Designing Virtually, Building Actually:
A Case Study Exposing Students to the Reality of Building in a Virtual World

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Abstract

As education continues to evolve in the midst of a digital world, many students are relying on computers and advanced computing systems to design and engineer their projects throughout their university experience and beyond. While these technological advances offer vast benefits, students are becoming more and more separated from the design of a structure and the reality of the construction process. The author has focused her pedagogy on actual projects and actual construction to allow students to not only design virtually, but to build actually. This paper will explore the process and reality of guiding students through a design and build project.

Increase of Virtual Modeling

The use of computers and intelligent software is booming in design education and beyond. Current university students are expected to be advanced operators of various computing systems and design software programs. Most students are even required to have their own personal laptop with which they will produce the majority of their academic projects. Design students' virtual creative ability is rapidly increasing, and these current students are the leaders of these quickly emerging software programs, with the prowess to produce both beautiful and accurate three dimensional models of interior and exterior spaces alike. Computer programs such as Google Earth™ and Autodesk Revit™ are such powerful programs, that students are able to create a complete set of construction documents with one, single, intelligent three dimensional model. This advancement is both exciting and incredible. However, with the increase and reliance on the computer to create student projects, the author is discovering that students are often losing the ability to communicate ideas through the use of physical modeling or hand sketching.

Project Case Study: Building a Pavilion

An advanced architectural drafting class was tasked with designing one small pavilion as a class. The requirements of the pavilion were that it had to have some sort of closeable opening in which to serve food and beverages from, it needed to be able to seat the entire class of ten students comfortably on its floor, and it must also act as a potential stage for a speaker. The pavilion should also serve as an area for student lounging and studying, and should also be considerate of providing shelter from the outdoor elements. It also needed to provide architectural interest, and should be capable of withstanding minor exposure to the surrounding climactic elements. Lastly, it needed to be completely removable and reusable for future classes, and had to be structurally constructed from wood elements. The budget for all of the construction materials, fasteners and finishing materials was to be under $1500.00.

Decrease of Tangible Product

In the spring of 2013, the author asked students to put their computers away, and to literally get their hands dirty. After spending the majority of the semester designing and documenting in Autodesk's Autocad™, the class shifted its attention to the task at hand: actually building what they had been designing all semester on the computer. The once confident faces of students quickly turned to looks of uncertainty and to a total lack of confidence. It became clear that although the class was more than confident in their ability to use the computer to create something pleasing and accurate, they were uncertain of where to even begin as the class pontificated about how to get our small pavilion actually built on campus. The class started with sketching on top of the computer generated construction documents, where the students immediately discovered that the supposedly completed construction drawings, were anything but complete. As they talked about how to physically start building this small pavilion, the omissions and discrepancies were prevalent.

Problem Solving

The class was met with many challenges regarding the construction of the pavilion, including: administrative approval, budgetary concerns, safety concerns, construction detailing and construction materials acquisition. The simple pavilion project that the students believed was too elementary for them just weeks before, quickly turned into a frustrating and overwhelming experience because of their inability to draw, detail and visualize what would actually happen in building this structure in a physical, full scale application. Many hours were spent brainstorming, and dividing and conquering small parts and pieces of the project to each individual student or various project pairs. The design evolution and problem solving which happened in the days that followed closely mimicked the true design and construction process that takes place every day in professional offices around the world.

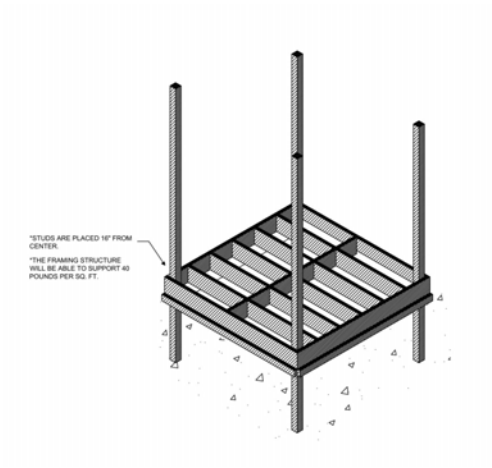

Figure 1.1: The drawing below shows student problem solving on how to physically build the pavilion.

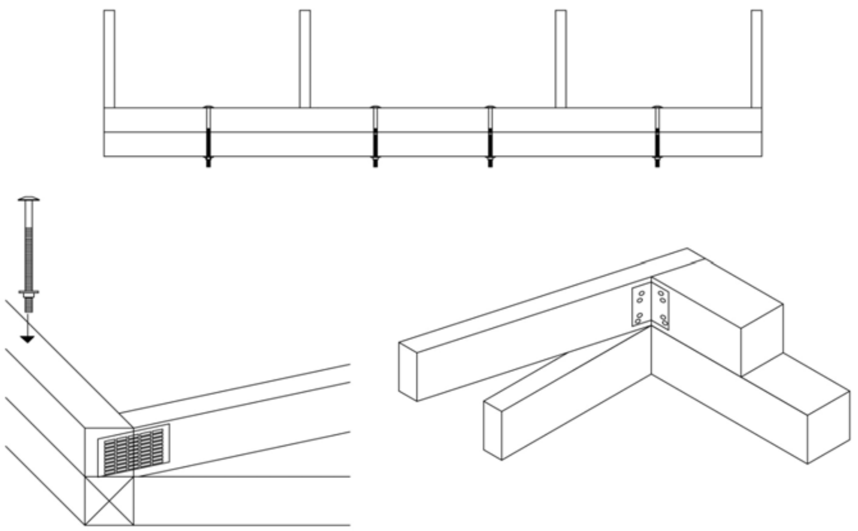

Figure 1.2: *The drawing below shows student problem solving on how to physically build the pavilion.*

Site Selection and Approval

The first area of problem solving was to determine where the university administration would allow the pavilion to be built. It was first decided and approved by key faculty members that the students could create a foundation, with the condition that the foundation could be quickly and completely removed. The students' ingenious idea was to construct typical footings, except instead of concrete and rebar, which is very permanent, they would contain the foundation in 5 gallon buckets filled with course gravel and fine sand (see Figure 1.3). Treated heavy timber posts would then be inserted in buckets, and would function as the actual foundation system. Therefore, at the end of the project, these foundations could be completely removed and reused for future projects, at the semester's close.

Figure 1.3: The photo below illustrates the students' design solution of creating removable foundations in five gallon buckets.

Figure 1.4: The photo below illustrates students staking out the site and measuring the outside perimeter of the pavilion, before the administration required the class to stop work.

Towards the end of the semester, students began the excavation process using shovels and spades to create large enough holes for the five gallon buckets. After a morning of digging and getting the foundation system into place (see Figure 1.4), the administration decided that they did not want students to have anything in the ground, due to the safety issues of underground, active utility lines. The class was ordered to stop work immediately, thus leaving the semester project unfinished and at a standstill. Students were excited to build what they had designed, but the administration left them with more questions than answers. It was decided by the administration that the students could build, as long as the structure did not penetrate the earth's surface, and that the class would remove it at the end of the semester. So, after weeks completing and detailing an underground foundation system, once again the students were back at the drawing board revising the foundation condition to reflect the latest administrative approval.

The students decided to create a floor framing systems directly on top of the existing top soil (see Figure 1.5). The only site preparation that would take place would be to rake the existing grade to make it appear level. The administration also desired a more conspicuous building site, so other students would be less likely to manipulate or vandalize the pavilion. After a week spent in the classroom, re-designing and re-drawing what the revisions entailed, the students were once again starting over, with the very real deadline of the end of the semester looming.

Figure 1.5: The photo below illustrates students building in the second approved location, and the construction of the wood framing floor system on grade.

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Building Materials Acquisition

In an attempt to expose students to all aspects and avenues of building construction, a considerable amount of time was spent developing and working within a project budget. Because the project was university funded, the students had a limited amount of money with which to work. The students were divided into different groups, and each group was assigned to be responsible for different portions of the project. They essentially became the project manager of that portion of the project, as they were responsible for the design, drawing, detailing and budgeting of that particular portion. The portions of the pavilion were designated as follows: floor framing, wall framing, pass through window, and roof framing.

As a class, the students went to a local home improvement store to view different product options, as well as to get ideas for innovative uses for inexpensive building materials to keep the total project cost down. Each project team was responsible for designing, drawing, detailing, quantifying and budgeting for their individual pieces and parts. The class then reviewed the overall budget to ensure the overall dollar amount was respected. The university was willing to cover $1500 of building materials, so cost was a very prominent factor in the design and construction. Luckily, the university has a vast amount of construction tools, both hand powered and electric powered, so students did not need to be concerned with the purchase of costly tools.

One of the requirements for the pavilion was a pass through window for food and beverage service. The student group who was assigned this portion of the project had significantly overrun their budget of $200. They had specified hinges that were upwards of $20 per hinge, and needed several of these hinges. So, the class worked to value engineer this portion of the project by selecting a more industrial grade hinge that would function in the same way, without the added cost of a high end hinge cabinet hinge.

Additionally, the student group responsible for the wall framing also ran into some budgetary constraints. Originally, the students had proposed framing the walls with dimensional 2”x4” lumber with ¾” thick plywood on both sides. The cost of this sturdy construction method was way beyond the budget for the wall framing. So, after careful consideration of both structural safety and overall aesthetic, the student group decided to revise the walls to be more transparent with the use of 1”x 1” dimensional lumber installed in a unique, shadow producing arrangement.

After the budget had been satisfied for all of the portions of the pavilion, one team was responsible for the overall project budget and overall materials list. This team then grouped the materials needed based upon the tasks at hand for the next class period. The acquisition of the materials was limited to one pickup truck, so several trips on several different days were needed to obtain all the materials necessary in order to complete the project. The students kept an active, working budget which reflected the actual cost of various materials, and they were sure to note any discrepancies.

MATERIALS (FOUNDATION ONLY)	QNT	PRICE	TOTAL
2”X6”X8’ PRESSURE TREATED LUMBER (FLOOR JOISTS)	23	5.19	119.37
4’ X8’ ¾” PLYWOOD	4	25.97	103.88
SCREWS (FLOOR FRAMING) SKU # 2305550	1	11.99	11.99
4”X4”X8’ TREATED POST (FOANDATION)	3	7.88	23.64
4”X4”X8’ PINE (BACK COLLUMNS)	2	7.59	15.18
4”X4”X10’PINE(FRONT COLLUMNS)	2	14.19	28.38
4”X4” POST CAP (FOUNDATION CONNECTION TO FLOOR JOISTS) SKU: 1712814	6	10.88	65.28
HEAVY DUTY TRUSS HANGERS	44	4.12	181.28
5 GAL BUCKETS (FOUNDATIONS	6	2.6	15.6
MULTI-PURPOSE GRAVEL (FOUNDATION)	4	3.36	13.44
TOTAL			578.04
GATE LATCH (PASS-THRU WINDOW) SKU# 2250014	4	$5.39	$21.56
2"X4"X8' PINE OR PREMIUM LUMBER Sku: 1021017 (WALL FRAMING)	35	$2.99	$104.65
3/4" x 4' x 8' BCX Plywood SKU#1251049	2	$30.47	$60.94
1/4" X 4' X 8' BCX PLYWOOD SKU# 1251007	2	$20.55	$41.10
1/2" x 4' x 8' BCX Plywood Sku: 1251023 (WALL SHEATHING)	24	$23.97	$575.28
VP 244 HINGES (2-13/16" X1") SELF -CLOSING SURFACE FLUSH ECONOMY (PASS THRU)	4	$7.34	$29.36
GRIP FAST 3" CONST. SCREWS (CUBE WALL FRAMING) 450 PC. PKG.	2	$6.43	$12.86
BOXES 3" MULTI-PURPOSE WOOD SCREWS	2	$6.43	$12.86
BOXES GRIP FAST 1-3/4" CONST. SCREWS (SHEATHING) 750 PC. PKG.	2	$12.08	$24.16
4" X 4" X 8' PINE OR Standard & Better Grade Lumber SKU: 1022401 (TOP OF CUBE)	4	$7.59	$30.36
Mastercraft 4" Satin Nickel Steel Exterior Door Hinges	3	$11.99	$35.97
TOTAL			$949.10

MENDING PLATE 2-3/4" x 5-1/4" model# TPP36	6	$0.81	$4.86
Triple Zinc Angle Clip, 1-7/16" X 1-7/16" X 2-3/4" sku#:2271220	25	$1.23	$30.75
2" X 4" X 8' PINE OR PREMIUM LUMBER Sku: 1021017 (BRIDGING @ CANOPY)	2	$2.99	$5.98
2" X 4" 10' PINE OR STANDAR & BETTER GRADE LUMBER Sku: 1021114 (BRIDGING @ CONOPY)	4	$4.15	$16.60
4" x 4" x 8' PINE OR Standard & Better Grade Lumber SKU: 1022401 (CANOPY SUPPORT)	1	$7.59	$7.59
1" X 4" X 8' STANDAR PINE BOARD Sku: 1031010 (TRIM)	2	$2.06	$4.12
1" X 4" X 10' STANDARD PINE BOARD Sku: 1031023 (TRIM)	2	$4.29	$8.58
GripFast 1/2" X 8" Galvanized Hex Bolts, SKU: 2326770 - (2 pcs CANOPY CONNECTION)	2	$4.59	$9.18
GripFast 1/2"-13 Hex Nut Zinc, SKU: 2321046 - (6pcs canopy connection)	1	$0.99	$0.99
GripFast 1/2" Flat Washer Grade 8, SKU: 2325945 - (16pcs PKG)	1	$2.19	$2.19
Triple Zinc Anchor Double Plate, Reversible 18 Gauge #RT7A-TZ SKU: 2273467	12	$0.58	$6.96
Grip Fast #6 x 1-1/4" Phillips Flat Head Wood Screw Zinc - (125 pc canopy connection) SKU: 2330136	1	$3.29	$3.29
CANVAS DROPCLOTH (CANOPY) 9' X 12' SKU#5612121	1	$18.47	$18.47
Conco Exterior Satin 100% Acrylic Water Base Enamel 3Gallon Sku: 554689	3	$21.97	$65.91
Bondz Max Adhesion Primer 3 GALLONS	3	$36.98	$110.94
Pittsburgh Paints Ultra Exterior Latex Satin Paint (JJC PURPLE CANOPY COLOR)	1	$11.47	$11.47
TOTAL			$307.88

Figure 1.6: A detailed look at the students' overall project budget. Consideration was given to both unit cost and total cost for building materials and hardware alike.

Pavilion Construction

After successfully purchasing and acquiring all of the necessary building materials, the next challenge was how to keep a class of ten students all busy within such a small building footprint. Much effort was dedicated to keeping every student engaged and working throughout the duration of each class session. Some students were responsible for updating the construction drawings on the computer, in order to accurately reflect what was actually being constructed. Other students became the experts with power tools, and they spent the class duration working with power tools to cut, saw, install and connect various pieces of construction materials. Other students were responsible for accurately measuring and marking the materials for cutting. The remainder of the students was responsible for the correct installation of the various pavilion systems. Additionally, students worked to stain and paint various exterior surfaces. After two weeks of hard work and manual labor, the pavilion structure was almost complete.

Figure 1.7: The photo below illustrates students working on the floor and wall framing to create the pavilion.

Figure 1.8: The photo below illustrates students working together to frame the walls and roof for the pavilion.

Figure 1.9: Student progress on the pavilion.

Figure 1.10: The final days of the pavilion construction project.

Student Delegation

While the author was the primary faculty member who oversaw this project, the students went above and beyond to ensure the successful implementation and completion of this project. The students worked hard to communicate with one another over email and phone to ensure that all loose ends were successfully completed prior to the semester end deadline. Students delegated and assumed responsibility for all portions of the project, independently of the instructor's direction. The students really took ownership of this project and exhibited a level of dedication often hard to find at the end of the school year. They stayed late and arrived early to ensure that the pavilion would indeed be completed.

Education Mimicking Reality

The pavilion project truly emulated the reality of real life project construction. This was the first time the university had undertaken anything of this scale or magnitude. As a result, much opposition and pushback was encountered from university administration, much like what happens in the construction industry with the authorities having jurisdiction and construction companies alike. The students' challenges included getting administrative approval, designing and constructing within a monetary budget, meeting required schedules, acquiring and purchasing necessary materials, and phasing and constructing in an efficient way.

All of these challenges are similar to those faced in the construction industry, thus creating a true professional experience for design students. In the end, the project was a true learning experience for the students, that any challenges faced, seemed well worthwhile. While there are things to be considered when beginning a design/ build project, the author knows that the extra effort is worth the unmatchable experience of designing and then constructing. The author knows that this combination of the two successfully bridges the gap of designing virtually with building actually.

Lessons Learned

As the author continues to move forward with her design/build pedagogy, this case study has served its purpose to evolve the incorporation of design/build in the classroom. The author considers this pavilion project case study an overwhelming success, even with the included battles that ensued. However, there are several lessons learned that will be implemented in coming semesters to streamline, and enhance future design/ build projects.

First, administrative approval will be sought early and often. There were several miscues throughout the pavilion project, all relating to a disparity of information communicated between the faculty and administrative staff. The author has learned that even if she feels certain that the necessary permission has been granted, the best course of action is to double check and verify that the correct people have been given the correct information. The author would also recommend that the person directing the design/ build project be the direct point of contact with the administrative authorities. In her experience, information was often diluted and convoluted through the misinterpretation of other well meaning faculty members. The recommendation would be to communicate as soon as possible with necessary administration, many weeks or even months in advance to ensure that an administrative paper trail does not thwart an otherwise robust construction experience.

Secondly, the author recommends starting with very clear project guidelines for the students. In an attempt to allow creative freedom to the class, some ambiguity was unnecessarily produced because students were either uncertain of project program or construction abilities with the given materials. The instructor should feel the freedom to create stringent project boundaries including, but not limited to, allowable construction materials, construction cost, construction schedule and design aesthetic. The clear explanation of the above allows students to focus on the task of actually designing something to be constructed by them later. In the author's experience, freeing the students up to focus on constructability, allows them to more fully mentally engage in the business of getting a structure built. Additionally, keeping the overall size of the project to a manageable size would be another important consideration to ensure student success.

Thirdly, the author recommends hand selecting project pairs whenever possible. This method ensures that each pair or group will be relatively evenly matched. The author would further recommend including various skills set in each group. For example, maybe one student is excellent with designing on the computer, while the other has experience with actual construction. These two students could potentially make a great team, as they both are able to capitalize on their existing skill set.

The author also learned to never underestimate the power of a motivated student group. Through the adversities of the pavilion project, there were several points where the author was receiving feedback from the administration that the best course of action would be for the students to abstain from completing the project. The students were passionate about creating and building something, even if they had to compromise what was originally proposed. While the author may have complied with the administration's recommendation, the students' eagerness regarding the successful implementation of the pavilion project gave the author the necessary motivation to continue working to resolve outstanding issues.

Conclusion

In a world of smart phones and computers, much can be learned through the tangible creation of a structure. Though the work of educating through the pedagogy of design/ build is not the easiest or most streamlined process, it is invaluable to both students and instructors alike. The student feedback for the pavilion project was overwhelmingly positive, and the author knows that the students left with a vast understanding of building actually, and a sense of accomplishment. The rewards for this project type are great for both students and faculty alike. And while computers and intelligent designing software will continue to evolve, the author is devoted to continue to use the business of designing digitally to enhance the students' experience of building actually.

Figure 1.11: The thrill of success at the end of the pavilion project build.