2018 ASEE Annual Conference & Exposition
June 24–27, 2018 Salt Palace Convention Center Salt Lake City, UT
Paper ID #22056

Serving through Building: Sustainable Houses for the Gnobe People in Cieneguita, Panama

Prof. Lauren W. Redden, Auburn University

Lauren Redden holds a Masters degree in Building Construction from Auburn University. Her industry experience includes working in Pre-Construction Services as an Estimator, and working in various positions in Operations including Project Management and Quality Control/Assurance. She is currently a Tenure Track Assistant Professor with the McWhorter School of Building Science at Auburn University. Her research interests center around construction education, mobile technologies, service learning, hands-on engaged learning, and historically significant construction events throughout the world. She has published in several conferences proceedings. Contact Information: 118 M. Miller Gorrie Center, Auburn, AL 36849, USA. Phone: 334.844.5341. Email: wybenlm@auburn.edu

Mrs. April E. Simons P.E., Auburn University

April E. Simons joined the faculty in the McWhorter School of Building Science at Auburn University in August of 2016. Prior to that, she worked for the U.S. Army Corps of Engineers for over 5 years where she served as project engineer on 16 different construction projects. Mrs. Simons earned a Bachelor of Civil Engineering degree in 2009 and a Master of Civil Engineering degree in 2013, each from Auburn University. Ms. Simons has been a registered Professional Engineer in the State of Alabama since 2014.

Prof. Scott William Kramer, Auburn University

Scott W. Kramer, Ph.D. is a Professor in the College of Architecture, Design, and Construction at Auburn University. He received his B.S. and M.S. in Civil Engineering from Auburn University and Ph.D. in Learning Design & Technology from Purdue University. Since 1993, he has taught undergraduate and graduate classes in scheduling, project management, and information technology. His research and consulting work involves international construction and designing study abroad classes for university students. His project management experience includes 9 years of professional practice working for two Engineering News Record (ENR) top 50 commercial builders. Kramer co-authored the research article, Teaching Project Management Through an Information Technology-Based Method, which was named the 1997 Paper of The Year by the PMI Project Management Journal. Kramer has also received several national teaching awards including the Associated Schools of Construction National Teaching Award (1996) and the Outstanding Educator Award (2003). In 2013, Kramer received the McWhorter School of Building Science Faculty Excellence Award for Leadership in Study Abroad classes.

Mr. Trenton Huffines

Serving through Building: Sustainable Houses for the Ngobe People in Cieneguita, Panama

Introduction and Background

The Ngobe people are a native tribe to Cieneguita, Panama who often live in provisional homes comprised of walls made of sticks and floors made of dirt which are not structurally sound and therefore are often susceptible to failure. Previous research at Auburn University initiated a basic design for a more stable structure to be constructed in these villages based on an extensive study of the local region's available resources. The basic design of this structure focused on location appropriate materials, cultural sensitivity, sustainability, ventilation and cooling, rainwater collection, aesthetic design development, computer aided modeling and simulation, and construction documents. The initial design consists of a concrete slab, steel tube framing supported by shallow concrete footings, a pitched metal roof, and the flexibility to utilize mixed materials for the walls.

This research builds on the aforementioned research by engaging in the construction of the structure using the initial design in Panama and carefully documenting the construction processes in Panama to identify needed improvements to the design based on limitations due to the remote work site location and limited resources available (e.g. tools, equipment, trained labor, etc.). A second structure was built in Lineville, AL which implemented solutions to the limitations identified at the construction site in Panama. This second structure will also be used as a training demonstration site for mission teams to visualize and help plan for construction when in Panama. Shop drawings were created based on the design and implementation. This research involved community-based activity and engagement in Cieneguita, Panama as well as Lineville, AL.

This research is the second phase of a multi-phase research effort. The research was accomplished as part of a scholarly capstone project in the Auburn University's McWhorter School of Building Science (BSCI) Master of Building Construction (MBC) Program. The purpose of the capstone project is to demonstrate the student's ability to independently explore a new topic, demonstrate appropriate application of the materials, and successfully communicate the information in a professional and academically rigorous format. Capstone projects are assessed based on the research quality and efforts, final report document, and presentation of the research. The research presented herein was accomplished as one graduate student's capstone project which centered around hands-on engagement, community outreach and service-based learning.

This paper documents the construction of an initial structure in Panama followed by a prototype structure in Lineville, AL as it relates to the student's scholarly capstone project. The primary goal of this paper is to present lessons learned from each project and provide recommendations for streamlining and improving the construction process for future projects of this scope. A secondary goal of this paper is to discuss work with and for the Ngobe people in Panama in relation to Community Driven Development (CDD). The principal aim of this research seeks to empower the Ngobe people to have a future of building safe and sustainable housing on their own. The Ngobe people and the Auburn United Methodist Church (AUMC) have since used the findings of this capstone project to erect at least 10-12 more homes. Future research seeks to document the implementation of structures of this type built in Panama and further refine the basic design. Future research also seeks to monitor Community Driven Development (CDD) among the Ngobe people. By gauging the effectiveness of empowering the Ngobe people with the skillset and knowledge to build a sound structure, this process can be extended to other areas of Panama and other parts of the world.

Literature Review

Community Driven Development (CDD) forms the basis for this and previous research at Auburn University focusing on the Ngobe people in Panama. CDD is a way to provide social and infrastructure services, organize economic activity and resource management, empower people with limited financial resources, enhance security of these people, and improve governance [1]. The goal behind CDD is to work *with* the community rather than *for* the community and providing them with the skills and confidence needed to prosper on their own. Experience has shown that, given clear rules of the game, access to information, and appropriate support, impoverished men and women can effectively organize to provide goods and services that meet their immediate priorities [1].

With mission trips beginning in 2012, the goal of AUMC has been implementing Community Driven Development with the local Ngobe people. On these mission trips, church members have been able to work hand-in-hand with the local tribe to build simple yet sustainable houses. This experience has provided many of the Ngobe people with the skills needed to replicate the process thereby building houses for other local Panamanians. The McWhorter School of Building Science (BSCI) at Auburn University partnered with AUMC in 2016 to build upon the group's previous work. By offering construction expertise, BSCI worked to design a safe, stable structure which can be effectively built in the jungles of Panama. To provide the best use of the one-week timeframe of each mission trip, the work of BSCI focused on prefabrication methods.

The construction industry has been known as labor-intensive, time sensitive on long processes, costly, and waste expensive. To reduce impacts on the environment, costs, and time while improving standards, techniques, and quality, prefabrication has been used in the process [2], [3]. Li et al. [3] found structural components are a viable area of a building to prefabricate regardless of the project site conditions; whereas conventional methods of construction are more suitable for foundation work due to the need for adaptability to change in site conditions. The first iteration prototype of the Panama steel tube frame house focused on a design in which all of the steel pieces to the home are prefabricated offsite and transported easily by the volunteers to the construction site for the home. The primary objective of this study was to develop the design further, in order to mitigate issues observed with the first iteration of the design. The researcher investigated the "make-to-order structure design method" for improvement to supplying standard or configurable component designs for production by locals who do not have access to sophisticated equipment or shop space for steel fabrication [4]. Refining the prefabrication design of the steel frame also should simplify logistics onsite further, reduce risk of theft and vandalism of materials, and protect the materials from weather damage [2].

The research presented herein takes the form of hands-on service-learning. The National Society for Experiential Education has defined service-learning as “any carefully monitored service experience in which a student has intentional learning goals and reflects actively on what he or she is learning throughout the experience” [5]. Service based, hands-on research has proven effective in university level construction programs. One particular study [6] describes the development of an undergraduate construction management course at California Polytechnic State University intended to incorporate service-learning goals and objectives into a hands-on construction experience.

Post-completion student surveys highlighted the success of the course, with comments such as “It was a great feeling to apply previous class materials while at the same time helping families in need.” Another set of researchers [7] tested the effectiveness of engaged hand-on learning with a field exercise as part of a preconstruction course in the construction management curriculum at a university located in the Southeast. Statistical analysis of pre- and post-exercise surveys demonstrated that the completion of the exercise itself (including post-exercise analysis with the students) facilitated the achievement of course objectives and assisted students in understanding where deficiencies existed in their estimating abilities. With the separate and combined benefits of hands-on and service-learning projects, the research herein seeks to build upon the theory that service-based hands-on projects offer added benefits to the traditional learning experience.

Objectives and Methodology

The objectives of this research were:

- Participate in construction of a previously developed housing design in Panama and make recommendations throughout the construction process.
- Document areas of needed improvement to the basic design and local processes used.
- Construct a prototype of the structure in a controlled environment, implementing the perceived improvements.
- Develop shop drawings for specific portions of the work as needed.
- Further clarify the set of recommendations for design and construction to achieve a safe, stable, and sustainable home for the Ngobe people of Panama.

The methodology began with the travel to Cieneguita, Panama in May 2017 to observe, research, and assist with current home building projects with the Ngobe people. One researcher combined with a college ministry team from the Auburn United Methodist Church made up the volunteer team from the United States. The team members, who had varying backgrounds and limited construction experience, worked alongside the Ngobe people to complete the project in less than a week. An observation of the steel fabrication process was essential in understanding how to refine the design. The final major source of data collection for this trip was the observation of local methods employed for the erection of the structure in its entirety.

Phase two of the research consisted of analysis and redesign of specific design details based on observations made during the Panama trip. Steel components were fabricated in Alabama and transported to a remote simulation site in Lineville, AL. The researcher used a pool of untrained volunteer labor to construct a second prototype at this location, implementing the design improvements noted during the Panama construction. This prototype will also serve as a training demonstration site in the local area for future teams who are travelling to Panama to build these structures.

Results and Discussion

During the month of May 2017, Auburn MBC Student Trent Huffines traveled to Panama with a college ministry team from the Auburn United Methodist Church. The aim of this trip was to observe, research, and assist with, current home building projects for the Ngobe people near the town of Cieneguita, Panama. The team consisted primarily of college-aged students with varying backgrounds and limited construction experience. This trip allowed initial input from research personnel regarding construction to the local teams as well as observation of current materials and construction processes used in Panama. Information gained from this trip was used to construct a prototype structure in Lineville, AL which allowed implementation of improvements to the Panama construction.

Using the previously developed design, the mission team and a small group of locals successfully constructed a home with limited resources and limited construction training within 4 days. Each of these homes constructed empowers the local people by offering the opportunity to engage with the missions team in the construction of the structure, and then take ownership in the completion of the home with walls and any finishes. Steel fabrication for the project was performed primarily in a garage at the mission team staging area. At this site, steel columns were cut, and baseplates and mounting brackets were welded to the columns with a generator driven stick welder. Some steel parts were plasma cut by a CNC equipped facility in Panama City and shipped to Cieneguita, but the assemblage of the components was local to the construction site, with final transportation to the construction site by offroad vehicle. Figure 1 shows the remote steel fabrication shop in Panama.

Figure 1: Remote Steel Fabrication Shop Area in Panama

Baseplate to Column Connections

Confusion arose during the fabrication of the columns, as each baseplate was designed differently, and was placed uniquely on each column. The columns were designed to have uniquely placed baseplates, and were not easily repeatable. This required re-fabrication of at least two of the nine columns. Fortunately, this problem was observed before final assembly. The design employed in Panama skews the load of the column to the edge of the baseplate and to the edge of the foundation at times as many baseplates are off-center. The Panama design also neglects to secure the baseplate to the foundation appropriately. The corner columns of the current design are not centered on the baseplate and are fabricated to exclude the use of 1 of the 4 anchor bolts, limiting the positive connection to only 3 of the 4 anchor bolts. This construction also skews the rebar anchor rod embedment to the edge of the foundation. This increases the probability for failure in the foundation as typically rebar and anchor bolts require anywhere from 3” to 4” of concrete cover. However, in this case the rebar is pushed to the edge of the foundation, and in some cases could even be exposed below grade, promoting water damage and corrosion. Figures 2-3 show the skewed base plates used, sometimes only allowing 3 anchor bolts rather than 4.

Figure 2: Variation in Panama Base Plates

Figure 3: Column Skewed to Edge of Baseplate

To streamline production and ease assembly, the second iteration prototype home was constructed in Lineville, AL using a standard baseplate design for each column. The standardized baseplate design, as opposed to the previous methods employed in Panama, leads to a more streamlined and efficient fabrication and construction process. The new baseplate design also provides greater strength, as it allows for the load from the column to be transferred directly onto the center of the baseplate and therefore to the center of the supporting foundation. The new design also incorporates flanges to support the column-to-baseplate welded joint, as there is a potential for failure along this joint. Figure 4 shows the standardized baseplate design.

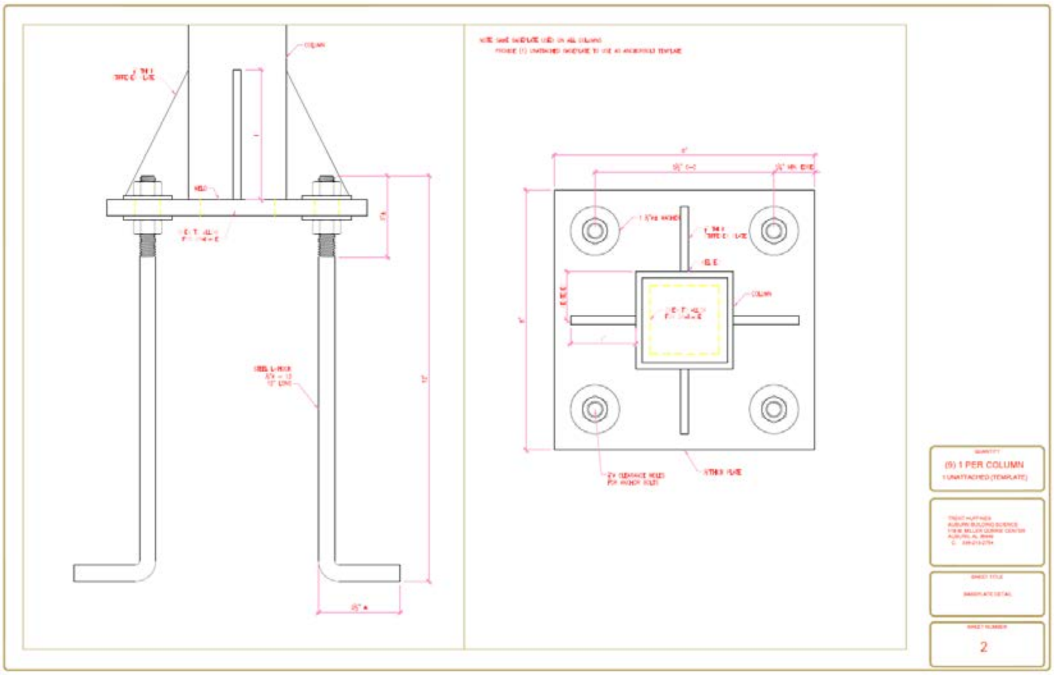

Figure 4: Baseplate Design for Second Iteration Prototype Home in Lineville, AL

Anchor Bolt/Base Plate Assemblies

Similar problems arose in Panama in the setting of the anchor bolts, due to the current design of the baseplate and the rebar anchor rods. The current anchor bolts are embedded into the concrete foundations in a unique, and unconventional manner. Rebar is bent to form “L-hooks”, then the rebar L-hooks are welded to a baseplate. This baseplate then has standard grade machine bolts welded to the baseplate to serve as the anchor bolts. This assembly is then embedded into the concrete foundations, only achieving eye-level using rocks and sticks to adjust the height and level. In this previous design, a correctly leveled baseplate is difficult to achieve, yet is critical for the columns to be installed plumb. The baseplates being installed out of level drives extra effort and time for later processes downstream in the construction process, including out of plumb columns which do not align properly with roof framing which requires difficult roof modifications by a labor force with limited training. Figures 5 and 6 show the anchor bolt and base plate assembly fabricated in Panama and the leveling methods used by Panamanians, respectively.

Figure 5: Panama Baseplate/Anchor Bolt Assembly

Figure 6: Leveling the Baseplate in Panama

The new design of the prototype home in Lineville, AL allows the anchor bolts to be precisely aligned, leveled, checked and tested before the concrete is poured. Figure 7 shows the new design of anchor bolts being installed. These were laid out and leveled using the same surveying tools and resources available to the teams in Panama which include basic trigonometry, a tape measure, and string. Due to time constraints and the desire to achieve near-perfect leveling, a builder’s level was utilized when checking vertical placement at the Lineville, AL site, yet a string and bubble level could be used similarly if time permits. The new design allows for small inaccuracies in height and level to be adjusted after the anchor bolts are securely embedded in the concrete pour by tightening or loosening the leveling nuts that the baseplate rests on. As shown in Figure 7, a steel plate template was utilized to ensure anchors were centered, and to pre-level the leveling nuts before the placement of the columns. Final leveling adjustments were made after the columns were installed. These final adjustments were necessary due to fabrication limitations of the baseplate to column weld. It was difficult for the steel fabricator to ensure a perfectly 90 degree joint between baseplate and column, and a slight variance off 90 will extend up the column. Non-shrink grout was then applied underneath the baseplates.

Figure 7: Baseplate Installation using Templates Lineville, AL

Concrete Slab

One problem that Panama teams were having with the layout of the structure was ensuring that the slab was square and level. The project foreman in Panama, in an attempt to expedite the layout process used the slab formwork to layout the foundation and anchor bolt placement. When the formwork was out of square and level, the foundations were being installed out of place, therefore the columns were being installed out of place and out of square and plumb. Light gauge metal drywall frames were used for slab formwork in Panama. These are prone to bending and warping which further exasperated the problem since construction layout was based on the accuracy of these forms. One solution that was implemented in Panama was the addition of a brace and a hinge at the corners of the edge forms to keep the formwork square. Variances along we length of the forms due to warping and bending were still noted, but overall keeping the formwork square was a positive improvement that was simply implemented.

During the prototype construction at the Servants In Faith And Technology SIFAT campus in Lineville, AL a new approach was tested for the slab preparation and layout. Care was taken to ensure the columns were precisely laid out in the correct location using basic trigonometry and string lines. Anchor bolts and foundation forms were then placed directly under the layout lines, ensuring an accurate placement within an approximate 1/8” tolerance. To accurately place the anchor bolts, anchor bolt formwork was constructed to hold the anchor bolts in place and level during the pouring of the foundation concrete. Once the concrete foundations cured and the forms were stripped, the slab edge forms were easily secured to the already square and level foundations. Gravel was then installed once the edge forms were in place, and the slab was poured.

Another difference between the Panama house and the Lineville, AL house was the scheduling of the slab pour. The Lineville, AL house used a ready mix truck instead of hand-mixing concrete. Since the trucks have chutes to deliver the ready mix, having the columns erected prior to the installation of the slab would interfere with the ability to swing the chute across the area of the pour. Also, due to weather and a few days of hard dry dirt, the slab was poured prior to column erection to prevent muddy conditions or possible delays. The Panama teams have different working parameters, and the scheduling of the slab pour is the final step in construction. The teams in Panama are required to hand mix concrete, which is a labor intensive but flexible installation method. Since the labor required to hand mix concrete is so great, the teams chose to erect the steel and the roof first, which affords laborers the ability to work in the shade. The erection of the columns can take place after the foundations have cured and before the slab pour, as the concrete is hand-delivered there are no chutes to swing.

Steel erection using the previously employed techniques in Panama was imprecise and time consuming yet acceptable for the local people. Laborers and time are commodities the Panama teams have in abundance, with cost being the major limiting factor in their construction. By implementing a few more controls to the project, however, a safer and more stable structure could potentially be produced for the local people of Panama.

Roof

The roof installation was almost identical between the Panama and Lineville, AL homes. Once the roof structure was in place, sheet metal roofing was screwed into the metal purlins using self-tapping screws. The only difference between roofing structures was that in the Lineville, AL house, more purlins were added to create 24” centers and greater strength. One improvement that is recommended for future homes is to install the wider face of the roof purlins upwards, with the wide side touching the roof. This allows for a larger area for roofing screws to be installed, making it easier to connect each screw to a purlin without “missing” the purlin. The final product looks nearly identical in each of the two locations. Figure 8 shows the final product in Lineville, AL.

Figure 8: Completed Structure - Lineville, AL

Conclusions and Recommendations

The work completed in this study constitutes progress in an early step towards a future work. The initial observation and construction trip to Panama identified the following areas of potential improvement: baseplate to column connections; anchor bolt/baseplate assemblies; concrete slab; and roof. The baseplate to column connections were inconsistent at times, with some columns skewed to the far corner of a baseplate, limiting the baseplate to column connection to 3 anchor bolts rather than the typical 4. The researcher developed a standard baseplate design and conducted a successful implementation of this design with a prototype structure in Lineville, AL. It is recommended that future structures in Panama utilize the standard baseplate design which will provide consistency in column fabrication and proper load transfer through the structure to foundations.

The anchor bolt/baseplate assemblies fabricated in Panama consisted of bent rebar welded to the bottom of a base plate with standard grade machine bolts serving as anchor bolts. Additionally, these assemblies were embedded in the foundations achieving only eye-level and using sticks and rocks as support while the foundations cured. The fabrication of the assemblies presents a question of adequacy in strength and the failure to achieve true-level presents problems in achieving plumb columns, leading to further difficulties with roof purlin to column connections. A simple anchor bolt/baseplate template was created and successfully utilized in the construction of a prototype structure to achieve level and consistent anchor bolt/baseplate connections. It is recommended that similar templates are used in Panama construction to ensure good baseplate/anchor bolt connections, plumb columns, and simple purlin connections.

Light gauge metal drywall frames were used for slab formwork in Panama. This slab formwork, which was often warped and out of square, was also used to layout the foundation and anchor bolt placement. The warped and out of square nature of the formwork created foundations, a slab, and an overall structure that was out of square and needed adjustments. The prototype structure created in Lineville, AL laid out the foundations independently of the slab which provided good alignment for the remaining structure. The prototype also utilized un-warped formwork, limiting the imperfections in the finished slab edge. It is recommended that future construction in Panama uses independent foundation/slab layout and seeks to use quality formwork for slabs.

The roof structure in Panama utilized purlins spaced at approximately 40” on-center and oriented with the narrow face to the metal roof panels. The prototype structure was built with slight variations to identify any potential improvements. Improvements that were implemented in the prototype structure include decreasing purlin spacing to 24” on-center for added strength and orienting the purlins on the wide face for an easier connection of the roof panels and fewer missed screw-connections.

Overall, the finished structures in both Panama and Lineville, AL look very similar and perform their intended function under normal conditions. Implementing the recommendations mentioned above could provide a more structurally sound dwelling for the Ngobe people while cutting down on construction time due to field adjustments. Future Research should focus on structural testing of the completed structures, evaluation of other structural systems, viable wall/cladding systems and potential ways to decrease overall cost.

The graduate student's global community engagement in this study created motivation for the student's research of improving and detailing the first iteration of the steel tube house design. The ability for the researcher to engage and serve in Panama translated to a refined design which several churches hope to employ and build at least 50 more homes in the remote jungles of Panama.

This research is the second step in an ongoing effort to (1) design and implement a basic but stable structure that can be easily built in remote areas without extensive training and (2) evaluate and improve the implementation of this structure with the Ngobe people of Panama and (3) extend CDD to other parts of Panama and other parts of the world. Future research seeks to perform a deeper evaluation of the construction of these steel framed homes and determine the effectiveness of CDD as the Ngobe people begin to construct the homes with limited to no face-to-face engagement from the mission teams. The researchers suggest the next steps to be: (1) further analysis of the training program implementation in Panama based on the lessons learned from this study, and (2) identify the needs of the local labor forces for gaining further knowledge necessary to erect the structural frames efficiently and safely.

References

[1] P. Dongier et al., "Community Driven Development," in *A Sourcebook for Poverty Reduction Strategies*, J. Klugman Ed. Washington, DC: The World Bank. 2002. Vol. 1, pp. 301–31.

[2] A. Dy Buncio. "Pros and Cons of Prefabrication and Modularization Techniques." 2014 [Online]. Available: http://www.viatechnik.com/blog/pros-cons-prefabrication-modularization-techniques/ [Accessed 4.30.16].

[3] Z. Li, G.Q. Shen, M. Alshawi. "Measuring the impact of prefabrication on construction waste reduction: an empirical study in China," *Resources, Conservation and Recycling*, vol. 91, pp. 27-39. Aug. 2014.

[4] J.C.P. Cheng, K.H. Law, H. Bjornsson, A. Jones, R.D. Sriram. "Modeling and monitoring of construction supply chains," Advanced Engineering Informatics, vol. 24, pp. 435-455. July 2010.

[5] A. Furco. "Service-Learning: A Balanced Approach to Experiential Education." in *Introduction to Service Learning Toolkit*, pp. 9-18. 1994.

[6] P.L. Barlow, "Case study in implementing a service-learning class in a construction management curriculum," in *Proceedings of the Associated Schools of Construction 45th Annual Conference.* Gainesville, Florida. April 1, 2009.

[7] W. Collins and L. Redden, "Improving Student Estimating Accuracy through Hands-On

Learning: A Case Study," in *Proceedings of the Associated Schools of Construction 53rd Annual Conference*. Seattle, Washington. April 2017.