THE IMPACTS OF COST DETERMINISM IN ARCHITECTURAL FOUNDATION DESIGN EDUCATION: AN ANALYSIS OF COST INDICATORS

A Dissertation

by

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ABSTRACT

This research concerns teaching cost as an integral design determinant during architectural foundation design education. It is an assumption of this research that most design students are encouraged to provide unique but often costly solutions without regard for the reality of financial limitations. Despite its importance, this issue has yet to be systematically investigated. This study suggests ways to improve and strengthen architectural foundation design education with learning objectives that include cost as an integral design determinant. Critical design methods and approaches in teaching cost considerations during foundation design education was developed for students to interpret indicators and integrate them with other design considerations. Furthermore, this study assessed the effectiveness of indicators and the integrative quality of students' design to improve the value of cost determinism as a part of the foundation design curriculum.

The U.S.-based architecture educators and design professionals were surveyed to investigate their perspectives and methods of teaching cost conscious and economic design concepts in foundation design education. Individual interviews were accompanied to determine and define cost indicators responding to fundamental building elements. Finally, a quasi-experiment was conducted in order to compare an existing second-year design course with a newly developed course with an aim to enhance students' understanding of cost conscious design in architectural foundation education.

The survey result suggests that a gap exists in foundation design education with respect to cost as an integral design determinant. The key informant interviews further confirm that there is a gap in architectural education pertaining to the topic of cost as a fundamental design determinant, and identified the importance of teaching the topic in architectural foundation design education. Cost indicators that affect construction cost were defined as they are appropriate to the second-year design students. Cost indicators were used as a device in this experiment to test and measure the effectiveness of cost indicators. As a result, this study found the impact and appropriateness of learning cost as a fundamental design determinant compared to the existing second-year design studio course.

This research implies that teaching cost as an integral design determinant in foundation design studio courses is an effective educational method to improving students' perspective of cost. The implications of cost indicators and understanding of cost as a design determinant should help young designers produce and appreciate realistic design. This study should be of particular interest to design instructors and educators, as well as affordable housing design and construction practitioners.

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NOMENCLATURE

ACSA	Association of Collegiate Schools of Architecture
ADA	American Disability Act
AIA	American Institutes of Architects
B/CS	Bryan and College Station
BVAHC	Brazos Valley Affordable Housing Corps.
CBA	Choosing By Advantage
IBC	International Building Code
IECC	International Energy Conservation Code
IRB	Institutional Review Board
HUD	United States Department of Housing and Urban Development
NAAB	National Architectural Accredited Board
NHI	National Housing Institute
RIBA	Royal Institute of British Architects
RU/H	Research University / High
RU/VH	Research University / Very High
TVD	Target Value Design
ULI	Urban Land Institute
p	Probability Value
t	Test Value

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CHAPTER I

INTRODUCTION

The purpose of this research is to develop and test an instructional strategy to improve awareness of cost affecting architectural foundation design. The investigation identified indicators to better influence and achieve cost conscious design, and suggested ways to improve and strengthen foundation design education with learning objectives focused on cost as an integral design determinant. Critical design methods and approaches in teaching cost as an integral design determinant to foundation design students was developed for students to interpret indicators and integrate them with other design considerations. Furthermore, this study assessed the effectiveness of indicators and the integrative quality of students' design to improve the value of cost determinism as a part of the foundation design curriculum.

Every year, approximately 27,000 students graduate from accredited architecture schools (National Architectural Accredited Board [NAAB], 2013a). Despite this large number, only 1% of registered architects are working with affordable projects, and similarly only a small number of references are devoted to affordable design in many U.S. architecture and urbanism books (Mallach, 2006). Architects and designers often frown on affordable design, but do not attempt to provide effective solutions to ensure better quality designs. Stansfield Smith (1999) stated that the key to a successful architectural profession is not only that profession's ability to represent quality and deliver high standards, but also its ability to represent the values and aspirations of the society it serves (Standfield Smith, 1999).

The problem may be “rooted in an [architectural] educational system” (Gellner, 2011, para. 2). The educational tendency is to separate program from design, conceptual education and technical education, and university context from the real world (Dutton, 1982). Architectural educators encourage students to provide unique designs that often result in costly solutions to hypothetical and real projects because students have an “absence in practical training” (Gellner, 2011, para. 11). Moreover, the recent tendency in design education is toward shaping “signature architects” like Frank Gehry or Zaha Hadid, rather than nurturing fundamental skills and architectural contributions to society (Nicol & Pilling, 2000).

Residential architectural projects often address affordable housing in ways closely associated with cost and the consequences of low-cost designs are often unpleasant and severe. Unfortunately, general affordable design often results in inferior, ill-equipped, and aesthetically unappealing projects. People commonly misunderstand that aesthetic value often suffers when less money is put into the design and the architectural project is “designed with an eye on quantity, not quality” (Casselman, 2007, para. 3). This is a misconception, as all projects associated with material qualities and conditions that rely on economic value. Although NAAB Conditions for Accreditation address the understanding of financial consideration during architectural education, students’ ability to integrate cost into quality design in its expected outcomes for accredited professional programs has not been represented (NAAB, 2013b). It is true that NAAB Conditions for Accreditation only applies to professional programs.

However, any undergraduate program introducing the NAAB required cost awareness can be expanded at the accredited Master in Architecture level.

Researchers found that design education is offered as part of many types of undergraduate architecture degrees (NAAB., 2013a). For architectural students to meet qualifications to take the architectural licensing examination in the United States, they must hold an architectural degree from an accredited professional degree program approved by NAAB. However, not all architecture students want to become registered architects; they often seek careers in fields related to architectural design (NAAB., 2013a). Commonly based on 8- to 10-semester programs, pre-professional degrees include the Bachelor of Arts, Architectural History, and Environmental Design. Professional degree includes the Bachelor of Architecture. Regardless of the accreditation, most architecture schools refer to the first and second-years of design education as foundation design education or lower design education.

Foundation design education refers to the first and second-year of undergraduate study in an architecture school in which educators teach the fundamentals of architectural design. Most students develop a design process and mold various design skills during foundation design education. During the foundation years students are most open and susceptible to suggestions of architectural philosophies, ideas, and processes. Therefore, the foundational design courses provide the opportunity to introduce students to approaches in design with cost as an integral design determinant. Also, *how-to* design with quality aesthetics cannot be taught unless *why-to* can be also cultivated.

1.1 Statement of the Problem

At the 69th annual Association of Collegiate Schools of Architecture meeting, Comerio and Protzen of University of California at Berkeley raised concerns about the shrinkage of architectural services. They stated that, along with proliferating specializations in the profession of architecture, architectural education no longer bothers to make the economic and financial problems of buildings its own (Comerio & Chusid, 1982). The structural and environmental aspects of buildings are now left to engineers, whereas the impacts to community and the large-scale architecture are surrendered to urban planners. Yet, it is the social, economic, and political imperatives that make architecture more than an ordinary building (Kostof, 1977).

What one commonly sees in architecture schools is the separation of academic minds from the world around them. Expensive houses or heroic projects are often examples of the quality and quantity of distinguished architecture in today's landscape. This viewpoint leads to a lack of awareness in the inequality of the global economy (Fisher, 2012). It is the assumption of this study that current architectural foundation design education does not recognize cost as an integral design determinant. This study is concerned that current foundation design education does not inform students of the cost aspect of architecture in producing realizable designs. In addition, current foundation design education understates modest architectural projects that do not require wealth, yet demonstrate that aesthetically pleasing, functional, and affordable designs can be achieved. Designers' ethical responsibility extends beyond wealth, and architectural education plays a key role in this transition.

1.2 Hypothesis

This research hypothesizes that what is absent in architectural foundation design studio education today is the teaching of cost as an integral design determinant. The foundation design studio education is an appropriate place to introduce these concepts. An awareness of cost indicators can help enable students' perceptions of the role of cost in design and affordability. It is hypothesized that understanding cost as an integral design determinant will enhance cost awareness in students' design, change students' perception of affordable design, and act as a guiding principle to achieve quality affordable designs in future projects.

1.3 Definition of Terms

For the purposes of this study, the following terms are defined.

- [*Architectural*] *Foundation design education:* Basic design education or beginning design education is often used as a synonym of foundation design education. Architectural foundation design education refers to the first one (1) or two (2) year (depending on the program) preparatory courses in architecture. The root of foundation design education was established in the German Bauhaus Foundation Course (*Vorkurs*) in the 1930s. After the closure of the German Bauhaus, Bauhaus master immigrants brought many Bauhaus ideas bolstering and integrating into the U.S. architectural foundation design education we know today (Lerner, 2005). Foundation design education includes design, drafting, architectonics, and history (Clayton, 2006) while exploring human conditions, place making, and technology (Chandler et al., 1999, as cited in Golja & Schaverien, 2015). Although the projects and exercises in the foundation design education aim to explore basic properties in materials, colors, textures, structures, and compositions, the foundation design education ensures students move into advanced architecture. Although the core subjects in foundation design education are similar, each program's curriculum is organized differently (see Chapter 2 for additional reviews on foundation design education). Discussion of similarities and differences across selected architectural schools appear in section 3.1.

The first-year design studio courses focus on teaching basics of architectural form, and often retain an emphasis on abstraction, proportion, and Bauhaus principles of graphic design (Clayton, 2006). It is where the design students begin the explorations of materials, geometry, surfaces, and detailing (Washington University at St. Louis, 2013). In the meantime, the second-year design studio courses let students incorporate fundamental principles into a building and site. The second-year design students focus on the relationship of architecture to the landscape and to the urban environment. In any event, it would be difficult to incorporate the concept of cost in the first-year design studio projects because abstract forms often exclude context. Hence, the second-year design studio course would be more appropriate to teach cost conscious design with small building projects with programmatic context.

The details of the first and second year design studio courses are discussed in section 3.1.

- *Quality design in architecture:* Design is a process that cannot be measured in a predetermined way. Searching the root of the term architecture, *arche* refers to a realm of first principles that lead to Plato. First Principles, according to Plato, manifest from goodness, truth, and beauty, realized through unity, generative, formative, corporeal, and regenerative processes (as cited in Tabb & Deviren, 2013). Vitruvius also indicated in the first book of the *Ten Books on Architecture*, that architecture depends on order, arrangement, eurhythmy, symmetry, propriety, and economy (Vitruvius, Morgan, & Warren, 1914/1960). When architects apply these principles as a whole, architecture can be recognized as high quality design.
- *Cost indicators:* Cost indicators refer to the corporeal principle in Plato's first principles mentioned above. The corporeal principle responds to the process of realistic and practical effort. Like cost, indicators are substantive, quantitative, and tangible. Here, the term refers to quantitative formal and spatial design factors that affect costs in building construction. Based on fundamental architectural elements, which correspond to building construction, cost indicators provide a dynamic system for designing and evaluating cost with application to affordable design. In addition, this dissertation describes methods to attain cost

indicators in the research method section (see 4.2 Research instruments: Cost indicators).

- *Cost determinism:* Determinism is often referenced as causal determinism in physics, aligned with Aristotle's prime mover. Aristotle claimed, in Book 8 of *Physics* and Book 12 of *Metaphysics*, nothing is uncaused or self-caused (as cited in Bodnar, 2012). Similarly in psychology, McLeod (2013) argued that the determinist approach implies that all behavior is caused by preceding factors, and is therefore predictable. Determinism suggests that with an idea or implication as a causal factor, its responding active behavior will be reacted (McLeod, 2013). Under this principle, cost acts as a causal agent to govern design with other design considerations in this research. Thus, it is predicted that a cost deterministic approach will actively impact quality design.

1.4 Significance of the Study

The principal benefit of the study is that it will contribute to knowledge about how to enhance the teaching of foundation design with cost as an integral design determinant. To achieve this end, this study examined and evaluated the effectiveness and applicability of affordable design concepts, indicators, and processes that could be applied to the foundation design education. The implications of cost indicators and understanding of cost as a design determinant will help young designers produce and appreciate realistic designs. This study will be of particular interest to design instructors and educators, as well as affordable housing design and construction practitioners. The experimental study demonstrated that a new course can effectively teach design with cost as a design determinant. This outcome or this course has not only the potential to change students' perception of affordable design, but to act as a guiding principle to achieve high quality affordable designs.

1.5 Research Objectives

The objectives of this study follow:

- To identify the need to include foundation design education pertaining to cost as a fundamental design determinant;
- To determine the indicators that contribute to cost as a fundamental design determinant in foundation design;
- To determine the effectiveness of cost indicators in the foundation design.

1.6 Theoretical Framework

This study proposes to understand impacts, effectiveness, and methods of cost as a fundamental design determinant in foundation design education, as well as to identify a need to improve foundation design education on the basics of affordability knowledge. In the eyes of positivists, reality "is only that, which can be observed" (Pickard & Childs, 2007). Knowledge is objective, clearly independent of those who observe it (Gall, Borg, & Gall, 1996). From this perspective, as conceptually described in the *time-cost-quality trade off*, when cost is reduced, quality, or quality and time must suffer (Rybkowski, Abdelhami, & Forbes, 2013). This leads to the conclusion that the "ugliness" in affordable architecture has nothing to do with those participating in the process, but what was provided at cost.

This perspective suggests that the root of the problem, manifesting as the lack of number of architects involved in budget constrained architectural projects or social housing projects, is the lack of understanding of inequality in the global economy, and the misconception that the ability of society to build affordable or low-income housing could lie in the architectural education. In addition, the current education does not recognize the importance of cost as a design determinant. If this is the case, then the awareness in correlation between qualitative design factors and cost (American Institutes of Architects [AIA], 2007a) will be lost, as long as architects continue to participate in design projects without cost constraints.

In contrast, in the perspective of constructivists, reality is socially constructed and different participants create different environments. Constructivists assume that the idea may not be generalized or repeated in field settings, but will continuously be recognized to evolve across time, space, and those who are interested in it (Gall et al., 1996). Such belief puts a closer link between knowledge and its seekers (Groat & Wang, 2002). Thus, the researcher plays a key role in searching for knowledge along with the participants in the study (Gall et al., 1996). This viewpoint also suggests a concern that the researcher who also participated as an instructor in the experiment can affect the result of the experiment positively or negatively. This is discussed again in the research limitations section.

This study searches for new knowledge through qualitative and quantitative processes, in order to strengthen the results and balance objectivity. However, the foundation of the process still lies in interactions between the researcher and the participants. Therefore, the transactional and subjectivist stance is better suited for this research. According to the epistemological stance of the transactional and subjectivist framework, the results are created as study progress (Pickard & Childs, 2007). In addition, as the study focuses on cause from effect, close observation between the known and knower and how they influence each other is significant. Because the researcher is participating in the research, initiating the cause, experimenter bias may appear to affect the outcome. With initial recognition of such conditions and neutral behaviors, efforts to eliminate experimenter bias shall be made. Thus, times will occur when the researcher must be separated from the participants to observe and investigate.

1.7 Overview of Dissertation

This dissertation contains six (6) chapters that outline systematic procedures of this research (see Figure 1). Chapter I introduces the fundamentals and the nature of this research. Chapter II is a literature review of relevant theories in the foundation design education, focusing on cost awareness in the architectural foundation education, and affordable housing. The literature review discusses how the architectural industry and academics view cost as an integral design determinant, and builds foundational grounds to support the need for this research.

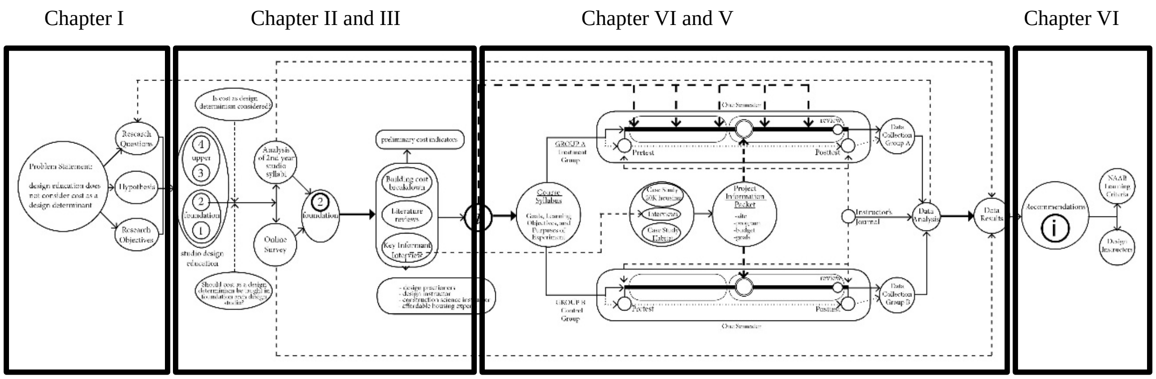


Figure 1: Research diagram as it relates to the dissertation chapters (see Appendix A for the complete research diagram)

Chapter III addresses the research methods, results, and discussions of findings from the content analysis, online surveys, and key informant interviews. This chapter explains in detail the process that took a place to select architectural programs in the U.S. to analyze similarities and differences in their foundation design studio courses. This chapter also describes the development of the online survey designed to reveal how academics and design professionals perceived the need and appropriateness of cost awareness in the foundation design studio education. Last, this chapter discusses the process that took a place during the key informant interviews and their significance in finalizing cost indicators, which are the main instrument in this research. Portions of Chapter III have been previously published, but this chapter has been reworked and adopted for this dissertation.

Chapter IV discusses the main part of this research, which is quasi-experimental in nature. This chapter defines the structure and procedure of a quasi-experiment. It also includes details of research instruments: the cost indicators and the 20K House project, which were used to measure the impacts and the effectiveness of each cost indicator. Last, this chapter explains the process of evaluations of the quasi-experiment.

Chapter V reports findings from the quasi-experimental 20K House design, which consists of following:

- Pretest and posttest differences between the control and treatment groups
- The 20K House design evaluation rated by selected evaluators, comparing the control and treatment groups
- The instructor's analysis of students' 20K House designs
- The preliminary cost estimation of four (4) selected 20K House projects

Chapter V also compares findings from the 20K House design along with the instructor's journal, noting subjective findings from two experimental (2) classes. The final chapter, Chapter VI presents the conclusion of this research. Implications and recommendations for design studio educators are included. Furthermore, limitations of the study, proposed future research directions, and research contributions are discussed.

CHAPTER II

REVIEW OF LITERATURE

A literature review provides additional information beyond what researcher already possesses. It advises to make the research possible with various sources. The purpose of this literature review is to connect the topic of cost in architectural foundation design education to disciplinary sources. In addition, various literatures found this research identify inquired topic, state of knowledge, and further respond to ways to contribute (Groat & Wang, 2002).

The review of literature follows four lines of research relevant to this study:

- research on architectural foundation design education;
- research on the need, methods, and appropriateness of cost determinism in architectural design education;
- research on teaching strategies that support understanding cost determinism; and
- research in the specific area of affordable housing.

2.1 Architectural Foundation Design Education

Design education is offered as a part of many types of professional and pre-professional architecture degrees. Architectural students must hold an architectural degree from an accredited professional degree program approved by National Architectural Accredited Board in order to be eligible to take the architectural licensing examination in the United States. However, not all architecture students want to become registered architects; they often seek careers in fields related to architectural design

(NAAB., n.d.). Undergraduate programs are commonly 8- to 10-semester, pre-professional degrees including the Bachelor of Arts, Architectural History, and Environmental Design. Professional degrees include the Bachelor of Architecture and the Master of Architecture degrees. Regardless of the accreditation, the initial content analysis of the selected architectural programs identified that most architecture schools refer to the first and second-years of design education in the bachelorette programs as the foundation design education or the lower design education.

Research conducted by Sunwoo (2012) at Princeton University identified the frameworks of vertical studio teaching, the unit system used as a pedagogical medium at the Architectural Association in London, England. Sunwoo's research highlighted programmatic and generational improvements made at the Architectural Association from 1971 to 1990, and described course objectives in the design-studio year-system curriculum that still applies today. The introductory year separates architecture into "fundamentals." The first-year students are introduced to three-dimensional design, representation, and visual arrangements of planes and forms, whereas second-year students advance to small-scale town planning and more complex construction techniques. Similarly today, the first studio course exposes design students to spatial and formal concepts in abstract ways, and it is generally not until the second-year that educators introduce small-scale architectural projects. This suggests that the awareness in cost can be considered in abstract ways during the first-year, and then applied it with small-scale architectural projects in the second-year.

Chandler, Gaskin, Lasala, and McKinney (1999) presented the assessment of the beginning design education of the University of Southwestern Louisiana at the 87th ACSA Annual Meeting. Their report explains that the foundation courses and their sequence are pertains to architecture and human condition, architecture as the making of place, and architecture and technology. In their pedagogy, architecture finds its meaning through the realization of space for life with its fundamental task as the place-making. The consideration of the technology is crucial as it is bound to the process of making. In addition to their emphasis, the program promotes the conviction that the design and construction are inseparable components of the architecture as it addresses the interaction of the spatial, programmatic, and tectonic issues. This foundation education pedagogy has resulted students' improvements in design skills, work habits, and quality of their work.

2.2 Research on the Needs, Methods, and Appropriateness of Cost Determinism in Architectural Design Education

Following the literature reviews to understand the architectural foundation design education, the researcher sought to understand the needs, methods, and appropriateness of cost determinism in architectural design education. Vitruvius describes the importance of economy in the Book 1. It is obvious that the plans should be carefully developed and with the greatest attention before the structures are begun. It is the tradition and architectural practice to calculating and stating the limit of expense. Vitruvius states that is a part of the education of architects (Vitruvius et al., 1914/1960):

> In the famous and important Greek city of Ephesus there is said to be an ancient ancestral law, the terms of which are severe, but its justice is not inequitable. When an architect accepts the charge of a public work, he has to promise what the cost of it will be. His estimate is handed to the magistrate, and his property is pledged as security until the work is done. When it is finished, if the outlay agrees with his statement, he is complimented by degrees and marks of honor. If no more than a fourth has to be added to his estimate, it is furnished by the treasury and no penalty is inflicted. But when more than one fourth has to be spent in addition to the work, the money required to finish it is taken from his property. Gentlemen would not be misled into limitless and prodigal expenditure even to ejectments from their estates, and the architects themselves could be forced, by fear of the penalty, to be more careful in calculating and stating the limit of expense, so that gentlemen would procure their buildings for that which they had expected, or by adding only a little more (Vitruvius, Morgan, & Warren, 1914/1960, p. 281).

Schon (1988) called design studio a virtual world, relatively free of the pressures, distraction and risks of the real world, but yet it is a setting designed for the task of learning a practice. In this practice world, students learn by doing, by undertaking projects that simulate and simplify practical aspects of architecture. Notwithstanding its fundamental grounds, the architectural design studio is geared toward being innovative without providing practical and real solutions. The greatest weakness of architectural education has become a lack of preparedness for architectural practicality.

Winter (1984) describes value engineering as the concept to reduce building construction cost without sacrificing the quality of finished building. In addition, value engineering is intended to add value as it reduces the construction cost, however, such value is difficult to define depending on how it is measured or to whom it is applied to. Furthermore, reduction in building cost should not reduce vulnerability of a building. Winter indicates while it is the architect's obligation to design buildings with values at its optimal cost effectiveness, there is a lack of incentive for such effort and often architects are not compensated to research alternates for cost savings. In spite, organizations such as the Department of the Housing and Urban Development, National Science Foundation, and the National Bureau of Standards continuously study and invest in research to reduce building cost through "design, construction techniques, technology, energy conservation, durability, life safety, and hazardous reduction" (Nicols & Pillings, 2000, p. 278). He also, attests that regardless of its significance, architectural schools do not emphasize training future architectural designers to design with optimal cost effectiveness through its education. Winter concludes that the architectural education should consider addressing building elements deemed to add value attributing to cost and benefit of the building. Winter advocates for the architecture schools to develop research and teaching programs with an aim to develop cost effective design.

Hannes Mayer, former head of the Bauhaus at Dessau, defines architecture as a process of giving form and pattern to the social life of the community (Schon, 1988). Schon (1988) states that Morrow (2000) advocates more inclusive design in schools of architecture. His research uncovered that when students share similar backgrounds, social classes, aspirations and political affiliations, they often fail to take account of the ‘otherness’, and that it neglects differences in ability, age, gender, income sexuality, race or culture (Schon, 1988).

According to Akin (1982), every design conditions demands a unique, visual, solar, topographic, social, financial, and programmatic response that most conventions have to be reprioritized and re-expressed to fit the new circumstances. Likewise, design abilities are achieved where new knowledge is presented through engineering, building technology, history, economics, planning and so on, then students apply such knowledge to specific design problems.

Architectural education should more firmly address issues of social, political and economic relevance, such as the control and distribution of the world’s resources, landownership, class conflict, methods of capital accumulation, and political/economic power and its effect upon social decision-making (Dutton, 1982). Dutton provides demanding implication that architectural education must stop excluding social, political, and economic realities from students. Undiscovered at school, students design in “an imaginary universe”, and there must be integration of educational context and the “real world” context (Dutton, 1982, p.145). If these issues are taken into account when designing, the physical structure, architecture can be practiced in ways that it may alter the prevailing political and economic structure of society today.

The content analysis of the syllabi for this research showed that *Architecture: Form, Space and Order* (2010) by Ching is the most commonly used textbook for foundation design studio courses. Often, architects and designers try to solve design problems focused on form and space; this book focuses markedly on formal and spatial ideas and concepts. However, Ching only briefly discusses the importance of social, political, and economical aspects of architecture, and mentions that equal emphasis should be given to the conditions of function, purpose, and context. The purpose of Ching's book is not to teach *how-to,* but to understand the foundations of architectural form and elements.

Similar to Ching (2010), Friedman addresses the importance of fundamentals of form and space in the book, *Creation in Space* (1999). Friedman implies that as architects try to solve design problems, they should integrate structural strength (firmness), spaciousness (commodity), and beauty (delight). A basic tenet in the profession of architecture is to make the design aesthetically apealing. However, "architecture is not easy. Its difficulty is what makes true architecture all too rare" (Friedman, 1999, p. 125). Similar to Ching, this book on fundamentals of architecture is focused highly on formal ideas and concepts, and does not address the importance of the reality of social, political, and economic aspects of architecture.

Fisher (2012) summarized and narrated educational discussions led by MacKay-Lyons for the March 2012 edition of the *Journal of Architectural Education*. A group of educators and practitioners gathered at an international conference to discuss what should be taught in the beginning design curriculum. The participants posited that wealth is required to fund examples of quality and quantity of craft in today's construction; however they recognized the issue is not only concerned with economics, but also ethical responses. The educators and practitioners agreed that architects' primary responsibility rests in performing high quality architecture. The conference did not create a manifesto, but participants identified “architectural and educational responses to the homogeneity, unsustainability, and inequality of the global economy” (Fisher, 2012, p. 15).

In the interview with Winston (2016), the 2016 Pritzer Prize winner, Alejandro Aravena addresses the importance in learning budgetary constraints in architecture school. Aravena calls himself lucky that he happened to be engaged with right people interested in economy, of policy, of the building industry at Harvard University. He also, noted that with more than one million architects in the world, presumably there would be more solutions and more proposals try to address the issue in lack of quality social housing if architectural education attends to these topics. Nonetheless, budget constraints are intertwined with building logic, political framework, and policies that are too vast for architecture education to include. Architects do not have to become policy makers or economists. “Our contribution to a problem is as designers” (Winston, 2016, para 63).

According to the basic scope of services defined by the American Institution of Architects (AIA), seven phases of services exist: preliminary design, schematic design, design development, construction development, construction documents, bid or negotiation, and construction administrative services. Student projects in the design studio are equivalent to schematic design deliverables of architectural services. The deliverables: schematic design often produces a site plan, floor plan(s), sections, an elevation, and other illustrative documentations in the form of hand sketches, diagrams and drawings, computer images, renderings, or models. Within the profession, schematic design drawings include overall dimensions, and a construction cost is estimated (AIA, 2007b, para 10). Thus, at a minimum, a conceptual level of construction, an awareness of construction scheduling, and an estimation of a construction project should be taught in the foundation design studio.

Target Value Design (TVD) is a collaborative design process to produce projects that provide the best value for clients; the target is largely identified as the budget of the project. In experimental research by Rybkowski et al. (2011), 18 postgraduate university students were asked to design a wine stand using Styrofoam plates and cups, and an 8.5 x 11 size sheet of paper. Researchers only gave one group cost as a constraint. They photographed the wine-stand designs and graphically rendered them to remove confounding variables, which were not identified in detail. The 120 participants then evaluated the designs. This experimental research suggested that "higher cost might support better aesthetic quality in design, but the influence is quite mild" (Rybkowski at al., 2011, p. 7). The purpose of this research was to address the concern that Target Value Design produces aesthetically inferior designs; however, researchers explored a relationship between cost and aesthetics, which is a continuous challenge and embodies concerns for affordable housing design.

Jarrett (2005) discusses blind spots in the design studio. According to his article, 'Social practice: Design education and everyday life', design education continues to represent design theory secluding the studio work from everyday life. The current design studio education portrays exclusion of people in the neighborhood and community. He applies an example of the coatmaker to an archiect's role in the society. The architect's role is not to make the object-the building, but cultivates the sense of place. Jerrett attests design with attention to context, climate, space, movement, light, surfaces, codes, budgets, systems, materials and joints shall accomplish the goal in making a place.

In a recent discussion, Patric Schumacher of Zaha Hadid Architecture criticized the selection of this years's Pritzer Prize Laureate, Alejandro Avarena. He condemned that the Pritzer Prize has mutated into a prize for humanitarian work. Although he did acknowledge that Aravena's "half a good house" projects were an intellectual solution to the lack of affordable housing crisis, but like Schumacher, most architects see ideal projects as iconic, timeless, radically futuristic (Solis, 2016). As Solis argues, a deep understanding of the economic context can effectively guide architectural ingenuity as much as understanding of the formal, spatial, or geographic context of a project. What Aravena has achieved to deserve the Pritzer Prize is that he demonstrates the understanding of the economic context of architecture by looking at an economic limitation not as a compromise, but as an opportunity. Architects and other design professionals must recognize the fact that economics and finance drive the solutions they come up with to address many design challenges. Such understanding of economics and finance may be the additional skill set architects and other design professionals need to create design opportunities.

2.3 Research on Teaching Strategies that Support Understanding Cost Determinism

Every design and design decision is associated with cost, but architects achieve the greatest potential savings in design by driving decisions in the early phases of design (Gevaux, 2010). Although cost-conscious design may lead to low cost design at the time of construction, the architect must consider affordability for the duration of the project lifecycle. According to a recent case study by McGraw Hill Construction, builders have seen an increase in environmentally sustainable affordable housing. Its study indicates that with more attention given to global health and well-being, issues of sustainability are more important in the affordable-housing field than in the luxury field. With green-design elements incorporated into affordable design, efficient buildings could provide the resident with savings for the duration of their stay (H. Bernstein & Russo, 2014).

Another reason for cost to be considered as a design determinant is that most designers confront limited economic resources in ways that designs become unfeasible or require amended implementation. Researchers found that early implication of adequate economic resources results in producing optimum design from the beginning to the delivery (Kirk & Dell'Isola, 1995). UniFormat and MasterFormat are two commonly used frameworks of construction cost categories suggested by the design and construction industry. UniFormat is organized by building system whereas construction labor trades arrange MasterFormat. One of the benefits of understanding and applying UniFormat is that it presents cost estimates during the schematic design phase. At the elementary level, UniFormat prices substructures, shells, interiors, and services, without defining the technical solutions.

An attitude in education, which confronts values and value differences directly may offer new possibilities for achieving not only more effective practice and greater service, but also a more profound aesthetics. Architectural education is a process of value formation, characterized by concerns for beauty, environmental quality and technical performances. The educational process should therefore equip students to anticipate, recognize, and work with value differences (Ledewitz, 1982).

Instructors may teach students the best tools to use in design and the most efficient digital media to produce quality design, but if the designer does not choose the soundest decision to provide the best value in the process, the final product will suffer. In the book *Choosing By Advantages*, Suhr (2014) states that the purpose of the Choosing by Advantage (CBA) decision-making system is to “improve the quality of life” by making sound decisions (Suhr, 2014, p. 17). The fundamental rule of the CBA decision-making system is to base decisions on the importance of advantages. Understanding and correctly using the decision-making system could help improve students’ designs by encouraging sound design decisions. Architects must make sound design decisions regularly, whether they are overall forms, structures, or finish materials (what CBA calls alternatives). Every design option has characteristics (attributes) and by comparing the options, architects can identify the advantages from one or another.

Morrow (2000) attests that teaching in architecture schools assumes similar backgrounds, social class, aspiration, and political affiliations, and such assumption in architectural education contributes to the failure of architects to take account of different needs, which is crucial to consider in design. He adds that understanding of users and their different needs affect how the users perceive and utilize the space. Morrow writes that the architectural education excludes environmental and social factors during design, which results in poor design. In addition, such architectural assumptions separate architecture apart from the society and its context. Morrow encourages more inclusive design, which develops a deeper understanding of user context in respect to others.

May (1982) states that the learning objective of foundation level architectural education is the shared recognition that architectural decisions involve value judgements, and that teaching impact increased value orientation further guiding students architectural philosophy. Architectural education serves its purpose when it educates people to the responsibilities of practical, ethical, and political architecture (Libeskind, 1995). Libeskind notes that these responsibilities can only be understood when students are aware of what is happening in the world.

2.4 Research on the Need to Improve Design Quality in Affordable Housing

Dutton (1982) states that quality design arises when it is socially responsible. Education should encourage students to design environments, which impact social, economic, and political messages in, an attempt to more inclusive society to qualitative state so that there may be a more qualitative architecture. The National Housing Institute (NHI) indicated that (as cited in Mallach, 2006),

> good design matters particularly with respect to affordable housing, which not only should embody social and community objectives that go well beyond the mere provision of shelter, but also overcome the stigma of its association with the hulking towers and barren blocks of many public housing project (para. 1)

The NHI found that The HOME housing project competition by Habitat for Humanity may promote quality designs for affordable housing, but raised concerns about the program’s entertainment value rather than the practical utility of the building projects (Mallach, 2006).

City Design Center at the University of Illinois at Chicago hosted the Architecture for Change Summit in 2010 to discuss design challenges, opportunities, and core principles of low-and moderate-income community design. The executive summary from the meeting indicated that the discussions included topics such as efforts to restoration, and preservation, environmental restoration and sustainability, household diversity, social and cultural vitality, and economic security (Architecture for Change Summit, 2011). The summary also identified that adequate and sufficient governmental financial support is needed to support these critical design goals. In addition, participants recommended national wide consistencies across regulation and codes, and implementation of zoning regulations that limit affordable housing design innovations. Participants targeted discussions toward policy, regulation, and governmental funding. Discussions focused on a systematic approach to quality design have not yet occurred.

Recent studies have shown that many affordable housing projects throughout the world demonstrated that low-cost housing need not to be of poor quality. However, many people continue to believe that high-quality designs are appropriate only for a few select citizens of society. There are more challenges in designing affordable housing such as local building codes, neighborhood skepticism, and technical constraints that make the process even slower and frustrating endeavor, (Schmitz, 2005). Architects, developers, and public officials need encouragement to consider innovative approaches to provide shelter to those with precarious economic circumstances.

An article by The Atlantic Cities forwarded the misguided premise that well-designed and aesthetically appealing affordable housing design would expensive and should not be a priority. The article then presents case-study examples of quality low-cost design that "does not scream 'affordable'" (Arieff, 2011, para #1). The article exhibited recent affordable housing designs in California, Michigan, and New York that are modest, yet incorporate sustainable and healthy living into the building design. This article provided evidence that high quality design ay be achieved at low cost; however, the article did not address how the low cost designs were achieved. Many systematic design discussions will be needed to change the misconception of unsatisfactory aesthetics in affordable housing.

There is a lack of references on the topic of affordable housing design. Exceptions were three books by Davis (1995), Jones, Pettus, and Pyatok (1999), and the Urban Land Institute (Schmitz, 2005). According to the NHI article written by Mallach (2006), *Good Neighbors* (1999) by Jones et al. is one of few references advocating affordable housing today. Based on research and practical experiences, Jones et al. provided comprehensive and detailed explanations of "affordable housing development from its conception through the design and development process to its culmination as a living community" (Jones et al., 1999). Compared to Ching's (2010) and Friedman's (1999) textbooks, *Good Neighbors* is not a textbook for foundation design students, due to the authors discussions of high level of technological, political, and social aspects of affordable housing the authors discuss in the book. In addition, Jones et al. do not discuss formal and conceptual design ideas in case-study projects. However, all case-study projects were highly recognized nationally for their excellence in award-winning designs. Their study also showed that no systematic cost differences exist between the case-study projects and affordable housing projects. Each case study does illustrate the importance of the architects' understanding of the individual clients' financial hardships along with an awareness of their needs. This enabled the architects to better integrate aesthetic considerations with cost.

CHAPTER III[1]

CONTENT ANALYSIS, ONLINE SURVEY, KEY INFORMANT INTERVIEWS

This research employs a combination of quantitative and qualitative methods. The quantitative research paradigm search for objective reality identifying measurable impacts of cost awareness among students in the foundation design studio courses. It involves a deductive process of seeking cause-and effect explanations. Meanwhile, qualitative research paradigm infer interaction with researcher and participants through inductive process continuously shaping the factors to identify the topic and related discipline. Thus, this research is underlying concept that organizes both objective and subjective results (Groat &Wang, 2002).

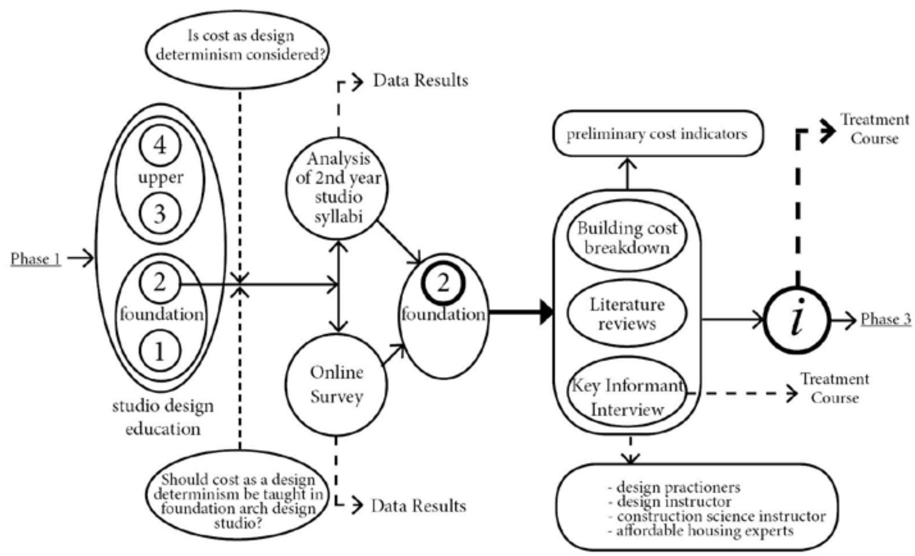


Figure 2: Phase 2 - a partial research diagram (see Appendix A for the complete research diagram)

[1] Portions of this chapter were reprinted with permission from “The Impacts of Cost Determinism in Architectural Foundation Design Education: an Analysis of Foundation Design Studio” by Lee. S., Tabb. P., Rogers. J., Rybkowski. Z., & Van Zandt. S. 2016. *Procedia-Social and Behavioral Sciences* in vol. 216, pp. 923-932. Copyright (2016) by Elsevier.

The Chapter III is associated with the qualitative analysis based on the content analysis, online survey, and key informant interviews (see Figure 2). Its inductive process of inquiry attempts to clarify the needs of teaching cost as an integral design determinant in the foundation design studio course, seeks for information from live experiences from design instructors and professionals in practice in association to cost awareness. Both online survey and key informant interview have strong reliance on participant's experience and observation on cost awareness in the foundation design studio education.

3.1 Content Analysis of the Selected Architectural Design Studio Courses

The purpose of the content analysis to identify similarities and differences across of the selected architectural foundation design studio courses to further understand the architectural foundation design studio education. Furthermore, the content analysis of selected schools' foundation design course descriptions, syllabi, and project briefs have discovered a gap in architectural education pertaining to teaching cost as an integral design determinant.

3.1.1 Research Method

The structure of the architecture program at the Texas A&M University guided the selection of the schools that participated in the research. The program at Texas A&M University is composed of a 4-year undergraduate degree program (Bachelor of Environmental Design) and a 2-year NAAB-accredited graduate program (Master of Architecture). Only schools in the United States having accredited architectural programs approved by Association of Collegiate Schools of Architecture were used during the preliminary selection phase (ACSA, 2013). These schools were then sorted by their ranking in the U.S. News & World Report (2013)'s Best University National Ranking, Design Intelligence Ranking, and Carnegie Classification for the 2012-2013 academic year. Further selections were made based on the structure of the degree program, the number of studio courses offered and the studio enrollment so as to generate comparable data to the architectural program at the Texas A&M University. The final list of schools were contacted and, then asked to participate in the research by sharing their internal course information. Design studio course syllabi for all four (4) foundation design studio courses of selected schools were received, then analyzed.

Research design steps prepare and warrant the main research design. Qualitative content analysis of existing syllabi, projects, and foundation courses in the select schools was performed. The selected schools are (in alphabetical order): Ball State University, Muncie, IN.; North Carolina State University, Raleigh, NC.; State University of New York, Buffalo, NY.; the University of Colorado, Boulder, CO.; the University of Florida, Gainesville, FL.; the University of Minnesota, Twin Cities. MN.; Washington University, St. Louis, MO.

During the data collection phase, design instructors and program coordinators of the selected architecture schools were contacted to review their school's foundation design courses, syllabi, and projects. In this process, Microsoft Excel was used to organize the keywords from various documents, identify the similarities and differences between design programs, search for the most used keywords on the topic of cost awareness. Analysis of course outcomes, goals, and required or referenced textbooks were also analyzed.

3.1.2 Result and Findings

The National Architectural Accrediting Board reported that there were only (126) NAAB approved professional architecture programs in the United States in 2013 (NAAB, 2013a). Among the NAAB approved programs, 60% (76 out of 126) of the accredited architectural schools were included in the top 200 of best national university ranking by the U.S. News & World Report (2013). The filters of the NAAB accreditation and the U.S. Weeks & World Report indicate that 66% (83 out of 126) of accredited schools are privately funded. Additionally, approximately 58% (73 out of 126) of the NAAB accredited institutions were categorized as Very High or High in their classification under the Carnegie Classification of Institutions of High Education during 2013 (The Carnegie Classification of Institutions of Higher Education, 2014) (see Table 1).

Table 1: Accredited architectural institutions in the U.S. (Lee, Tabb, Rogers, Rybkowski, & Van Zandt, 2016)

Total number of NAAB accredited architectural schools in the U.S. = 126			
Ranked vs. Unranked (Top 200 Best National University by U.S. News & World Report)	50 Unranked (40%)		76 Ranked (60%)
Private vs. Public	43 Public (34%)		83 Private (66%)
Carnegie Classification of Institutions of High Education	52 VH (41%)	21 H (17%)	53 No Classification (42%)

Among the (126) NAAB accredited architectural schools (NAAB, 2014) in the U.S., only thirty-three (33) schools (25%) were composed of a 4-year undergraduate degree program and a 2-year NAAB-accredited graduate program like Texas A&M University. However, only fifteen (15) out of the thirty-three (33) schools were offering design studio courses, which consist both lectures and hands-on design studios from the first semester at the first year level. Moreover, only eleven (11) of these schools were listed as the top 200 best universities by the U.S. News & World Report. When the initial contact was made to each program coordinators, only seven (7) out of the eleven (11) schools consented to participate and to be compared to the reference architecture program at Texas A&M University (see Table 7). The final list of schools are (in the top 200 best national university rank order): Washington University at St. Louis (14), Georgia Institute of Technology (36), the University of Florida (49), Texas A&M University (69), the University of Minnesota, Twin Cities (69), North Carolina State University (101), the University of Buffalo, SUNY (108), and Ball State University (181). Each program's course description was published on the school webpage.

With the exception of Washington University at St. Louis, the other seven (7) schools are public universities. They also, hold Research University/Very High (RU/VH) standing of the Carnegie Classification of Institutions of Higher Education except for Ball State University, which is classified as Research University/High (The Carnegie Classification of Institutions of Higher Education, 2014). Although the fundamental outlines of the four (4) year undergraduate programs were similar, the degrees were listed as the Bachelor of Science in Architecture or the Bachelor of

Environmental Design. While each school's course titles and numbers were different, five (5) out of the eight (8) schools' first year program was called the common year, which shares their first year of foundation design studio courses with other departments within the college such as the interior design, the landscape design, and the urban planning.

While the selected eight (8) architectural institutions' organizational differences such as course name, course number, and number of credit hours were discovered to be different, the contents within the courses were found to be similar. Abundant similarities were found in the foundation design studio course descriptions for the first year and second-year foundation design studio courses. Review of course descriptions discovered similarity among eight (8) selected programs that as Clayton (2006) argued in *Replacing the 1950's Curriculum*, fundamental design courses focuses on abstraction, proportion, and Bauhaus principles of design and adapting architectural education model from Europe. The basic design was all mandatory for all architectural design students to learn "artistic and aesthetic theory applied to practice" (Findeli, 2001, as cited in Golja & Schaverien, 2015).

Since this research focuses on the second-year design studio course, in depth analysis was conducted to understand similarities and differences in the second-year design studio courses. Each school's program coordinators was contacted on the phone and they have confirmed that their courses include lectures and hands-on studio hours. Nevertheless, the credit hours varied as low as three (3) credits at Washington University at St. Louis and as high as six (6) credit hours at the University of Minnesota, North

Carolina State University, and the University at Buffalo, SUNY. The second-year design studio courses at Texas A&M University were four (4) credit hours for the first semester and five (5) credit hours for the second semester.

Across the eight (8) participating schools, the second-year design studios were generally introductory courses, which investigate architectural form and space, materials, building technology, programing, and terms related to sites (or site analysis). Furthermore, these terms and other similarities mostly appeared in the course description. Overall, no term that relates to cost as an integral fundamental design determinant or economic aspects of architecture was found in any of the four (4) school's second-year design studio courses' descriptions (see Table 2).

The in-depth analysis of the second-year design courses' syllabi and project briefs, discovered additional similarities and differences. Out of the eight (8) schools previously mentioned, only four (4) schools consented to participate and share their internal documents. Course syllabi and project briefs for the two (2) second-year design courses were collected from four (4) architecture schools (in alphabetical order): Ball State University, Texas A&M University, the University at Buffalo, SUNY, and the University of Minnesota.

In exception to Texas A&M University, the other (3) programs enforced all studio sections to use identical course syllabi and studio project briefs to retain consistency. Students throughout the same year used same recommended textbooks, performed the same studio exercises, worked on the same studio projects. On the other hand, the unique characteristics at Texas A&M University allowed each studio instructor to tailored syllabi while maintaining the mainstay in the course description. Therefore, recommended textbooks and studio exercises were tailored to support individual studio projects' design goals. Such course design helps, in a way, to prevent all classes to share the same textbooks and projects in the second-year design studio courses at Texas A&M University.

Since the course outcomes and goals were directly related and referenced to the course description the analysis was focused on required and recommended textbooks, reading materials, and studio projects. Consistently, none of them inferred any terms related to cost or its awareness. Based on the projects issued by the instructor, reading materials varied, and there were indications that the list was not final. Ball State University had the same reading list for the both semesters, and they were all pertained to architectural history, theory, and critical thinking. In summary, there was no common textbook or author across the four (4) schools in exception to Francis Ching's Architecture: Form, Space, Order (2010), which was listed as reference. Although there was no single common textbook found from the (4) schools' syllabi, the required textbooks were all focused in architectural principles and theory.

The four (4) schools' syllabi included short descriptions of studio projects offered in the courses. In addition, each school has provided detailed project briefs along with the syllabi. The second-year design studios at all four (4) programs offered two (2) to three (3) small to medium scale projects per semester, and the types of building varies from a small form transformation project to a large community project with contains detailed program requirements. In such a case, there were at least two (2) to three (3) page long project briefs with detailed breakdown of square footage and the required program of activities. However, no information was pertained to practical or economic aspects of the project. With the exception of materials suggested in the scaled architectural models, there was no suggestions of building materials or finishes. Furthermore, there were no particular limitations to building materials or finishes either. As to any project types, which may inform the financial realm of architecture, only one (1) affordable housing project was found in a second-year design studio course instructed by Dr. Mark Clayton at Texas A&M University. While it was a prospect project with a real client, it focused in learning computer programs using affordable housing as a design objective. Therefore, less emphasis was given to the cost or economic aspects. Clear evidence of discussions or teaching of cost as an integral fundamental design determinant was absent in both syllabi and project briefs from all four (4) programs. In summary, the concept of cost or cost awareness was absent consistently across the architectural programs analyzed.

Table 2: Content analysis of foundation design programs and course description (Lee et al., 2016)

	Washington Univ. at St. Louis	Georgia Institute of Technology	University of Florida	University of Minnesota	Texas A&M University	North Carolina State University	University at Buffalo, SUNY	Ball State University
Types of University	**Private**	Public	Public	Public	Public	Public	Public	Public
The U.S. News Ranks (2013)	14	36	49	69	69	101	108	181
Degree Title	Bachelor of Science in Architecture	Bachelor of Science in Architecture	Bachelor of Design in Architecture	Bachelor of Science in Architecture	**Bachelor of Environmental Design**	**Bachelor of Environmental Design**	Bachelor of Science in Architecture	Bachelor of Science in Architecture
Common First Year	No	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**
The First-Year Design Studio Credit Hours	6	7	8	8	8	8	10	6
The First Year Design Studio Description Key Words (Catalog)	**Basic principles, 2 and 3 dimensional**, scale	Role of presentation, interdisplinary, collaborative	**Basic organization**	Design-thinking, project based, **design principles**	**Design principles, 2 and 3 dimensional**, human, physical, cultural	Human measurements, scale, **design concepts**	**2-3 dimensional**, spatial relationship	History and contemporary, elements of space, form, function, and human use
The Second Year Design Studio Credit Hours	6	8	10	12	9	12	12	8
The Second Year Design Studio Description Key Words (Catalog)	**Bldg.** analysis, structure, organization systems, **programing**, **materials**	**Building and site, programing**, technical, **context**	**Materials**, culture, **context**	**Material,** construction methods, **relation to site**	**Materials,** methods, scale, fabrication, production	**Environment,** solar, vegetation, topo, electronic media	**Materials,** methods, tools, conventional design	Technology, research, analysis, **programing**
The Second Year Studio Projects	-	-	-	**Form Transformation,** Retail, **Site** Development, **Housing**, etc.	**Form Transformation**, Fabrication, **Housing,** Museum, Analysis, etc.	-	**Form Transformation**, **Site** Development, Mixed-Use, **Housing**, etc.	**Form Transformation**, Hospitality, **Housing** Competition, etc.
Words pertains to cost	No	No	No	No	No	No	No	No

3.2 Online Survey

As the topic of cost was identified as absent in the foundation design studio education among the selected architectural program, an online survey was distributed to identify "the separation of the mind from the hand and of the academic for the world around it" (Fisher, 2012, p. 13). The purpose of the online survey was to further confirm that the gap identified through the content analysis exist in the eyes of academics and design professionals as well. Furthermore, the online survey determined whether the topic of cost as a fundamental design determinant is or was inclusive in architectural design studio courses.

3.2.1 Method

The online survey was targeted to current architectural design studio instructors and architectural design professionals. The survey also attempts to, determine how often budgetary considerations are challenged in the practical field. This account for the fact that not all design studio instructors worked in the field as design professionals. The online survey was also used to understand how academics and design professionals perceived the concept of cost as a fundamental design determinant. For duration of three (3) months (July to September, 2014), an online survey invitation was sent to over 300 recipients in various architectural schools and design firms using contacts from the Texas A&M Alumni Association, various accredited Architecture schools approved by NAAB, and sponsoring firms all over the States. Participants were required to identify themselves as either:

- A design professional who already has an architectural degree and is practicing architecture or a related field
- An academic who is teaching foundation design studios and has experience teaching basic architectural principles that help students understand architecture and design

The online survey questions were tailored specifically for design professionals and academics. (See Appendix B for the list of questions provide to both groups). The online survey examined the architectural educational background of design professional in search for architectural institutions, which discussed the concept of affordable design in the design studio courses. Concurrently, similar questions were provided to academics to determine whether they are teaching or have taught the concept of affordability to foundation design students. The program content analysis of selected architectural programs may have identified the inclusiveness of the topic of cost in the foundation design studio courses, however this online survey seeks information from individual design instructors to correlate data from the content analysis and online survey. This structured set of online survey questions produced additional evidence to confirm earlier content findings (Gall et al., 1996).

Participants

As shown in the Table 3, this online survey involved a sample of 170 people (141 design professionals and 29 academics) from various design firms and architectural institutions in the U.S. A total of (143) design professionals were initially registered, but two (2) did not quality as participants as they did not hold an architectural degree.

Table 3: Total number of online survey participants (Lee et al., 2016)

	Design Professionals	Academics
Number of online survey participants	141 (83%)	29 (17%)

3.2.2 Result and Findings

The absence of the topic of cost has notably appeared when comparing the online survey responses between academics and design professionals. Simultaneously, the survey identified the gap in the architectural education and the practical realm of architecture (Fisher, 2012). The results from the online survey showed that academic participants are currently teaching at eight (8) different architecture schools in the U.S. and three (3) international institutions. In addition, six (6) participants have indicated that they teach at multiple architecture schools. More than a half of the academic participants indicated that they are currently teaching the first or second-year design studios, and among these instructors, 67% (10 out of 15) have indicated that they already teach or discuss affordability and economic ways to design in their studio courses. Overall, eighteen (18) out of twenty-eight (28) participating design studio instructors stated that they are already discussing such topics in their design studio courses.

Table 4: Currently teaching economic design or affordability in the foundation design studio courses (Lee et al., 2016)

	Currently Teaching Foundation Design Studio	Currently Discussing Affordability and Economic Design in Studio		Will you teach such topic if new course was developed	
Yes	15 (52%)	Yes	10 (67%)		
		No	5 (33%)	Yes	3 (67%)
				No	2 (33%)
No	13 (45%)	Yes	8 (44%)		
		No	4 (30%)	Yes	2 (50%)
				No	2 (50%)

The next question asked whether the instructors would adopt a newly developed course to inform cost as an integral design determinant or not. This question was directed toward those instructors who were not currently discussing affordability and economic design in their design studio courses. The responses were evenly divided that only a half of them are willing to adopt a newly developed course to inform cost awareness in design studio courses if such curriculum is developed (see Table 4).

In the same degree, it was stressed that while it is important that design students grasps the mindset of cost awareness, their design should not be cost-driven impeding their creativity. The fine line between pursuits of ‘cost as a fundamental design determinant’ versus cost-driven design appeared to be the recurrent concern of design educators which is difficult to achieve, therefore design instructors appeared to be hesitant toward giving in-depth discussion around this topic. Many academics showed concerns that teaching cost as an integral design determinant might limit and reduce students’ creativity and design exploration. Cost in design may impede quality design, however, “despite cost pressure, high-quality projects can still be developed if commitment is high” (Thill, 2012, p. 458). Despite this distress, approximately 87% (including those who are already teaching such topic) of foundation design studio courses and 80% (including those who are already teaching such topic) of design studio courses in general, stated that they would adopt and take systematic approaches for students to increase awareness of cost as integral design determinant if such course was developed. This is a reassurance that academics believe learning and teaching such topic will be beneficial and enhance students' design quality, and furthermore the earlier the better to learn such topics in formal education.

Concurrently, the design professionals have responded to a different set of questions than the questions provided to the academics. The results from the design professionals' responses indicate that they are graduates of fifty-four (54) different U.S. architectural schools and fourteen (14) international schools. Approximately 37% (49 out of 130) of the overall participants have graduated from architectural schools in between 2001 and 2010 resulting the majority in the participation. The participants graduated in between 1991 and 2000 were at 21% (28 out of 130) resulting the second largest group in the participation. The graduates in between 1981 and 1990 and after 2011 were similar in size at 16-17%.

Table 5: Years of graduation and architectural programs (Lee et al., 2016)

Years of Graduation	4 Year Pre-professional degree	5 Year Accredited Degree	4+2 Year Pre-professional degree with accredited master degree	Others	Total
Before 1980	2	6	1	0	9
1981-1990	4	7	7	3	21
1991-2000	2	13	9	4	28
2001-2010	11	9	18	11	49
After 2011	3	8	8	3	23
					130

Overall, a large number of design professionals received either the five (5) year accredited Bachelor in Architecture degree or a 4+2 year program with a pre-professional undergraduate degree and an accredited graduate degree. In its ten (10) year increment comparison, the larger numbers of the five (5) year degree holders were found in “before 1980” and in between 1981 and 1990. On the other hand, increase in the 4+2 year program degree holders were found in between 2001 and 2010. A balanced spread between the five (5) year programs and 4+2 year programs was discovered in between 1981 and 1990, and participants whom graduated after 2011.

The survey asked the current design professionals whether they learned or discussed economic design or affordability when they were in foundation design studio courses. Approximately 80% (113 out of 137) of the participants responded that they did not learn such topics and the other 17% (24 out of 137) of the participants who have indicated that they learned such topics in foundation design studio courses, commented that cost was an inclusive topic in the discussion of sustainability or affordable housing. Approximately 90% (80 out of 113) of the participants who have not learned such topics, stated it would have been beneficial if they were informed of cost awareness during the foundation design studio courses.

Lastly, 75% (103 out of 137) of the design professionals indicated that they teach cost implication to their interns in their office. The remainder 25% responded either a) they do not have interns, b) they are interns themselves, or c) they are not in the level to teach anyone yet. Since the topic of cost does not appear in the current architectural education, the majority of design professionals responded that they introduce and teach cost implications in building design and construction to their interns. This suggests that cost awareness is necessary in the architectural practices and it is one of the first and most important items discussed in any design meetings. This also leads to a concern that awareness in cost after completing the architectural education may weakens recognition of its significance. Therefore, the design professionals stressed the importance of embellishing the mindset of cost awareness during the architectural education thus the topic of cost does not strain upon the young designers entering the architectural practice.

Table 6: Learned economic design or affordability in foundation design studio courses (Lee et al., 2016)

	Learned Foundation Design Studio	Would have been beneficial		Teach Interns about economic design and affordability	
Yes	24 (17%)			Yes	18 (75%)
				No	5 (21%)
No	113 (80%)	Yes	90 (80%)	Yes	69 (76%)
				No	21 (24%)
		No	21 (19%)	Yes	16 (76%)
				No	5 (24%)

Despite of this high number of academics responded that they are currently discussing topics concerning building cost in their foundation design studios, 80% of participating design professionals stressed that they did not learn anything about it during their architectural foundation design studio education. This has displayed clear contradiction in responses between instructors and students. This may raise a question what if the “time-learned” and “time-taught” may not coincide. However, an even distribution of responses, “no” by the design professional participants was found during the ten (10) incremental period of participants’ graduation. Therefore, this result helps conjecture that for the past (50) years, majority architectural students have not experienced learning cost as a fundamental design determinant in a foundation design studio course (see Table 7). The needs toward teaching cost as a fundamental design determinant can also be found in an interview with Alejandro Arevena, the 2016 Pritzer Prize winner. He expressed his concern toward the current architectural education and that "we never teach the right thing at university. I was just lucky enough at Harvard to meet the right people that did speak the language of economy, policy, and the building industry" (Winston, 2016, para 63).

Table 7: Comparison between design professional participants graduating year and responses in learning cost as a fundamental design determinant in foundation design studio courses

Graduation Year	Responses in learning cost as fundamental design determinant in foundation studio course		
	No / Yes	Percentage within Year Increment	Total
Prior to 1980	8 / 1	88.9 % / 11.1%	9
1981 - 1990	14 / 7	66.7 % / 33.3 %	21
1991 - 2000	23 / 5	82.1 % / 17.9 %	28
2001 - 2010	44 / 6	88 % / 12 %	50
2011 –	19 / 4	82.6 % / 17.4 %	23
		100 %	131

One of the participants had an opposing view that teaching cost as an integral design determinant is indeed unnecessary given that it is not included in the current NAAB Condition. Although student's ability to integrate cost into design is not represented in the NAAB's expected outcomes for accredited professional programs in the current report, the NAAB conditions for Accreditation address the importance and understanding of financial consideration during the architectural education (NAAB, 2013b). While it is true that none of the NAAB Conditions are enforced in the pre-professional programs, it should be encouraged in the pre-professional programs since it leads to accredited master's programs. As discussed earlier in Chapter 3, architectural students receiving pre-professional degree must obtain an additional degree from accredited institution in order to be eligible to take the architectural registration examination. In addition, social, political, and economical aspects of architecture are crucial, and that equal emphasis should be given to the conditions of its purpose, function, and context (Ching, 2010). After all, early recognition in cost awareness and its implication will help students further flourish at the graduate level.

3.3 Key Informant Interview

The content analysis of the design studio syllabi, and projects, along with the online survey became the foundation for key-informant interviews. A key informant interview is commonly used in educational research in order to collect data from individuals who have special knowledge or perceptions that are not commonly available to the researcher. This part of the study includes semi-structured interviews with various experts in the design and construction industries. This interview approach involves open-form questions to obtain additional information and it is known to have the advantage of providing reasonable standard data across respondents (Gall et al, 1996).

The purpose of these interviews is to identify what needs to be taught in the foundation design studios to help students understand cost as a design determinant so as to improve the quality of their design. In addition, the interviews are intended to review the preliminary cost indicators and gather experts' opinions to finalize the list of indicators. Identification of these indicators will be essential in developing a new studio design course with a learning objective of increasing awareness in cost.

3.3.1 Method

Key informants were selected based on their contribution and involvement in architecture education and the construction industry. Each key informant had specific knowledge of economic and practical design, and construction in housing. Interviewees include one local builder, one architectural design professor, one construction science professor, two (2) practicing architects, and two (2) directors from different affordable housing organizations. Their years in experience varies from 15 to 30 plus years in architecture and construction, and more than 50% of their current and previous projects involved constricted budgets. Identities of the participants shall remain anonymous per the IRB, and only their primary roles in the architectural industry are recognizable to understand their similar and different perspectives on the topic of cost as a fundamental design determinant. Conversational results from each participants are coded as indicated in below Table 8.

Table 8: Participants for key informant interviews

Participant Code	Primary role the field of architecture
Interviewee 1	Professor in the Department of Construction Science
Interviewee 2	Non-Profit Organization in Housing
Interviewee 3	Non-Profit Organization in Housing
Interviewee 4	Local Home Builder
Interviewee 5	Professor in the Department of Architecture
Interviewee 6	Architect
Interviewee 7	Architect

These experts in affordable design and construction had the opportunity to express their experiences in teaching and producing quality designs with restricted budget constraints. See Appendix E for the list of IRB approved questionnaire used during the key informant interviews. The key-informant interviews, it suggested ways to instruct students to reinforce architectural elements and concepts related to the list of indicators. The key-informant interviews thus not only established cost indicators, but also revealed the concepts and theories in which these indicators may be embedded. The results from the interviews led to the development of teaching strategies and lesson topics used in a studio course for the treatment group. In addition the results informed the development of evaluation criteria for students' designs of affordable housing projects.

3.3.2 Result and Findings

Following the online survey to academics and design professionals, seven (7) key informants were interviewed. All seven (7) participants attested their substantial involvement in the architectural education and practice. Interviewee 1 is currently teaching construction management courses. He expressed that he tends to put a heavy weight in design students' understanding of building construction and financial implication. He believed that realistic and practical realization in design projects would make the students better architects and construction managers. Interviewee 2 and 3 are the financial and construction managers at two (2) different non-profit affordable housing organizations. Over the past fifteen (15) years, they have been involved in exposing architectural design students to building construction in their collaboration with Texas A&M University. They have witnessed significant differences in students' design quality with or without the knowledge in the building elements. Interviewee 4, the local builder, advocated in the significance of alternatives construction materials and methods and the importance of learning building elements in order to achieve quality design at low cost. He lectures at various institutions and conferences internationally promoting quality affordable housing using alternative materials. Interviewee 5, a design professor, has been teaching architecture over the (10) years. He gravitates toward seeing architecture as a form in design education, carefully separating design education from practical rim. Interviewee 6 and 7 were both design practitioners who face cost as a design determinant in their day-to-day practices, and applauded in the idea of cost awareness in young designer's mindset.

The first part of the interview was geared toward the idea of cost. They were asked for the optimal time to discuss cost during architecture design and process. It was agreed by all interviewees that, cost implications for any projects must be discussed at the programing, the conceptual stage, or at the start of the project. Not is only the construction cost or budget the first topic that the design team discusses, but it also effects everything from design to construction. As the Interviewee 7 explained, "while no architect wants to design frugal buildings, but it is the mindset" (Interviewee 7, personal communication, February 3, 2015). While the six (6) interviewees agreed with the idea of foundation design students cultivating the mindset of building cost during design, only the Interviewee 5 responded that the topic of cost should be discussed during design phase.

The next question sought to identify the optimal time to introduce cost awareness to architectural foundation design students. With the exception of Interviewee 5, the other six (6) interviewees asserted that it should be as early as possible, starting from the first semester of the architecture school. However, Interviewee 6 and 7 added that the building cost should be implied at the level of awareness, and the students' design should not be cost-driven. Interviewee 1 explained his experience with the Perot Family, the wealthiest family in Texas. When the Perots started planning for Perot Museum in Dallas, they had a set budget for the project, and it was closely monitored and recognized throughout the design and construction. He also stressed that architects must understand budget and financial constraints at the early stage in the process. Interviewee 5 responded that cost awareness should be introduced only when the students start working on buildings, which is generally by the third year in the architectural program. Even then, he insisted that it should be exploratory and not driving students' design. All seven (7) interviewees suggested teaching the preliminary cost estimation at the conceptual level and building elements as basic inclusive strategies to introduce cost as a fundamental design determinant is crucial. This suggestion aligned with the teaching instrument of this research to ensure effectiveness and appropriateness of this research.

Key informant interviews identified the needs and relevance of teaching cost as a fundamental design determinant and appropriateness in learning such concepts during the foundation design education. Regardless of their role in the architecture industry, most interviewees strongly felt that financial aspects of architecture and construction must be addressed as early as possible in the architectural education, especially within studies that introduce actual buildings to design. Although they all agreed in the importance of teaching financial aspect of architecture, industry practitioners voiced strongly toward inclusion of cost as a part of the mainstream architectural principles. The interviewees also, presumed that introduction of such topic to young designers will bring long-term benefits of broadening the architectural market. This result indicates that industry practitioners are faced with the hardship of financial needs on day-to-day basis opposed to the design educators who have indirect opportunity to experience these basic assumptions in the field (Glasser, 2000).

Value engineering is the concept of reducing building construction costs without reducing quality of design (Winter, 1984). Often value engineering is discussed after design is completed or during construction for many different reasons, but primarily due to the expenditure exceeding the initial budget. Then, alternative solutions must be considered. As to the concept of value engineering, participants all agreed that once the design is completed or under construction, only limited alternates can be implemented without a substantial plan change. Interview results indicated that mechanical, electrical, and plumbing fixtures and equipment are the first ones to be value engineered.

Interviewee 6 explains that for instance, mechanical equipment may be specified with costly, but energy efficient systems at first; however, it may not be feasible if the construction cost exceeds the budget or go over budget. Then, the system is substituted with a low cost and less energy efficient system. Second, materials and finishes get value engineered commonly to reduce cost. Interviewee 7 added that based on the selection of finishes, the cost of the building assembly can be added or reduced significantly. As we have seen, all seven (7) interviewees made voice over why early recognition of cost in design and construction is important to eliminate such risk that increases the possibility of trade-offs between quality and cost.

Collectively, all participants identified foundation, wall, roof, floor, mechanical, electrical and plumbing, square footage (area), structural framing, building form, volume, and doors and windows as indicators that affect the cost of building. Interviewees also voiced that these indicators are all linked with each other. For an example, the Interviewee 6 explained, "…the windows are more expensive than solid wall, but it may bring environmental issues. What we typically expose can be covered up, but it could also be problem, because it reduces circulation" (Interviewee 6, personal communication, February 3, 2015). Notwithstanding, Interviewee 5 stressed that the indicators should be as simple as structural framing, enclosure, roof, and floor. In his opinion, the foundation should be included as a part of the structural framing, and enclosure in solid and void represents a separation between windows, doors, and wall; thus, no additional breakdown is necessary. This is interpreted as that while details and assemblage of building construction may be implied to foundation design studio education, yet, the culture of the studio is strongly toward formative ideas (Glasser, 2000). However, this would be misleading to generalize the culture of design faculty based on this particular participant as the sole contributors to this interpretation.

After gathering the interviewees' opinions of the cost indicators, which affect the building cost, the researcher presented a list of preliminary cost indicators; site, foundation, structural framing, wall, roof, floor, doors and windows, circulation, area, materials and finishes, and complexity of form. Interviewee 6 suggested combining materials and finishes with building elements such as wall, floor, and roof since it applies to all building components. Interviewee 1 suggested maintaining the list of cost indicators concurrently with the UNIFORMAT. Thus, students could refer to resource books such as the RS Means, and find easier linkage between indicators and cost when performing a preliminary cost estimation. Based on the indicators discussed, all participants voiced that building structure would affect the cost of building the most, because it leads to the building form. All interviewees also mentioned mechanical, electrical and plumbing system to be added as cost indicators, however, it was explained to them that mechanical, electrical and plumbing system are not appropriate topics at the foundation level. The consolidated recommendations of seven (7) participants informed the final list of cost indicators. The cost indicators were used as the main instrument in developing new design studio course for the treatment group.

Participants suggested additional means of methods to contribute to cost awareness in the foundation design studio courses. Teaching concepts of preliminary cost estimation was advised to apply these cost indicators to further enhance affordable design. Another suggestion was to emphasize on simple designs, and understand what is conventionally available before seeking unique alternatives. Consideration of the concept of life cycle cost during design was also recommended. It was mentioned multiple times that students should be imaginative, and use rationale to convince the clients for the better use of budget.

Interviewee 1 raised his concern on the current architectural education that architectural education today is “too focused in preparing students to become artists rather than architects. They know nothing about how buildings are put together” (Interviewee 1, personal communication, December 18, 2014). Similarly, Interviewee 3 stressed that architecture education is lacking the notion of one size does not fit all, especially when they are working on low-cost housing. He added that students must be aware of the context and where they are building. Interviewee 7 feared that although different schools offer various curricular, public institutions’ “curriculum is very tight and there is no room for anything else. There are other courses beneficial to architecture as well – courses about just life. Critical thinking should be needed” (Interviewee 7, personal communication, February 3, 2015).

All participants concluded that architectural education was missing the practical piece of puzzle. Interviewee 2 gave his newly hired intern as an example. His intern was a graduate student from the Department of Architecture, who wanted to learn more about affordable housing and its process. Evidently, he demonstrated no understanding of building construction and budgetary factors. His suggestions for improvements on the construction site were all costly items, and no consideration of infrastructure to form a community was evidenced.

The result from the key informant interview also raises a common concern toward architectural education today. They were all concerned with the lack of practicality or social contribution of architectural design education. It is interpreted as that architectural education appears to be leaning toward promoting artist or design ideology, rather than educating socially responsible practitioners. Furthermore, it infers that with greater attention to formative ideologies, something as basic as understanding building assemblage is absent in design education. This can also be observed as what Glasser (2000) has indicated in *the Reflections on Architectural Education* that a growing number of faculty members with PhD degrees are without having had “the opportunity to design and erect a building or evaluated treasured predilections” (Glasser, 2000, p 250). While a broad range of scholarly and intellectual inquiry is appreciated, fundamental educational approach is not challenged.

CHAPTER IV

QUASI-EXPERIMENT RESEARCH METHOD

Chapter III described the research methods, results and discussions of content analysis of selected architectural foundation design programs, online survey, and key informant interviews. While the purpose of the previous research methods is to validate the significant and the needs of this research as well as determining grounds to develop a new second-year design studio course including cost awareness, the purpose of quasi-experimental study is to test the newly developed second-year design studio course. In addition, the quasi-experiment measure the impact of treatments against a comparable control group. An experimental approach to causal research is most common in education and a quasi-experiment is an effective way to test a new educational curriculum (Gall et al., 1996). Balfour (1982) at Georgia Institute of Technology uses a quasi-experiment to determine the influence of studio teaching on shaping architectural attitudes and roles. He conducted the research by comparing three (3) design studios of the same level from three (3) different schools of architecture. Balfour uses a fictional program as a vehicle to measure and draw a comparison among the design studios, which is similar to this present research where the 20K House design is used to draw a comparison between the control and treatment groups (see Figure 3).

In field settings like offices or classrooms, random assignment in research studies cannot be achieved. In this situation, which is the condition of this research, the researcher adopted a quasi-experiment design to teach an existing design studio course, and then used another design studio at the same education level with treatment of cost as an integral design determinant. Since ARCH 205 is a prerequisite prior to taking ARCH 206, the groups were nonequivalent.

The problem of this research implies a particular single cause, teaching cost as a fundamental design determinant, and its effects will be evaluate inferring the treatment effects. John Stuart Mill stressed that the cause has to precede the effect in time and that the cause and effect have to be related (as cited in Cook, Kimbell, & Day, 1979). The concept of the control group is implicit and central in measuring the effect of inferring the cause. To illustrate, some positive or negative effects will occur when students are taught cost as a fundamental design determinant in a design studio course, and no impact will be made unless cost awareness is cultivated in the design studio course.

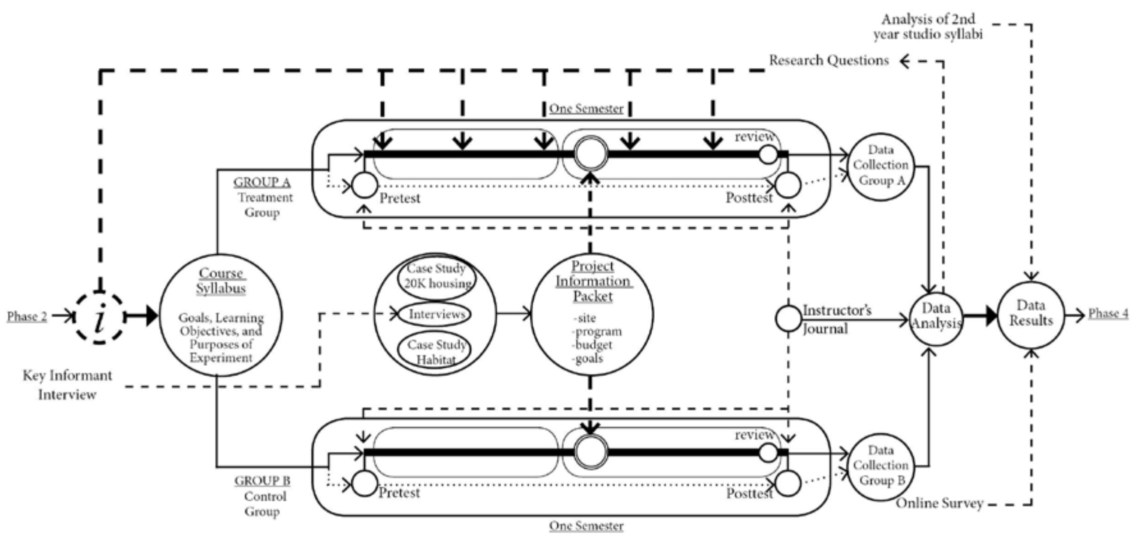


Figure 3: Phase 3 - a partial quasi-experiment diagram (see Appendix A for the complete research diagram)

4.1 Research Design

A quasi-experiment follows a nonequivalent control-group design, which involves a nonrandom assignment of research participants to one control group and one treatment group, as graphically represented below in Figure 4. In educational research, the quasi-experiment is the most effective and commonly used method to evaluate a new educational curriculum or course (Gall et al., 1996). The research is conducted using a pretest–posttest quasi-experimental design during one (1) semester.

Nonequivalent control-group design
O   O
O X O
Key: O = observation, pretest and posttest
X = experimental treatment

Figure 4: The quasi-experimental design

This quasi-experiment took place with second-year architectural design studios for two consecutive semesters: a control group in a spring 2015 semester and with a treatment group in a fall 2015 semester. An existing semester-long second-year design studio course (the control group) and newly designed semester-long second-year design studio (the treatment group) were independent variables in this study.

At the beginning of the semester, as required by the Institutional Review Board (IRB), the consent process was directed by one of faculty advisers. The consent process did not involve the researcher who was also the design course instructor for this experiment. This way the students' participation in the research did not affect the actions of the instructor toward students. Following consent, a pretest in the form of a survey was administered to students in the control and treatment groups by the instructor. Five (5) survey questions were in the pretest including two (2) questions to ascertain students' initial knowledge and academic level in architectural design, and three (3) questions to discover the students' pre-existing perspectives and understanding of affordability in design (see Appendix G). While the students in the control group were enrolled in an existing second-year design studio course, the students in the treatment group were enrolled in the newly developed design studio course. At the end of the semester, a posttest in the form of a survey were provided to each group. The posttest included three (3) questions from the pretest, and four (4) new questions to measure the outcome from the experimental intervention with the treatment group and access the students' actual ability to apply cost determinism in design (see Appendix H). The awareness and application of cost indicators will be dependent variables in this study. Because students in both groups were tested at the beginning of the semester and at the end of the semester, the timing of the pretest and posttest were within-subject variables.

4.1.1 Participants

Fourteen (14) students were registered into the control group. One student in the control group immediately dropped the course following the first week. Fifteen (15) students were registered into the treatment group, and one student also dropped out of the treatment group course on the twelfth week of classes. One or two drop outs during the design studio course is common. One student in the treatment group did not consent to participate in the research. Overall, an equal number of thirteen (13) students for each experimental groups were enrolled in the two courses. Each studio lasted fourteen (14) weeks per semester. Students in both groups learned fundamental building elements through an analysis project, and a play structure project. The final 20K House ($20,000 construction cost) project allowed students to share their knowledge of building elements with a small residential project. The 20K House project was small enough in scope as to not confuse or overly challenge the second-year students, yet went beyond the typical small residential project often seen in second-year design studios as it attempted to test students' ability to achieve cost conscious design.

4.1.2. Learning Objectives

The course structure and objectives were different for both the control and treatment groups. It is important to note that both groups were exposed to an understanding of building elements at the fundamental level. However, the treatment group's learning objectives were tailored to enhance the students' understanding of cost conscious design in architectural foundation design education. The learning objectives of the new course are as follows:

- Students will be able to analyze fundamental architectural elements and understand the craft and construction.
- Students will demonstrate a basic knowledge of typical and innovative materials and construction methods.
- Students will be able to communicate preliminary cost estimating concepts to incorporate budget consideration of architectural elements at design-decision making process.
- Students will have knowledge of cost indicators as applied to design.

4.2 Research Instrument I: Cost Indicators

The researcher reinterpreted the residential construction cost breakdown referenced by the National Association of Home Builders (see Figure 5) into fundamental building elements, then the appropriate measures were identified for the second-year design studio (see Table 9). The content analysis of the selected architectural program discovered that most second-year design studios are designed to teach fundamental building elements along with contextual factors of the site. In addition, this infers that it is the appropriate time for students to have a basic understanding of building elements, and it is where cost considerations can be introduced. Based on the curriculum (2014-2015) of the Bachelor in Environmental Design program at the Texas A&M University, only the courses taken before or during the second-year were recognized as appropriate.

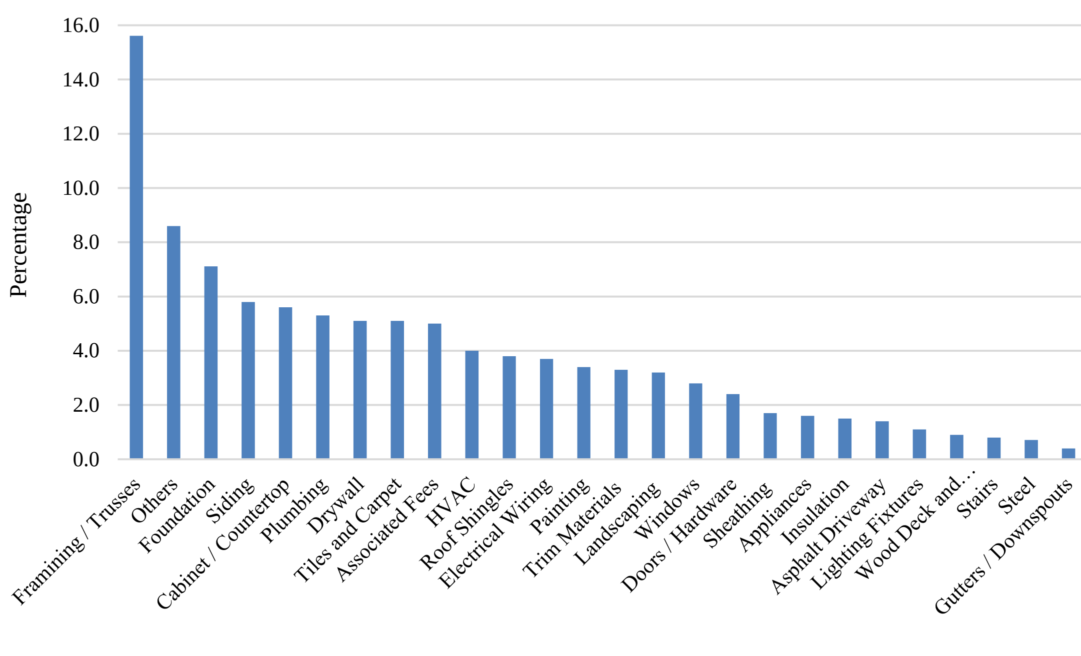


Figure 5: Typical residential construction cost breakdown (NAHB, 2013)

Table 9: Construction cost breakdown of architectural elements

Residential Construction Cost Breakdown (Figure 5)	%		% in Architectural Application[2]	Architectural Response to	Appropriateness to 2nd year design students	Uniformat II (Level 3 - Group Elements)
Building Permit Fees	1.9		N/A	N/A	N/A	N/A
Impact Fee	1.4					
Water and Sewer Inspection	1.7					
Others	8.6					
Subtotal		13.7				
Excavation, Foundation, and Backfill	7.1		8.2	Foundation	Yes	Foundation
Subtotal		7.1				
Steel	0.7		18.9	Structural Framing	Yes	Framing
Framing and Trusses	15.6					
Subtotal		16.3				
Landscaping and Sodding	3.2		6.4	Site	Yes	Site
Wood Deck and Patio	0.9					
Asphalt Driveway	1.4					
Subtotal		5.5				
Windows	2.8		9.8	Doors and Windows	Yes	Doors and Windows
Exterior Doors	0.9					
Interior Doors and Hardware	1.5					
Trim Materials	3.3					
Subtotal		8.5				
Stairs	0.8		0.9	Circulation	Yes	Stairs
Subtotal		0.8				
Siding	5.8		20.3	Wall	Yes	Wall (Exterior)
Sheathing	1.7					
Insulation	1.5					
Drywall	5.1					Wall (Interior)
Painting	3.4					
Subtotal		17.5				
Gutters and Downspouts	0.4		25.1	Mech/Elect/ Plumbing	No	Mech/Elect/ Plumbing
Plumbing	5.3					
Electrical Wiring	3.7					
Lighting Fixtures	1.1					
HVAC	4.0					
Appliances	1.6					
Cabinet and Countertop	5.6					
Subtotal		21.7				
Tiles and Carpet	5.1		5.9	Floor	Yes	Floor
Subtotal		5.1				
Roof Shingles	3.8		4.4	Roof	Yes	Roof
Subtotal		3.8				
TOTAL	100	86.3[1]	100			

Note: 1. Only the % directly impacting building elements were added for new total %.
2. Based on the % calculation of residential construction cost breakdown, only the items directly impacting building elements were re-calculated into the percentage.

Similarly, each item was applied to the Level 3- Group elements classification based on UNIFORMAT II. UNIFORMAT II is an elemental classification involving the separation of a building into its component or functional parts (Charette & Marshall, 1999). Regardless of building size or building types, the general scope, design concepts, scale, and relationship between different parts of the project are established in the design phases. Therefore, the cost estimation using UNIFORMAT II is suitable and reasonable at preliminary and schematic level.

Because this residential construction cost breakdown is based on real projects, which requires fees for inspections and permitting, it may be adequate for budgeting purposes, but inappropriate for the design students to recognize. Students' awareness in associated fees in construction is beneficial to understand construction process, but not necessarily during the design studio project's preliminary cost estimation. The typical architectural curriculum requires students to take the building systems courses including structures (mechanical, electrical, and plumbing systems) along with materials and finishes courses during the upper years. Therefore, such item is not appropriate to be included as one of the cost indicators.

Based on reviews of the Rural Studio projects and fundamental architectural elements defined by Koolhaas, Palladio, and Vitruvius, preliminary cost indicators were identified, then further established into the final list of cost indicators through interviews with key industry experts. The 20K House project in this research serves as a vehicle through, which the cost indicators can be identified and then, tested and evaluated. The project is appropriate in scale and program complexity, for the second-year design studio. The identified cost indicators only appreciate for small-scale residential projects completed at the second-year design level.

The Rural Studio approaches in designing their 20K Houses did not define the list of cost indicators. However, the Rural Studio's design approaches and research findings were implied and used as a reference when describing and defining each cost indicators to students in the treatment group. While the architectural and theoretical definitions of cost indicators were explained to the treatment group to fulfill fundamental needs of teaching building elements at this second-year level, their cost implications, and examples of different approaches to meet cost effective solutions were discussed.

The final eleven (11) cost indicators include site, foundation, structural framing, wall, doors and windows, floor, roof, circulation (steps or stairs), area, materials and finishes, and complexity. The first eight (8) cost indicators are referenced to physical building elements while the later (3) cost indicators (area, materials and finishes, and complexity) applies to each cost indicator ascertaining building elements. These (11) cost indicators are used as the instrument for the treatment group to utilize in order to recognize cost efficiency and effectiveness during their decision making process in the 20K House project.

1. Site

   Economy indicates the proper management of materials and of site, as well as an economical balancing of cost and common sense in the construction of building (Vitruvius et al., 1914/1960). While Frampton suggests modernization adheres to "clear and flatten the site" approach thus optimizing the economy of earth-moving equipment and also making way for the rational layout of building (Frampton, 1981), Tabb suggests valuing the site and its self-contained potential to be “the place” rather than contributing value by cracking a new landscape (Tabb & Deviren, 2013). Both approaches have cost implications.

The Architectural Practice Handbook identified site analysis as a vital step in the design process (AIA, 2000). Zimmerman (2000) describes site analysis as the first step to understanding the site’s development constraints and opportunities. Any designs for a building should respect the nature of the region and the diversities of climate. A building must respect the position of the sun and wind, and consider its effects on climate When well studied, site analysis shall suggest an essential foundation for cost-effective, environmentally sensitive, and rational approaches to design. While this provides the client with the feasibility of the project, it provides climatic, topographic, geotechnical, and utility, and immediate surroundings information, which are highly related to designing structure.

The 20K House research projects by the Rural Studio often intentionally leave sites in their natural forms. This is not to disregard or ignore the site, but because such site designs or treatments are not feasible under their stringent budget of $20,000. Furthermore, indication of Rural Studio’s use of technologies for analyzing a geotechnical survey was not found. However, learning from ‘Place’ is very important for the Rural Studio.

Students must understand the relationship between the site and their chosen project. Quality of light, which varies throughout the day, and how the local soil drains in the rain are all very important to consider (Freear, Barthel, Dean, & Hursley, 2014).

2. Foundation

Palladio defines foundations as the basis of the fabric in the Book 1, Chapter VII (Palladio, 1965) in *The Four Books on Architecture*. The foundation is underground and because it sustains the whole structure above, no errors can be committed. Errors in the design and construction of the foundation are more pernicious, and they can ruin the whole fabric, creating situations in which rectification cannot be completed without extreme difficulty. For this reason, architectural design should apply its utmost diligence in foundation. When foundations become defective, this cannot easily be replaced like other parts of the building such as wall, floor, or roof (Vitruvius et al., 1914/1960). Simplicity of a building foundation often results in overall cost savings.

The 20K House research project by Rural Studio has tested two different foundation type during research. Whereas the Rural Studio's early projects were using the slab on grade foundation type, they gradually shifted to post and pier foundations. Because their projects were driven by cost, the post and pier foundation type was selected because it is less expensive, it is easier for unskilled workers to construct, and lastly it has less impact on the existing site and the landscape. In addition, it also reduced termite and moisture problems (Freear et al., 2014), and accommodated sloping sites. Although this type of foundation may have been suitable for Hale County, Alabama, where the Rural Studio is located, geological soil condition and climate consideration must be appropriate to meet optimal economical solution for any given site.

3. Structural Framing

Palladio (1965) underlines on the strength or duration of the edifice and stresses that it is governed by the structures being carried directly upright, thicker below than above, and their foundations strong and solid. A structural system is required to support the shell of the building and its interiors, and the weight of structure is systematized and distributed to the substructure. Structural components allow their superior strength characteristics to utilize the form of a building (Simmons, 2000).

With conventional structural framing systems, a tradeoff often exists between the weight of the structural materials, the ease of assembly of the structural materials, the skill level of the construction personnel required for assembly, the insulation properties of the structural materials, the material weathering and corrosion resistance characteristics, the material fire resistance, and the strength of the final structural assembly (Simmons, 2000). Similarly, the economic feasibility of the structural framing is influenced by material availability, fabrication process, transportation requirements, labor and equipment requirements, and erection time (Ching, 2014).

The 20K House projects by the Rural Studio promotes the use of conventional wood frame construction for multiple reasons. The Rural Studio favored wood frame construction, because it is cost-effective, renewable, and locally available. Perhaps more importantly, it is light weight and workable. Its use had the great benefit of teaching wood construction to unskilled and inexperienced architectural students. Wood was flexible to convey many ideas and its mistakes were easy to fix (Freear et al., 2014).

According to a research completed by HUD in 2002, although steel frame construction has been more common for commercial projects, it is now being applied to residential construction. Steel frame construction is made up to 60% recycled materials. It is strong and straight, and there is minimal waste. It is not affected by termites/pests or mold, is equal or close to wood in material cost (HUD, 2002). However, its use in the residential market is impeded in that it requires experienced framing crews and its steel framing package (material and labor) cost is 42.4% higher than identical wood framing package (HUD, 2002).

4. Wall

Koolhaas (2014) defines the meaning of the wall as (a) providing structure (exterior), and (b) dividing space (interior). While the exterior wall is recognized as the skin of a building, it also presents the core architectural understanding of building envelope. The exterior wall moderates between opaque, porus, and transparency, providing different exposures to different rooms servicing its purposes. The exterior wall most often serves as shelter providing protection. The exterior wall traditionally focused on style, composition, and representation (Vitruvius et al., 1914/1960). It is not only symbolic, the wall assembly must include insulation and waterproofing, physically securing protection inside from changing conditions outside.

The interior wall defines spaces, organizes movement within the resulting container, and is as changeable as our forms of sociability (Koolhaas, 2014). Increasing standards of modesty and individualism demand new walls around new bedrooms. For example, new family norms even divide off the nursery from the parents' room, and each bedroom has its own bathroom. As walls define spaces, it facilitates circulation and create privacy. Both exterior and interior walls are becoming thinner and are permeated with wiring and plumbing, insulation and acoustic engineering, even as outwardly the wall appears increasingly bare, minimal, even transparent (Koolhaas, 2014).

5. Doors and Window

LeCorbusier (as cited in Koolhaas, 2014) speaks of doors as an introduction of access: access between exterior and interior and threshold between different interior spaces. The door' main function is providing access and control, and its hardware brings different levels of access in privacy. Its quantity influences cost, and its quality deals with its resistance to weather. As mentioned earlier, the standard in individualism demands new walls dividing spaces, and this concurrently applies to the amount of access required between spaces, thus also increasing its quantity.

The functions of windows are to provide light, natural ventilation, views, fire means of egress, and solar heating. Koolhaas (2014) indicates that the main purpose of the window is to introduce light. While the purposes of different rooms require different exposures, the window is also suited to convenience. Windows should not take in more or less light or be fewer or more in number, than what necessity requires. Therefore, care must be given to the sizes and functions of the rooms, which are to receive the light from windows. A large room requires much more light to make it lucid and clear than a small one. If the windows are made either smaller or fewer than what is appropriate, they will make the places obscure, and if too large or many, they will limited habitable space, because they will let in so much hot and cold air (Palladio, 1965).

International Building Code by the International Code Council (2012) requires all habitable rooms to have an aggregate glazing area of no less than 8 percent of the floor area of such rooms. Natural ventilation shall be through windows, doors, louvers or other openings to the outdoor air. Such openings should be provided with ready access or shall otherwise be readily controllable by the building occupants. All emergency escape and rescue openings are also required to be a minimum net clear opening of 5.7 square feet (International Code Council, 2012).

Custom dimensions of both doors and windows are comparably more costly than the industry standard windows and doors. Large quantity production reduces cost, and the standardize size of pre-made windows make them easier to replace (P. Turney, personal communication, December 2, 2015). As much as its size, the energy-efficiency and performance options must be considered to suite project climate and region. Consideration must be given to standard window materials (vinyl, wood, aluminum, fiberglass or composite) along with specifications including coatings, gases, impact resistance and light-transmittance values (Andersen Corporation, 2016). These factors highly influence temperature control of interior space affecting heating and cooling cost. Therefore, an efficient penetration (windows, skylights, and doors) design must be determined and comply with the International Building Code (IBC) accompanied by the International Energy Conservation Code (IECC). This not only ensures the acceptable energy consumption, but also satisfy the comfort inside a building (Ching, 2010).

6. Roof

Palladio (1965) describes “roof” in Chapter XXIX in Book 1 of *The Four Books of Architecture* as:

The walls being raised up to their summit, the vaults made, the joists of the floors laid, the stair-cases, and all those things accommodated of which mention has been made before, it is necessary to make the roof: which embracing every part of the fabric, and with its weight pressing equally upon the walls, is a kind of a ligament to the whole work, and besides defending the inhabitants from rain, snow, and scorching fun, and moisture of the night, it is no small assistance to the fabric, in casting off the water from the walls when it rains, which may seem to be, but of little prejudice, are, nevertheless in time the cause of great damages (Palladio, 1965, p. 36).

Early on, flat roofs in dwellings provided lessons about protection capabilities from rain or snow. Compelled by necessity, over time, roofs began to be formed more rigidly, or raised in the middle. These ridges ought to be made higher or lower in accordance to the regions where construction occur. Higher the altitude, the roof slope is steep to sustain the snow loads, and comparably, the roof slope is flat in the lower altitude. For example, the great quantity of snow that falls in Germany necessitates the roof pitch to be made very acute, and covered with shingles or very thin tiles. Otherwise, roofs would be destroyed by the weight of the snow (Palladio, 1965). Furthermore, much regard must be considered in choosing roof height, which makes a roof appear agreeable and with an attractive form, and that easily withstands any natural disasters.

As a roof fulfills its functional responsibility providing a shelter, it also conveys identity of the regional tradition and culture. Although the modern movement may have taken away the signifying power of the roof, the form of roof either flat or pitched, basically expresses locality of architecture (Koolhaas, 2014). The traditional Apulian dry stone hut with a conical roof of Trulli is one of the best examples of roof form and structure representing the local culture and traditional building techniques. Each conical roof represents an individual room portraying its traditional layout and living style, and small aperture in pinnacle of the conical roof allows ventilation. The local limestone slab are stacked and slightly tilted outwardly ensuring protection from water damage.

7. Floor

Architecturally, the floor portrays a horizontal surface, which is useful and habitable. This surface expresses how spaces are used in two dimensions, and then it leads to the three dimensional volume. The floor also represents the horizontal shape of the building form, which is often in layers for multi-story buildings. Because it is often understood as a surface beneath our feet, and it is usually ignored, flat, and undecorated in design (Koolhaas, 2014). Similarly, the term floor is often interpreted as floor area in construction because it provides its simple methods of a square foot calculation for the construction cost.

Despite the lack of articulation of floor, there are cost effective ways to deliver floors. For example, different types of foundation implies different floor types. A simple coating of epoxy or hardener on a slab on grade can enable the foundation to become the floor. When post and pier foundations are used, the floor is elevated and a wooden or metal platform floor has to be constructed. A raised floor may signify hierarchy, it may provide more security or privacy and it may be used to zone space. Freear et al. (2014) spoke from their experience in Rural Studio's 20K House projects that a raised floor suggested more aesthetically pleasing form.

8. Circulation

Circulation (hall, stairs, steps, and ramp) is a fundamental element in architecture that provides access and organizes space. It serves as "in between" space, which services a guidance system as well as meeting and exchanging points. Leon Battista Alberti (as cited in Koolhaas, 2014) reasons the fewer staircases that are in a house, and the less room they take up, the more convenient they are. This idea has proven to be a prophesy for the contemporary condition. Often, the staircase is considered dangerous. Safety requirements limit an architects' ambitious use of stairs and people are endangered only in existence in order to fulfill the requirement of having an exit strategy.

9. Area

The architectural area of a building is the sum of the areas of the floors of the building, measured from the exterior faces of exterior walls. AIA's recommendation on Best Practice (AIA, 2002) indicates that building size has a major influence when making design decisions, and these decisions substantially affect cost. Koolhaas (2014) also describes that area dominates financial and cultural valuation of the space, and that this is the prevailing reason why most preliminary and schematic estimation is done using area (square footage or square meter) of buildings. However, this is a practice commonly unknown to foundation design students.

Understanding of area of building leads to the architectural volume. The architectural volume (cubic volume) of a building is the sum of the areas of the floors of the building multiplied by the floor to floor heights or floor to mean finished roof height. In addition to the area of the building, representation of the volume and its calculation organize the space into the three dimensional array. Three dimensional thinking is vital in design and science, and have implications to cost.

10. Materials and Finishes

Buildings are constructed with suitable materials for each part of building, thus the cost ranges widely. The quality of materials can also very greatly. Precedent can play a large part in materials selection. The experiences gained from other buildings help determine best practices related to material selection and application (Palladio, 1965). Today architects can specify a large range of materials even though these materials are not found locally. When this occurs, cost can be an important determinant.

Technological advances, cultural contingencies, social orders, economic cycles, and political ideologies are all represented in material selection. Research finds that common wall materials for low cost housing are Hardi planks, local wood siding and panels, and aluminum corrugated metal sheets (P, Turney, personal communication, 2014). Unfortunately, these selections are cost-driven without any respect to their texture, patterns, or environmental impacts.

11. Complexity

Palladio (1965) states that beauty results from the form and correspondence of the whole. In respect to parts of buildings and to the whole, the structure may appear to the form, which architects have intended. The building geometry and degree of articulation in the basic plan affect building cost. From a cost perspective, a perfectly square or rectangular footprint is the simplest to build and theoretically less expensive. However, this geometry may not be appropriate for the program requirements and may appear overly simplistic for most projects. Beginning design students typically, employ irregular geometry and overly complex forms that generally are very expensive if they were to be built. Every time there is a corner, cost increases.Plan geometry and exterior articulation are issues that require proper budgeting and oversight during the design process. Shadow lines, notches, and projections all may benefit the building form aesthetically, but their complexity represents potential additional costs for labor and materials **(**AIA, 2013).

4.3 Research Instrument II: the 20K House

The eleven (11) cost indicators previously described were applied as a guideline for the treatment group to develop a small residential project with limited construction budget. The researcher reinterpreted the 20K House project developed by the Rural Studio and reformatted into the 20K House project for this present experiment. Both the control and treatment groups were instructed to design the 20K house as their final project. The interim exercises in the newly designed course demonstrated whether the treatment group can produce quality affordable designs with respect to each cost indicator. The interim exercises were based on the recommendations and findings from the review of literature and key-informant interviews. Conceptual cost estimation, lifecycle cost, and the choosing-by-advantage decision-making system were incorporated into the new course.

4.3.1 Introduction of the Rural Studio's 20K House Project

The 20K House research project at the Rural Studio at Auburn University, Alabama was used as the guide and reference for this part of the experiment. The Rural Studio at Auburn University is a long-running design-build program found by architects and educators, Sam Mockbee and D.K. Ruth in 1995. These legendary educators were convinced that architects should be leaders to bring social and environmental changes, and help those who do not have access to design services (Dean & Hursley, 2002). The Rural Studio is permanently based in the rural Hale County, Alabama where nearly 30% of the individuals live in poverty. Since the first group of architecture students arrived in Hale County twenty (20) years ago, the program has been educating "citizen architects" with hands-on teaching methods that include implementing designs on site, and the architectural students have been designing and building houses and community projects throughout Hale County (Freear et al., 2014).

The 20K House is an ongoing research project launched in 2005 to make the Rural Studio's work more relevant to the needs residents living in west Alabama. The goal of this project is to address the pressing need for decent and affordable housing in Hale County. However, it has demonstrated the real potential to improve living conditions beyond the region of Alabama. The program chose a $20,000 price point because that figure represents the most expensive mortgage a person receiving today's medial Social Security check of $758 per month could realistically repay. In 2005, a $20,000 loan value represented a monthly mortgage of approximately $108 (Freear et al., 2014). This low budget constraint effects the size of the dwelling at a little over 500 S.F. with only one bedroom. In addition, the houses constructed using the student labors, which reduces overall labor cost.

The Rural Studio operates on students' initiative, and has gained its fame as a student design and build program. The studio projects and all of their previous 20K Houses have been built by students with donated funds and materials without having to go through any zoning and permitting process as standard construction practice. In their continuous effort to advance the 20K House product line, the Rural Studio has recently partnered with Serenbe, a progressive sustainable community in southwest Atlanta, Georgia. Serenbe and the Rural Studio has recently field-tested two (2) of the Rural Studio's 20K House projects and these houses were built by contractors in accordance to local ordinance, residential construction practices, and permit requirements. As they celebrated their 20th Anniversary in 2015, two (2) of seventeen (17) 20K House prototypes have undergone the zoning and permitting process and have been completed by January 2016. Although these two (2) 20K Houses and a connecting deck cost $135,000 (Fox, 2016, para 26) vastly over their anticipated budget, the Rural Studio continues to search for ways to reduce cost and improve construction processes.

Although the 20K housing at Rural Studio focuses on hands-on, design-build projects for students, their experiences are respectable references for both design and programmatic challenges for projects with small square footage and limited budget. Most importantly, it is one of the Rural Studio's missions to change the pre-existing perception of soulless, cheap looking images of affordable housing (Freear et al., 2014). Thus, the 20K House project by the Rural Studio is a well-suited reference to test students' awareness in cost during the foundation studio design course in this research experiment.

4.3.2 Project Goal of the 20K House Project in the Quasi-Experiment

The project goal of the 20K House project in this present experiment was to design various small house types with assurance of their feasibility and constructability under a budget of $20,000. This goal was explained to both the control and treatment groups in the beginning of the project. The internal emphasis for this project is a designers' understanding of the contextual and cultural conditions of the given environment with an emphasis in practical representation of building elements. The project studies inclusive design considering site context, and investigates building structure, assemblage, and form with emphasis on affordable materials, finishes and construction systems. The proposed design solutions should be unique and time-less both spatially and formally and yet, realistic and practical.

4.3.3 Problem Statement of the 20K House Project

Each student is instructed to design a small house for the Falls Creek Ranch Subdivision located in Bryan, Texas. The house has a specific budget of $20,000 excluding cost of land, site work, mechanical, electrical and plumbing systems, equipment, and appliances. As previously mentioned, systems servicing the building, site engineering, and selecting fixtures and appliances were discovered to be inappropriate topic at the second-year level. The students typically begin to take courses in these topics later in their architectural program, thus they were excluded in the 20K House project. While the design responds to the specific context in Texas, it also reflects changes in the technology and contemporary lifestyle. The design challenge is to make a small house feel big, and to consider future expansion. The optimal goal for the 20K House project is to provide well-designed house for anyone.

4.3.4 Project Location

The project is located in the Falls Creek Ranch Subdivision in Bryan, Texas. The Falls Creek Ranch Subdivision is an affordable housing development owned by the Brazos Valley Affordable Housing Corps. The Brazos Valley Affordable Housing Corps has been actively participating on various architectural studio projects and urban planning projects with the Department of Architecture at Texas A&M University since early 2000. When this experiment was first discussed and planned, Paul Turney, director of the organization and Ben Fortner, the construction manager at the Brazos Valley Affordable Housing Corps were willing to take a part in this experiment in pursuit to improve affordable housing development. Affordable housing was first established as a stepping-stone to address local *affordable housing* needs and to promote better quality living in the Brazos Valley. However, the new reality has that affordable housing is now proven to be a necessity for a large portion of American families. There is therefore, an increase in demand for quality affordable housing, and architects and designers are striving to supply better quality design (Jones at al., 1999).

The Brazos Valley Affordable Housing Corps understands the significance of affordable housing and its importance in architectural education. The organization acted as a hypothetical client, offered the Falls Creek Ranch Subdivision, one of their properties in Bryan, Texas, as the 20K project site for this experiment. The real site represented unique site contextual information such as geographic location, demographics, and climate. The architectural culture and surrounding built-environment, the existing structures and the infrastructure were to be inclusive in the students' design considerations.

Geographic Location

Bryan is a medium-sized city approximately 43.4 square miles in size located centrally in Brazos County, Texas. Bryan borders the city of College Station to its south see Figure 6). Because if its economy and social life centered around Texas A&M University in College Station, Bryan and College Station is often referred to as Bryan

College Station metropolitan area in the Brazos Valley, and this area is popularly known as the “Aggieland”.

Before the City of Bryan, there was Millican, an essential distribution center for freights and troops throughout the Civil War. A single square-mile track in the north of Millican was sold to William Joel Bryan in 1860, and it became the City of Bryan in his honor. Byran had replaced Millican and Boonville in 1870, and its growth benefited from the Agricultural and Mechanical College (Texas A&M University) in College Station, which opened in 1875. The College was inaugurated in 1876 as Texas’s first State institution of higher education.

Bryan, along with the city of College Station flourished continuously throughout the 1900s. With a movement toward downtown revitalization in 1980s, its goal is to bring businesses and interest back to Downtown Bryan. While Bryan’s downtown business district demonstrates cultural heritage, the East Side Historic District created in the 1980s, approximately fifty (50) Bryan homes, and other structures are listed on the National Register of Historical Places. In the past ten (10) years, both Bryan and College Station have experienced a growth boom, which is evident from the annexation and extension of the city limit boundaries and new development, thus resulting in an increase in population (City of College Station, 2016). Today, businesses are opening, expanding and relocating in Downtown Bryan, breathing new life into the area. This push toward downtown revitalization is now enabling people to experience the shops, restaurants, hotels and businesses that are working together to restore Downtown Bryan to thrive.

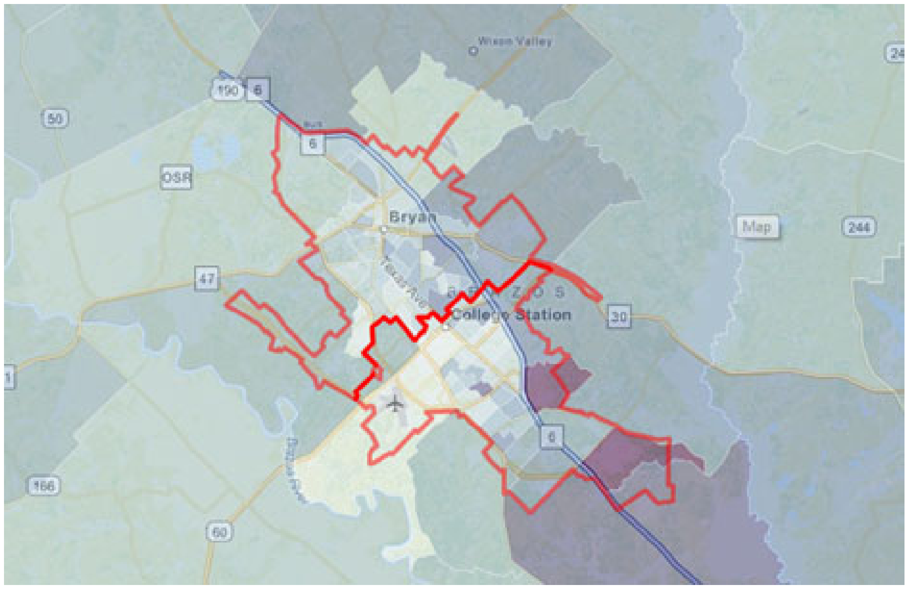


Figure 6: Map of College Station-Bryan, Texas
Source: cstx.org (2013)

Demographics

In the *Handbook of Interior Architecture and Design* (2013), Brooker and Weinthal argued that understanding demographic structure is significant to know different housing requirements and needs by particular population since it refers “to social, emotional, mental, and cultural needs of individuals across different parts of the world. College Station-Bryan Metropolitan’s population has steadily increased since its incorporation in 1938. College Station-Bryan is recognized as the largest city metro in Brazos County representing approximately 45% of the population in Brazos County. As Texas A&M University and Blinn College’s enrollment increased, the population of the surrounding city did as well. The enrollments at Texas A&M University and Blinn College continuously grow reaching 45,000 students (Hester & Prochazka, 2012, p.4).

As the population grew, so did the median income. According to the United States Census Bureau (U.S. Census Bureau, 2015), the median family income in Bryan actually increased between 2000 and 2014 by about $7,000 to $39,231 in 2014. However, it is still 25% below the median family income in the State of Texas implying continuous struggle with poverty among substantial number of Bryan residents. These result that 27.3% of local families were living below the poverty line, and more than 60% of households in Bryan are family household with an average 2.6 people per household. Due to the students and faculty population growth in Bryan and College Station, the median rent is expected to be increasing, and this indicate increase in financial burden on family household needs in increase in the number of affordable housing (City of College Station, 2015).

According to the Analysis of Impediments to Fair Housing: 2015 Update by the City of Bryan, the single-family housing in the Bryan-College Station is less affordable than similar sized university communities such as Abilene, Denton, Lubbock, Nacogdoches, Tyler, and Waco. Not only the price of dwelling is higher than the comparable markets, but also the number of the single-family affordable housing in the Bryan-College Station has decreased (City of Bryan, 2015). The City of Bryan reports that they plan to continue rehabilitation and reconstruction programs of dilapidated housing and improve the affordable housing awareness to the City boards.

Climate

Climate informs the basic knowledge of the natural environmental and site details affecting the design, its contents are demonstrated by conducting site analysis. Climate includes factors such as temperature, humidity, solar orientation, and wind (Autodesk, 2014). College Station Bryan Metropolitan, Texas has a warm humid temperate climate with hot summers and no dry season. The area within 25 miles of this station is covered by croplands (82%), grasslands (14%), *and* forests (3%) (City of College Station, 2013).

Project Site

The site for the 20K House is located in the Falls Creek Ranch Subdivision in north Bryan. The Falls Creek Ranch Subdivision includes 56.43 acres of land with a fishpond in the middle of the property (see Figure 7). The site is generally flat with existing vegetation and trees.

Figure 7: (Left) Area map and (right) vicinity map of the 20K House project site

The subdivision currently is re-plated into five (5) blocks, which are divided into thirty nine (39) individual lots. Fifteen (15) out of thirty-nine (39) lots are already developed. The project set a place within the Block 2 with seven (7) individual lots. This block had an advantage of facing existing driveway in the front with the large fishpond in the back of the property. Based on zoning at the Falls Creek Ranch Subdivision, each lot was one (1) acre, which is extravagant lot size for affordable housing. The instructor subdivided each lot into two (2) long rectangular lots thus, the individual lot's opportunities and constraints are all the same (see Figure 8). Not only, the lots were much smaller, but this also allow the number of lots to meet the number of students in the design course for both groups.

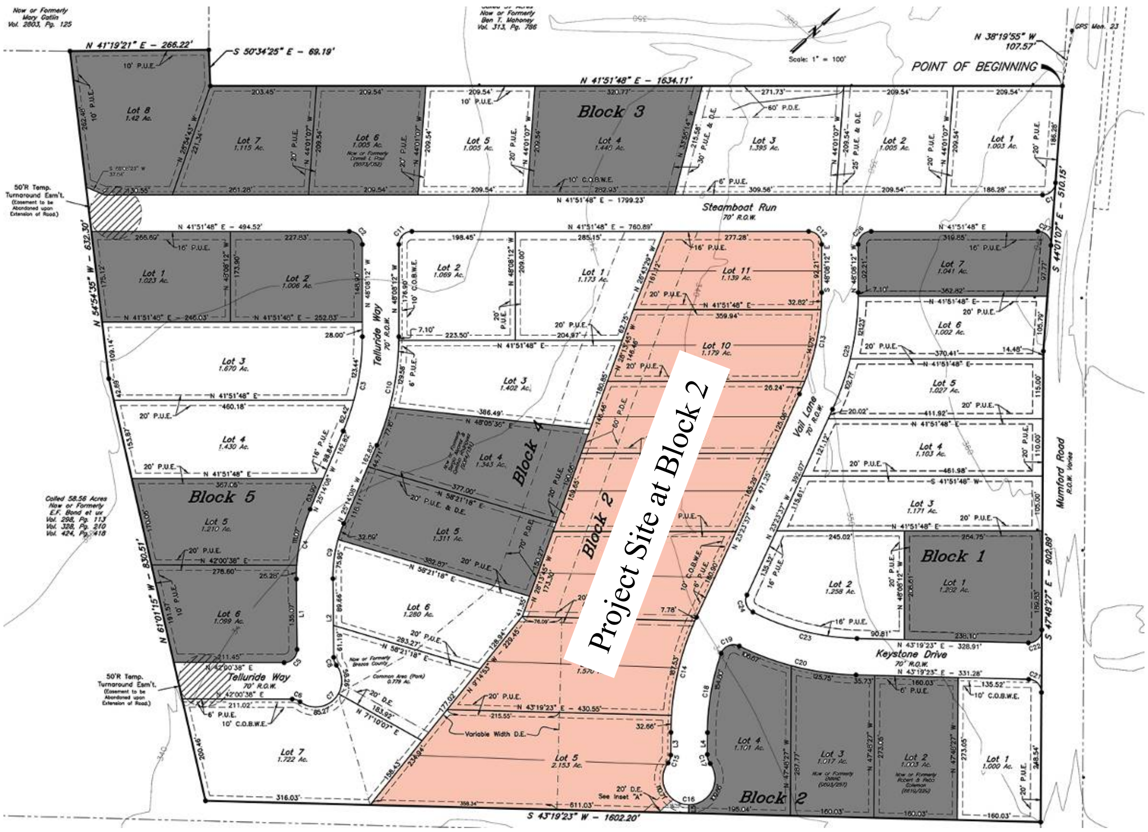


Figure 8: The subdivision map of Falls Creek Ranch.

4.3.5 Architectural Program for the 20K House

Students in both the control and treatment groups were given the same architectural program that was based on the 20K House research program at the Rural Studio. Students were told the architectural design must comply with local building code, Energy Star rating, and Americans with Disabilities Act (ADA) accessibility regulations. Conventionally, the 20K Houses at the Rural Studio are designed for single or double occupants, and the occupancy was considered the same in this research (see Appendix J for the 20K Housing project information packet). Based on the research of the Rural Studio's 20K House, the range of the building area is in between 330 S.F. to 750 S.F. (average 550 S.F.). In respect to the southern culture, each house has an outdoor porch area in between 60 S.F. to 382 S.F. (average 175 S.F.). The current research project required students to design a 20K House with a maximum area of 600 S.F. with a maximum of 150 S.F. for an entry stoop and porch. Although 600 S.F. is slightly larger than the average S.F. of the Rural Studio's 20K house, this allowed a little more flexibility for the students in the experiment, and gave an advantage for preliminary area calculation with plan dimension at 20' by 30'. Loft space was allowed as long as the budget was sufficient. A garage or carport was not considered because either would be built as an extension in the next phase of construction.

Students in both groups were instructed not to consider any interior furnishings, mechanical system, electrical and plumbing systems, fixtures, and appliance or their budgetary factors. The Rural Studio's 20K House include the basic electrical and plumbing systems, and fixtures that service the house. However, interior furnishings, mechanical system, or appliances are not included in the $20,000 budget, but often donated to the residents. These factors were not considered for the purpose of this experiment since these topics are inappropriate at the second-year level. Topic appropriateness at the second-year level was previously discussed in section 4.2.

4.3.6 Deliverables and Presentation Requirements

Both the control and treatment group were instructed to prepare one (1) group site plan displaying all proposed 20K Houses at the community level for the Block 2 at the Falls Creek Ranch Subdivision (see Figure 9). Then, each student in both groups was required to prepare two (2) boards presenting their 20K House design (see Figure 10). Identical presentation board requirements were provided to both control and treatment groups. Two (2) 22"x 34" matte-printed boards in color were also required. A separate handout indicating fixed locations for individual images were provided for consistency between groups (refer to Appendix J).

Figure 9: Overall project site plan prepared by the control group

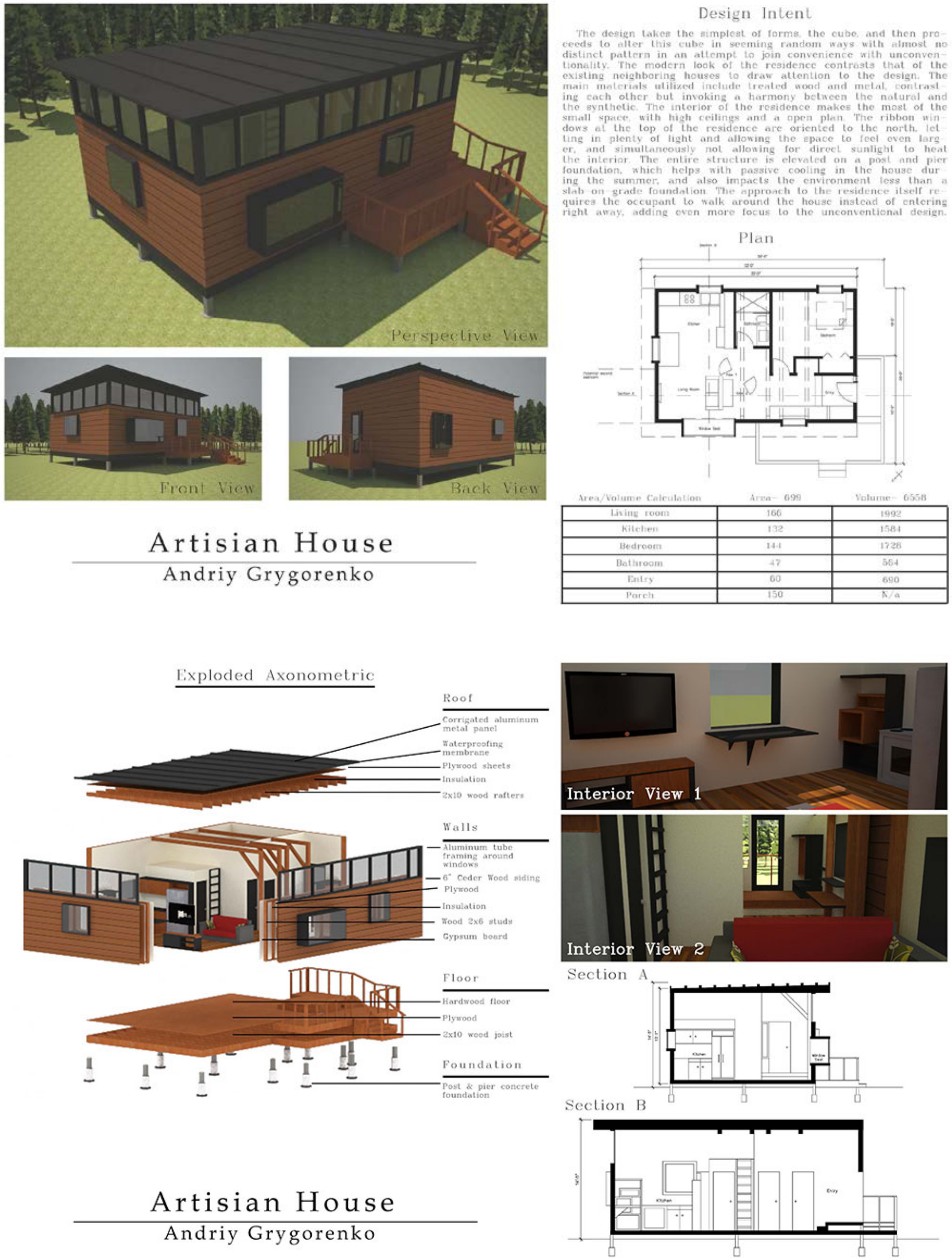


Figure 10: Individual 20K house presentation boards presented by the treatment group

Students were required to write a design intent statement of no more than 200 words to clarify ideas. The design intent statement serves to describe students' design intent and the strategies they employed in the project. A discussion of "why" he or she employed select strategies was required. The students were to include formal design ideas discussing architectural elements and principles of design such as line, shape, light, value, color, texture, pattern, space, and time, and principles of design, such as unity and variety, balance, symmetry, emphasis, scale and proportion, volume, setting, and interior/exterior relationship.

The exploded axonometric diagram demonstrates students' understanding of fundamental building elements by separating the building skin from its architectural structure and interior and exterior skin by exploding foundations, roof assembly, floor assembly, wall assembly, and interior walls. The floor plans, exterior elevations, building sections, interior renderings, and exterior perspective drawings serve as basic instruments to portray the students' design.

Each of the control or treatment group were to prepare one site model and one site plan showing the entire Block 2 at the Falls Creek Ranch Subdivision. The site model including contours and existing landscape of the site (road, trees, and pond) is to accommodate all thirteen (13) – 20K House buildings to portray projects in a community level. One detailed building model demonstrated students' understanding of building assemblies and massing in physical form and further explain their use. As evidence of an idea being structured, students would begin to understand the complexity in its immediate setting (Dunn, 2007). As Dunn explained in his book, "the Ecology of

Architectural Model”, students are to use the architectural model along with drawings, sketches, and rendered images as a tool to communicate their project.

4.3.7 Other Studio Projects

As identified above, the 20K House project was used as the main part of this research to identify the effectiveness in the students’ understanding of cost as an integral design determinant through their 20K House design. In addition, two (2) additional studio projects were provided to both groups, thus students worked on the three (3) identical studio projects within the semester. As an introduction to fundamental building elements, students worked on their first project “Analysis”. Groups of two (2) design students analyzed the intent of design, construction methods, materials and finishes, and architectural elements in selected small residential projects by well-known architects: Glenn Murcutt, Marlone Blackwell, Brian McKay-Lyons, Rick Joy, Tadao Ando, and Tom Kundig. The emphasis of the analysis was on building assembly and details. The architects were selected because of their architectural philosophy recognizing social, cultural and contextual values and their impacts on the community. For four (4) weeks, students analyzed the selected projects, built digital three-dimensional exploded axonometric diagrams using Sketchup, and created a physical sectional model demonstrating their understanding of architectural elements and details (see Figure 11 and 12).

Figure 11: (Left and right) Final section model of Leis House by Peter Zumthor assembled by the treatment group

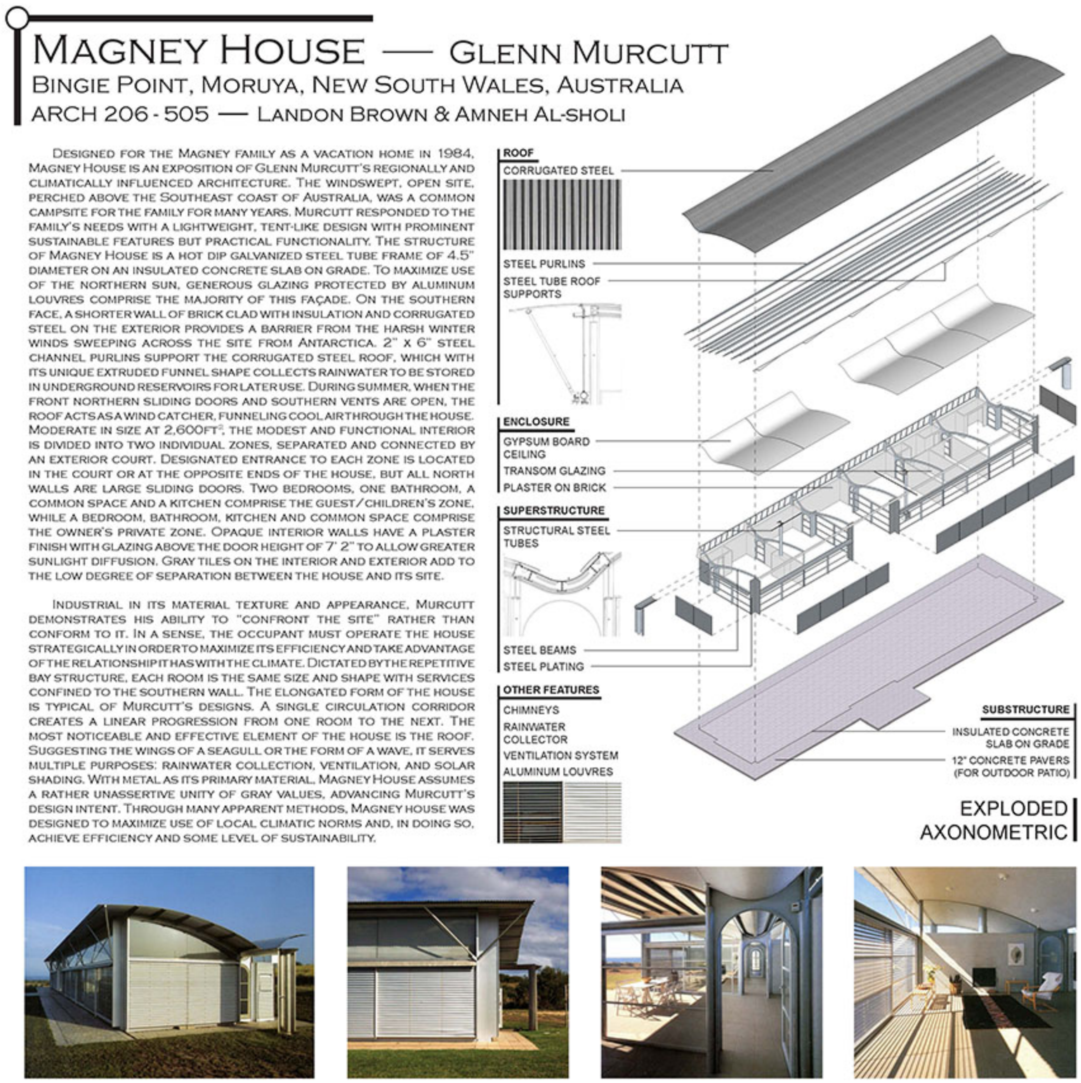


Figure 12: Final presentation poster of analysis of Magney House by Glenn Murcutt prepared by the control group

Following the analysis of projects, the students' knowledge of building elements and assembly was demonstrated with construction of a life-size children's play structure for a local child development center. The students worked in groups of two (2) and three (3) designing and fabricating structures at the Automated Fabrication and Design Lab of Texas A&M University. The foundation of the play structure was portrayed using movable wheels. Base platform (floor), framing, enclosure (wall and roof) were built incorporating different playing responding to children's different learning stages. Materials and finishes were selected for durability, ease of maintenance and weather protection (see Figure 13).

Figure 13: (Left) 'Musical Imagination' play structure, design and fabricated by the treatment group (right) 'Dream Zone' play structure designed and fabricated by the control group

4.3.8 Supporting Guest Lectures for the Treatment Group

Based on discussion with the other second-year studio instructors in the beginning of the semester, it was agreed to adopt "Fundamentals from 2014 International Architecture Biennale" by Rem Koolhaas as a reference to discuss architectural elements in the studio courses. For both groups, a list of fundamental architectural elements were introduced to students. Cost indicators identified in this research were predominantly presented only to the treatment group to convey such elements and different ways to design considering its financial impacts. Additional lectures were provided the treatment group to support learning objectives. Based on recommendations, the topics of conceptual cost estimation, lifecycle cost, and the choosing-by-advantage decision-making system have been incorporated into the new course.

Table 10: Schedule of lectures

Week	Control Group	Treatment Group
1	Introduction	Introduction
2	Architectural Graphics and Architectural Elements 1	Architectural Graphics and Architectural Elements
3	Architectural Elements 2	Cost Indicator 1: Overview and Site
4	-	Cost Indicator 2: Foundation and Structural Framing
		Design Process: Michael Rey (Guest)
5	Rural Studio Documentary (DVD)	Choosing by Advantage: Dr. Zofia Rybkowski (Guest)
6	Rural Studio and Serenbe	Cost Indicator 3: Structural Framing
		Housing: Dr. Shannon Van Zandt (Guest)
7	Materials and Finishes	Rural Studio Documentary (DVD)
		Alternative Materials: Dan Phillips (Guest)
8	Alternative Materials: Dan Phillips (Guest)	Cost Indicator 4: Wall, Roof, Floor, Doors and Windows
9	-	Preliminary Cost Estimation and Construction Management: Dr. Ben Bigelow (Guest)
10	Probono	-
11	Architectural Details	Cost Indicator 5: Area, Complexity, and Materials and Finishes
12	Materials and Finishes	Architectural Details
13	-	-
14	Final Presentation	Final Presentation

Additional guest lecturers were invited to discuss their specialties in its association to cost awareness. Architect Michael Rey from Overland Partners, San Antonio, Texas discussed design processes of typical in architectural practice. His lecture described the steps from project proposal, preliminary design, schematic design, to construction documentation including specifications, and construction administration.

Budgetary consideration and its awareness throughout the design phases and construction were also emphasized.

Dr. Zofia Rybkowski from the Department of Construction of Science at Texas A&M University lectured on the topic of Choosing by Advantages, the decision making system. A quick exercise of purchasing a car was administered for students to understand the step-by-step instruction of how to make sound decision for any given problem, especially design related problems going forward. This lecture identified the fairness in understanding the facts from each attributes and their contribution in decision-making based on reasonable justification (see Figure 14).

Figure 14: Dr. Rybkowski giving a lecture on Choosing by Advantages, the decision-making system

Dr. Shannon Van Zandt from the Department of Urban Planning and Landscape Design at Texas A&M University focused her lecture on fairness and significance in housing. Students were introduced to the true meaning of housing and its social and personal impacts on everyday people. Understanding the value of housing led the students to grasp the homeownership, its financial and economic implications, its long-term maintenance, and overall well-being of people.

Dr. Ben Bigelow from the Department of Construction of Science at Texas A&M University introduced the profession of construction management. He explained what it takes to lead a successful project. Dr. Bigelow explained that financial implications and construction schedule must be thoroughly understood and applied to every project. The importance of preliminary cost estimation and budgeting was also emphasized. The RS Mean reference to construction data was explained, and it was suggested to the treatment students that they seek cost per square foot data during the design phase (see Figure 15).

Figure 15: Dr. Bigelow giving a lecture focusing on construction management and cost estimation.

4.4 Evaluation of the Quasi-Experiment

When the experiments for both the control and treatment groups were completed, the instructor generated statistical comparisons between the control and treatment groups. First, pretest-posttest results from both groups were derived to recognize differences in the outcome, the appropriateness of the topic, and the ability to apply cost consciousness in design at the foundation level. Statistical significance was conducted based on a *t* test result. Due to the small sample size (N $\leq$29), it was advised by Gall et al. (1996) to do the *t*-test to compare two sample means. An analysis of variance of means was considered, but it was found to be equivalent to doing a *t* test. This study chose to use one-sided p-values, as the treatment group was expected to end up with either larger or smaller means than the control group due to the impact of the experiment. By doing one-sided p-value test, statistical power was increased.

Second, at the end of each semester representatives of design instructors, construction-science instructors, urban planning instructors, and housing officials whose work focuses on affordable design, evaluated the students' designs, based on cost indicators. These evaluators had no way of knowing which group had cost awareness in their learning objective. A Likert scale chart showing low to high cost criteria per cost indicators accompanied by a presentation booklet including students' presentation boards was provided to the reviewers to evaluate students' 20K House design (see Appendix K). Evaluated mean scores for each cost indicators, their overall mean scores, and were revealed through the *t*-tests. The mean scores on some characteristics of students' design decisions were compared using *t* tests. In doing *t* tests, it was hypothesized that the control group's mean would result in higher cost, thus one-tailed test of significance was done. Additionally, magnitudes of the relationship between each cost indicator's evaluation scores and certain characteristics of students' design decision was expressed using correlation coefficient (r).

Finally, each class was asked to select the most successful affordable design and provide systematic reasoning for their selection. The students' top two (2) choices were compared to their evaluation scores. Preliminary cost estimations of the four 20K Houses (two from each group) were conducted by the researcher to validate that they truly are affordable.

In summary, a quasi-experiment was conducted to compare the existing second-year design studio course with a newly developed second-year design studio course. The new teaching strategy focusing on cost awareness only applied to the treatment group. While both groups were instructed to design 20K House as their studio project, the cost indicators were used as the research instrument to guide cost as an integral design determinant in the treatment group. Both selected evaluators and the instructor used the cost indicators to evaluate students' 20K House designs. Lastly, each group selected two (2) projects representing the most successful projects in the course, and the instructor performed preliminary cost estimations to compare the cost.

CHAPTER V

QUASI-EXPERIMENT RESULT AND FINDINGS

This chapter presents findings from the quasi-experiment results comparing the control and treatment groups' pretest-posttest surveys and the 20K House design are disclosed demonstrating the effectiveness and the impact of teaching cost as an integral design determinant in the second-year foundation design studio education.

The pretest-posttest surveys provided to both the control group and treatment group generated comparable results; they uncovered students' perspectives of cost in architectural design and indicated the effectiveness of the treatment. The final studio project of the 20K House design highlighted differences in students' design solutions and approaches between the control and treatment groups. The cost indicators identified in the Chapter 4.2, were used as the instrument in the treatment group as well as a measuring tool to compare the effectiveness of the treatment.

5.1 Pretest-Posttest Differences

The pretest and posttest results from the quasi-experiment infer foundation design students' lack of tendency toward cost or cost awareness. Along with students' response in the pretest survey, instructor's journal was used to determine students' true pre-existing knowledge of building elements, structures, or any cost-related topics. Out of thirteen (13) control group students, one (1) student was a transfer student who had already taken six (6) semesters of design studio courses. For the rest of the students in the control group, it was a typical design studio sequence in the second semester of the second year.

First, the survey asked about the students' preexisting knowledge and experience from other courses they have taken within the subjects of this experiment. Only two (2) control group students have indicated that they had taken an architectural structure course. The rest of the control group indicated no initial knowledge in building construction or the cost estimation. Regardless, a total of three (3) control group students demonstrated previous experience in learning about building structure from construction experience. The three (3) control group students actually had a good conceptual understanding of building structure and assemblies. These (3) students assisted other students to comprehend construction documents throughout the experiment and positively collaborated with other students in developing studio projects. Including the transfer student, five (5) out of thirteen (13) control group students indicated that they have taken a material and methods course either from the architecture or construction science department, or had a guest lecturer in their previous studios discussing such topics. However, their knowledge in building materials and finishes were superficial and it did not affect the researcher to determine students' pre-existing knowledge for the control group. As a required elective course, two (2) out of thirteen (13) students have taken a sustainability course, and the rest were taking it during the experimental semester, or planned to take it in the following year. No one has taken other technical electives such as mechanical and electrical engineering, construction management, construction estimation, and housing affordability courses.

Among the treatment group students, there were three (3) summer – change-in-major students. They had undergone two (2) back-to-back first year design studios during the ten (10) week summer module. This concluded their architectural experience in the ten (10) weeks prior to this experiment. Five (5) treatment group students had taken an architectural structure course. However, the five (5) treatment group students failed to prove their knowledge in building structure through their design or discussions. The nine (9) out of thirteen (13) students including the three (3) summer module students had taken a material and method course. However, similar to the control group, their knowledge in materials and methods was too superficial to affect this experiment. Similarly, four (4) students had taken a sustainability course as a required elective course. The treatment group indicated that no one had taken mechanical and electrical engineering, construction management, and housing affordability courses. One (1) treatment group student indicated that she had taken a construction estimation course, but she demonstrated no more substantial knowledge in construction estimation than the other students who had not taken one. It is difficult to generalize that the students in ARCH 206 had more knowledge in building structure and assemblies than students in the ARCH 205, but it can be determined that the control group in ARCH 206 had slightly deeper previous knowledge in architectural elements and assembly than the treatment group in ARCH 205 in this research experiment.

Table 11: The quasi-experiment participants

		Control Group	Treatment Group
Enrollment		13	13
Pretest/Posttest Participation		11	13
Special Note		1 transfer student (3rd year)	3 summer module students
Courses Taken	Arch Structures	2	5
	Materials and Methods	5	9
	Sustainability	1	4
	Construction Estimation	0	1
	Mech, Elect, Plumb	0	0
	Construction Management	0	0
	Affordable Housing	0	0

Based on the attendance and tardiness, only eleven (11) students in the control group participated in both the pretest and posttest surveys to generate the pretest-posttest comparison. All thirteen (13) treatment group students participated in both tests causing a difference in the sample number. The statistical *t*-test can be still performed with unequal sample numbers; therefore, the number of students did not influence the *t*-test (Gall et al. 1996). The three (3) questions concerning students' pre-existing perspective toward cost or wealth to achieve high quality design appeared at both the pretest and posttest surveys to generate comparisons. Additional two (2) questions were provided in the posttest to obtain students' input in the appropriateness in learning cost as an integral design determinant at the second-year design studio education level.

First, both groups were asked to rank the order of importance to achieve high quality design in the architectural design studio course on the first day and the last day of the semesters (see Table 12). Both groups found architectural "function" as the most important factor, and "materials and finishes" as the least important in achieving high quality design. While the topic of cost remained as the second highest rank for the control group, the same topic ranked down from the second to the third for the treatment group. The pretest-posttest results with the control group demonstrate a solitary change in between “technology” and “form”, while it indicates rank changes between “cost” and “form” in the treatment group. Consistently, architectural “form” was found to be the most important factor at the end of the semester for both groups.

Table 12: The order of importance rank

	Control Group (n=11)		Treatment Group (n=13)	
Rank	Pretest	Posttest	Pretest	Posttest
1	Function	Function	Function	Function
2	Cost	Cost	**Cost**	**Form**
3	**Technology**	**Form**	**Form**	**Cost**
4	**Form**	**Technology**	Technology	Technology
5	Materials and Finishes	Materials and Finishes	Materials and Finishes	Materials and Finishes

A comparison of the pretest and posttest results for both the control and treatment groups discovered that there was no significant change in the ranks of importance to achieve quality design. Both control and treatment groups selected “function” as the most important factor in both pretest and posttest. This outcome suggests that foundation students at Texas A&M University were taught the function of a building is more important than unique forms or aesthetic of a building. Similarly, “materials and finishes” were selected as the least important factor to achieve quality design. This was quite ironic because, as mentioned earlier, many students from both groups had indicated that they had taken materials and finishes courses or participated in lectures on such a topic. It was noted in the instructor’s journal that there was a lack of student’ effort to research in general for both the control and treatment groups. For example, when students saw a material with "wood grain," they automatically thought it was some sort of natural wood. According to Frayling (cited in Savic, 2014), there are two(2) kinds of architectural research – one with a small "r," which is aimed at producing a design, and the one with a big "R," which is a scholarly source with a pre-defined research question that leads to discussable and shareable knowledge (Savic, 2014). In this case, students in both groups were performing "r"esearch, which suggest that foundation design students generally do temporal "r"esearch without intent to further enhance or explore new knowledge. This also infers that foundation architectural education does not inform students about the needs of continuous research efforts accompanying design process.

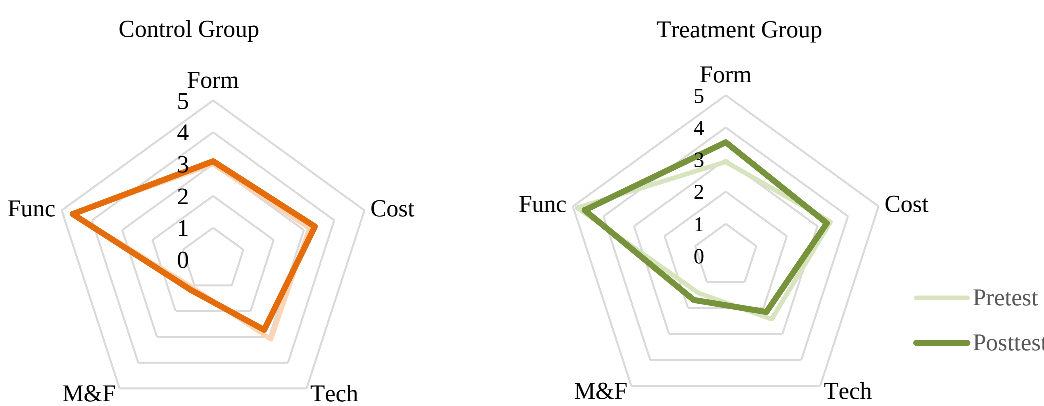


Figure 16: Pretest – posttest difference in 'order of importance" to achieve quality design

Based on the order of ranks, different points were given. For instance, if ranked at the highest, five (5) points were given; if ranked at the lowest, one (1) point was given. Based on cumulated points, a radar graph was designed, indicating changes in students' inclination toward the order of importance (see Figure 16). Unfortunately, the statistical analysis indicates that there was not a significant difference between the control group and treatment group. Furthermore, the treatment did not bring in a significant impact on the treatment students with regard to how they evaluate the concept of cost in design. For both groups, “cost” ranked second highest after “function” while no particular background of the students was suspected to produce such an outcome. Given the fact that the pretest was given on the first day of class for both the control and treatment groups prior to discussing course agenda to introduce the 20K House design as a project, this result was somewhat unusual. The treatment group selected “cost” as the second most important at the pre-test, and it became the third most important at the posttest. Statistical analysis discovered that there was no significant difference, yet the sample size was too small to generalize. However, as noted in the journal, the treatment group began to recognize how the complexity of building form affecting building cost. Such recognition was displayed throughout the course of the experiment as well as in the 20K House design.

Next, the pretest-posttest changes in students’ perspectives on wealth and its impact on doing high quality architecture were compared between the two (2) groups. Strong differences between the control and treatment groups’ pretest-posttest results were found, particularly in their perspectives toward “wealth.” Most students in the control group responded that wealth “sometimes” represents high quality products in today’s construction. The control group’s perspective on the impact of wealth toward quality design did not change on the posttest. Initially, the treatment group’s responses were similar to that of the control group at the pre-test; however, their responses changed from “rarely” in the pretest to “never” in the posttest (see Figure 17).

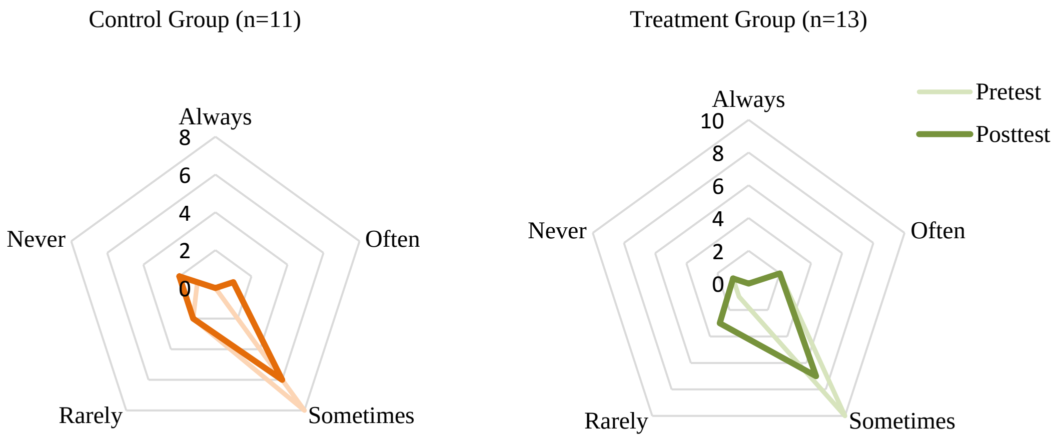


Figure 17: Pretest – posttest difference in the significance of wealth in quality design represented in radar graphs

As can be seen in the Table 13, there was a statistically significant difference between the control and treatment groups’ perspectives on the impact of financial affluence in producing quality design. The research treatment changed students’ perspectives to see that financial affluence does not necessarily imply high quality design in building construction. It can be inferred that studying various examples of quality low-cost design affected the treatment group’s perspective on quality design apart from wealth. Concurrently, the treatment group has acknowledged that awareness in building cost should begin early, while they also need to build a mindset for its recognition and tools to deal with it.

Table 13: Pretest – posttest differences in the significance of wealth in quality design

Control Group (n=11)				Treatment Group (n=13)						
Pretest		Posttest		Pretest		Posttest		df	t-test	p-value
Mean	SD	Mean	SD	Mean	SD	Mean	SD	23		
3.364	0.674	3.071	0.730	3.455	0.934	4.214	0.426		3.524	0.0009

Note: mean score is based on students' selection of 1=always, 2=often, 3=sometimes, 4=rarely, 5=never. Difference of pretest-posttest between two groups significantly differ with one-sided $p < 0.05$.

Students in both groups were asked about the most appropriate time to question how much "*this*" would cost to build. "*This*" in the question referred to any projects that designers are currently working on or would be working on, and this question measured students' attitudes toward gaining their practical awareness of cost during school. Both groups' responses were similar: the results fell between "during construction" and "during design phase of project" in the pretest.

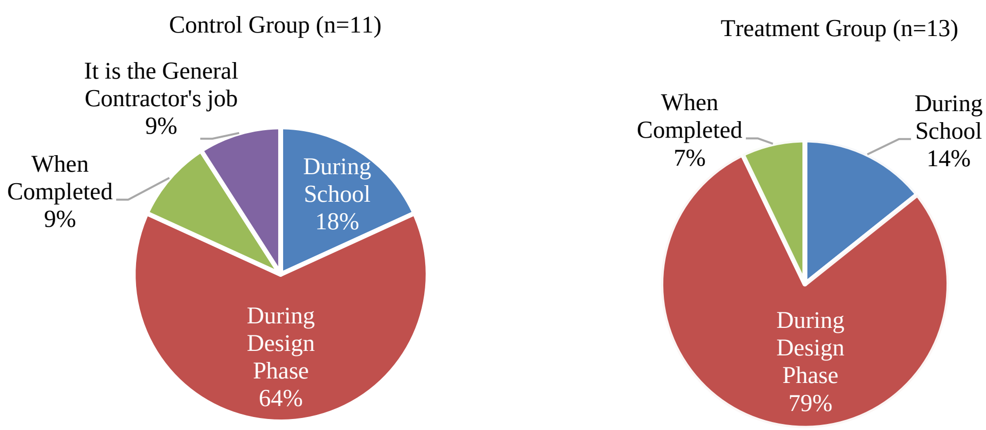


Figure 18: Pretest – posttest differences in the appropriate time to ask how much their project is going to cost to build

It was found that there was a statistically significant difference between the control and treatment groups' perspectives on when to start learning about and questioning about building cost and cost implication in architecture (see Table 14).

Table 14: Pretest – posttest differences in the most appropriate time to ask "how much is *this* going to build?"

Control Group (n=11)				Treatment Group (n=13)						
Pretest		Posttest		Pretest		Posttest				
Mean	SD	Mean	SD	Mean	SD	Mean	SD	df	t-test	p-value
3.909	0.831	4.071	0.475	3.909	0.831	4.571	0.514	23	2.538	0.0092

Note: mean score is based on students' selection of 1=never, 2=it is general contractor's responsibility, 3=during construction, 4=during design, 5=during school. Difference of pretest-posttest between two groups significantly differ with one-sided $p < 0.05$.

The majority of students in the control group responded that learning cost can "sometimes" influence producing quality design. However, the majority of students in the treatment group have responded that "often" awareness in cost will influence developing quality design.

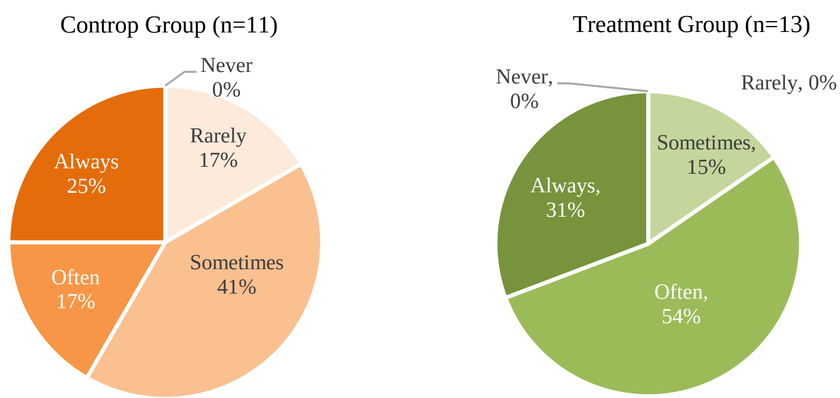


Figure 19: Posttest differences in between two groups' perspectives of the impact of learning cost to produce quality design

Notwithstanding this difference in between the two (2) groups (see Figure 19), the statistical analysis has indicated that there is no statistically significant difference between two (2) groups indicating one sided $p>0.05$.

When students in the both groups were asked whether learning cost as an integral design determinant is appropriate at the second-year design education level, all (n=13) in the treatment group marked “yes.” In the case of the control group (n=11), everyone but one (1) student indicated “yes.” This student from the control group commented in the survey that learning cost would be more appropriate as upper level content and would not be suitable at the second-year level. As a result, both the control and treatment group indicated that learning cost as an integral design determinant, is appropriate at the second-year level. It was evident looking at the treatment group’s change in perspective as mentioned above. The instructor believes the experience with the 20K House project made students began to recognize the importance of cost awareness in design. Budgetary factors are unavoidable in any real projects, and students have learned the importance of cost awareness to achieve success of projects through this experience.

While learning cost as an integral design determinant is appropriate, the control group indicated that it could be either in a form of lecture or design studio course. Evidently, the control group went through a semester long existing program where they did not gain awareness in cost. But having benefited from learning it through design studio course, the treatment group indicated that it should take part in design course (see Figure 20). In sum, the pretest-posttest comparison discovered the significant differences in the treatment students' attitude toward cost in architecture, and found that students are susceptible toward learning cost as an integral design determinant.

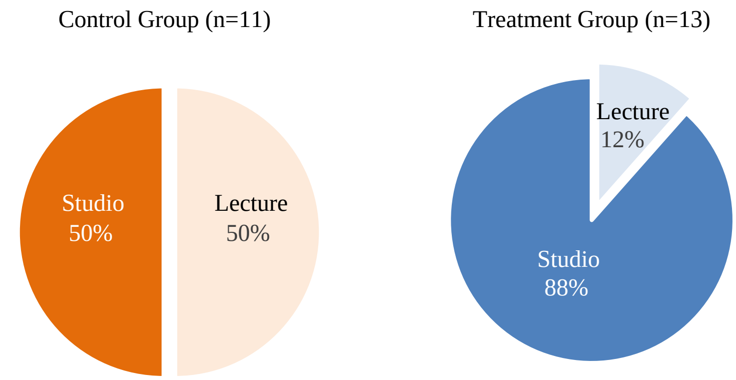


Figure 20: Posttest differences in between two groups' preference in learning cost in a lecture course or a design studio course

There was a statistically significant difference between the two (2) groups' attitudes toward learning cost as an integral design determinant during a studio course versus a lecture course (see Table 15).

Table 15: Posttest differences between two groups in the appropriateness of learning cost as an integral design determinant during studio versus lecture course

Control Group (n=11)		Treatment Group (n=13)				
Mean	SD	Mean	SD	df	t-test	p-value
1.455	0.522	1.143	0.363	23	1.760	0.046

Note: mean score is based on students' selection of 1=Studio, 2=Lecture. Difference of pretest-posttest between two groups significantly differ with one-sided $p < 0.05$.

5.2 20K House Design Comparison

Cost indicators serve as the main instruments driving this experiment and also, used as the evaluation criteria to determine students' awareness in cost. The quasi-experiment discovered the effectiveness of cost as a fundamental design determinant in foundation design education as well as the impacts of cost indicators in students design by comparing results from the control and treatment groups. Four (4) selected evaluators: a design instructor, a construction science professor, an urban planning professor, and a construction manager, performed evaluation on both the control and treatment groups' 20K House designs using an evaluation matrix based on the cost indicators. The instructor of both the control and treatment group courses performed a separate evaluation of both groups' 20K House designs based on detailed breakdown of the cost indicator. Lastly, the instructor conducted preliminary cost estimations of four (4) student selected projects to generate actual cost comparison between the two (2) groups.

5.2.1 Selected Evaluators' Mean Scores Comparison

In exception to one evaluator whom was invited to both groups' final presentations as the representative of the Brazos Valley Affordable Housing Corp., the other (3) evaluators were not informed of which group received the treatment in this experiment prior to reviewing the students presentation boards. Overall, the range of effectiveness of each cost indicators and their comparison demonstrate that the treatment group proposed less costly solutions to their design and took more cost-conscious approach in design decision-making.

A total of twenty-six (26) different 20K Houses designs were proposed from both the control group (n=13) and treatment group (n=13). These (26) 20K Houses were individually rated based on the cost indicators by a group of evaluators representing different disciplines within the rim of architecture. Their evaluation points were accumulated and mean scores were calculated for both the control and treatment groups. The evaluators were asked to appropriately scale construction cost based on the cost indicators provided. A “low” in the Likert scale matrix indicates that evaluators found students’ design decisions as more practical and economic while a “high” in the evaluation suggests costly and exorbitant design solution based on the magnitude of area, complexity, and materials and finishes (see Appendix K). Then, the quantifiable score of the minimum point of one (1) was given to “low” and maximum points of five (5) was given to “high” as reviewed by the evaluators.

The control group’s mean score was 3.05 out of five (5) total points, while the mean score for the treatment group was 2.69 out of five (5) total points. Although both group’s mean scores were in the intermediate range, the statistical analysis showed that the overall mean score for the control group is 13.3% higher, and presumably 13.3% more expensive than the treatment group design, and such a difference is considered statistically significant. In addition to the fact that this result was proven to be statistically significant, the treatment made positive influence on the students’ design and perspective toward cost as a fundamental design determinant. As inferred earlier, the pretest results for both control and groups reflecting their perspectives of cost and wealth in producing quality design were similar. Nevertheless, it is true that, the students in the control group were enrolled in sequentially (1) higher level design studio course than the treatment group. Therefore, it can be conjectured that if it both groups were enrolled in the same level of architectural design course, the difference between the control and treatment group could have been greater than 13.3%.

However, differences in the individual cost indicators' mean scores were not found to be all significant. The one sided *P*-values of the evaluation scores indicated significant differences between the control and treatment groups' design on the site, structural framing, doors and windows, and floor. The highest mean score difference was discovered in the doors and windows revealing approximately a 34% difference. It was followed by the site with a 24% difference in the mean scores received. The mean scores of the structural framing and floor were also calculated, with approximately an 11-12% different between the two (2) groups. Nevertheless, there was no significant difference in the foundation, wall, roof and circulation in between the control and treatment groups (see Table 16 and Figure 21). The lowest mean score difference was found in the wall, which showed a 2.44% difference between the two (2) groups. Overall, each cost indicator's mean scores in the treatment group were lower than the same categorical mean scores of the control group.

Table 16: the control group and treatment group paired *t*-test differences in their 20K House design evaluation scores based on Cost Indicators

	Control Group (n=13)		Treatment Group (n=13)					
Cost Indicators	Mean	SD	Mean	SD	df	t-test	p-value	Difference in %
Site	3.153	0.857	2.538	0.548	12	1.760	**0.047**	**24.24**
Foundation	2.557	0.587	2.365	0.262		1.022	0.163	8.13
Structural Framing	3.230	0.450	2.903	0.331		1.914	**0.039**	**11.26**
Wall	3.230	0.461	3.153	0.389		0.470	0.323	2.44
Doors & Windows	3.365	1.087	2.5	1.060		1.904	**0.040**	**34.62**
Roof	3.493	0.870	3.211	0.465		0.929	0.185	8.78
Floor	3.096	0.495	2.743	0.445		1.926	**0.039**	**12.85**
Circulation	2.288	0.865	2.134	0.440		0.621	0.273	7.21
TOTAL Indicators	24.416	3.014	21.551	2.370		2.739	**0.009**	**13.30**
AVG Indicators	3.052	-	2.693	-		-	-	-

Note: The mean score is based on reviewers' evaluation of 1=low, 5=high in building cost. Difference of pretest-posttest between two groups significantly differ with one-sided $p < 0.05$. The scoring was also based on the magnitude of complexity, area, and materials and finishes.

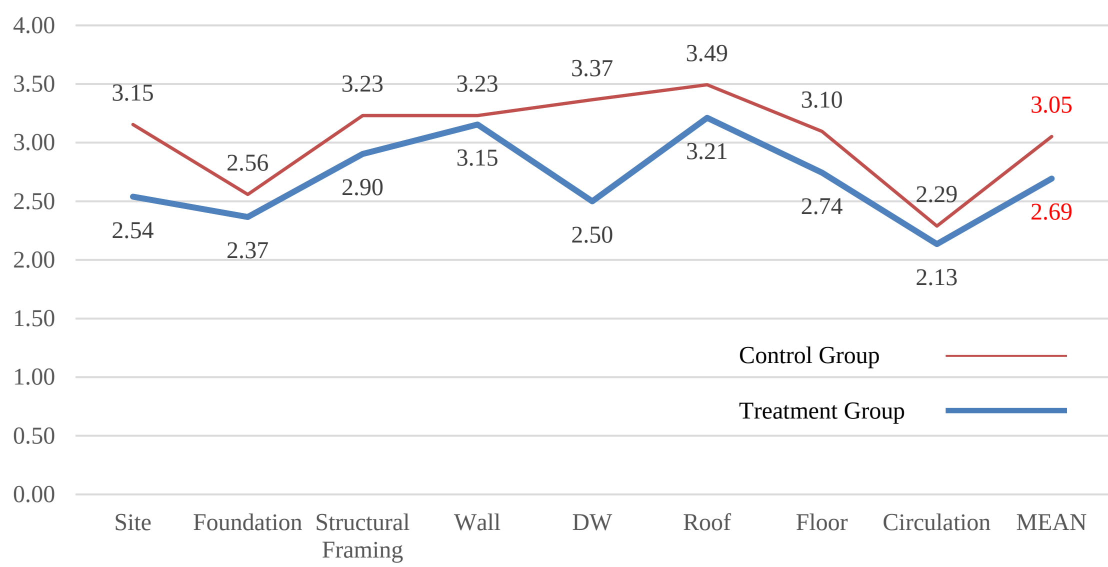


Figure 21: Overall 20K housing design evaluation scores based on cost indicators

Correlation Between Cost Indicators

Following the comprehensive range of effectiveness in each cost indicators, the Pearson's correlation was conducted to discover relationship between indicators for both groups. While the correlation coefficients (*r*) explains potential causal inference, statistically it does not generally lead to strong conclusion thus it does not imply causation between cost indicators (Gall et al., 1996). Considering perfect positive correlation at *r* =1.00, total five (5) correlational relationships were discovered from the control group's evaluation mean scores. The high positive correlations have been found between the structural framing and roof (*r* = .562) and the doors and windows (*r* = .60) for the control group's design indicating that mean score values increased together. Results between the foundation and structural framing (*r* = .477), the structural framing and wall (*r* = .449), and the doors and windows and floor (*r* = .471) have also been identified as fair positive correlations (see Table 17).

Table 17: Pearson correlations (*r*) between evaluation scores based on cost indicators for the control group

	Site	Foundation	Structural Framing	Wall	Doors & Windows	Roof	Floor	Circulation
Site	1.000							
Foundation	0.095	1.000						
Structural Framing	-0.073	**0.477**	1.000					
Wall	0.008	0.062	**0.449**	1.000				
Doors & Windows	0.041	-0.207	0.345	0.140	1.000			
Roof	0.129	0.310	**0.562**	-0.087	**0.600**	1.000		
Floor	-0.246	-0.074	0.289	0.464	**0.471**	0.392	1.000	
Circulation	0.251	-0.015	0.296	0.263	-0.166	0.139	0.234	1.000

As expected, more statistical correlation inferences were discovered for the treatment group. Six (6) high positive correlations were found in the following pairs: the site and structural framing (*r* = .538), the site and roof (*r* = .720), the structural framing and roof (*r* = .514), the wall, and doors and windows (*r* = .618). Moderate positive correlation between the structural framing and doors and windows (*r* = .415) were also observed.

Table 18: Pearson correlations (*r*) between evaluation scores based on Cost Indicators for the Treatment Group

	Site	Foundation	Structural Framing	Wall	Doors & Windows	Roof	Floor	Circulation
Site	1.000							
Foundation	0.292	1.000						
Structural Framing	**0.538**	0.078	1.000					
Wall	-0.079	0.067	0.084	1.000				
Doors & Windows	0.152	0.131	**0.415**	**0.618**	1.000			
Roof	**0.720**	0.167	**0.514**	0.035	0.306	1.000		
Floor	0.250	0.304	0.395	0.066	0.243	-0.127	1.000	
Circulation	0.128	**-0.641**	0.382	0.143	0.323	0.027	0.323	1.000

While the foundation and circulation indicated a high correlation with (*r* = -.641), it rather moves in the opposite direction that as the mean scores of the foundation increases, the mean scores of the circulation decreases (see Table 18). This is conjectured that during the treatment group evaluation, the reviewers' felt that while the slab on grade foundation type is more expensive, it decreases the circulation by eliminating stairs or steps to access. A negative correlation was also found in between foundation and circulation within the control group, however, the value of the correlation inference was not significant.

5.2.2 Instructor's Evaluation Comparison

An additional evaluation to compare the students' 20K House design was conducted by the instructor after the experiments were completed with both groups. While the four (4) selected reviewers evaluated the students' projects based on information displayed in their final presentation boards, the instructor actually measured and calculated quantifiable information within their working drawings to draw better comparison.

1. Site

   First, the placements of the houses in relation to the existing road on site were measured. The difference in the length of driveways to approach houses between two groups was clearly vast. Average length of the driveway for the control group was approximately sixty-nine (69) feet while it was approximately fifty-seven (57) feet for the treatment group resulting 20% difference in the average length. Its *t*-test result indicated that such difference is statistically significant between two (2) groups (see Table 19). In terms of the complexity of the driveway shape, students in both groups similarly proposed linear driveway with the average twelve (12) to fifteen(15) feet driveway width (see Figure 22).

   A similar engagement was found in students' selection of driveway paving materials. As expected, most students in both groups used either concrete pavement or gravel for their driveway. For a statistical analysis, the numeric score “1” was used for gravel, “2” was used for concrete pavement, and “3” was used for others. Only (1) student from control group has used stone pavement, and the rest selected either concrete pavement or gravel. While most students in the control group used concrete pavement, majority of students in the treatment group proposed compacted gravel to reduce site cost. This design decisions has resulted a 20% difference between the control and treatment groups. For this category, p-value>0.051 was statistically resulted, but based on its value, the two group’s relationship is almost significant.

Figure 22: Site – difference in the driveway length between the control and treatment groups

The t-test differences for the complexity and materials for Site were found to be statistically significant. The evaluators visually recognized the difference in the placement of houses within each property. When graphically measured, the average length of the driveway for the control group was 69.8 ft. compared to 57.5 ft. for the treatment group. This shows 20% difference in length between two (2) groups.

Especially when a material like concrete pavement is proposed for such long length of driveways over materials like gravel, the construction cost difference becomes much greater. As noted in the instructor's journals, students in the students group and a few students in the treatment group focused on the pond view on backside of each property, they ended up locating their houses further back from the street requiring accessibly long driveways. The similar discussion occurred with both groups studying Woodstock Farm by Rick Joy, an architect who suggested to place the house near the street to shorten the driveway, and thus not only it is economic, but also practical in terms of safety and sustainability to weather conditions (youyounadal, 2010).

2. Foundation

The students in both the control and the treatment group made similar decision on the foundation types. The building foundation presented in both group's 20K House were concrete, thus no difference was discovered. The students were required to design within the same 600 S.F. for both groups;

therefore, there was no significant change in their foundation square footage between two (2) groups. An equal number of three (3) students from each group chose the post and pier type foundation type raising the building by nearly two (2) feet. Footings were placed at each corner of the building, and were twelve (12) to fifteen (15) feet apart as instructed. An eight (8) inch thick concrete slab was used for the slab on grade foundation type as instructed.

Table 19: The control group and treatment group paired t-test differences in the 20K House design based on cost indicator – area, material and finishes, and complexity (of form)

Cost Indicators			Control Group (n=13)		Treatment Group (n=13)					
			Mean	SD	Mean	SD	df	t-test	p-value	Difference in %
Site	1a	Complexity (ft)	69.846	17.174	57.538	15.538	12	1.953	**0.037**	**20.11**
	1b	Materials[2]	1.692	0.480	1.384	0.506		1.759	**0.051**	**22.25**
Foundation	2a	Complexity (Type)[3]	1.230	0.965	1.230	0.965		0	0.5	0
Structural Framing	3a	Materials[4]	1.384	0.650	1	0		2.132	**0.027**	**38.40**
Wall	4a	Complexity (# of Exterior wall planes)	8.384	2.142	7.076	2.531		1.888	**0.041**	**18.48**
	4b	Area (Average Clear Height)	10.57	1.60	12.63	1.69		-3.17	0.002	-19.45
Doors and Windows	5a	Complexity (# of Doors)	5.923	1.037	4.846	1.519		2.102	**0.028**	**22.22**
	5b	Complexity (# of Door Types)	3.230	0.599	3	2.395		0.610	0.276	7.66
	5c	Complexity (# of Windows)	13.769	7.037	9.384	5.393		1.886	**0.041**	**46.72**
	5d	Complexity (# of Window Types/Sizes)	5.61	3.640	2.692	1.109		2.434	**0.015**	**108.39**
	5c	Area (Window Opening in SF)	257.27	127.13	138.61	87.122		2.77	**0.005**	**185.59**
Roof	6a	Complexity (# of Planes)	3.69	1.97	2	0.91		2.80	**0.004**	**54.16**
	6b	Materials[5]	2.53	0.769	2	0.833		1.395	0.094	26.5
Floor	7a	Materials[6]	1.846	0.688	1.384	0.506		1.897	**0.041**	**33.38**
	7b	Complexity (Perimeter in ft)	114.80	13.84	117.23	16.80		-0.401	0.345	-2.11
Circulation	8	Complexity (Hallway Length, Stairs, & Steps)[7]	1.76	1.012	1.384	0.760		1.162	0.133	27.53

Note: Difference of pretest-posttest between two groups significantly differ $p < 0.05$.

[2] For materials proposed for driveway and pavement for student's 20K House design, quantifiable scores of 1=gravel, 2=concrete, and 3=others were used.
[3] For materials proposed for foundation type, quantifiable scores of 1=slab on grade and 2=post in pier were used.
[4] For materials proposed for structural framing materials, quantifiable scores of 1= wood framing and 2=metal framing 3=others were used.
[5] For materials proposed for roof, quantifiable scores of 1=asphalt shingles, 2=corrugated metal, 3=standing seam metal, 4=others were used
[6] For materials proposed for floor, quantifiable scores of 1=use sog as final floor, 2=hardwood, 3=tile and carpet, 4=others were used
[7] Based on reviewer's comments, long hallways, stairs, and steps were all added to points

As found in the journal, students in both groups contemplated between slab on grade and post and pier foundation types. While the Rural Studio design favored post and pier foundation type (Freear et al., 2014), all existing residences at the Falls Creek Ranch were on the slab on grade foundation type. During the site walks at the Falls Creek Ranch, the property owners raised several concerns for post and pier foundation type. The first concern was, local wild animals either house or gnaw electrical or plumbing pipes underneath the floor platform. The second concern was accessibility concerns based on the fair housing act. The Fair Housing Act mandates any government funded housing including detached single family housing must abide by design and development guidelines (HUD, 2013). The Section 4 in the Fair Housing Accessibility Guidelines (HUD, 2013) indicates that entrance must be accessible by a handicap person. Thus, the entrance must be leveled with existing terrain or accessible by ramp. Freear et al. (2014) also brought up this concern, but it was not enforced at the Rural Studio design because they were not government funded single- family residences.

Similar to the t-test differences of mean scores by the evaluators, instructor's evaluation found no difference in both groups' foundation design. Following basic guidelines by the instructor, the students graphically illustrated the similar size of footing and depth in the presentation boards when proposing the post and pier foundation type, and they occurred at 10 to 15' increments or at each turning corner of exterior walls. Similarly, the 8" slab on grade followed the footprint of the building. It is unusual to find students at this foundation level to either disregard foundation in their design or neglect the fact that it is a fundamental building element. Although there was no significant differences between two groups, students in both groups learned the importance of foundation in building

3. Structural Framing

Only (1) student from the control group proposed the heavy gauge metal framing, and two (2) students proposed the light gauge metal framing. Remainder of students from the control group and everyone from the treatment group used the wood framing. For materials proposed for the structural framing materials, quantifiable scores of 1= wood framing and 2=metal framing 3=others were used. Its result indicated that there was a 38% difference in material proposed for two groups, and such difference is statistically significant (see Table 19).

The mean evaluation scores for structural framing were significantly different between the control and treatment groups. As noted in the instructor's journal, different types of structural framings: wood, light gauged metal and heavy gauged metal were explained to both groups. Although wood framing was recommended to both groups in the beginning of the project, in reference to the Rural House projects, separate in-depth discussions on scale and cost efficiency of framing types were made only with the treatment group. Opposed to everyone in the treatment group using the wooden framing, the control group explored the light gauge metal framing as well as heavy gauge metal framing. This result infers that while the decision of the treatment group on the structural framing was based on cost efficiency of the project, their attempt to explore different and creative framing method was absent.

The complexity of building forms was different between two groups. While most of the treatment group’s designs were in a simple rectangular form rarely introducing any irregular corners, many designs by the control groups were angular and irregular in form. Later, in the students’ selection of the best 20K House design, the two selected were both rectangular form, this indicates that students later recognized that simplicity in form leads to low cost in overall design.

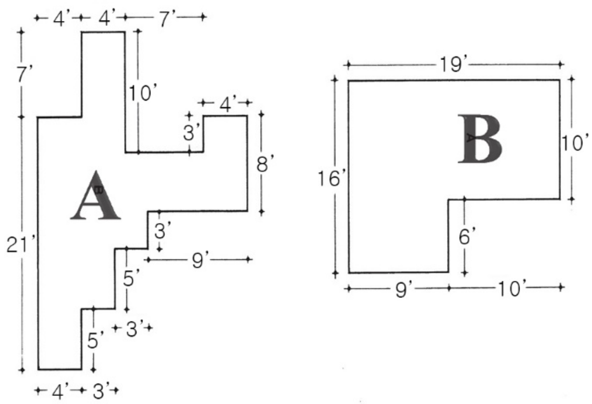
4. Wall

The students’ proposal for the exterior wall materials were similar for both groups, they were well-balanced mix of wood paneling, wood siding, corrugated metal paneling, or standing seam metal paneling. As majority of exterior walls were simple following simple form of the houses, the major evaluating criteria was made on the proposed materials (C. Hunter, personal communication, January 29, 2016). In exception to one (1) project from the control group that proposed using a sandwich insulated panel with a cedar siding, students’ treatment on wall were all very similar. This little variation in wall between both the control and treatment groups resulted in similar mean scores. Thus, there was not a strong distinction between the two (2) groups.

Students in both groups proposed wood siding in various width or board and batten. Knowing higher cost for metal paneling, only one (1) student from each group proposed standing seam metal panel and one (1) student from the control group proposed stucco. It appeared from the instructor's journals that students were drawn to wood panels from personal familiarity and pre-existing perception of affordable housing. All 20K House projects from the Rural Studio and existing residences at the Falls Creek Ranch were finished with inexpensive wood siding.

It is true that siding is the most commonly used exterior wall materials. According to data from the Census Bureau's Survey of Construction (SOC), 55% of new homes constructed in 2013 used either wood, composite, or vinyl siding (Chaluvadi, 2014). Without full comprehension of various siding materials, most students in both the control and treatment groups indicated wood siding. This results led to instructor's disappointment in the level of research among students.

However, greater differences between groups were identified through numbers of corners forming houses and average wall height. The number of wall planes resulting corners demonstrated magnitudes of complexity of building form. The average number of exterior wall planes for control group was 8.3 planes opposed to 7 planes for treatment group. The statistical analysis discovered that this difference is significant between two (2) groups although difference in (1) plane may not appear as abundant.



Floor area for both A and B is 244m2

Perimeter length of external wall
Building A = 100m
Building B = 70m

Assuming a 3m storey height, wall to floor ratios:
Building A = 1.23 (100m x 3m) = 300m2/244m2
Building B = 0.86 (70m x 3m) = 210m2/244m

Figure 23: Cost implications of design variables (Ibram, 2012).

The number of corners shaping building influenced foundation, structural framing, floor, and roof. Ibram (2012) spoke the importance of budget and financial awareness at the 2012 RIBA Conference. Ibram explains that given the exact same square footage of floor, the additional number of corners complicate the plan shape. Therefore, the different number of corners give different perimeter length and change overall square footage of walls (see Figure 23). The average number of exterior wall corners for the control group was eight (8) corners as opposed to seven (7) corners for the treatment group (see Figure 24). This result discovered to be statistically significant in their difference. Furthermore, when the same number of wall height is applied, the difference even becomes larger.

Control Group Treatment Group

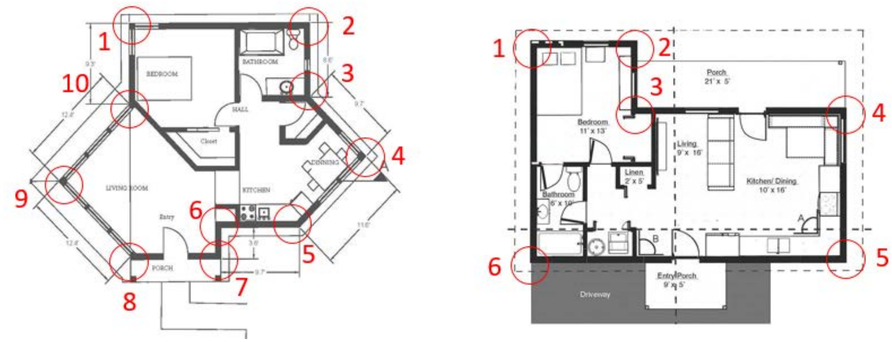


Figure 24: Wall - difference in the number of corners between the control and treatment groups

Although students in the control group were drawn to complex plan shape with many corners increasing the cost to the building, the average building height as a whole was measured to be at 10.57 feet in height, which is two (2) feet lower than what was proposed by the treatment group. In 2006, the NewYork Times identified design trends in the increase of the average ceiling height in residential projects. The article stated that between 1995 and 2004, the eight feet average ceiling height was replaced by nine feet height, and it keeps increasing. At the same time, mass production housing also led to a standard for low ceilings. Developers looked to create the most housing for the least cost, and decorators advised the use of dark floors, to make that plane recede, and vertical accessories, like floor-to-ceiling drapes, to maximize the appearance of height (Bernstein, 2006). The students in the treatment attempted to follow most current design trend in building height, but as they kept the building shape simple, they increased the volume of the building thus increasing the overall wall square footage thus. It concludes that the students missed the opportunities in interlinking variables to approach well-round decisions.

5. Doors and Windows

The mean score difference between doors and windows were the highest among cost indicators identifying statistically significant difference in both the control and treatment groups. Difference in the control and treatment group were particularly prominent when their design solutions for doors and windows were compared. A number of doors, a number of door types, a number of windows, a number of window types, and total glazing area proposed per student' design were calculated. In exception to the number of door types proposed per house, significant differences were found between two groups.

The control group proposed average six (6) doors while the treatment group only indicated average five (5) doors in their 20K House design. The statistical analysis found a significant difference between the two (2) groups with one-sided p-value at 0.028 ($p\text{-value} < 0.05$). Both groups proposed the average three (3) door types in the 20K House design, thus statistical analysis found no significant difference between the two groups as for the number of door type. Evidently, the three (3) basic types proposed are exterior entry door, interior door, and some type of utility doors for a closet or storage. Most difference was found in the bathroom doors. Many students from the control group proposed double access to the bathroom, meaning an access through a bedroom and another from public space such as a living room or through hallway, and obviously this accounted toward additional door. Since the views were toward the pond in the rear, additional door type such as a French door or sliding door were also found in their design. In a positive note, the students in the control group try to fulfill many different aspects of residential needs beyond basic, when the students in the treatment group kept their design simple and practical (see Figure 25).

Control Group Treatment Group

Figure 25: Doors and windows- difference in the number of doors between the control and treatment groups

The total number of proposed windows, number of window types and sizes, and total SF of glazed area were found to be significantly different between the two (2) groups. While the average number of windows was approximately 13.7 for the control group, it was only 9.3 for the treatment group. The control group designed to use over five (5) different window types, while the treatment group proposed in between two (2) to three (3) different window types. In addition, the most window sizes proposed by the treatment group's design were concurrent with the industry standard dimensions, while the control group proposed custom size windows at many incidents. Many students in the control group designed windows to suit their design alignments or modules, therefore most of the windows turned out to be oversized and custom size. Triangular and trapezoid shapes were often found following the roof slopes as well. However, students in the treatment group learned about industry standard sizes. Not only had this applied to doors and windows, but also to thickness and sizes of most construction materials. For this reason, evaluators assessed the control groups' proposals on windows and doors as excessive and high cost, but moderate and low for the treatment groups. Ribbon windows, full height windows, or full length clerestory windows were often proposed by the control group and these were deemed more expensive in their evaluation.

Control Group　　　　Treatment Group

Figure 26: Windows - difference in the number of windows, window types, and total glazing area between the control and treatment groups

Even more eminently, custom design windows were often found in the 20K House designs by the control group students. Triangle or trapezoid shaped windows following the unique shape of building form or roof slope were evident. Almost every window was unique in its size and shape. Full height windows, extra-large windows over 6’ in both length and width were also frequently found. As discussed earlier, industry standard size windows are more economic in their price (P. Turney, personal communication, December 2, 2015). Comparably, most students in the treatment group used industry standard size windows with minimum number of variation in window sizes and types. However, it was commented during the final design review that (2) of the 20K House design appeared to lack desirable lighting and views. Moreover, beyond being practical and efficient, these (2) designs appeared to be inappropriate.

The Section 1205, Lighting under the Chapter 12, Interior Environment of International Building code (International Code Council, 2012) mandates that the minimum net glazed area for one or two dwelling residential building shall not be less than 8% of the habitable floor area. Given the habitable floor area at 600 S.F., this 20K House only requires approximately forty-eight (48) S.F. of glazing area to allow for the natural light and ventilation. While this was explained to both groups, the average glazing area for control group was excessively addressed at 257.27 S.F. The treatment group's design had an average glazing area of 138.61 S.F. (see Figure 26).

In exception to one (1) 20K House design by a student in the treatment group, both control and treatment group's design satisfied and exceeded the building code of the minimum glazing area at 8% of all habitable rooms. Given the 20K House program's required interior space at 600 S.F., minimum of 48 S.F. of overall glazing area must have been met. The average overall glazing area for the control group was 257 S.F. exceeding the minimum S.F. approximately by six times, and ranging from 86 S.F. to 463 S.F. While still exceeding the minimum glazing area by three times more at average, the treatment group's design demonstrated average 138 S.F. of glazing area ranging between 36 S.F. and 355 S.F. Large void in the building envelope (as glazing) has an effect to horizontally extend the space of the house to exterior and connect between interior and exterior spaces (Ching, 2010). However, if overly designed, it makes it difficult to control the interior temperature and daylighting, increasing cooling and heating cost in its maintenance depending on its orientation. The U.S. Department of Energy recommends that following building code, windows shall be designed to provide adequate daylight level and to take advantage of desire views thus condition at specific site must be considered and well-studied (the U.S. Department of Energy, 1997). These results in students' doors and window design indicates that the treatment group was more conscious to the sizes and types when designing doors and windows. Especially with regard to the window design, students began to recognize cost implication of window as a building product, and collectively began to consider lighting, view, and energy efficiency associated to their design decisions. Lastly, students in both groups did not make clear indications of material selections (eg. vinyl, metal, or wood) for both doors and windows, thus no comparison was made.

6. Roof

The mean score comparison of roof did not demonstrate notable differences between two groups. The form of roof and materials proposed mostly drove evaluation of the roof (C. Hunter, personal communication, January 27, 2016). The number of roof planes displayed the complexity of roof form proposed by both groups. Approximately, an average of two (2) more roof planes were proposed from control group design and the statistical analysis was proven to be significantly different between the two (2) groups. Complexity in roof form, led to complexity in structural framing and it was equally reflected in the structural framing evaluation. There was no curved roof proposed by students in both the control and treatment groups. Therefore, a higher number in roof planes led to higher cost.

Control Group Treatment Group

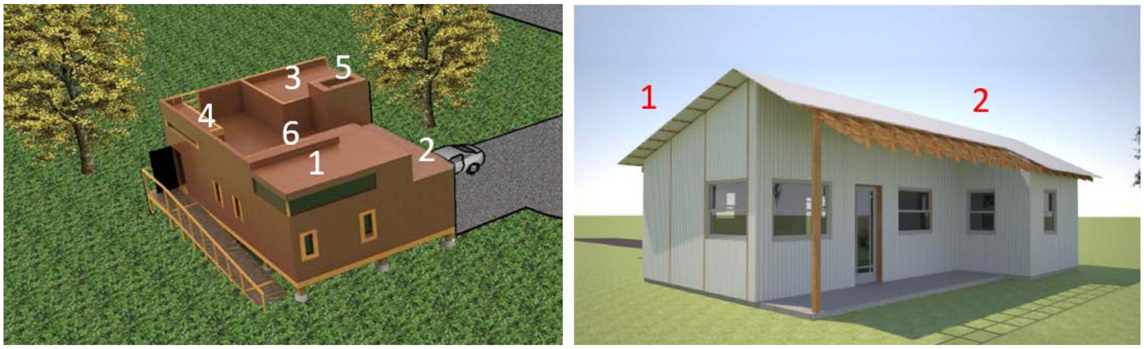


Figure 27: Roof - difference in the number of roof planes between the control and treatment groups

Although it was found to be statistically significant, the complexity of the roof was also conjugated with complexity of structural framing and wall. The complexity in roof expressed in the number of roof planes, consequently resulting in joints. The average number of roof planes designed by the control group was four (4) planes while it was two (2) planes for the treatment group. The average of two (2) roof planes indicate that the treatment group proposed simple shed roof or gable roof. While maintaining the simple roof form, students in the treatment group expanded and explored design ideas by proposing a roof with two different roof pitch, extending portions of roof covering habitable exterior areas, purposely uncovering parts of roofs where can be exposed to weather, or delving into roof assemblies (see Figure 27).

Most students in the control group proposed standing seam metal roofing, and the students in the treatment group proposed mixture of asphalt shingles, corrugated metal, and standing seam metal. Many of the Rural Studio houses use corrugated metal roofing (Freear et al. 2014), and composite asphalt shingles were used for all existing residences at the Falls Creek Ranch. For their proposed roofing materials, quantifiable scores of (1) for asphalt shingles, (2) for corrugated metal, (3) for standing seam metal, and (4) for others were used. Most roof designs were proposed using either corrugated or standing seam metal roofing from the control group, and one (1) design from the control group contained a concrete slab roof with parapets. On the other hand, it was equally varied between asphalt shingles, corrugated, or standing seam metal for the treatment group. One (1) design carried same exterior wood plank paneling to the roof proposing continuous materials in both the wall and roof.

7. Floor

When comparing two groups mean scores for floor, the result indicated significant differences in students' design. None of students in both the control and treatment groups proposed any particularly unique treatments in floor. Therefore, complex floor shapes and proposed flooring construction and finishes dictated evaluation scores. The 20K House designs of the treatment groups were represented in simpler rectangular shapes inferring simpler construction and material costs.

The complexity of floor was identified by measuring overall perimeter length of floor. The average perimeter of the floor was three (3) feet more for the treatment group, therefore, no statistical significance was found between the two (2) groups. The distinct difference in floor design between the two (2) groups was found in their use of the foundation slab (see Figure 28).

Control Group   Treatment Group

Figure 28: Floor - difference in the use of foundation slab between the control and treatment groups

Similar to the differences in the evaluators' mean score comparison, the instructor's evaluation shows significant difference in students' design of floor. The difference was evident in the use of slab on grade foundation. The same number of students from both the control and treatment groups proposed the slab on grade foundation type. However, only the treatment group took advantage of slab on grade by applying concrete hardener and sealer for interior use, thus the foundation holds double functions as floor as well. Most control group students applied additional layering of floor using hardwood, carpet, or tile. This is interpreted as that while the treatment group paid more attention to added cost by applying additional layers of material in its recommended assembly, students in the control group was more concerned with industrial aesthetics of concrete floor.

Addressing the complexity of floor, students in both the control and treatment groups worked with the same required maximum square footage of 600 S.F. with maximum 150 S.F. for entry stoop and porch. Although there were slight variations in building perimeter length due to different shape, but no prominent difference was identified in comparison. Similarly, there was not a notable difference in students' design in circulation. Students in general tried to eliminate unnecessary circulation passage or steps and utilized every square footage into adequate spaces.

8. Circulation

Due to such small square footage required in the project, students in both group utilized every square footage available reducing dead spaces or unnecessary circulation spaces such as hallways and stairs. As noted in the instructor's journals, students in both groups aimed for open-plan designs, which allowed no internal division between kitchen, dining, and living allowing open flow between spaces. The same number of (3) students out of thirteen (13) students from each group proposed post and pier foundation requiring stairs to access raise platform adding handicap ramps. Therefore, no significant difference between the two groups mean scores was found.

A similar range of mean scores for the circulation (stairs, hallways, and steps) was found in both the control and treatment groups. This was evident due to the equal number of post and pier foundation type proposed from the each group and simple architectural programing to design a 600 S.F.

house. Only one (1) students from the treatment group, and (2) students from the control group established a long hallway for almost the entire length of the building connecting spaces, while the rest insisted on open floor plan without creating any hallway. One (1) student from the control group proposing a two-story house mandating a flight of stairs. However, the overall mean score of the circulation complexity was not noticeably different between two (2) groups.

As previously explained, cost indicators such as 9. Area, 10. Materials and Finishes, and 11. Complexity, apply to all other cost indicators representing physical building elements. Thus the detail findings in their application to individual cost indicators representing building elements were already discussed above.

9. Area

Since the maximum building area of 600 S.F. was instructed to both groups, the overall building area between two (2) groups did not generate any difference. However, when applied to the other building elements, significant differences between two (2) groups were found in area as it applied to driveway paving area on site, wall area at various heights, and window glazing area.

10. Material and Finishes

As materials and finishes indicates the very outer layer of any building parts, it applies to all building elements. As there are so many different variations and kinds of materials and finishes to choose from, their range in cost is extensive. When comparing two (2) group's design decisions on materials and finishes, significant differences were found in all other indicators in exception to roof. First, the many students in the control group chose concrete for driveway paving at an average length of 69 feet. The control group experimented with light and heavy gauge metal in structural framing which have higher cost value without added structural value when compared to the conventional wood framing. Lastly, many students who proposed slab on grade foundation type among the control group, also proposed various flooring materials such as carpet, vinyl flooring, or hardwood instead of utilizing the slab foundation as the floor with coating.

11. Complexity

The levels of complexity associated with individual building elements, represent the overall complexity of the building. Evidently, simple form is easier and cost less to build. The significant differences were found in the number of corners in exterior walls and the number of roof planes between two groups. The number of variation in windows and doors sizes and types were also found to be significantly different between two groups. Many students in the control group attempted to complicate the forms to represent unique design in their creative effort, however, the most students in the treatment group tried to stay simple with less variation. While it generate differences between two (2) groups comparing the level of complexity in their 20K House designs, two (2) of 20K House designs did not present any improvement beyond what we commonly see as affordable housing and the designs were unfortunately cost driven.

Correlation Between Cost Indicators

In addition to the t-score results, correlation between cost indicators' mean scores for both groups were discovered. Although all indicators are interlocked affecting each other physically, not all evaluation scores of each indicators were discovered to be statistically correlated. This result does not measure effectiveness of cost indicators, but consistency in evaluator's evaluation of students' cost effective solutions for each cost indicators. When individual design solutions of cost indicators were analyzed to identify their correlational relationship, prominently high correlations were found between cost indicators in treatment group than the control group. Eight (8) reasonable correlations and four (4) fairly high correlations between cost indicators were found within the control group while nine (9) reasonable correlations and twelve (12) high correlations were found within the treatment group (see Table 20 and 21). This results indicated that both the intuitive act by the control group and instructed outcome by the treatment group have resulted positively. However, this infers that the treatment group had better consideration toward cost indicators and better understanding of how each one influences another. The strong correlational relationships among cost indicators from the treatment group also indicates that the students' design decision in reference to cost indicators support to increase awareness in their financial implications.

In exception to the correlated relationship between the structural framing materials and the roofing materials for the control group resulting $r = 0.402$, the structural framing materials for the treatment group was found to be uncalculatable. Since all (13) projects from the treatment group proposed the conventional wood framing for their structural framing, which is numerically converted to “1”, the correlation coefficient was unable to be mathematically calculated between itself and any other cost indicators. Since everyone chose the conventional wood framing for their answer, everyone ended up having the same numeric value that equals to “1”. As a result, the standard deviation of these values turned out to be “0”, which made the mathematical calculation of correlation between itself and other cost indicators impossible.

While the cost indicators are related to each other in one way or another, a fairly high correlational relationship was discovered in both group’s foundation types and floor materials. They discovered a fair correlation of $r = 0.483$ for the control group and a high correlation $r = 0.693$ for the treatment group. Secondly, the number of exterior wall planes and the number of roof planes along with the length of floor perimeters were reasonably highly correlated. A high number of wall planes also led to high number of roof planes with $r = 0.416$ for the control group and high correlation $r = 0.433$ for the treatment group, similarly lengthy floor perimeters indicated high number of wall planes resulting $r = 0.455$ for the control group and high correlation $r = 0.691$ for the treatment group.

Interestingly, an increase in wall height also meant decrease in the number of door types for both groups resulting negatively fair correlation of $r = -0.440$ for the control group and $r = -0.466$ for the treatment group. A negative correlation was also found between the wall height and circulation complexity. Higher the building, the lesser steps or hallway connection areas were presented with a strong negative correlation at $r = -0.541$ for the control group and $r = -0.485$ for the treatment group.

Although multiple correlations were calculated to identify correlational relationship between the magnitudes of areas, materials and finishes, and complexity for the doors and windows, only the number of doors and the number of door types indicated common correlation for both groups. As students added more number of doors into their design, they also introduced new types of doors to add variations to the design and functionality. Such a strong relationships were measured resulting correlation coefficients at $r = 0.595$ for the control group and $r = 0.823$ for the treatment group. Lastly, an increase in the number of windows resulted increase in glazing area square footage.

Finally, in order to validate the adequacy between the evaluation matrix score means and the researcher's evaluation for both groups. As shown in below Table 20, the statistical analysis discovered the relationships between evaluation mean scores and individual cost indicators evaluation by the instructor. Apparently, not all variables were found to be significantly correlated. Strong correlations of evaluation mean scores for both the selected evaluators and the instructors were found in site, structural framing, wall, doors and windows, roof, and circulation. This was anticipated because strong correlation was previously found in between structural framing and roof for both the control and treatment groups (see Table 20 and 21). Structural framing and roof visually inform the complexity of form of the enclosure of the house, and often roof framing is understood as an inclusion of structural framing (Ching, 2014).

While its correlation coefficients indicated that proposed site materials and its evaluation score means were not related, the length of its driveway was notably correlated with its given evaluation mean scores resulting $r = 0.812$. Such result implies that evaluators focused more on the placement of the houses when reviewing for site, and proposed material was not a significant factor in their evaluation. Different types of foundation in students' design apparently did not affect the evaluation scores either. Proposed structural materials whether they are metal or wood, however, strongly influenced the evaluation scores demonstrating strong relationship by $r = 0.514$. The results in the wall indicated that the number of exterior wall planes and average wall height did not influenced the evaluation, thus no significant factor affecting the wall evaluation was found.

Although the doors and windows were categorized as one cost indicators, its correlation coefficients indicates that while none of measurable indicators for doors impacted the evaluation scores, all measurable indicators for windows remarkably influenced the evaluation scores. Especially the relation between the number of windows and square footage of glazing area were predominant indicating correlation coefficients of $r = 0.800$ and $r = 0.769$. This result is also, associated with previously mentioned correlational statistics that, square footage of glazed area and number of windows were strongly interrelated for both groups.

The correlation coefficient (*r*) indicates that the selected evaluator's mean score is highly related to windows in its number and size, and yet students' design in door did not significantly influenced the evaluation scores. This explains that the solid and void ratio in the exterior enclosure noticeably impacted the financial implication of the building. Table 22 also, shows that the number of doors or door types did not make any major impact on the selected evaluator's mean scores. Although doors and windows were categorized as one cost indicator, this result implies that given the project program of a small one bedroom and one bathroom house, the reviewers understood that resolution of door as a cost indicator was similar across students in both the control and treatment groups, not making significant difference to the overall cost. In summary, the correlations between the two separate evaluations were moderately and strongly related confirming concurrent evaluation of student's design solutions based on cost indicators and leading toward the same conclusion in their evaluation.

Table 20: Pearson correlations (r) between students design decisions for the control group

Cost Indicators			Site		Found	Str. F	Wall		Doors & Windows					Roof		Floor		Circ ul
			1a	1b	2	3	4a	4b	5a	5b	5c	5d	5e	6a	6b	7a	7b	8
Site	1a	Complexity (ft)	1.00															
	1b	Materials	0.25	1.00														
Found.	2	Complexity (Type)	-0.22	0.04	1.00													
Struct. Framing	3	Materials	0.02	0.11	0.16	1.00												
Wall	4a	Complexity (# of Ext planes)	0.08	-0.15	0.06	0.28	1.00											
	4b	Complexity (Average HT)	**-0.44**	0.28	0.15	-0.27	-0.11	1.00										
Doors & Windows	5a	Complexity (# of Doors)	0.32	-0.14	-0.02	0.06	0.27	**-0.44**	1.00									
	5b	Complexity (# of Door Types)	0.24	0.15	-0.19	0.14	-0.12	**-0.44**	**0.59**	1.00								
	5c	Complexity (# of Windows)	0.14	0.01	0.00	0.35	-0.01	-0.12	-0.11	-0.043	1.00							
	5d	Complexity (# of Window Types/Sizes)	-0.17	-0.20	0.03	0.24	0.09	0.07	0.01	0.009	**0.52**	1.00						
	5e	Area (Opening in SF)	0.34	0.06	0.18	0.17	-0.03	-0.27	0.04	0.024	**0.72**	0.45	1.00					
Roof	6a	Complexity (# of Planes)	0.29	0.23	0.14	0.32	**0.41**	-0.03	0.32	0.117	0.30	0.27	0.19	1.00				
	6b	Materials	0.09	-0.16	0.13	**0.40**	0.35	-0.23	0.23	0.167	0.06	0.07	-0.17	**0.45**	1.00			
Floor	7a	Materials	-0.08	-0.04	**0.48**	0.11	0.19	0.11	0.21	0.012	0.03	0.38	0.12	0.38	0.32	1.00		
	7b	Complexity (Perimeter in ft)	0.07	-0.06	0.02	-0.17	**0.45**	-0.04	-0.07	-0.318	0.02	-0.20	0.09	0.14	-0.24	-0.09	1.00	
Circul.	8	Complexity (Hallway Length, Stairs, & Steps)	0.37	-0.17	0.27	0.20	0.29	**-0.54**	0.27	0.015	-0.04	-0.28	0.12	0.20	0.26	0.05	0.08	1.00

Table 21: Pearson correlations (*r*) between students design decisions for the treatment group

Cost Indicators			Site		Found	Str. F	Wall		Doors & Windows					Roof		Floor		Circ ul
			1a	1b	2	3	4a	4b	5a	5b	5c	5d	5e	6a	6b	7a	7b	8
Site	1a	Complexity (ft)	1.00															
	1b	Materials	**0.63**	1.00														
Found.	2	Complexity (Type)	-0.20	0.05	1.00													
Struct. Framing	3	Materials	-	-	-	1.00												
Wall	4a	Complexity (# of Ext planes)	-0.02	-0.17	0.20	-	1.00											
	4b	Complexity (Average HT)	-0.05	0.06	-0.01	-	0.12	1.00										
Doors & Windows	5a	Complexity (# of Doors)	0.06	0.24	-0.06	-	0.35	-0.20	1.00									
	5b	Complexity (# of Door Types)	0.34	0.32	-0.19	-	0.06	**-0.46**	**0.82**	1.00								
	5c	Complexity (# of Windows)	0.01	0.18	0.31	-	-0.33	0.31	-0.22	-0.23	1.00							
	5d	Complexity (# of Window Types/Sizes)	-0.20	0.21	0.15	-	0.06	**0.44**	0.16	-0.07	0.06	1.00						
	5e	Area (Opening in SF)	0.17	0.35	0.79	-	-0.18	0.15	-0.12	-0.14	**0.59**	0.23	1.00					
Roof	6a	Complexity (# of Planes)	0.25	**0.54**	0.00	-	**0.43**	0.22	**0.48**	0.27	-0.01	0.16	-0.01	1.00				
	6b	Materials	0.28	**0.53**	**-0.42**	**-**	**-0.45**	-0.17	0.08	0.17	0.30	**-0.62**	-0.25	0.38	1.00			
Floor	7a	Materials	-0.20	-0.02	**0.69**	**-**	**0.43**	0.15	0.19	0.01	0.03	**0.52**	**0.50**	0.18	**-0.64**	1.00		
	7b	Complexity (Perimeter in ft)	0.18	-0.28	0.20	-	**0.69**	-0.01	-0.14	-0.24	-0.16	-0.35	-0.28	0.28	**0.48**	0.21	1.00	
Circul.	8	Complexity (Hallway Length, Stairs, & Steps)	0.36	0.23	**0.53**	-	0.03	**-0.48**	0.12	0.12	-0.04	-0.28	0.01	0.01	-0.14	0.27	0.21	1.00

Although its proposed materials for the roof did not strongly dominate its evaluation scores, the number of roof planes visually expressing its complexity has found to be affecting scores by the evaluators indicating noticeably strong correlation of $r = 0.737$. Evidently, the materials were not evaluating factors for both the site and roof. Comprehensively, the length of hallway connecting spaces within the spatial layout shown in floor plans, and number of steps and stairs were found to be strongly related to evaluation scores of circulation.

Overall, the statistical data identified that most indicators and their evaluating scores by selected reviewers suggested a range of moderate and strong positive correlational relationship. This has stipulated that such use of high cost materials and complexity in form would logically lead to high cost remark in their evaluation.

Table 22: Pearson correlations (*r*) between instructor and selected evaluators' mean scores for both the control and treatment groups

			Evaluation Scores (Refer to Table 10 for mean and p-value of evaluation scores)							
			Site	Found	Struct. Frame	Wall	Doors & Windows	Roof	Floor	Circulation
Site	1a	Complexity (ft)	**0.812**							
	1b	Materials	0.137							
Foundation	2	Complexity (Type)		-0.310						
Structural Framing	3	Materials			**0.514**					
Wall	4a	Complexity (# of Ext planes)				-0.264				
	4b	Complexity (Average HT)				-0.097				
Doors and Windows	5a	Complexity (# of Doors)					0.039			
	5b	Complexity (# of Door Types)					0.066			
	5c	Complexity (# of Windows)					**0.800**			
	5d	Complexity (# of Window Types/Sizes)					**0.564**			
	5e	Area (Opening in SF)					**0.769**			
Roof	6a	Complexity (# of Planes)						**0.737**		
	6b	Materials						0.244		
Floor	7a	Materials							0.296	
	7b	Complexity (Perimeter in ft)							-0.269	
Circulation	8	Complexity (Hallway Length, Stairs, & Steps)								**0.650**

5.2.3 20K House Design: Student Selected Design and Preliminary Cost Evaluation

At the end of the semester, students from each group were instructed to select the two (2) best 20K Houses design. The students were instructed to make the selection based on project goals to design various small house types with assurance of their feasibility and constructability under a budget of $20,000 and to provide unique and time-less design solution both spatially, formally, and yet, realistic and practical. The intent was to compare the two (2) selected projects as they are voted to be representing the most successful projects from each group. Given that there were thirteen (13) projects from each group and individual student selected two (2) projects, a total of twenty-six (26) votes were submitted. Students' votes were compared to the overall evaluation scores by the evaluators. Students in both groups did not provide well-articulated reason for their selections, but most students have indicated that their decisions were based on the simple form of the houses.

Students from the control group have voted Wood Glazed House and Timbertiilt (see Figure 29) as they represent the best examples. Each has received (6) votes indicating that everyone in the group selected at least one of these two (2) projects. The treatment group went through the similar process to select the best two (2) 20K Houses. The students in the treatment group selected Tin House and Woodridge House (see Figure 30) with six (6) and four (4) votes respectively.

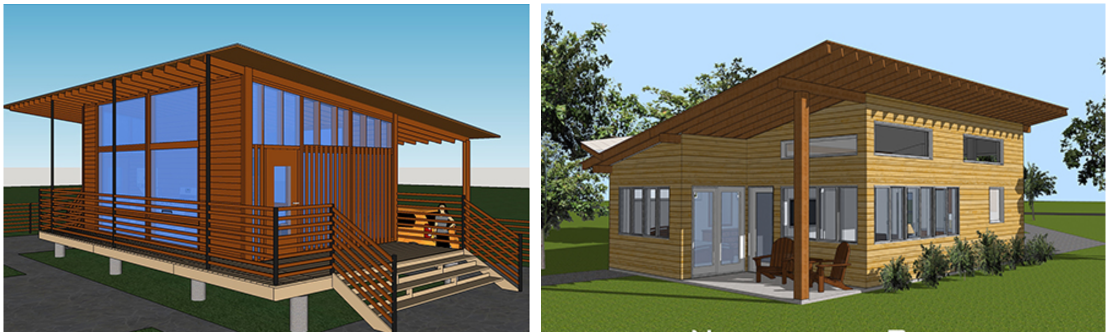


Figure 29: (Left) Wood Glazed House, (right) designed by the control group

Figure 30: (Left) Tin House, (right) Woodbridge House by the treatment group

These selections were not exactly concurrent with the evaluation score means in exception to Tin House from the treatment group. The lowest total mean score representing the low cost in building, Timbertillt and Wood Glazed House were evaluated at the 8th and the 7th place at the midst range within the control group. The control group' evaluation criteria in affordable design appeared different from how they were evaluated by the reviewers. On the other hand, Tin House from the treatment group was evaluated as the lowest cost based on the total evaluation mean scores. Woodbridge House was evaluated as the 5th place. Tin House by one of the students in the treatment group was voted the most by the fellow students, which was also evaluated as the most cost efficient house by the selected reviewers. Cost conscious design does not mean the lowest cost, therefore this research does not look for the alignment of the students' selections and the evaluator's mean score ranks. However, this result reveals that the students in the treatment group have developed well round eyes to examine architectural projects beyond a glimpse of the formal complexity, but also by scrutinizing the projects by cost indicators to reach sound evaluation of projects.

Comparing the four (4) projects' site designs, three (3) projects proposed gravel as site driveway material, and Wood Glazed House has proposed concrete. While (2) projects from the treatment group proposed moderately short driveway at approximately fifty-six (56) feet, Timbertiilt was placed eighty-eight (88) feet away from the main street, and the driveway of Wood Glazed House was approximately fifty-two (52) feet in length. In exception to Wood Glazed House, all three (3) projects showed the slab on grade foundation. However, the two (2) projects from the treatment group took advantage of the concrete as the finished floor, and Timbertiilt proposed additional carpet and vinyl flooring layers on top of the slab on grade foundation. Wood Glazed House from the control group was on post and pier creating a platform floor with stairs to enter the house through its front porch.

Following project recommendations, all four (4) projects were framed using the conventional wood construction using 2x6 lumber for the exterior and plumbing walls, and 2x4 for the interior walls. Both Timbertiilt and Wood Glazed House have average clear height at twelve (12) feet, and Tin House was lower at ten (10) feet in height. Wood Bridge House showed fifteen (15) feet average clear height, which was the tallest within the treatment group. While the number of corners at the exterior walls, wood siding as the exterior finish, the total number of doors and windows were similar for all four (4) projects, the significant difference was found in the proposed amount of the glazing area. While the two (2) projects from the treatment group purposely used standard size windows with minimum variation in size, the two (2) projects from the control group proposed various custom sized and shaped windows, and clerestory windows. Many full height windows were particularly displayed in Wood Glazing House.

Similarity among the four (4) projects was evident in their visual form. The selected 20K Houses from both groups were in the simple rectangular form with minor modification, and their simplicity in the roof form was also comparable presenting either one (1) plane of slanted shed roof or two (2) planes of hip roof at the most. While Woodbridge House proposed wall wood siding to be use for roof finish completing wrapping the wall and roof intersecting edges, the other three (3) project proposed the metal roofing.

Based on students' selection, the researcher conducted preliminary cost estimations of the four (4) projects based on cost indicators (see Table 22). As indicated in the Chapter 4.2, any interior furnishings, mechanical system, electrical and plumbing systems, equipment, appliance, and landscaping were not taken into consideration due to their inappropriateness for the second-year architectural design studio course thus, it also was not deemed in the preliminary cost estimations. Estimating the construction cost of students' shell and core design, all four (4) projects were calculated to be exceeding the budget of $20,000.

Table 23 shows preliminary cost estimation of the student selected (4) projects from both the control and treatment groups. The $20,000 as a construction budget is difficult to conceive, even for the Rural Studio projects. When tested in construction, (2) prototypes of the Rural Studio's 20K Houses with connection porch costed $135,000 to build (Fox, 2016). However, the purpose of putting in this inspiring dollar value was for students to build a mindset of financial awareness.

As can be seen in below Table 23, the two (2) projects from the treatment group are similar in estimated cost and much lower than the estimated cost of the two (2) control group projects. However, they were still exceeding the $20,000 budget and were both estimated at approximately $30,000. On the other hand, the two (2) projects from the control group were estimated to be twice or more over the budget. Wood Glazing House was estimated closed to $50K and Timbertiilt was estimated at $35K much exceeding the budget as well. This cost estimation was based on the building assembly students demonstrated in the presentation boards. This was also based on the core and shell construction, and mechanical, electrical, plumbing, interior fixtures, appliances, and landscaping were excluded from this preliminary cost estimation.

All four (4) students chose wooden framing, and their costs were similar. However, the cost estimation in site and windows were vastly different. Longer driveway toward the house added cost, and concrete paving in such length added even more cost for site. One (1) project from the control group proposed the post and pier foundation type, which was less expensive than the slab on grade foundation type, but it eventually costed more to build the platform for floor and stairs to access. With no particular criticism to Wood Glazed House, proposing concrete pavement for the entire fifty-two (52) feet length of driveway at twelve (12) feet width and space to allow for cars to turn around and park, it cost much higher than installing loose gravel.

Comparing the cost estimations of projects from one group to another, the predominant difference was found in their windows. The cost in wall and windows caused the vast difference between the groups. Timbertiilt has the total glazing area at 232 S.F. and Wood Glazing House shows 397 S.F. of glazing enclosure, which is close to nine (9) times more than what is required. Although it was still twice more than the required minimum glazed area, Tin House and Woodbridge House indicated moderate total glazing area of 98 S.F. and 77 S.F. While the (2) treatment group projects proposed minimum number of windows types in industry standard dimension at reasonable glazing area, the control group projects proposed custom size windows with much larger glazing area. Therefore, while their cost in exterior wall siding may be less than the (2) treatment group projects, their window costed much more than double of the treatment group projects.

The combination of excessive amount of glazing area and installation of concrete pavement have vastly increase the construction cost for Wood Glazed House. Given that it was constructed on the post and pier foundation, it automatically created raised platform with stairs to access and guardrail to secure safety from falling, it had the impact of increase in the accumulating cost.

In summary, the pretest-posttest survey discovered the difference in students' attitude toward cost as an integral design determinant, and identified its appropriateness in the second-year design studio education. Both evaluations by the selected evaluators and the instructor have discovered the significant difference in the students' 20K House design between the control and treatment groups. Cost indicators such as site, structural framing, wall, doors and windows, area, materials and finishes, and complexity were found to be more effective than foundation, floor, roof, and circulation in teaching cost as an integral design determinant in the second-year foundation design education (see Figure 31). Furthermore, the doors and windows were the most effective cost indicators among the eleven (11) indicators.

Figure 31: Cost indicators – (clockwise from the left) site, structural framing, wall, doors and windows in the magnitude of area, materials and finishes, and complexity were found to be more effective than the other indicators.

Lastly, the preliminary cost estimation conducted by the instructor also identified the actual cost difference between the control and treatment group's selected projects. While the selected four (4) projects' preliminary cost estimations resulted all over the budget, the two (2) projects from the control group were estimated to be closer to reaching the $20,000 goal.

Table 23: Preliminary cost estimation of (4) selected projects from both control and treatment groups

Project	Control Group				Treatment Group			
	Wood Glazed House		**Timbertiilt**		**Wood bridge House**		**Tin House**	
	Area (SF)	Volumn (CF)	Area (SF)	Volumn (CF)	Area (SF)	Volumn (CF)	Area (SF)	Volumn (CF)
Entry	19	247	16	176	16	208	16	168
Living Room	164	2,132	194	2,134	155	2,015	144	1,512
Bedroom	140	1,820	205	2,255	140	1,820	143	1,502
Bathroom	60	780	92	1,012	60	780	60	630
Kitchen / Dining	159	2,067	132	1,452	259	3,367	254	2,667
TOTAL:	542	7,046	639	7,029	630	8,190	617	6,479
Porch	208	2,704	110	1,210	124	1,612	124	1,302
TOTAL w/ porch:	**750**	**9,750**	**749**	**8,239**	**754**	**9,802**	**741**	**7,781**
Average Clear HT	13'		11'		13'		10.5'	

Cost Indicators	Material	Cost	Material	Cost	Material	Cost	Material	Cost
Site	Concrete	$ 4,092.00	Gravel	$ 1,777.90	Gravel	$ 1,375.94	Gravel	$ 1,375.94
Foundation	Post and Pier	$ 3,555.00	SOG	$ 3,962.21	SOG	$ 3,988.66	SOG	$ 4,052.14
Structural Framing	WD Framing	$ 8,310.05	WD Framing	$ 9,469.96	WD Framing	$ 9,851.89	WD Framing	$ 9,769.53
Wall	WD Siding	$ 2,857.25	WD Siding	$ 3,467.75	WD Siding	$ 4,166.25	WD Siding	$ 3,876.00
Doors and Windows	Doors	$ 2,074.50	Doors	$ 2,133.50	Doors	$ 3,112.50	Doors	$ 2,452.50
	Windows	$ 16,800.00	Windows	$ 5,386.00	Windows	$ 2,180.00	Windows	$ 3,910.00
Roof	Standing Seam Metal	$ 5,250.00	Standing Seam Metal	$ 5,243.00	WD Siding	$ 4,810.52	Corrugated Sheet Metal	$ 3,064.00
Floor	Hardwood	$ 2,604.00	Ceramic Tile	$ 1,048.02	Conc Hardener and Sealer	$ 420.00	Conc Hardener and Sealer	$ 420.00
	Ceramic Tile	$ 728.00	Carpet	$ 1,595.70				
Circulation	WD Stairs	$ 460.00	-		-		-	
SUBTOTAL		**$ 46,730.80**		**$ 34,084.04**		**$ 29,905.76**		**$ 28,920.11**
(Porch)	WD Decking with Guardrails	$ 2,653.60	Concrete Slab	(included)	Concrete Slab	(included)	Concrete Slab	(included)
		$ 49,384.40		**$ 34,084.04**		**$ 29,905.76**		**$ 28,920.11**

CHAPTER VI

CONCLUSION

This study demonstrated that there is a gap in architectural education pertaining to the topic of cost as a fundamental design determinant, and identified the importance of teaching the topic in architectural foundation design education. Moreover, this study revealed that the second-year design studio education is the appropriate time to introduce cost. This study developed a new second-year design course with objectives to introduce and promote cost as an integral design determinant. Cost indicators that affect construction cost were identified as they are appropriate to the second-year design students. Cost indicators were used as a device in this experiment to test and measure the effectiveness of cost indicators. As a result, this study found the impacts and appropriateness of learning cost as a fundamental design determinant, compared to the curriculum in existing second-year design studio courses. Last, this study demonstrated that considering cost while designing would promote and enhance quality design at low cost.

Figure 32: Phase 4 – a partial research diagram for conclusion (see Appendix A for the complete research diagram)

6.1 Research Implications

This research consisted of the three (3) underlying objectives addressed earlier.

- To identify the need to include foundation design education on cost as a fundamental design determinant
- To determine the indicators that contribute to cost as a fundamental design determinant in foundation design
- To determine the effectiveness of the cost indicators in the foundation design.

This research identified that academics and design professionals recognize the need and appropriateness to teach cost as a fundamental design determinant in the foundation design studio education. Furthermore, this research revealed that the second-year design studio education is the appropriate time to introduce cost as an integral design determinant because educators of the second-year design studio begin to introduce architectural elements and their associated design implications to students. Students undergoing the quasi-experiment also indicated that the benefit of learning cost as an integral design determinant in the second-year design studio education.

This research determined the indicators that contribute to cost as a fundamental design determinant in the second-year foundation design. The cost indicators of site, foundation, structural framing, wall, doors and windows, floor, roof, circulation, area, materials and finishes, and complexity were identified as elements that affect building construction cost. The cost indicators were used as the research instrument for the treatment group as well as the evaluation criteria to understand the impacts of cost determinism.

Using cost indicators as a guide, the treatment group demonstrated cost conscious and realistic approaches to design the 20K Houses. In addition, this research determined the effectiveness of each cost indicator. The cost indicators of site, structural framing, wall, doors and windows, area, materials and finishes, and complexity were more effective indicators than others, as they were portrayed in students' 20K House designs.

6.2 Contribution to New Knowledge

Based on the implications of the research, this research contributes to the awareness of students in the second-year foundation design studio education about cost as an important design determinant. As they begin to acquire cost awareness while developing design skills in the architectural foundation design education, their knowledge of financial implication as required by the NAAB, would expand and mature in the accredited Master in Architecture program.

This research developed a new second-year design studio course that includes cost as an integral design determinant. Systematic approaches to improve cost awareness in the foundation design education were not researched, and this research introduced a second-year design studio course that fulfills general course objectives with additional objectives to include cost as an integral design determinant.

Last, this research identified tools that enable students to accomplish affordable design solutions. Cost indicators as an instrument, would introduce architectural elements and their cost impacts into the building cost for foundation design students. Interdisplinary approaches to support cost awareness during the foundation design studio course would enable students to understand continuous efforts to derive affordable design solutions to challenge social and financial inequality around the globe.

6.3 Recommendations

This research offers several recommendations to design educators. First, it is most important for students to build the mindset of cost awareness rather than having cost drive or limit their design creativity. Second, cost reference books are available for students. There are free online versions of cost data provided by the RS Means website, and students in cost estimation courses in the Department of Construction Science at Texas A&M University also use this online program to learn how to estimate construction projects (Interviewee I, personal conversation, January 8, 2015).

In this research, the RS Means cost analysis reference book was used to introduce preliminary cost estimation by the guest lecturer, Dr. Ben Bigelow in the Department of Construction Science. However, many other resources are available to architectural students in any library. A cost estimator from a renowned design firm in Seattle attested that *The Guide* (2014) is one reference book commonly used by architecture firms in Seattle (S. Ouzbiakova, personal communication, July 22, 2015). Similar to the RS Means reference book, *The Guide* is an annual publication following the sixteen (16) division MasterFormat® classification; it is easy to follow and comprehend. Thus, either *The Guide* or the RS Means reference books can be used to introduce the concept of preliminary cost estimation to young designers.

6.4 Limitations

This research had limitations in different stages of the project. As described in previous chapters, this research began with a content analysis of design studio course descriptions, syllabi, and project briefs of selected schools. Selection of schools was fairly easy, because schools offered different degree programs and the program rankings were available from various web sources. However, once selections were made in reference to the architectural program at Texas A&M University, it was difficult to find and contact the appropriate personnel who could provide the researcher with appropriate and necessary documents. Not every school had an administrative chair for its undergraduate architectural program or lower year architectural education. Multiple phone calls and emails were made and exchanged, but not all documents were stored collectively or handled by a designated person from each institution. On some occasions, it was difficult to receive a call back or e-mail response, thus it was necessary to adjust to the final school selection.

Second, some challenges arose in collecting project briefs from various schools. Some schools mandated that common syllabi and projects had to be assigned throughout concurrent studios. In some schools having similar program structure to Texas A&M University, instructors were allowed to tailor studio syllabi so it better fits their own research or design agenda. In such cases, instructors often built their own projects, which differed across design studios in the same academic year. Although the official letters approved by the IRB were sent to the selected schools indicating that the requested documents would be used only for the research purposes, instructors were concerned that their creation might be used elsewhere; thus, they hesitated to share the documents. With such concerns, some instructors sent only pdf copies of their documents or documents from previous years.

For the online survey, the number of responses from academics was much lower than anticipated, especially when compared to the number of responses from design professionals. This resulted in a small sample size for academic participants. Fortunately, the number of academic samples was large enough to analyze for the study to identify the needs to teach cost as a fundamental design determinant. This result infers a concern for the passive tendency of academics toward participating in other academic research besides their own.

From the early stage, it was predicted that a quasi-experiment would be the most effective method to test a new educational curriculum or strategy compared to any other research method. Due to the limitation of teaching appointments provided by the department, uncertainty arose about fixed timelines to conduct experiments. Fortunately, two (2) consecutive second-year design studios were used as the research laboratory, approved by the department. However, two (2) consecutive semesters inferred progressive design studio courses that “history” and “maturation” of students in the control and treatment groups attributes as exogenous variables to experimental variables (Gall et al., 1996). Early recognition of such challenges required this research to be designed as a non-equal quasi-experiment, and the dissertation committee approved its process ahead of time. Thus, students’ previous learning environment and earlier education, and the fact that students in the control group experienced an additional semester of architectural studio course were considered.

However, students' maturation influenced this research more than was expected in the beginning. First, there was difference in students' preexisting knowledge in architecture from what was anticipated. This maturity was found to be more predominant among the treatment group students in ARCH 205 than the control group. Because students were enrolled in the first-year studio courses taught by different instructors with different course agendas, their preexisting architectural knowledge was very different. Especially those who had freshmen studios with a special focus on computer generated solid forms had no preexisting experience learning basic architectural elements. This was evident when they first drew floor plans because their plans represented a wall as a single line without any means of access. These kinds of differences broadened the knowledge gap among treatment group students at the beginning of the experiment, and ultimately impeded their growth rate as a whole.

Fortunately, this was not a concern with ARCH 206 students in the control group. Although, the students also had various learning experiences in their first year, they spent the first semester of the second-year design education studying fundamentals of architecture as a building. Therefore, the difference in preexisting knowledge of architecture was insignificant. However, the researcher proposed to conduct this quasi-experiment with two (2) equal second-year student courses of ARCH 205 or 206. Because students in ARCH 206 were presumed to be similar in level of preexisting knowledge in architecture, the research was also presumed to be much more effective with two (2) equal second-year studio courses tested.

In this research, the investigator and experimenter were the same person. Therefore, there was no concern for experimenter failure to follow protocol effect (Gall et al., 1996). In contrast, this dual role can be perceived as a weakness when analyzing the findings. The dual role also implies that this experiment may not be repeated except by the same instructor. This lack of dispersal may threaten the external validity of this study. As the study focuses on cause and effect, close observation between the known and knower and how they influenced each other are significant. A particular instructor's teaching style and techniques could positively or negatively influence this experiment, thereby failing to bring about the same results, if conducted by a different instructor. To properly implement this new curriculum, well-assessed experiment protocols must be completed.

6.5 Future Research Directions

This study recommended the following areas to be considered for future research. First, a study that involves teaching cost indicators and their application to other building types than a small residential project would be beneficial. Even though a small residential project is appropriate at the second-year level, generally instructors schedule two to three different studio projects per semester. Cost indicators would provide as a guideline to help students become aware of the cost implications of their design; thus, types of building should not matter. In addition, systematic application of the cost indicators to different building types may further reveal the effectiveness of these indicators as well as students' awareness of cost.

As discovered in the pretest surveys in this experiment, often architectural students assume cost estimation is not an architect's task, but is either the contractors' or construction manager's job. Therefore, the second recommendation is to conduct a collaborative design studio with construction management majors. Construction management students must also, understand that their participation during the design phase contributes to overall success of projects and ensures the final product to represent the architect's design intent. As critical as it is for architectural students to develop awareness of cost as early as possible, it would be beneficial to examine the effectiveness of collaborative synergy by recruiting construction management students.

As continuous research following this experiment of applying cost indicators, a future research could limit foundation design students with a kit of parts in materials and more restricted design guidelines to develop a small housing design. For example, students could only use gravel for driveways, slab on grade for foundation, wood for structural framing, doors and windows in limited number, size, and type, wood panels for exterior wall, and more. Limited resources may constrain students to research newly developed materials or technology further, but this may force students to focus fully on developing unique designs. Limited resources may further contribute to students' design quality by challenging their architectural creativity with limited resources, which is often the reality many architects and designers face in building low-income and public housing.

This study also recommends monitoring the growth of students who participated in this research. The impact of this experiment may have contributed to the growth of participating students in their upper years in the architectural education. If so, the comparison could be made among three (3) groups: students in the same year who were not enrolled in the experiment, the control group, and the treatment group. Especially for the treatment group, it would be beneficial to discern their career interest and whether such a career path leads to the architectural licensure. As discover at the beginning of this research, not everyone in the pre-professional degree pursues the accredited Master in Architecture degree.

Last, future research should focus on the nature of improving design quality in affordable or low cost housing. This research revealed that teaching cost as an integral design determinant in foundation design studio courses is an effective educational method to improving students’ perspective of cost. Other educational means and methods improving design quality of students should be continuously studied and developed to improve the affordable housing industry.

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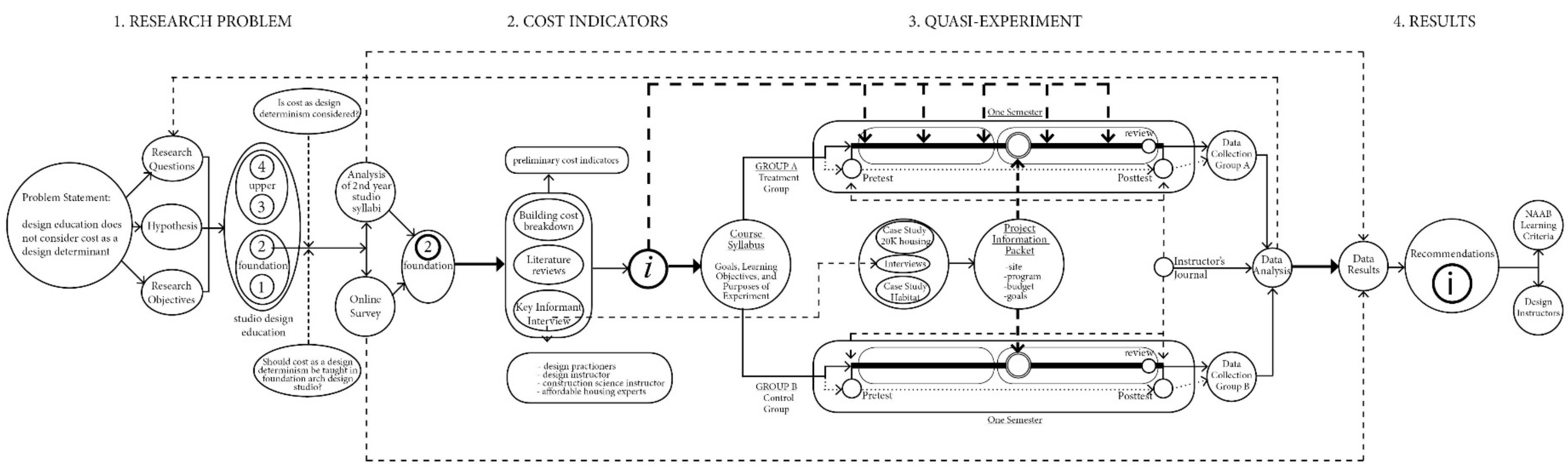
APPENDIX A

RESEARCH DESIGN DIAGRAM



APPENDIX B

ONLINE SURVEY QUESTIONS

IRB Approval #: IRB2014-0256

Approved on June 23, 2014

Consent

Project Title: A study of the impacts of affordability in foundation design education

You are invited to take part in a research study being conducted by Seyeon Lee, a researcher from Texas A&M University. The information in this form is provided to help you decide whether or not to take part. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefits you normally would have.

Why Is This Study Being Done?

The purpose of this study is to investigate the presence and the need of teaching "affordability" or "economic design" concepts in order to understand architecture and design in foundation design education.

Why Am I Being Asked To Be In This Study?

You are being asked to be in this study because you are a/an:

A. academic who is currently teaching the first or second-year design studios in an architectural institution

b. design professional who has a degree in architecture and working in a design firm.

How Many People Will Be Asked To Be In This Study?

120 people (participants) from various academic institutions and design firms will be invited to participate in this study across the United States.

What Will I Be Asked To Do In This Study?

You will be asked about your educational background and whether you think the topic of affordability is significant to be taught in the foundation design education or not.

Are There Any Risks To Me?

The things that you will be doing are no more risks than you would come across in everyday life.

Will There Be Any Costs To Me?

Aside from your time, there are no costs for taking part in the study.

Will I Be Paid To Be In This Study?

You will not be paid for being in this study.

Will Information From This Study Be Kept Private?

The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely.

Information about you will be stored in locked file cabinet; computer files protected with a password. This consent form will be filed securely in an official area. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly. Information about you and related to this study will be kept confidential to the extent permitted or required by law.

Will Photos, Videos or Audio Recordings Be Made Of Me during the Study?

The researchers will not take photographs, or make videos or audio recordings during the study.

Who may I Contact for More Information?

You may contact the Protocol Director, Seyeon Lee, PhD student in School of Architecture, to tell him/her about a concern or complaint about this research at 425-894-9129 or seyeon79@tamu.edu.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office at 1-855-795-8636 or irb@tamu.edu.

What if I Change My Mind About Participating?

This research is voluntary and you have the choice whether or not to be in this research study. You may decide to not begin or to stop participating at any time. If you choose not to be in this study or stop being in the study, there will be no effect on your student status, medical care, employment, evaluation, relationship with Texas A&M University, etc. Any new information discovered about the research will be provided to you. This information could affect your willingness to continue your participation.

STATEMENT OF CONSENT

I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I can ask more questions if I want a copy of this entire consent form will be given to me.

Yes, I would like to participate ☐ No, I will not participate ☐

My primary role in architecture is as a

Design Professional ☐ Academic ☐

Academic

1. At which institution do you teach?

2. Foundation design education refers to the first and the second-year of architectural program. Are you currently teaching a foundation design studio?

Yes ☐ No ☐

3. Do you address economic design or affordability for both hypothetical and real projects in your studio course?

Yes ☐ No ☐

4. (If Selected YES in #3) Please explain your methods and approaches to introduce economic design or affordability to your foundation students.

4. (If Selected NO in #3) If a new course was provided to address affordable and economic design to foundation design students and it would promote quality design at low cost, would you introduce these concepts in your studio course?

Yes ☐ No ☐

5. Please explain why or why not.

Design Professional

1. In what year did you graduate with a degree in architecture? (ex. 2013)

2. What is your architectural degree?

- 5 year: Bachelor of Architecture (NAAB Accredited)
- 4 year Pre-professional degree (Bachelor of Arts in Architecture, Bachelor of Science in Architecture, Bachelor of
- Architectural Studies, Bachelor of Environmental Design)
- 4 year Pre-professional degree with 2 year Master of Architecture degree (NAAB Accredited)

- Others

3. From which architectural institution did you graduate from? If you have earned degrees from multiple institution, list them all.

4. Foundation design education refers to the 1st and 2nd year of architectural program. Did you discuss economic design or affordability in the foundation design studios?

Yes ■ No ■

5. (If Selected YES in #4) how was it achieved?

5. (If Selected NO in #4) Do you think it would have been beneficial if you have learned different ways to achieve economic design or affordability in architecture?

Yes ■ No ■

6. Do you address or teach economic design or affordability in projects of your practice to your architectural interns ?

Yes ■ No ■

7. (If Selected YES in #6) Please explain your methods and approaches to introduce economic design or affordability to your architectural interns?

7. (If Selected NO in #6) Please explain why you do not discuss or teach economic design or affordability to your architectural interns.

APPENDIX C

KEY INFORMANT INTERVIEW: CONSENT FORM

IRB Approval #: IRB2014-0701

Approved on December 11, 2014

Project Title: ***The Impacts of Cost Determinism in Foundation Design Education: an analysis of cost indicators.***

You are invited to take part in a research study being conducted by Seyeon Lee, a researcher from Texas A&M University. The information in this form is provided to help you decide whether or not to take part. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefits you normally would have.

Why Is This Study Being Done?

The purpose of this study is to develop and test an instructional strategy to improve architectural foundation design education. The investigation will determine to what extend foundation design education bring positive effects in the design quality with cost as a fundamental and integral design determinant. In addition, this study will identify cost indicators to achieve quality design, and suggest ways to improve and strengthen foundation design education with respect to affordability.

Why Am I Being Asked To Be In This Study?

You are being asked to be in this study because you are an expert in architectural education, architectural construction, or design and construction of affordable [housing] projects.

How Many People Will Be Asked To Be In This Study?

Approximately 6 experts will be invited to participate in this study across the United States.

What Will I Be Asked To Do In This Study?

You will be asked about teaching and professional practice experience and what you perceive as significant cost indicators to enhance the student's understanding of cost as an integral design determinant and to improve the quality of design in the topic of affordability in the foundation design education.

Are There Any Risks To Me?

The things that you will be doing are no more risks than you would come across in everyday life.

Will There Be Any Costs To Me?

Aside from your time, there are no costs for taking part in the study.

Will I Be Paid To Be In This Study?

You will not be paid for being in this study.

Will Information From This Study Be Kept Private?

The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely.

Information about you will be stored in locked file cabinet; computer files protected with a password.

People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

Information about you and related to this study will be kept confidential to the extent permitted or required by law.

Will Photos, Videos or Audio Recordings Be Made Of Me during the Study?

The researchers will not take photographs, or make videos or audio recordings during the study.

Who may I Contact for More Information?

You may contact the Principal Investigator, Seyeon Lee, PhD student in School of Architecture, to tell him/her about a concern or complaint about this research at 425-894-9129 or seyeon79@tamu.edu.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office at (979) 458-4067 or irb@tamu.edu.

What if I Change My Mind About Participating?

This research is voluntary and you have the choice whether or not to be in this research study. You may decide to not begin or to stop participating at any time. If you choose not to be in this study or stop being in the study, there will be no effect on your student status, medical care, employment, evaluation, relationship with Texas A&M University, etc. Any new information discovered about the research will be provided to you. This information could affect your willingness to continue your participation.

STATEMENT OF CONSENT

I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the

researcher will tell me if I must be removed from the study. I can ask more questions if I want. A copy of this entire consent form will be given to me.

____

Participant's Signature

___________________________________ ___________________________________

Printed Name Date

INVESTIGATOR'S AFFIDAVIT:

Either I have or my agent has carefully explained to the participant the nature of the above project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

____

Signature of Presenter

___________________________________ ___________________________________

Printed Name Date

APPENDIX D

KEY INFORMANT INTERVIEW: RECRUITMENT LETTER

IRB Approval #: IRB2014-0701

Approved on December 11, 2014

October 6, 2014

Hello, my name is Seyeon Lee, and I am a third year PhD student in the School of Architecture at Texas A&M University. My PhD study focuses in the impacts and effectiveness of cost determinism in architectural foundation design education. I believe that most architectural students mold their philosophy and embody architectural objectives during foundation design education. Thus, their first two years of architecture program will be the most sufficient time to learn how to approach design with cost as design determinant.

I would like to ask you to participate in this interview because your research, education, and experience validate that you are an expert:

a. in architectural [foundation] education;
b. in architectural construction education; or
c. in affordable projects or cost conscious design in practice.

As a part of my dissertation research, I am seeking the most appropriate and optimal approaches to teach cost as an integral design determinant in foundation design studio course.

I understand that you have very busy schedule, but if you could spare approximately 45 minutes to an hour of your valuable time to share your expertise and experience, it will be very beneficial to further develop this research. Your responses are significant to conduct this research and to understand the meaning of affordability and teaching concepts of cost conscious design to future designers.

Thank you.

Sincerely,

Seyeon Lee

APPENDIX E

KEY INFORMANT INTERVIEW: INTERVIEW QUESTIONS

IRB Approval #: IRB2014-0701

Approved on December 11, 2014

Qualification

1. What is your primary role in the field of architecture and/or construction?
2. How long have you been teaching or practicing architecture and/or construction?
3. What kind of projects do you mostly work in? And what percentage of that are affordable [housing] projects? OR What kind of project do you mostly teach in the foundation design studio?
4. What is your involvement in architectural education?

Validation of Previous Research

As you already know, this research is focused in teaching cost as an integral design determinant in architectural foundation design studio education. It is assumption of this research that most design education encourages students to provide unique but costly solution to both hypothetical and real projects.

5. When were the first time you were exposed the financial reality of architecture and construction? What was your experience like?
6. When do you think is the most optimal time to discuss cost in architecture design/construction process?
7. When do you think is the most optimal time to expose students to cost implication in architectural design?

Cost Indicators

8. What is the most common and first design or building elements, which get “value-engineered” or eliminated from what were initially inclusive?
9. Based on your experience, what are the key cost indicators that could affect the cost of building?

Researcher will share the list of preliminary cost indicators.

10. Based on your experience, which cost indicators affect cost the most?
11. Based on your experience, can you suggest ways to apply these cost indicators in order to further enhance affordable design and reduce cost?

Other Means of Teaching Cost Determinism

Current architecture curriculum includes, design studio, history and theory, technology (structure and energy), communication, and professional practice.

12. What other means of methods would you suggest to improve cost awareness in foundation design studio education?
13. What is your general opinion of architectural studio education today and what do you think needs to improve the most?

APPENDIX F

QUASI-EXPERIMENT: CONSENT FORM

IRB Approval #: IRB2014-0728D

Approved on January 12, 2015

Project Title: ***The Impacts of Foundation Design Education***

You are invited to take part in a research study being conducted by Seyeon Lee, a researcher from Texas A&M University. The information in this form is provided to help you decide whether or not to take part. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefits you normally would have.

Why Is This Study Being Done?

The purpose of this study is to develop instructional strategy to improve architectural foundation design education.

Why Am I Being Asked To Be In This Study?

You are being asked to participate in this study because you are an architectural foundation design student who is registered in ARCH 206, the second-year design studio course.

How Many People Will Be Asked To Be In This Study?

Everyone who is registered for this studio section, ARCH 206-505, Spring 2015 is being asked.

Another second-year architectural design studio section will be asked to participate in the same research in the following semester, but its specific section has not been determined by the department at this time. The maximum number of participants per design studio is 15 people.

What Will I Be Asked To Do In This Study?

You will be participating in this study for the duration of one semester. ARCH 206-505, Spring 2015 will act as the control group [existing course] and there will be no change from the existing course. You will be asked to answer pre-test questions on the first day of class and post-test on the last day of class. The questions will be in regards to your educational background and perspective on architecture design.

Another second-year architectural design studio section will be asked to participate in the same research in the following semester as the treatment group. They will participate in the newly developed course; however, the changes are supplemental to the original course. The researcher is withdrawing full disclosure of the experimental design because it may influence the outcome of the research. However, the debriefing form will be provided to all participants at the end of the research identifying the changes made to the course.

Are There Any Risks To Me?

The things that you will be doing are no more risks than you would come across in everyday life.

Will There Be Any Costs To Me?

There are no costs for taking part in the study.

Will I Be Paid To Be In This Study or Given Extra Credit for This Course?

You will not be paid for being in this study, and be advised that partaking in this research study afford no compensation such as extra credit or an alternative assignment.

Will Information From This Study Be Kept Private?

The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely.

Information about you will be stored in locked file cabinet; computer files protected with a password.

People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

Information about you and related to this study will be kept confidential to the extent permitted or required by law.

Will Photos, Videos or Audio Recordings Be Made Of Me during the Study?

The researchers will not take photographs, videos or audio recordings, but they may collect images of certain studio project drawing or models to include in the research evaluation.

Who may I Contact for More Information?

You may contact the Principal Investigator, Seyeon Lee, PhD Candidate in School of Architecture, to tell her about a concern or complaint about this research at 425-894-9129 or seyeon79@tamu.edu.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office at (979) 458-4067 or irb@tamu.edu.

What if I Change My Mind About Participating?

This research is voluntary and you have the choice whether or not to be in this research study. You may decide to not begin or to stop participating at any time. If you choose not to be in this study or stop being in the study, there will be no effect on your student status, medical care, employment, evaluation, relationship with Texas A&M University, etc. Any new information discovered about the research will be provided to you. This information could affect your willingness to continue your participation.

STATEMENT OF CONSENT

I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I can ask more questions if I want. A copy of this entire consent form will be given to me.

___________________________________ ___________________________________

Participant's Signature Date

____

Printed Name

INVESTIGATOR'S AFFIDAVIT:

Either I have or my agent has carefully explained to the participant the nature of the above project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

___________________________________ ___________________________________

Signature of Presenter Date

____

Printed Name

APPENDIX G

QUASI-EXPERIMENT: PRETEST SURVEY

IRB Approval #: IRB2014-0728D

Approved on January 12, 2015

Name:____ **Semester: _________________**

1. Is this your second-year in college or university level education? □ yes □ no
   If no, indicate the year in college: ____

2. Have you taken any classes or attended lecture(s)* focused on topics listed in the table?
   *This includes an instructor inviting a guest speaker to discuss specific topic in class.

Course focused on	Taken a course	A lecture or a guest speaker
Architectural Structures		
Mechanical and Electrical Engineering		
Construction Management		
Construction Estimation		
Materials and Methods of Construction		
Sustainability		
Housing Affordability		

3. Rank the following in the order of importance to achieve high quality design in architectural design studio course?

1= extremely important, 2=important, 3=neutral, 4=not very important, 5=not important at all

______Unique and complexity of form
______Design and construction cost or budget
______Responses to the latest technology
______Use of trendy materials and finishes
______Functional utilization and efficiency of space

4. Often, expensive architectural projects or houses are presented as high quality crafts in today's construction. Is WEALTH required in doing great architecture?

   □ always □ often □ sometimes □ rarely □ never

5. When do you think is the most appropriate time to ask "how much is this going to cost to build?"

   □ During school
   □ During design phase of project
   □ When the design is completed
   □ That is for the general contractor to answer
   □ Never

APPENDIX H

QUASI-EXPERIMENT: POSTTEST SURVEY

IRB Approval #: IRB2014-0728D

Approved on January 12, 2015

Name:____ **Semester: __________________**

1. Rank the following in the order of importance to achieve high quality design in architectural design studio course?

1= extremely important, 2=important, 3=neutral, 4=not very important, 5=not important at all

______Unique and complexity of form
______Design and construction cost or budget
______Responses to the latest technology
______Use of trendy materials and finishes
______Functional utilization and efficiency of space

2. Often, expensive architectural projects or houses are presented as high quality crafts in today's construction. Is WEALTH required in doing great architecture?

□ always □ often □ sometimes □ rarely □ never

3. When do you think is the most appropriate time to ask "how much is this going to cost to build?"

□ During school
□ During design phase of project
□ When the design is completed
□ That is for the general contractor to answer
□ Never

4. Is awareness in cost as an integral design determinant important to achieve high quality architectural design?

□ always □ often □ sometimes □ rarely □ never

5. Do you think learning cost as an integral design determinant is appropriate at the second-year level?

□ yes □ no

Why?____

____

6. Is this topic of cost as an integral design determinant better as a standalone lecture course or an integral to design studio course?

□ Lecture Course □ Integrated into a design course

Why?____

____

7. What would you wish to have learned in the foundation design studio course to enhance the awareness of cost as an integral design determinant?

____

____

____

APPENDIX J

QUASI-EXPERIMENT: 20K HOUSE PROJECT INFORMATION PACKET

INTRODUCTION

The Rural Studio at Auburn University is a long-running design-build program found by architect and educator, Sam Mockbee and D.K. Ruth in 1995. These legendary educators were convinced that architects should be leaders to bring social and environmental changes, and help those who do not have access to design services but need them. The Rural Studio is permanently based in the rural Hale County, Alabama where nearly 30% of the individuals live in poverty. Since the first group of architecture students arrived in Hale County 20 years ago, the program has been educating "citizen architects" with hands-on teaching methods that include implementing designs on site. For the last 20 years, the architectural students at the Rural Studio have been designing and building houses and community projects throughout Hale County.

The $20K House is an ongoing research project launched in 2005 to make their work more relevant to the needs of west Alabama. The goal of this project is to address the pressing need for decent and affordable housing in Hale County. However, it has demonstrated the real potential to improve living conditions beyond the region of Alabama. The program chose $20,000 because it would be the most expensive mortgage a person receiving today's medial Social Security check of $758 per month can realistically repay, which turned out to be $108 monthly mortgage. (Freear & Barthel 2014).

PROJECT GOALS

The goal of the project is to design various small house types with assurance of their feasibility and constructability under a budget of $20,000. All proposed 20K house design will be compiled into a published book and will be submit to the potential builders and developers.

Internal emphasis for this project is designers' understanding of the contextual and cultural conditions of the given environment with an emphasis in practical representation of building elements. The project will study the building assemblage and investigate building structure and form with emphasis in materials, finishes and construction systems. The proposed design solutions shall be unique and time-less both spatially and formally and yet, realistic and practical.

PROBLEM STATEMENT

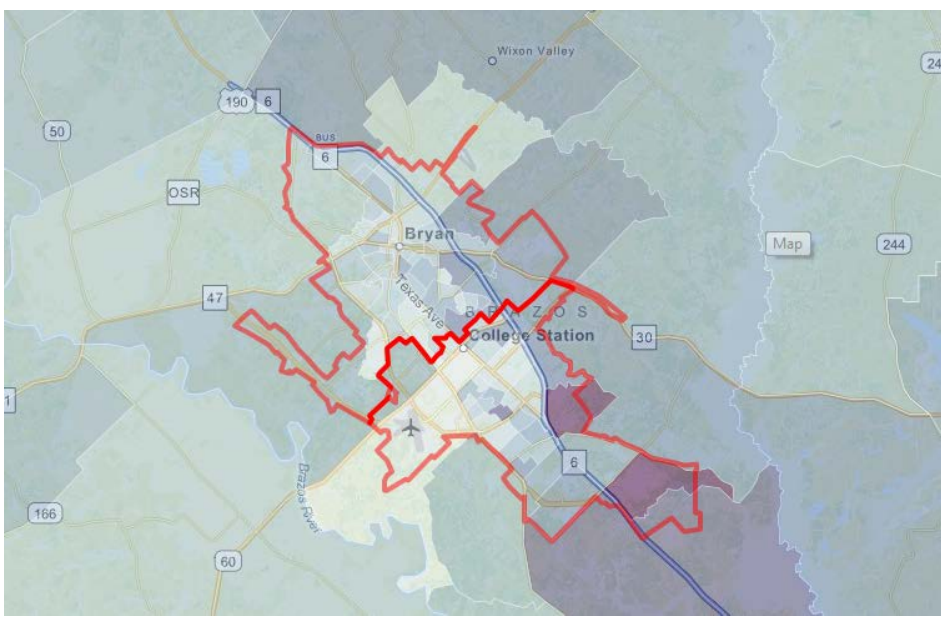
Each student is asked to design a small house for the Falls Creek Ranch Subdivision located in Bryan, Texas. The house has a specific budget of $20,000 excluding site work, mechanical, electrical and plumbing system, equipment, and appliance. While the design responses to the specific context in Texas, it shall also reflect the changes in the technology and contemporary lifestyle. The design challenge is to make a small house feel big, and to consider for future expansion. The optimal goal for the 20K house project is to provide well-designed house for everyone.

COLLEGE STATION – BRYAN

College Station, Texas is a medium-sized city approximately 50 square miles in size located centrally in the State of Texas. It is within the urban triangle created between Austin, Dallas, and Houston. In the past ten years, the City of College Station has experienced a growth boom, which is evident from the annexation and extension of the City limit boundaries and new development, thus resulting in an increase in population.

The City of College Station is a young municipality, with its beginnings in the founding of Texas A&M College. Texas' first State institution of higher education, the College was inaugurated in 1876. Because of the school's isolation, school administrators provided facilities for those who were associated with the College. The campus became the focal point of community development. The area was designated "College Station, Texas" by the Postal Service in 1877. The name was derived from the train station located to the west of the campus.
Bryan is located in the heart of the Brazos Valley bordering the city of College Station, which lies to its south.

With a movement toward downtown revitalization, its goal is to bring businesses and interest back to Downtown Bryan. While Bryan’s downtown business district demonstrates cultural heritage, the East Side Historic District created in the 1980s, approximately 50 Bryan homes, and other structures are listed on the National Register of Historical Places. Today, businesses are opening, expanding and relocating in Downtown Bryan, breathing new life into the area. This push toward downtown revitalization is now enabling people to experience the shops, restaurants, hotels and businesses that are working together to restore Downtown Bryan to thrive.



DEMOGRAPHICS

College Station-Bryan Metropolitan's population has steadily increased since its incorporation in 1938. As Texas A&M University and Blinn College's enrollment increased, the population of the surrounding city did as well.

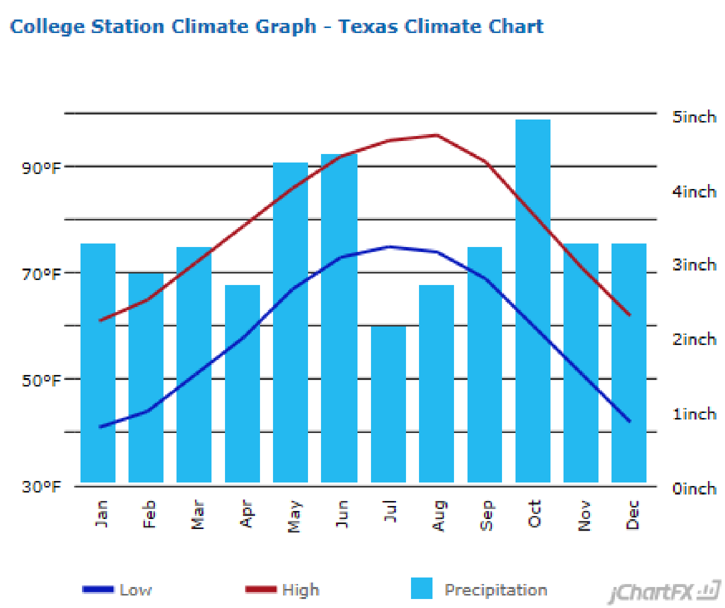
Bryan: Population in 2012: 78,061 (98% urban, 2% rural). Population change since 2000: +18.9%

College Station: Population in 2012: 97,801 (99% urban, 1% rural). Population change since 2000: +44.1% College Station is recognized as the largest city in Brazos County representing approximately 45% of the population in Brazos County. The enrollments at Texas A&M University and Blinn College continuously grow reaching 45,000 students.

Sources: http://www.cstx.gov/ http://www.bryantx.gov/

CLIMATE

College Station Bryan Metropolitan, Texas has a warm humid temperate climate with hot summers and no dry season. The area within 25 miles of this station is covered by *croplands* (82%), *grasslands* (14%), and *forests* (3%).



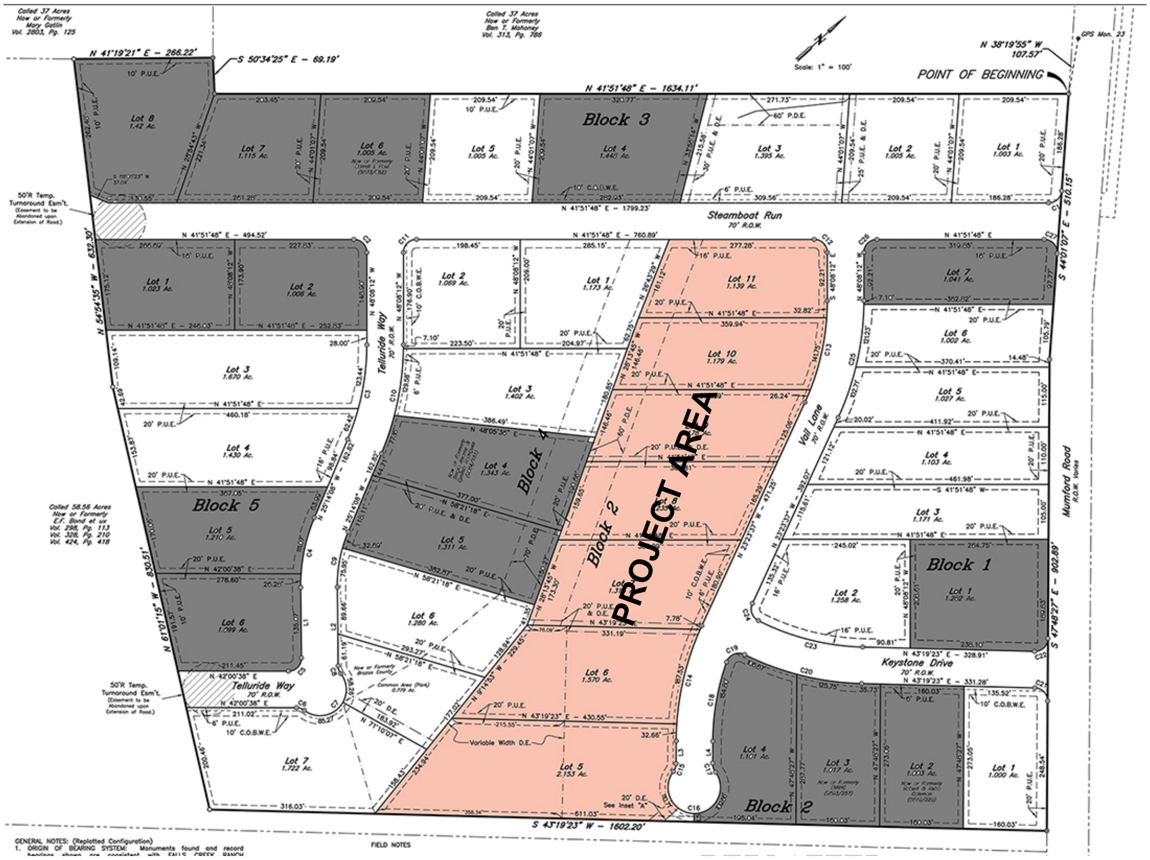
Source: http://www.usclimatedata.com/climate/college-station/texas/united-states/ustx2165

THE SITE

The site for the 20K house is located in the Falls Creek Ranch Subdivision in the north of Bryan. The Falls Creek Ranch Subdivision includes 56.43 acres of land with a fish pond in the middle of the property. The subdivision currently is re-plated into 5 blocks, which are divided into 39 individual lots. 15 out of the 39 lots are already developed. There is a large fish pond (in between block 4 and block 2) in the middle of the development.

DETAILS OF THE SPECIFIC SITE

See Appendix A for the enlarged property map with topography. The grayed-out lots are already developed, and the remainder of Block 2, highlighted in red will be used for this 20K house project. There is a large fishpond in between Block 2 and Block 4. For the purpose of the 20K houses and their placement, the remaining 7 lots in Block 2 will be consolidated into 1 larger property.



ARCHITECTURAL PROGRAM

The program for this project is based on the 20K House research program at the Rural Studio. It must comply with local building code, energy star rating, and ADA accessibility regulation.

Typically, the 20K houses are designed for single or double occupants, and it will be considered the same in this proposal. The total footprint of the house shall not be larger than 600 SF, with maximum 150 SF for an entry stoop and porch. Loft space is allowed as long as the budget is sufficient. Keep in mind that mechanical system, appliances, and site works are not included in the budget.

Garage or carport will not be considered because it will be built as an extension in the next phase of the construction.

The house must include at minimum:

a. Entry
b. Living Space
c. Bedroom
d. Bathroom
e. Kitchen and Dining area

f. Porch

The $20,000 budget does not include mechanical system, electrical and plumbing systems, equipment and appliances. They will not be considered for the purpose of this project.

BUILDING MATERIALS AND FINISHES– KIT OF PARTS

FRAMING
There are considerations for both wood and steel when framing a building.

- 2x4 or 2x6 wood studs @ 16” o.c.
- 2x6 or 2x8 ceiling joist
- 2x10 floor joist
- 2x8 rafters @16” o.c.

(Similar for light gauge steel framing)

-other alternative framing system may be discussed for consideration

ENCLOSURE – WALL, DOOR, WINDOW, and ROOF

a. Wood
b. Metal
c. Glazing (window – both fixed and operational)
d. Concrete

DELIVERABLES AND PRESENTATION REQUIREMENTS

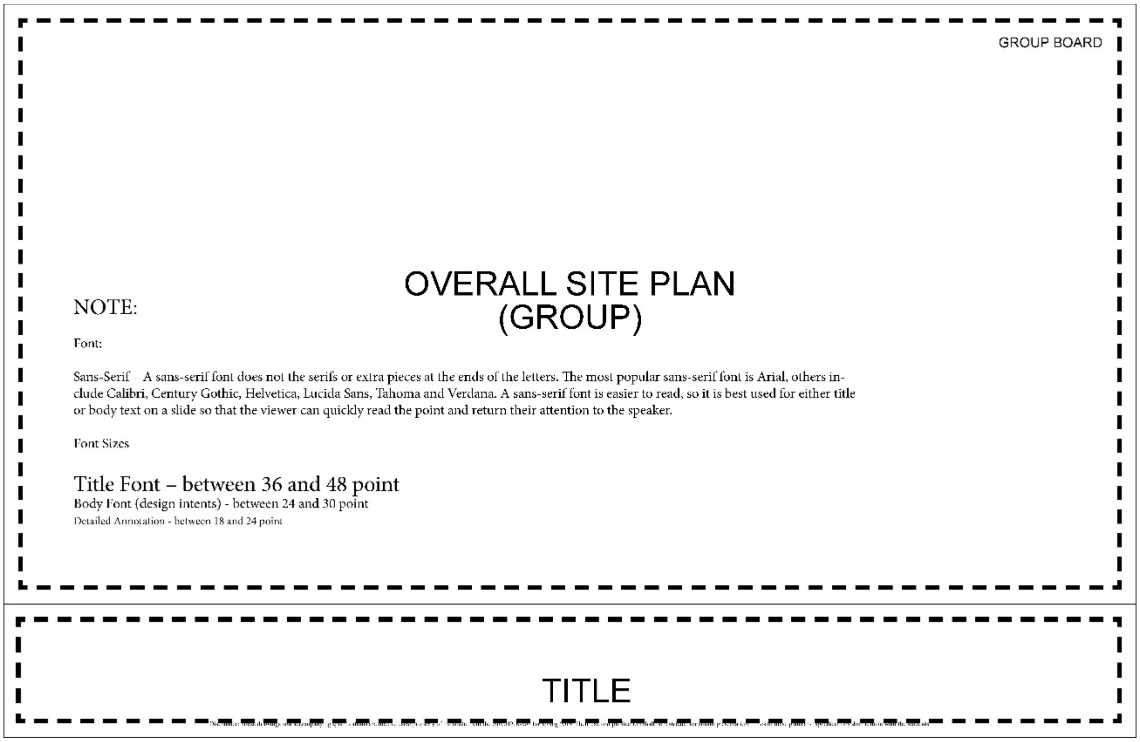
Presentation boards are to be 22”x 34” matte-printed in color. The presentation boards will be reprinted into 11”x17”, half size and submitted to the clients. Put your name, your course, and the date on the back of each presentation boards. All work (except for diagrams and sketches) must be with the use of computer. All presentations are to be printed in color. InDesign file of the required presentation board format will be provided via Email. See Appendix B for layouts.

GROUP BOARD

A. Title – Name of the development

B. One overall development site plan

One overall development site plan showing all 14 proposed houses will be prepared by all students. Site plan shall include roof plan of each proposed houses, existing houses, roads, and landscape.



<u>BOARD 1</u>

A. **Title – Name and location of project**

B. **Design Intent Statement**

The design intent statement shall serve to clarify ideas. This requires you to write one or two paragraphs (no more than 200 words) describing your design intent and the strategies you employed in the project. A discussion of "why" you employed select strategies must be included.

It shall include formal design ideas discussing architectural elements and principles of design.
-Architectural elements: such as line, shape, light, value, color, texture, pattern, space, time, etc.
-principles of design: such as unity and variety, balance, symmetry, emphasis, scale and proportion, volume, setting, interior/exterior relationship

The intent statements will be peer reviewed before inserting into the presentation board. First drafts will be submitted to the instructor and the assigned reviewer.

C. Area of the building

The architectural area of a building is the sum of the areas of the floors of the building, measured from the exterior faces of exterior walls. These areas must provide minimum of seven feet (2.13 meters) headroom height to consider into floor areas.

Building area as whole, and area breakdown at each required space shall be provided.

D. Volume of the building

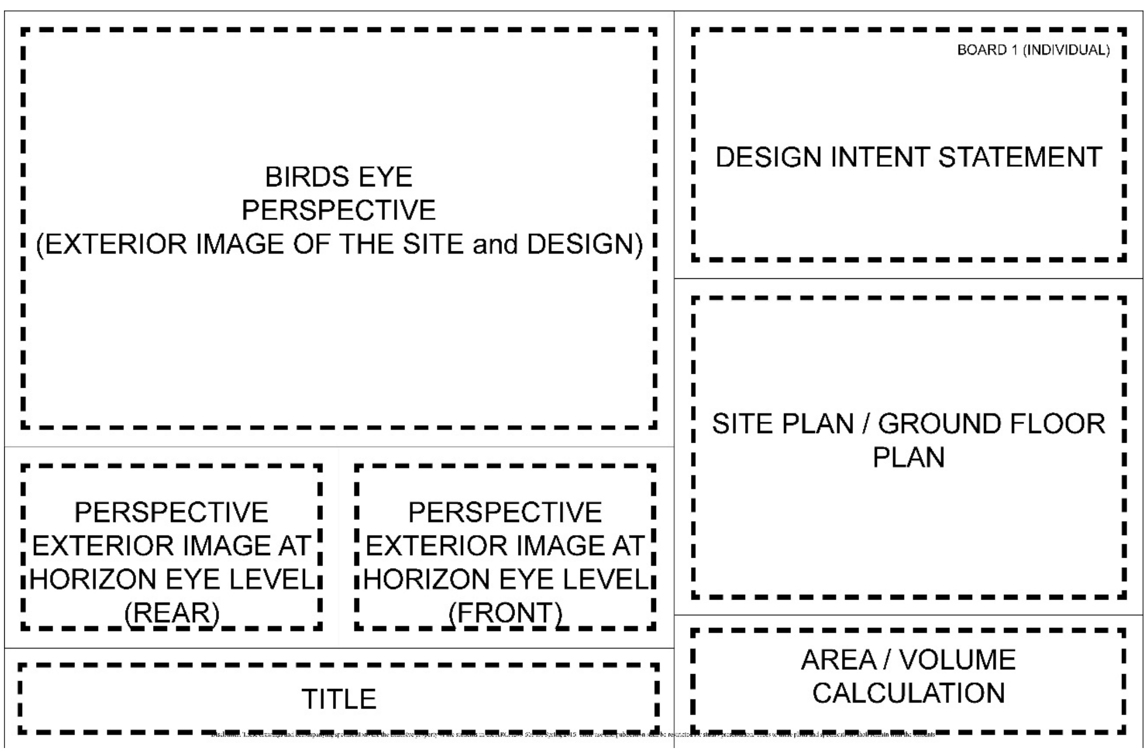
The architectural volume (cubic volume) of a building is the sum of the areas of the floors of the building multiplied by the floor to floor height or floor to mean finished roof height.

In addition to the area of the building, representation of the volume and its calculation organize the space into the three dimensional array. Three dimensional thinking is vital in design and science.

E. Site Plan/ground floor plan at ¼" =1'-0"

For the purpose of this project, the site plan and ground floor plan will be combined showing sidewalk, landscaping, and interior layout of equipment and furniture.

F. Birds Eye Perspective



BOARD 2

A. Exploded Axonometric Diagram

The exploded axonometric diagram shall separate the building skin from its architectural structure and interior and exterior skin by exploding foundations, roof assembly, floor assembly, wall assembly, and interior walls. Exclude interior cabinetry, fixtures, and equipment when building the digital model. The final image shall include call-outs and short description of each building element.

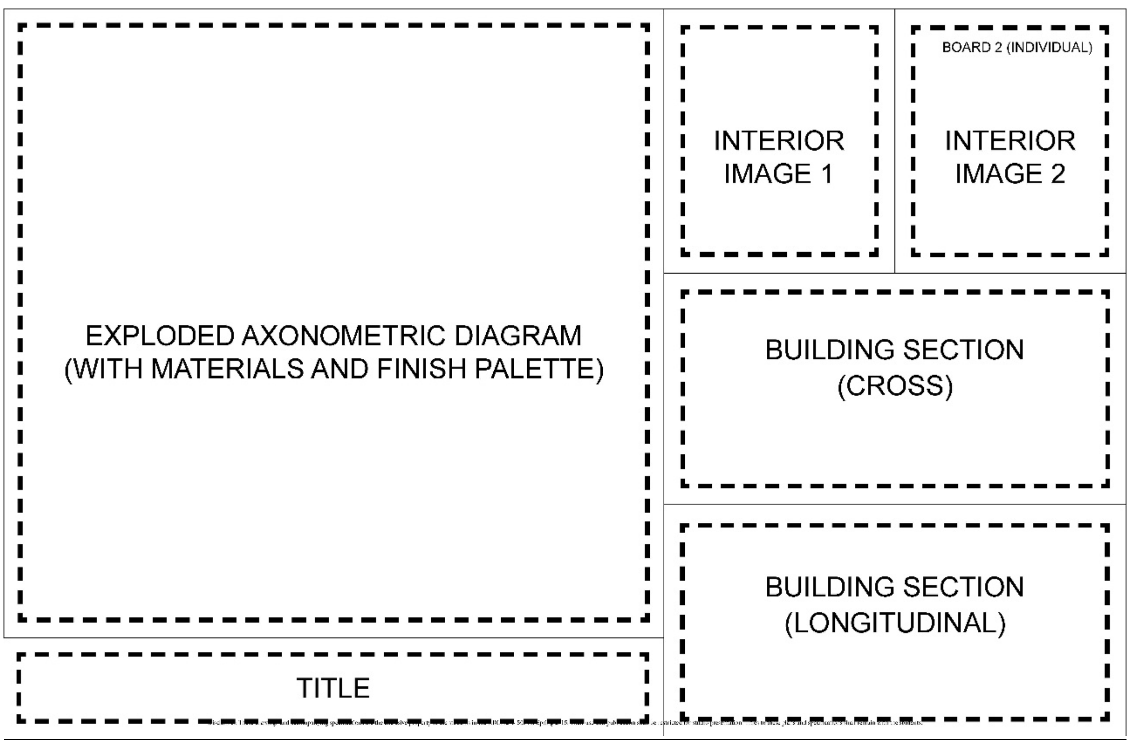
Assembly call-outs shall include enlarged thumbnails (1.5” x 1.5”) of material or finish proposed in color.

B. Building Sections (both longitudinal and cross) at ¼”=1’-0”

Building section drawings shall include people.

C. Interior images

Your digital model of the house shall produce interior images showing furniture arrangements, people living in the house.



FINAL MODEL

One site model at 1/32”=1’-0” shall be built and used by everyone. The site model including contour and existing landscape of the site (road, trees, and pond) will accommodate all 14 – 20K house buildings. The base is considered to be the water level and will be constructed of chipboard. A ¾” x 3.5” border of yellow pine will elevate the base (use 1” x 4” yellow pine). Use brown or gray chip board for contours and existing residences, and proposed houses shall be built using white museum board only.

One detailed building model at 1/2” = 1’-0”. Materials are limited to bass wood, and brown/gray chip board. Pay attention to details and how materials are joined. Include all interior walls, windows and doors and major furniture. Use the woodshop and remember no spray painting is allowed in the design studio. Use the paint booth.

SCHEDULE AND DUE DATES (differ for the treatment group)

	February 13	Initiate Project 2 and Visit Site
Week 5	February 16	Studio work session/ desk crits
	February 18	*Lecture 4: Rural Studio – Video*
		Site Analysis Due (individual)
		Project #1 review -10:30-12:00am
	February 20	Studio work session/ desk crits
		Site Model Due
Week 6	February 23	Preliminary Review – Study model, Plans, Sections, Elevations due (at ¼”=1’-0” scale)
		Building Area and volume calculation
	February 25	*Lecture 5: Rural Studio and Serenbe*
	February 27	Studio work session/ desk crits
Week 7	March 2	Preliminary 3D model and design intent statement due
	March 4	Lecture 6: Building Materials and Finishes I
	March 6	Studio work session/ desk crits
Week 8	March 9	Trip to Huntsville, TX
	March 11	Studio work session/ desk crits
	March 13	Test Print Due
	March 16-20	**Spring Break**
Week 9	March 23	Studio work session/ desk crits
	March 25	*Project 2 Due at 5pm.

APPENDIX K

QUASI-EXPERIMENT: EVALUATION MATRIX

Evaluation Matrix for Cost Indicators

Name of the 20K House: ________________________

Name of Reviewer: ____________________________

Cost of the ***Indicators*** will be impacted by the low, moderate, high magnitude of

AREA (SF) / FORMAL COMPLEXITY / MATERIAL & FINISHES

1 SITE

While it provides sufficient use of existing microclimate, landscape, topography, natural environmental features such as water, vegetation properties, geophysical properties of the soil, etc. proper application could provide the most cost effective solution to influence the other cost indicators

Low		Moderate		High

2 FOUNDATION

While it functions to transfer the building load into the soil, uses the most effective methods, creates necessary environmental footprint, protect superstructure from the condition of the soil.

Low		Moderate		High

3 STRUCTURAL FRAMING

It provides structural support and shape of the building by using sufficient framing material with advantages in structure.

Low		Moderate		High

4 WALL

It represents building's face and form, and response to the interior and exterior environment. Its full assembly allows for moisture, thermal, ventilation control, its effectiveness impact the maintenance and utility cost of the building.

Low		Moderate		High

5 DOOR and WINDOW

While it allows for natural light and ventilation throughout the structure, its overuse or underuse impacts exposures of differently purposed spaces influencing the uses and ease of circulation between the spaces

Low		Moderate		High

6 ROOF

Similar to wall, it enclosures the building by providing protection over-our-head. While it presents buildings face and form, its form and material is highly related with local condition and methods of construction

Low		Moderate		High

7 FLOOR

Its flat surface and or its characteristic defines functional program of different spaces. Yet, it shall perform to control sound and resist wear.

Low		Moderate		High

8 CIRCULATION (STAIRS & STEPS)

They are used to connect and organize spaces, less room they take up more convenience the condition.

Low		Moderate		High