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Evaluation of an Interdisciplinary Studio Experience to Teach Architecture and Construction Science Students the Design-Build Project Delivery Method

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This paper describes the authors' joint class project of design-build that was conducted in an interdisciplinary studio in the College of Architecture at a large Southern University during the spring semester, 1999. Students in ARCH 306, Architectural Design III, and COSC 455, Alternative Construction Delivery Systems, were joined in a studio to perform the design-build project, which was to design an ambassador's residence for a selected country on a pre-selected site in Washington, DC. The design-build studio project provides a perfect framework in which to initiate an interdisciplinary architectural studio that responds to the recommendations of the Boyer Report – the Special Report by the Carnegie Foundation for the Advancement of Teaching – on the future of architecture education and practice. The Boyer Report lists among its seven goals the need for a "full exploitation of the interdisciplinary potential for architectural education and practice," and "interdisciplinary connections to better serve society's needs." Evaluation of the integrated studio experience found it to be extremely rewarding for the students in that it gave them an accurate picture of professional practice.

Key Words: Project Management, Materials and Methods of Construction, Mechanical Systems, Alternative Project Delivery Methods, Value Engineering

Introduction

The design-build project delivery method is a system of construction project delivery in which one entity forges a single contract with the owner to provide for architecture/engineering design and construction services (Dorsey, 1997). Hence, a design-build project provides a perfect framework to initiate an interdisciplinary architectural studio that responds to the recommendations made by the Boyer Report (1996) -- the Special Report by the Carnegie Foundation for the Advancement of Teaching -- on the future of architecture education and practice. The Boyer Report lists among its seven goals the need for a "full exploitation of the interdisciplinary potential for architectural education and practice," and "interdisciplinary connections to better serve society's needs."

In response to the above recommendations and as a reflection of the authors' search for a teaching environment that better represents the realities of contemporary construction project delivery methods, a joint design-build project was initiated in which architecture and construction science students were teamed up in a studio experience to be taught how to prepare a single source contract package for an owner. The contract package included a design proposal, a conceptual project cost estimate, a conceptual project construction schedule, a cost-revenue curve, and value engineering analyses. It should be noted that the outcomes as well as the processes of this studio differ from other educational endeavors that are labeled as *design-build* which focus on actual construction of the projects in the course (Deamer, 1999).

In contemporary terms, a design-build studio simulates the professional practice where design-build becomes an important and viable construction project delivery option. The demand for a single source of responsibility that provides a seamless work environment between the design and construction teams, and the need for faster schedule delivery of the project contribute to the increased usage of design-build today. A number of authors on the topic of design-build have noted that as owners become increasingly familiar and comfortable with design-build services, and as firms continue to merge the design and construction teams, "…the prospects for firms offering design-build services will continue to be bright" (e.g. see Dorsey, 1997; and Tulacz, 1999a&b). These prospects demonstrate that design-build is becoming one of the significant trends in design and construction.

Furthermore, the link between today's design-build firms and the Master Builders of the Middle Ages, and of periods even before, demonstrates the importance of this system through historical precedent (Dorsey, 1997, p. 88). The Master Builder - part architect, part engineer, and part constructor - supervised the design and construction of important public/religion buildings throughout history. This one source of responsibility dominated building construction until the Industrial Revolution, when specialization of different professions such as architects, engineers, and constructors changed construction project delivery practices. In recent years, design-builders once again integrated design, engineering, and construction as a system of project delivery in which one entity is contracted to provide both design (architectural and engineering) and construction services. In contemporary practice of design-build, the Master Builder is replaced by a team of specialists who provide professional services to the owner under one "master" contract. Teaching an interdisciplinary studio of design-build, then, enhances the students' understanding of today's realization of design-build values in the light of history.

The Interdisciplinary Studio Project

This paper describes the authors' joint project of design-build that was conducted in an interdisciplinary studio in the College of Architecture at a large Southern University during the spring semester, 1999. Students in ARCH 306, Architectural Design III, and COSC 455, Alternative Construction Delivery Systems, were joined in the studio to perform the design-build project. "Interdisciplinary" in this instance means the combination of architectural design and building construction science students in one educational laboratory [studio] setting. The collaborative effort of an upper-level, six credit hour *Architectural Design Studio* (third year in the Architecture Program), and an upper-level, three credit hour *Alternative Construction Delivery Systems* class (fourth year in the Construction Science Program) in an interdisciplinary studio addressed the following preliminary objectives:

- Understand the process of design, construction and design-build by both disciplines;
- Create a realistic environment for design-build projects (simulating the professional practice); and,
- Develop the students' skills in working in interdisciplinary teams.

The Disciplinary Contributions

Architectural Design Studio (Architecture)

The main theme of the third year architectural design studio – architecture in an international context – was expressed by assigning the architecture students to design a residence for a foreign ambassador from France, Japan, South Africa, or Venezuela in Washington, DC. The project's specific location was at the corner of Massachusetts Avenue and Belmont Street NW, near a number of existing consulates. The residence was to serve as a residence, as a diplomatic government facility, as a place for receptions, and as a social hub for the embassy of the specific country. The total area of the facility was to be between 6,500 and 7,500 square feet.

The project was conducted in three main phases. First, the architecture class was divided into four teams of four students each. Teams were required to research and analyze the cultural and environmental background of the country of the ambassador, as well as the environmental conditions of the project site in Washington, DC. The results of this first stage were presented as conclusions and design guidelines that included the project concept (policy statement) and its operational objectives.

In the second phase, the architecture students worked in teams of two to develop their preliminary designs. The factors that influenced their building designs were their conclusions and design guidelines from the first stage, the programmatic requirements, and preliminary discussions of constructability with the construction science students.

In the third phase, the students finalized their designs based upon comments and criticism of their preliminary composition and the joint work with the construction science students. The final delivery of the design-build project of the residence for a foreign ambassador in Washington, DC included a summary of the research, the design proposal, and the analyses prepared by the construction science students. The project was submitted to the authors in a hard copy booklet and presented to a panel of reviewers as a digital presentation using PowerPoint™ software.

Alternative Construction Project Delivery Systems (Construction Science)

The construction science students of the *Alternative Construction Delivery Systems* class were assigned to work with the architecture students to prepare a conceptual cost estimate; a preliminary schedule analysis; a value engineering analyses of the foundation, structure, building cladding, roof system and selected equipment; a set of bid packages; and, a cost-revenue curve analysis for each building design. The results of these assignments completed by the construction science students were delivered together with the architecture students' designs as part of the final presentation of the project proposal.

Teams that included one or two construction science students prepared conceptual cost estimates for the preliminary architectural designs using a "square foot cost" multiplier to give the architecture students an idea how much their proposed facilities would cost. The students were required to use R.S. Means Systems Costs (1999) or some other similar source to prepare their estimates. In addition to the conceptual cost estimate the students prepared a preliminary schedule analysis of each proposed facility. Most teams proposed a bar chart diagram showing anticipated construction progress on a month-by-month basis.

The second assignment required the construction science students to analyze the architectural designs and to make suggestions about the proposed building materials and systems to satisfy the objective of value engineering. Thus, the students evaluated all parts of their team's project arriving at the best value commensurate with lowest life cycle cost. The students were reminded that "best value cost" implies that life cycle costs should be considered in making the value engineering recommendations.

Following refinement of the architectural design, each team of construction science students prepared a listing of the trades and activities required to build the design. Activities were grouped into bid packages according to a logical sequence of work. The subcontractors and suppliers required to complete each stage in the work were included in each package. The bid packages were based on the outline found in Dorsey (1997, p. 200) and in Construction Specifications Institute (CSI) divisions. In addition, the construction science students analyzed the cash flow from start to completion of their project. This analysis resulted in a chart showing the cost and revenue cash flows for each project over its construction life cycle. The purpose of the cost-revenue analyses was to determine the breakeven point where revenue equals cost. To develop the cost-revenue chart, a schedule of values was used to help predict the expected monthly cash flows. The cost and revenue curves were plotted from this information. The revenue curve on each chart reflected the expected payment, less retainage, that would be paid by the owner each month. The cost curve included all costs of the work including materials, equipment, labor, general conditions, and profit.

Joint Project Procedure

The joint project was conducted during the last 10 weeks of the 1999 spring semester. Students in both classes worked in teams that consisted of the random assignment of two design students with one or two construction science students. Team members from architecture and construction science were introduced to each other in a joint meeting of the two classes that was held at the beginning of the design-build project. This joint meeting occurred at about the mid-point in the semester. Additional joint meetings of the two classes were scheduled when the architecture students presented their research about their ambassador's country, when the architecture students presented their preliminary designs, and when the final presentations were made to a jury.

Figure 1 illustrates the various stages of the joint project and the deliverables of each stage. During the first phase, the architecture students researched the project's background, including the climate of Washington, DC, local building design practices; availability of materials, typical needs of this type of client, and related architectural programming matters. The architecture students also had to conduct research of similar facilities in the ambassadors' home countries to learn about traditions, history, climate, design and construction practices there. The construction science students did not take part in this stage of the project. Upon reflection, this procedure raised the important educational question of when interaction between the team members should begin.

In the second stage, the architecture students developed their preliminary conceptual designs for a critique by the architecture and construction science faculty members (see previous description of second phase of the project). With information provided by the architecture students, the construction science students were required to prepare a conceptual cost estimate, a list of the preliminary bid packages, and a preliminary project schedule for the first phase of the architecture students' designs, typically referred to as "schematic designs." Providing this information to the design student (the architect) and to the instructors (the client) at an early stage of the project helped in decision-making when the direction of the project was being established.

While the building program was not constrained by a fixed budget, the bid packages prepared by the construction science students translated the conceptual design of the architectural students into a sequence of construction, and cost. Introduction of the 16 CSI divisions and costs made the architecture students aware of the implications of using certain construction and finish materials, structural and mechanical systems, and construction methods. For some of these students this translation of drawings into cost served as a "reality shock," as design studio projects in classes up to this point had not paid much attention to cost. The construction science students developed their communications skills of being able to interpret the architectural conceptual designs visually and descriptively, and also to understand the process of architectural design.

The third stage of the project followed review of the preliminary architectural designs and the construction cost estimates. In this stage, the architecture students had to refine their designs and the construction science students had to refine their bid packages for the project. The construction science students consulted with their design colleagues and assisted them with value engineering of selected building materials and systems, and cost-revenue curve analyses. The value engineering analyses were submitted to the architecture students as a written statement of performance guidelines which included different construction alternatives (materials, systems, and methods), drawings of details, and their cost. The architecture students studied the analyses very carefully through discussions with the construction science students. Once a consensus was reached between the team members, some of the construction recommendations were incorporated into the final architectural designs and helped to refine the projects' estimated cost.

This process of interaction between the students in the two disciplines triggered important discussions in the architecture studio. The discussions focused on important practical questions such as: What is the appropriate level of incorporation of construction professionals' input in the architectural design process, and how much should the architectural image be modified due to costs of materials or structural systems? Furthermore, this process made the students of both disciplines aware of the importance of building technology, in addition to the understanding of how collaborative teamwork during the early stages of building design can assist the designer and the client in decision-making. It became obvious that this stage required more meetings of the team members to jointly discuss different recommendations and to subject some of them to more of a structured timetable.

The final stage of the joint project was delivery of the completed report. The architecture and construction science students prepared a 15-20 minute PowerPoint[Tm] presentation for a panel of reviewers that consisted of professors from the College of Architecture (Departments of Architecture and Construction Science), and from the College of Liberal Arts (Department of Political Science), representing the client. The slides in the presentation contained information about the process of decision-making (mostly designer's information), influences on the alternatives (mostly builder's information), and justifications for decisions made regarding the overall package going to the owner (joint designer and builder information). Specifically, the presentation included the background information on the project, the design proposal, a refined list of bid packages based on value engineering analyses and the Construction Specifications Institute divisions, an estimated schedule for constructing the project, and a cost-revenue curve. All student team members had to participate in the final presentation. In addition to this joint presentation the students submitted to both instructors – architecture and construction science - a booklet that included all the final design and construction information for this design-build joint project.

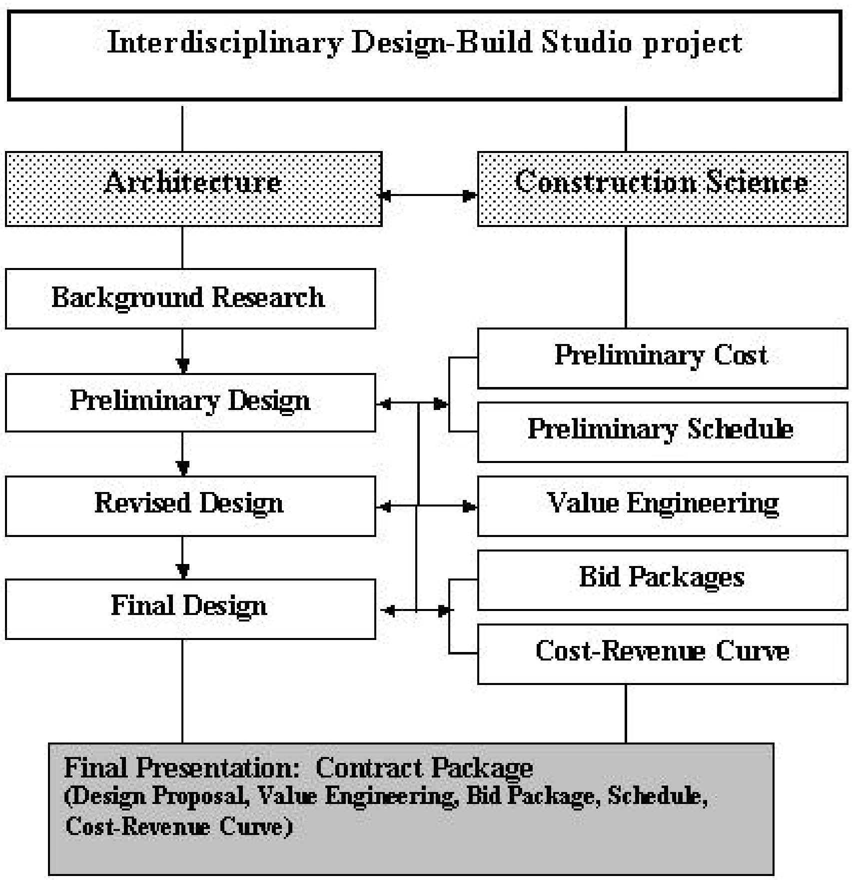

Figure 1. The procedure of the joint project

Examples of Student Projects

The examples demonstrate two typical teams' work and the factors that influenced the design and construction decision-making processes. The first project demonstrates the effectiveness of collaborations between the architecture and the construction science students early in the decision-making process. The second example shows a compromise design solution, which was the result of best value and cost analysis, owed in part to fewer joint meetings in the early stages of the project. As observed by the faculty, the students on this team waited until later stages of the project to seriously engage in collaborative exchanges of information.

The first project describes the design of a Japanese Ambassador's residence in Washington, DC. The joint team consisted of Travis Lucy and Luke Carnevale from architecture, and Justin Milam from construction science. The policy statement (architectural concept) of their design was: "This Ambassador's residence should be an accurate reflection of Japanese culture and direction, by incorporating aspects of both the traditional and modern Japanese architecture throughout." The team members prepared this policy statement through joint discussions and agreement at the outset of the project.

Figure 2 shows the influence of Japanese traditional site elements on the site development of the project and how each element of the house was tied together through the use of materials, color, and landscaping. Preliminary site development was analyzed by the construction science student, who followed the images of the designers and suggested some alternatives to finish materials (such as pavement), security details, and landscaping.

Figure 3 illustrates the floor plan and elevations of the project. The public areas of the Japanese Ambassador's house are located in the front as much as possible and represent a contemporary design, while the private areas, which express elements from Japanese traditional design, are in the back of the house, out of the public eye.

The differences in the images of the building's components called for different finish materials. The construction science student analyzed various options and helped the designers with the decision-making process. Eventually, the total area of the house was 6,678 sq. ft. and its estimated cost was calculated as $826,015, including security, overhead, and profit. The construction duration of the project was estimated as six to eight months. It should be added that this is an estimated duration of construction work. Pre- and post-construction activities would lengthen the overall project duration. Also, these estimates were prepared from schematic design drawings. More detailed construction drawings might suggest that a different overall project duration would be required.

These "impressive" estimated figures ($123.70/sq. ft.) were the result of the collaborative studio. Following analyses, evaluations, and discussions the designers incorporated the construction science student's value engineering analyses and recommendations early in the design process. This helped the team to produce a cost-effective design. In addition, the estimated preliminary cost calculated by the construction science student became the 'reality' framework for the designers who modified their work accordingly. For example, the position of the house on the site for this team's design solution required a minimum amount of soil removal and preserved almost all of the pre-existing trees. This was a very cost-effective decision on the overall cost of the site development. Making the building more compact and energy conscious was another example of cost-effective decision-making. For example, the building's circulation areas were cut to only about 11% of the total square footage; the bathrooms were grouped together; the mechanical system was split to fit the different functional zones of the house; and for energy conservation the glass was kept to a minimum on the west, east and south elevations. The selection of construction and finish materials was influenced by the architectural image as well as by best value (see Figures 4, 5, 6). The final presentation of the project also included analyses of the cash flows from start to completion of the designers' final proposal (see Figure 7).

Figure 2. Japanese ambassador residence in Washington, DC: site plan

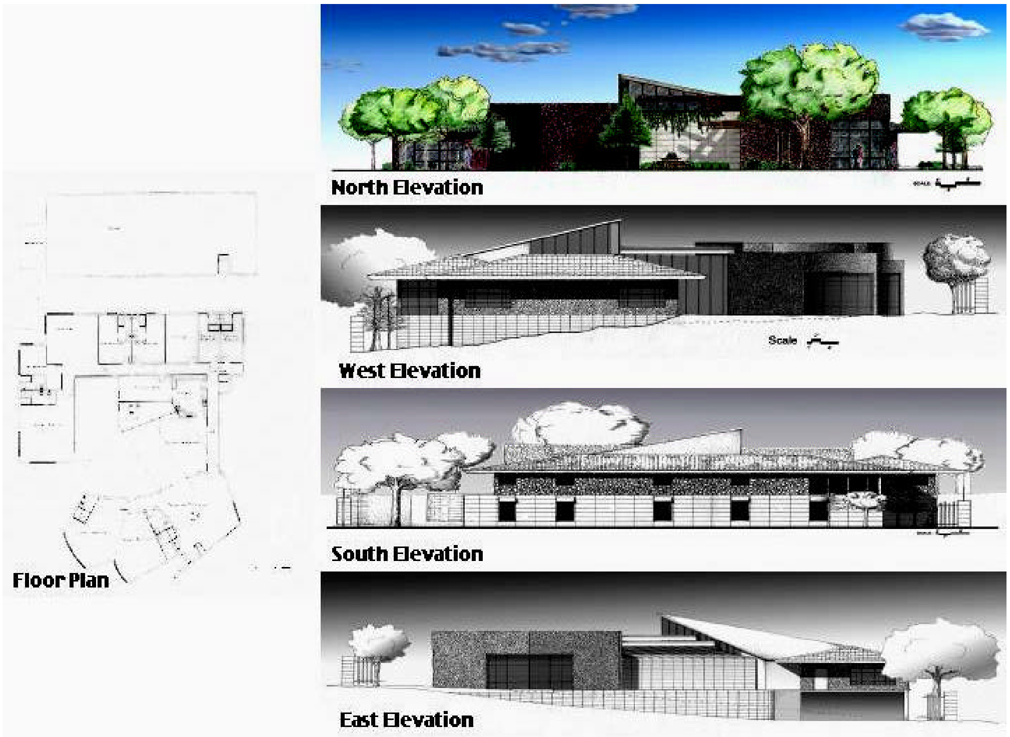

Figure 3. Japanese ambassador residence in Washington, DC: floor plan and elevations

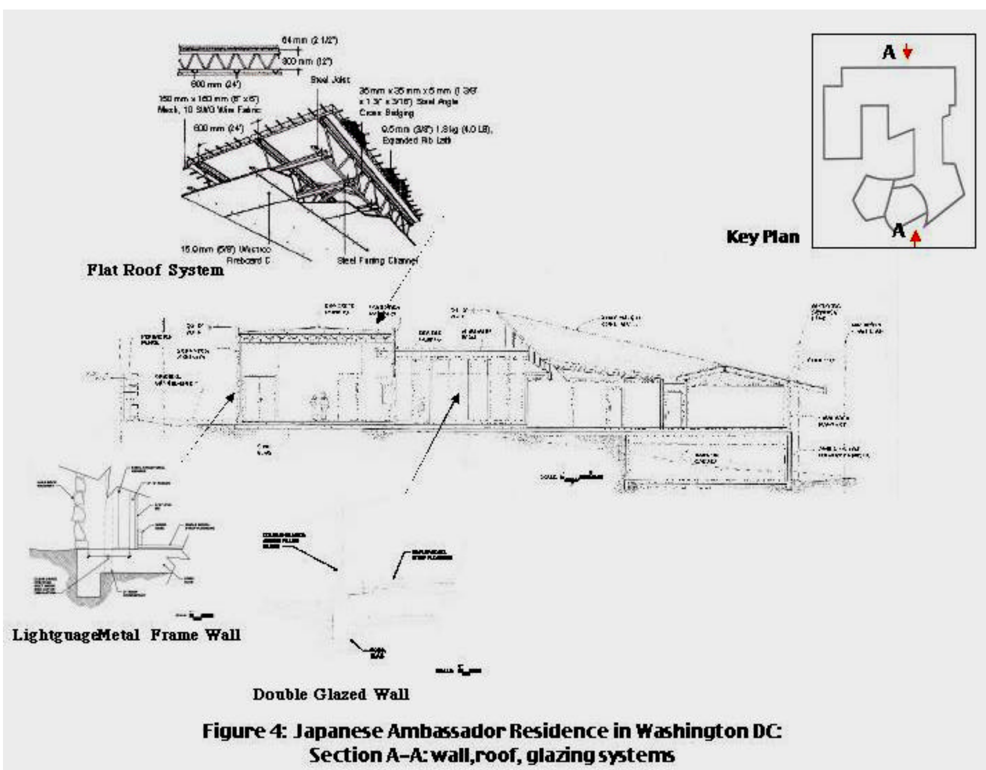

Figure 4. Japanese ambassador residence in Washington, DC: section A-A: wall, roof, glazing systems

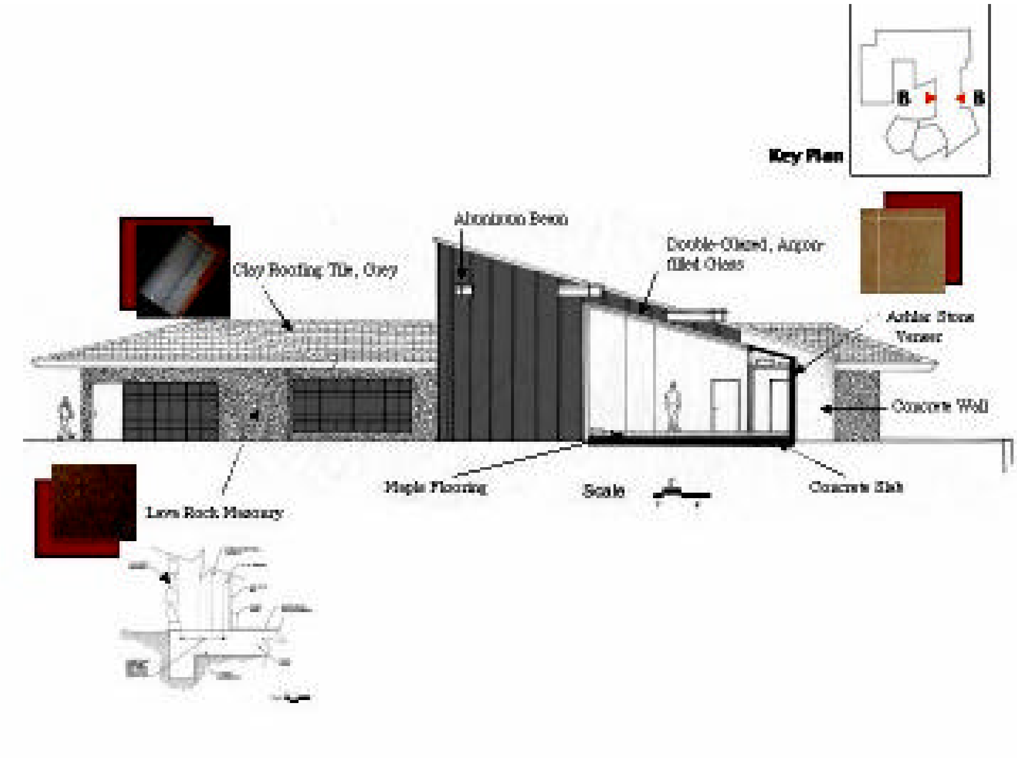

Figure 5. Japanese ambassador residence in Washington, DC: section B-B: finish materials

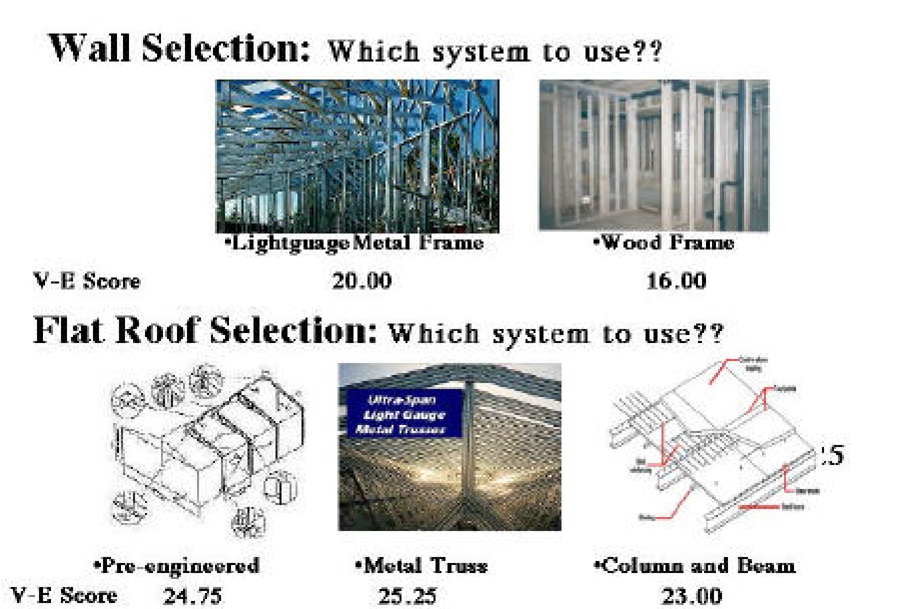

Figure 6. Japanese ambassador residence in Washington, DC: example of value engineering analysis

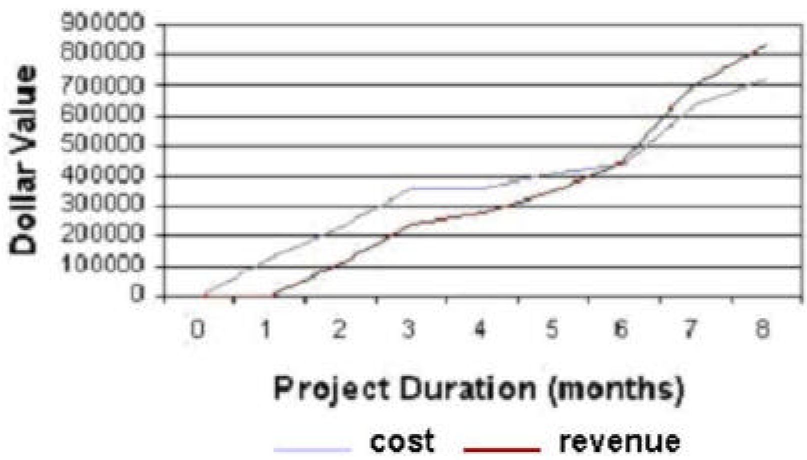

Figure 7. Japanese ambassador residence in Washington, DC: cost vs. revenue

The second example of the design-build studio describes the design of a South African Ambassador's residence in Washington, DC. The joint team consisted of Ben Callison and Lee Johnson from architecture, and Justin Lischka from construction science. This team's architectural concept was: "…to reflect the cultural heritage of South Africans in the context of the era of technology and in regard to Washington, DC's environment."

Figure 8 shows how this team's design expressed this statement and incorporated the shapes of traditional houses in South Africa, while using contemporary materials such as steel, concrete, and glass. The use of these materials was analyzed by the construction science student only toward the end of the design process (see Figures 9 and 10).

Figures 9 and 10 demonstrate the relationship of the design and the construction science analyses. The architectural sections in these figures show a split-level floor plan that divides the public, semi-public and private areas of the house. These spaces were connected by a glass/steel corridor that serves also as the focal point of the design. This kind of arrangement was not discussed with the construction science student beforehand and therefore the first conceptual cost was much higher than expected.

The materials chosen by the designers to express a certain architectural image dictated certain structural systems and construction methods. The construction science student prepared value engineering analyses that evaluated the suggested construction/finish materials, systems, and methods. These analyses considered design characteristics (e.g., fitness to neighborhood, accessibility, functions), construction issues (such as safety, speed, cost), and operation factors (e.g., energy efficiency, maintenance, durability). Since the joint effort started later in the design process, the results of the value engineering analyses showed that the suggested materials were not rated as best value for the owner. This result provoked an important and constructive discussion about the process of finding the balance between the project's image and its cost. It also triggered discussion of when the best time to involve the builder would be during the project's life cycle.

The final design of this residence consisted of 7,450 sq. ft. with a calculated total cost of $1,087,001, including security, overhead, and profit ($145.90/sq. ft.). The project's construction duration was estimated as eight to nine months and is illustrated in Figure 11.

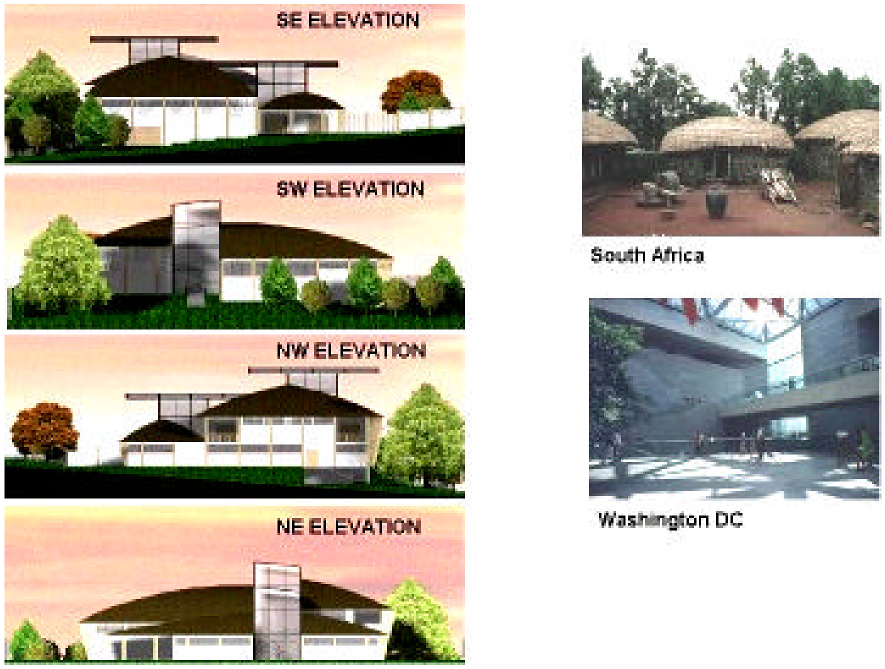

Figure 8. South African ambassador residence in Washington, DC: elevations

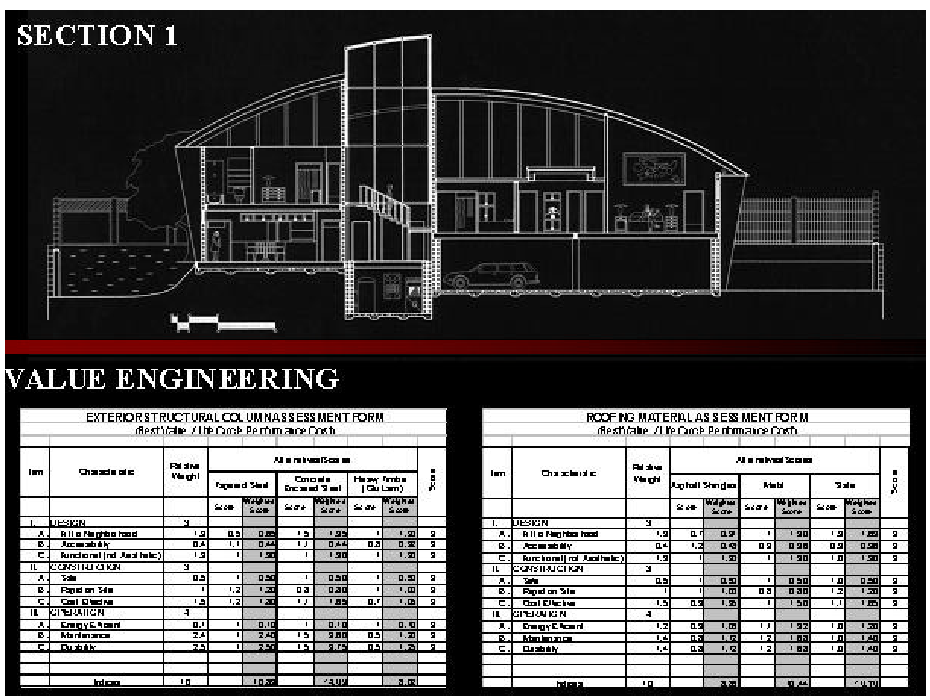

Figure 9. South African ambassador residence in Washington, DC: section 1 and examples of value engineering

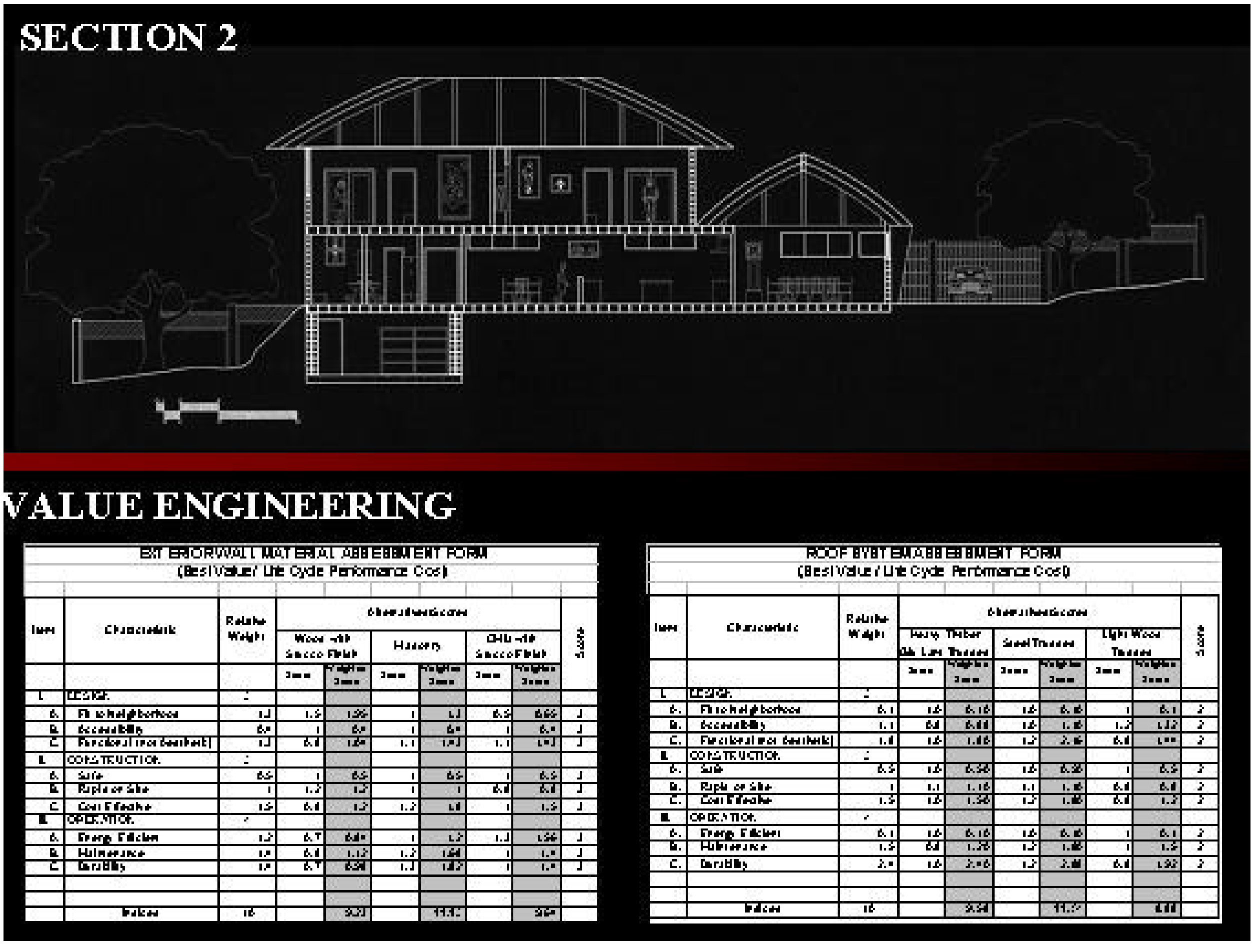

Figure 10. South African ambassador residence in Washington, DC: section 2 and examples of value engineering

Conclusion

Toward the end of the semester the students of both disciplines responded to an evaluation questionnaire on the joint design-build project. Their responses indicated that they were excited about this type of joint studio project. They identified the utility of exploiting the potential of interdisciplinary education, both in the discussions and in the final presentation that represented the joint effort of the design-build project.

The students' major conclusions supported the authors' ideas that led to this attempt to bring together architecture and construction science students to work on a joint studio experience incorporating the design-build project delivery method. In the project evaluations the students suggested some modes of improvement, primarily focusing on the logistics, and timing and amount of joint meetings. The students indicated that more time should be allocated for joint meetings, which should be coordinated by the instructors as part of the requirements/program of the project.

In addition to these suggestions, the instructors thought that one of the activities that should be undertaken in future joint projects would be a two or three hour session in which the students from the two classes were led through a team building exercise. An outside facilitator besides the instructors should lead this meeting because it is important to demonstrate the partnering workshop process to the students (see Ronco & Ronco, 1996, for a good overview of partnering workshops). In construction practice, an outside facilitator typically leads these exercises during a two-day workshop or retreat setting. Since one of the main objectives of the educational studio is to attempt to simulate the practice of design-build project delivery, the authors suggest conducting this exercise in one evening, at an off-campus location, and around a meal. Dedicating two days to a retreat to work through the partnering process, typical for industry, would not be possible in the academic setting, but the format could be presented in an abbreviated fashion and the students should still be able to develop a mission statement and partnering goals, which are common in these exercises.

Table 1 lists the scheduled activities that should be undertaken in an interdisciplinary studio where architecture and construction science students are given a joint design-build project. The activities in Table 1 are the result of input from the students in their course evaluation forms, and practical experiences noted by the authors. The construction science students asked for an opportunity to take the site planning process undertaken by the architecture students a step further and to let them (the construction science students) prepare a site logistics plan where the layout of materials, equipment, travel, and other activities during the construction period were planned and indicated on a site plan. In Table 1, therefore, preparation of a site logistics plan is scheduled near the end of the class project when the architecture students have made their decisions about facility design and location.

In summary, this design-build project demonstrated that “reality bites” in the studio were extremely important to the students and made them aware of the design and construction decision-making processes. The architecture students were made more aware of building materials, construction technology, and cost, while the construction science students were provided with an opportunity to better understood the process of design and the importance of architectural forms and images.

It is recommended that the collaboration between the two disciplines should continue in this mode of joint projects. Institutionalization of such efforts in formal syllabi will enable more effective and better-coordinated schedules of the classes involved. Such coordination will help to improve the educational experience for the students and prepare them better for the new realities of practice.

Table 1

Interdisciplinary Studio Deliverables for Design-Build Projects

Activity	Assignment	Description	Needs
1	Project Definition	Project program or scope of work	User group with a need; written description of the need
2	Team-Building Exercise	Two hour exercise led by a third party facilitator to get students acquainted, form teams etc.; accompanied by a meal	Experienced facilitator in team building; food; location; personal information such as telephone numbers and e-mail addresses
3	Conceptual Cost and Schedule Analysis	Preliminary analysis of overall project cost by CSI division; bar chart for project completion by billing period	Spreadsheet; cost guides; understanding of construction process; preliminary design drawings
4	Value Engineering	Analyses of least first cost and life cycle costs of the foundation, structural system, envelope, and selected equipment or finishes	Materials and methods references; equipment and furnishings specifications; knowledge of local construction conditions; climate etc.
5	Bid Packages	Grouping of activities and subcontractors activities into logical bid packages	Refined design drawings; CSI Divisions
6	Refined Cost and Schedule Projections	Revise and fine tune the conceptual cost and schedule projections in response to refined design drawings	Refined design drawings
7	Site Logistics Plan	Plan showing site access, contractor lay down, storage, trailer park, material deliveries, temporary traffic, temporary signage, contractor parking, crane and hoist locations etc.	Site plan with proposed construction, existing traffic circulation plan (around property), site access points, signalization and signage around site
8	Cost-Revenue Curve	Preliminary analysis of cost-revenue curves over the duration of the project	Cost breakdowns per month and applications for payment less retainage
9	Final Presentation	Computerized presentation (PowerPoint or other) of design-build proposal, 10 minutes maximum	Computerized slides with supporting graphics; jurors; computer projection equipment; presentation with question and answer period
10	Project Evaluation	Evaluation of the overall project by the faculty and the students	Project evaluation form; analysis of feedback; redesign of next iteration as required

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