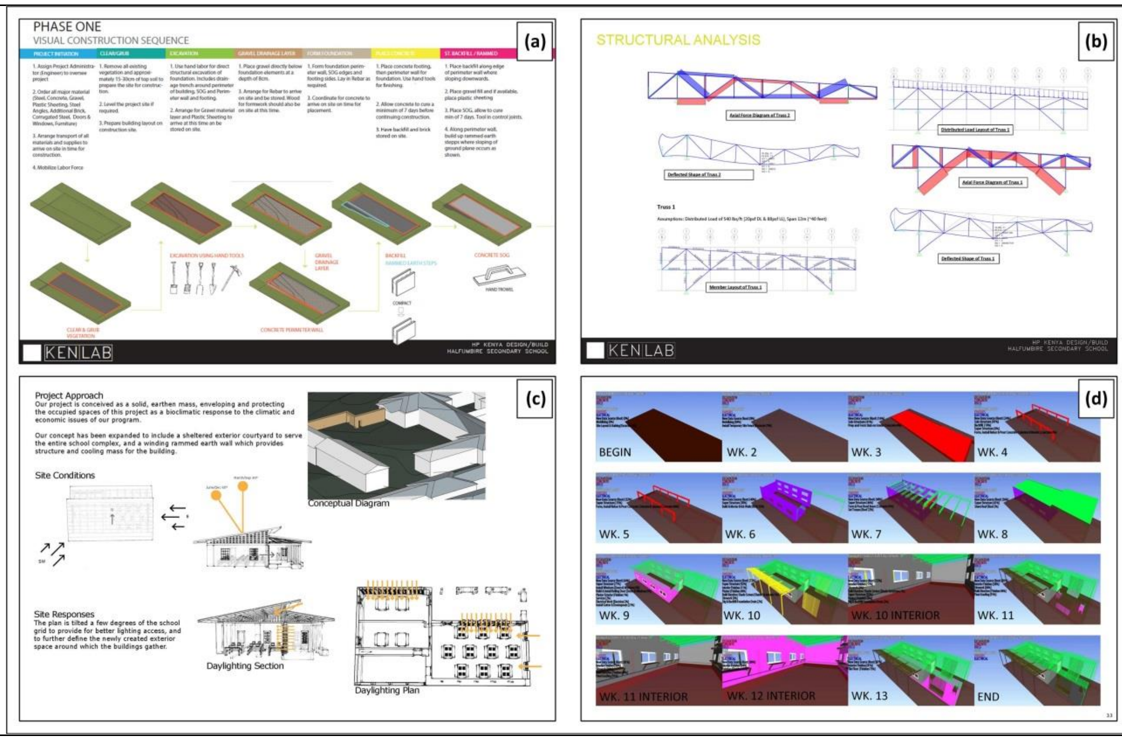

Figure 4: Examples of interdisciplinary work by teams. (a) sequencing and tool needs – Team 3; (b) Structural analysis of trusses – Team 3; (c) Daylighting – Team 2; (d) Sequencing and constructability – Team 1.

For instance, students were informed that Kenyan workforce mostly rely on informal laborers. Team 3 decided to incorporate this construction-specific issue into their work. Their proposed solution was a notebook that included an Ikea-type manual with a list of needed tools linked to a detailed sequence of tasks extracted from the construction schedule (Figure 4a). Team 3 also strongly relied on the CE student to verify the structural feasibility of the team's truss design while attempting to identify the optimum design between structural, constructability and passive ventilation requirements (Figures 4b and 3). Similarly, Team 2 explored different design concepts trying to optimize natural lighting while pursuing a high level of integration of their design concept with other building on campus and with local construction techniques (Figure 4c). Last, Team 1 strongly relied on BIM models to facilitate the interdisciplinary thinking as exemplified in their 3D schedule (Figure 4d).

Lessons Learned

Overall, the instructors learned from this pilot offering. They plan to build upon their lessons to develop an elective course for the CM and architecture curricula with the option for civil engineering students to seek admission in this course and obtain elective credits. Our lessons learned relate to *course scheduling*, *operational aspects*, *drawbacks from competitive environment,* and *handling teamwork as the prevalent part of a course*.

In terms of course scheduling, the pilot offering worked well. Even if only 3 hours per week were allocated for in-class work, each team was well staffed with a very diverse and comprehensive knowledge pool, so they were able to deliver high quality work while needing a level of interaction that was adequate to a 3 credit teaching load. A contributing factor to this success was that each team included some students experienced in team-based studios who were able to provide internal guidance. However, if this offering would develop into an undergraduate elective course for design and construction students, we may expect that a lesser amount of experience may be available to student teams due to a less homogeneous cohort. As a result, teams may need more in-class guidance especially for the design phase. This would mandate some changes in order to handle the course scheduling issues.

The pilot offering was somewhat plagued by communication issues with our partner in Kenya. While we were able to receive enough information to initiate the design process, this information flow was not continuous throughout the process resulting in some unneeded stress for the instructor team and the students. Especially during the generation of design concepts, our partners were not responsive in terms of feedback and responses to the design teams' questions. Similarly, feedback was not provided on the draft concepts that were submitted for client's feedback well in advance to the final competition.

Another lesson concerns the decision of running this course as a competition. In the construction management department, ASC researchers (Bigelow et. al 2013) found competitions to be a very effective tools for student engagement, (where the positive effects such as leadership development outweighed negative ones such as time), but this pilot has shown some drawbacks. While it is exciting to compete, it can be discouraging to lose the competition. The instructors and jurors jointly concluded that the competition seemed to inspire great student work and enthusiastic participation in the assignment; however, the instructors learned that students in the team placed third were disheartened in the end. They felt that their work was not thoroughly evaluated and were surprised by the results. While this is representative of the competitive nature of our industry and may constitute a learning opportunity in itself, it seems that the students, who do not win, feel discouraged and often do not have as positive a reflection after the course as they did during the competition. So, we wonder about the long term learning benefits of competitions versus as other types of motivations for working together - such as public service and community outreach (e.g. Clevenger and Ozbek (2013)).

As previously mentioned, teamwork was another challenging aspect of this curriculum. Throughout the quarter, we learned that because this was an independent study, we had less of a chance as faculty to intercede or coach the team through team tensions. However, the students were able to work out tensions on their own. While conflict in group assignments can be seen as a challenge and distraction, it can also be seen as a learning opportunity, where each student experientially learns to deal with others whom they find difficult to work with.

Overall, the pilot offering worked fine, but as instructors, we need to create space where students can feel successful in their project, while at the same time reflect on what they learned from challenges along the way.

Conclusions

The pilot offering suggested that this course model could be replicated once some of the lessons learned are taken into account. We envision that at least three replication paths are feasible depending on the program. First, utilizing this approach to offer a joint capstone course for students in the different design and construction programs sounds intriguing and challenging at the same time. Several design and construction schools already rely on team-based capstone courses. A team-based interdisciplinary and integrated design/construction capstone would prepare students to the industry environment and provide a bridge between academic and industry life. However, this approach adds significant complexity to the delivery of a capstone course and should not be considered if the student cohorts are not already familiar with team work and/or studios and have not been exposed to some level of interdisciplinary thinking throughout their previous coursework. A second path would be to include this course as an elective in the senior year before their capstone experience. At that time, students would build on their teamwork experience through previous studios or class projects to become familiar to interdisciplinary thinking before undertaking their capstone. This "softer" approach would reduce the stress of having a large interdisciplinary cohort as it would be for a capstone project. However, it would still rely on students to be somehow familiar with teamwork. Last, this course could also be offered earlier in the curriculum, maybe as a conclusion of their junior year, and be used to prepare students to same level of teamwork and interdisciplinary thinking. At that time, students may have little to none familiarity with teamwork, so we envision that a hybrid studio/independent study could be the solution. Under this approach, a traditional studio of 6 hours per week could be scheduled for Architecture students while the independent study course for CM and CE students could overlap for 50% of the time to allow in-class coordination and collaboration among disciplines. The extra studio time would allow students in architecture to refine their design and interact with the instructors. While involvement from CM and CE faculty and students would bring interdisciplinary experiences, balancing course loads and expectations from the various programs may be challenging and can be achieved by seeking support by leadership at the participating units. Last, if the primary goal of this course is to create a positive environment for cross-disciplinary collaboration, we have found that the public service aspect of this project provides a clear focus for the students–to help people by improving their built environment. The reality of helping people is huge motivator for students, and is an incentive for them to stay focused on the higher goals of the project, giving more purpose to their work than a synthetic project could. However, this objective can be achieved only if the partner/client organization is responsive and is willing to give back to the students in the form of feedback and comments as much as it receives from them. While being challenging, this issue can be resolved through a strategic partnership with a no-profit organization whose mission is aligned to the public service component of the project to be designed and built. While not totally successful in the pilot, the authors were able to create a cushion between the students and the clients so that lacking feedback from the client could be compensated by more feedback by the instructors and industry coaches.

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