Innovative Strategies for Teaching Graphics Communications – Designing Residential and Commercial Properties in an Introductory Course

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Introduction

This paper describes the integration of design projects during the Fall Semester, 2003, into the curriculum of an introductory graphics communications course at Penn State University at Harrisburg. These projects served a double purpose of reinforcing topics taught in the classroom as well as introducing students to the engineering design process with their first hands-on design experience. In particular, this article features ET 200, "Graphic Communications," a three-credit course taken by all students in the Structural Design and Construction Engineering Technology Program, generally during the fall semester of their junior year. The course content is conventional and develops basic skills in the student aimed at reading and interpreting commercial and residential construction drawings. For most students, ET 200 is their first engineering course with the potential for a design component. These design projects presented in this paper were developed and implemented with specific objectives in mind:

- To stimulate interest in engineering and design;
- To provide the user with an opportunity to perform a legitimate design based on realistic design specifications and constraints;
- To introduce the student to various aspects of architectural as well as structural engineering fundamentals.

With the scenario and content of each project keyed to the block of instruction being taught at the time, the design projects effectively highlighted and reinforced course topics taught throughout the semester. The projects themselves were structured to include – at the elemental level – all of the fundamental aspects of design as defined in the ABET accreditation criteria. The projects are based on real-world scenarios; they are open-ended, permitting many possible solutions; and they require formulation of problem-solving methodologies as well consideration of alternatives and economic concerns relating to the finished project.

In the paragraphs below, the author describes two actual design projects included in the most recent offering of ET 200, "Graphic Communications." The first project challenged the student to develop three alternative design proposals responding to a well-defined scope for a residential constructive endeavor. Students created isometric and elevation drawings and floor plans and completed comparative assessments for each of the final designs. The second design project involved the application of a computer-aided design (CAD) software package that guides the user through the design of a truss-type highway bridge, based on a specified design scenario; design submittals included isometric and elevation drawings for this unique commercial engineering application. Finally, students' end-of-course assessments are used to validate the effectiveness of the projects. Due to space limitations, examples of student solutions are not included; however, the author can provide copies of student solutions to interested educators upon request.

Project #1: Residential Design

Figure 1. Student perspective drawing submittal during Project #1, "Residential Design."

This initial project builds on classroom instruction in dealing with graphic communications issues for residential construction. With a principal purpose to provide students with some design experience as early in the course as possible, this project was administered in two phases to allow students to complete an initial design, receive feedback, and then make design refinements as part of a final submittal. The project required students to serve as architectural engineers developing a conceptual design for a new home for their "future" father-in-law. This fictional yet very realistic scenario described a very basic project scope involving an older couple retiring to a local area requiring a small "dream" home on a newly constructed Golf and Country Club. Design considerations included requirements for protection for two vintage sports cars and a customized golf cart with a built-in wet bar behind the drivers seat. The first phase of the project required the student to create at least three proposals with floor plans substantially different as to represent true alternatives. Each design included the following at a minimum:

- A 3-dimentional drawing representing a realistic picture of the proposed building in either a perspective projection or a parallel axonometric projection similar to that shown in Figure 1.
- A parallel multi-view, third-angle projection showing the front, a side/end (right or left), and a plan or top elevations similar to that shown in Figure 2.

- An oral presentation comparing and recommending one of the three alternatives.

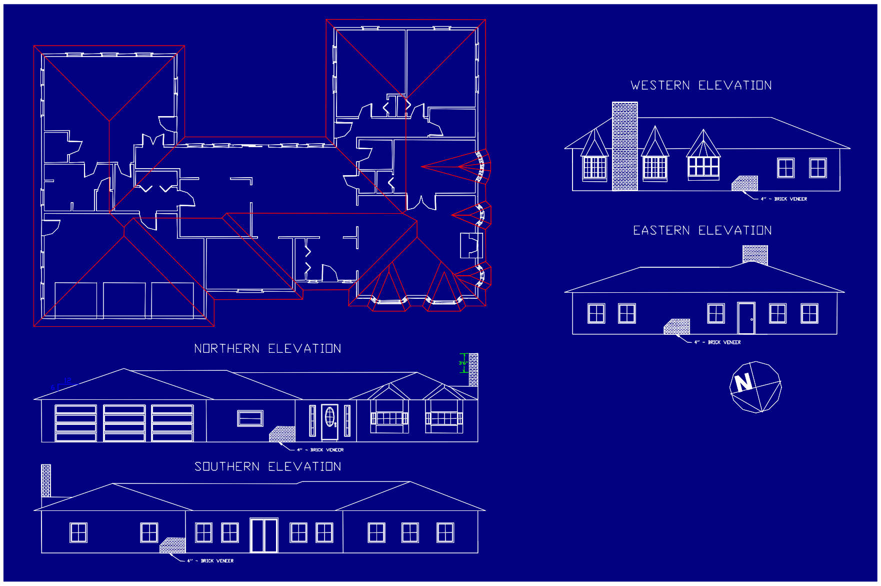

Figure 2. Student elevations submittal in partial fulfillment of the requirements for Project #1, "Residential Design."

Phase II expanded on the results of Phase I with each team taking the alternative from Phase I deemed most acceptable by the perspective "father-in-law" – their professor and developing a floor plan that laid out the details of the interior of the house for the retiring couple. Specifically, new design submittals included the following:

- A refined projection representing a realistic picture of the proposed building clearly showing appropriate salient features (doors, windows, etc.) and appropriate dimensions.
- A refined parallel multi-view projection.
- A detailed floor plan of the first floor of the home including at a minimum the master suite, guest rooms, garage, living/family room, and the kitchen indicating major home appliances (washer/dryer, dishwasher, sinks, toilets, etc.) as well as major architectural features such as stairs, patricians, and doors.
- A drawing detailing the interior elevations of the residence kitchen. Use appropriate conventions to clearly indicate the typical features of kitchens including major appliances, cabinetry, windows, etc.

- An oral presentation of the design along with an objective assessment of the strengths and weaknesses of the floor plan.

Student submittals proved to be imaginative and wide ranging in style and form including ranch style, split-level, two story colonial, and contemporary designs – in fact, no two were remotely similar. Although skillfully hand-drawn products were acceptable, students for the most part employed Computer Aided Design (CAD) software to produce the sketches and architectural renderings.

Project #2: Bridging the Gap

This second project plotted a seamless transition from residential design to a commercial construction venue employing a computer-aided-design software package. Project #2 continues the same scenario from the first project by stipulating that access to the new home site requires construction of a steel truss bridge over a small river. Each design required the student to complete the following:

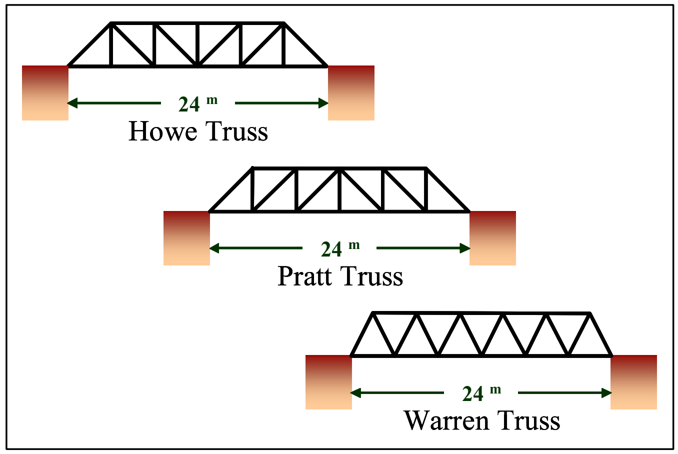

Figure 3. The three baseline trusses designed during Project #2.

- Create computer simulated structural models of a two-lane bridge with Howe, Pratt, and Warren truss variations as depicted in Figure 3; perform a base cost assessment to determine the most economic alternative.
- Redesign the Howe truss model to minimize cost.
- For the final, optimized Howe truss design, provide the following engineering graphic designs: (1) a 3-dimentional drawing representing a realistic picture of the proposed bridge in either a perspective projection or a parallel axonometric projection and (2) a parallel multi-view, third-angle projection showing the front elevation, a side/end view (right or left), and a plan or top view.
- An oral presentation presenting design results and assessing the strengths and weaknesses of the proposal.

To perform the bridge design itself, design teams employed a design software package – the *West Point Bridge Designer*. Currently available as free, downloadable shareware from the West Point web site (http://bridgecontest.usma.edu), the software guides the user through the design of a truss-type highway bridge and features real-world scenarios, open-ended solutions with many possible alternatives, formulation of problem-solving methodologies, and project assessments in terms of alternatives and economic concerns. Certainly not new to the academic community, this software has been used in multiple educational venues for both high school and college engineering students since its original conception in 1997 as a vehicle for outreach.[5] Applications have been successfully employed for middle schools,[3] for high schools,[2] and for first year college engineer students.[1, 4] During the design process, students followed a specific methodology to optimize the cost of the Howe truss model:

- Students developed an initial bridge design by constructing a drawing on the computer screen usually based on a template provided by the software. The template typically provided guidance on location of truss joints or nodes and employed a generally acceptable default size for truss members that would produce a viable design.
- Once the first design attempt was completed, the student could direct the *West Point Bridge Designer* software to test the bridge, to verify it was strong enough to carry the specified highway loads. The test includes a full-color animation showing a truck crossing the bridge. If the design is strong enough, the truck crosses it successfully; if not, the structure collapses.
- If the bridge collapses, the software automatically highlights the truss members that failed during the load test. The student can strengthen the bridge by changing the types of steel, adjusting the sizes of the structural components that make up the bridge, or by modifying the configuration of the bridge itself.
- Once the bridge successfully carries the loading without collapsing, students continue to refine the design to minimize cost while still ensuring that it can carry the specified loads.

The *West Point Bridge Designer* gives the student complete flexibility to create designs using any shape or configuration. Creating and improving designs was fast and easy so students ably experimented with many different alternative configurations as they worked toward the best possible solution. In many cases, hundreds of design iterations were recorded before the students felt the design was complete and a high level of economy achieved. Further, their enthusiasm for engineering as a field was heightened as the process so closely paralleled that used by practicing civil engineers as they design real structures. In fact, the *West Point Bridge Designer* itself is quite similar to the computer-aided design (CAD) software used by practicing engineers and served in the same way that CAD software helps them – by taking care of the heavy-duty mathematical calculations, so that they can concentrate on the creative part of the design process.

To evaluate and assess the student designs, the final structure was first checked to verify that it complied with program parameters and that the bridge was, in fact, sound. The "best" designs were those that proved to be most economical while maintaining their functional performance. With the Howe truss bridge, a standard template set by the computer produced an associated base cost that ultimately provided a yardstick to measure student efforts to optimize the cost of their bridge designs. The versatility and creativity can be seem by realizing that the project generated over 75 separate bridge designs with no two being alike. Throughout the bridge design process, the software automatically tracks the total cost of the bridge as the design team works to modify the

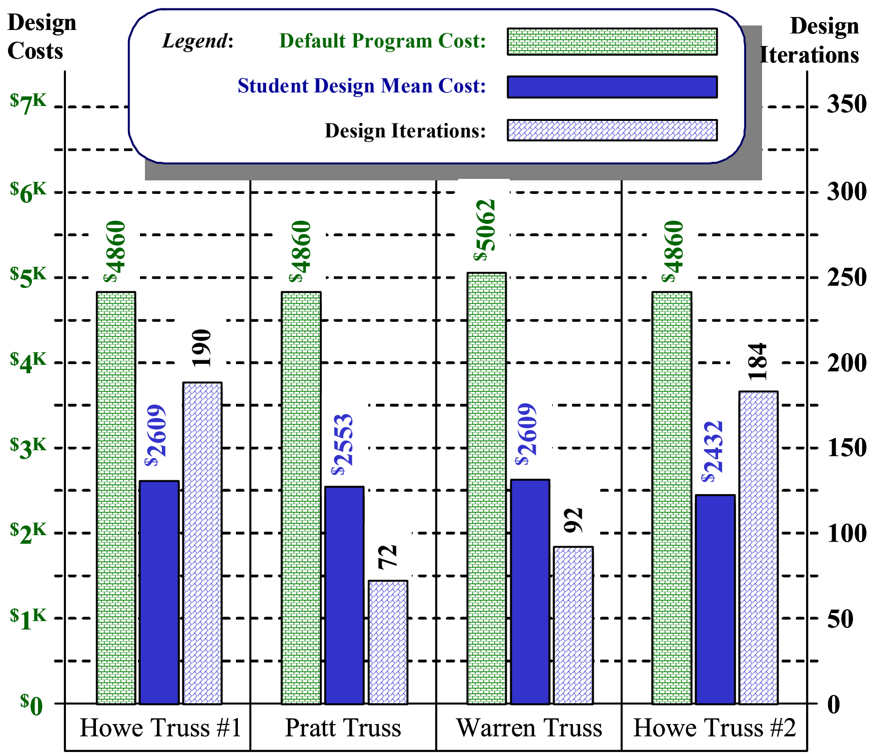

Figure 4. Student design results from the Computer Aided Design Software applied during Fall Semester, 2003.

bridge to optimize and reduce its economic worth. The basic programming of the *West Point Bridge Designer* affords the student opportunity to optimize the design even in the absence of any specific statics or strengths of materials knowledge or the benefits of an economic optimization course. Figure 4 indicates the degree of success enjoyed by students in producing sound, economic designs which was apparent as designs normally cut the *West Point Bridge Designer* base cost by nearly 50%. Design submittals included front elevation drawings of each of the original Howe, Pratt, and Warren truss variations and both a projection and a multi-view drawing of the final optimized design. The CAD software also tracked design iterations

Conclusion

ET 200 successfully employed design projects like these described above. The vast majority of student design teams have been able to complete the projects successfully, and many have developed insightful and highly creative solutions. Most students find the projects interesting, challenging, and enjoyable. On the most recent course-end critiques, many of the students enrolled rated the design projects as "very helpful" in promoting their understanding of the engineering design process. Similarly, nearly all reported that they felt "comfortable" or "very comfortable" with solving design problems as a direct result of their experience with these projects. The author found the projects exceptionally effective in reinforcing course topics, enhancing student-instructor interaction, and stimulating students' interest in engineering. As a result of this experience in ET 200, the author concludes that (1) it is indeed possible to integrate legitimate, realistic, open-ended design projects into introductory graphics communications courses, and (2) that these projects can serve as a viable introduction to the engineering design process.

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