



Research in Progress: Transforming and Integrating: Evolving Construction Materials & Methods to the Next Level

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Introduction

In recent years, many are concerned that successful engineering research does not necessarily translate into teaching engineering courses and that more effort should be made to incorporate existing and emerging research into engineering education.¹ In addition, the National Academy of Engineering has emphasized the importance of pursuing student-centered education and that one should ensure student learning outcomes focus on the performance characteristics needed in future engineers.² In defining this focus, the NAE suggests better alignment of engineering curricula and the nature of academic experiences with the challenges and opportunities graduates will face in the workplace.³

This research recently awarded by the NSF, Division of Engineering Education and Centers (EEC) aims at addressing these needs by adopting a successful engineering education research into existing engineering courses so that an improvement in student learning can be demonstrated particularly in the area of construction management and civil engineering technology (CM/CIET). Moreover, this study intends to incorporate service-learning projects, as supported by the Habitat for Humanity of Charlotte (Habitat Charlotte), that will provide CM/CIET students with opportunities to use and demonstrate acquired academic skills and knowledge in real life projects. These service-learning opportunities will enhance and reinforce what students have learned in the classroom.

At the University of North Carolina at Charlotte, two introductory courses – ETCE 1121, “Construction Methods” and ETCE 1222, “Construction Materials” – are primarily intended for first year students. In a traditional version of this course, each major topic, represented typically by a chapter in a text, is covered during a week or two of instruction (2 – 4 lectures). While this methodology is considered adequate for teaching the basics of construction methods and materials, it fails to adequately expose the students to how all the fundamental topics are interrelated, nor does it normally provide meaningful hands-on experiences on real job sites. This research intends to target these two courses to affect an evolutionary transformation marked by active-learning in the classroom coupled with real-world, hands-on construction experience at local job sites.

Project Components

In meeting the project requirements, this research deploys three important project components: adaptation and translation of a successful research result for new instructional strategies, demonstration of student learning improvement based on an active, service-learning approach, and dissemination of the project results to create a synergistic environment where best

practices in teaching similar courses are shared. Each of these components is described in much detail below.

Implementing New Instructional Strategies – Evolving the Classroom Paradigm Inside the Classroom

This project will implement strategies to reflect evolving pedagogical techniques not currently applied to engineering.⁴ It will develop, adapt, and test classroom materials, in the form of lecture modules, for a freshman level construction methods (Fall 2011) and materials course series (Spring 2011 & 2012) within an engineering technology curriculum. Guided by recent findings and developing pedagogical research, this project focuses on an active learning, team-based approach to education. In each module, students are moved out of the traditional setting involving passive listening to lectures given from platforms by learned professors. On the contrary, students work in teams to complete worksheets that guide them through the process of learning, actively engaging them in processing information, as well as routinely utilizing and developing important skills such as teamwork, communication, and critical thinking.⁵

Bridging the Learning Material, Teaching Strategies, and Service-Learning – Getting Experience Outside the Classroom

This project intends to formally deploy students to a local job-site to receive hands-on experience while participating in a housing construction program – Habitat for Humanity. Students will receive direct experience actually building a residential facility involving potentially a wide range of technical trades including concrete, carpentry, plumbing, electrical, HVAC, and masonry. These service-learning projects, supported by the Habitat Charlotte, will be part of the modules that will enhance student learning experiences. Student participation will evolve into a formally assessed and graded part of the course.

Developing Faculty Expertise – Training the Trainer

The intrinsic value of developing the planning, organizing, and delivering a new innovative style of classroom instruction emerges directly from the enhancement of classroom skills and instructional expertise of the faculty within the project at the University of North Carolina at Charlotte. However, an ingredient in the project methodology commences with a second year workshop for educating a small select group of faculty from other campuses that also teach courses similar in scope. The workshop will present the educational theory of this pedagogical approach, the emerging assessment data from the “proof of concept” exercise conducted during the first year, and detailed teaching modules suitable for implementing in their own respective courses. This workshop will serve as a springboard for exporting the project essentials into the similar courses and programs at the respective campuses. Consequently, development of faculty expertise will break beyond the bounds of the University of North Carolina at Charlotte into the external academic community.

Literature Review

Guided-Inquiry Learning Modules

This project builds specifically on the results of another curriculum development initiative under an NSF, CCLI-EMD sponsored work, “Development of Project-Based Introductory to Materials Engineering Modules” (DUE # #0341633). In this effort, a multi-university team of faculty developed five lecture modules for use in an Introductory to Materials course in a Chemistry program.⁶ The targeted course is commonly required by most engineering programs with an annual enrollment of 50,000 students. Modules were developed that teach how fundamental principles are interrelated to each other and applied to modern applications in a traditional introduction to materials course in the context of modern technologies. The guided-inquiry modules effectively transform the classroom environment characterized by students learning through lectures to a more engaging, active-learning posture of working in teams to complete topical worksheets. The guided-inquiry worksheets provide data or information as background material, critical thinking questions intended to lead students in understanding associated fundamental concepts, and practical exercises involving applicable problems. The instructor’s role is more consistent with that of a facilitator, guiding students through the material.^{7, 8}

In previous applications, guided-inquiry modules were designed to be utilized within the framework of traditional “lecture only” courses. The actual duration covered by a single module will vary but will typically cover more than one lecture period. Modules will be topic focused and may take 1 – 2 weeks of class time. To date, the modules have been used in multiple introductory to materials engineering courses covering major topics such as polymers and ceramics.⁹ Modules were designed to be independent, complete, and detailed to support portability to other faculty and universities. A module typically would be distributed in booklet form to the students and would include a variety of items necessary for them to master appropriate learning objectives. Student and instructor materials collectively would address a single topic and include the following:¹⁰

- Background information on the topic.
- Learning Objectives.
- Reading Review notes.
- Instructor notes and presentation materials (slides, models, etc.).
- Active In-Class Exercises.
- Demonstrations and Examples.
- An open ended team project.
- Homework problems and solutions related to the project.

Habitat for Humanity

Habitat for Humanity is a nonprofit, international housing program dedicated to eliminating poverty, housing, and homelessness through construction of shelters and homes. Student involvement on behalf of the University certainly provides an opportunity to lead through serving both those in need and the larger community as well. Since it was founded in 1976, Habitat has built more than 250,000 houses around the world, providing more than 1 million people in more than 3,000 communities with safe, decent, affordable shelter.¹¹ Through volunteer labor and donations of money and materials, Habitat builds and rehabilitates simple, decent houses with the help of the homeowner (partner) families. Habitat houses are sold to partner families at no profit and financed with affordable loans. The homeowners' monthly mortgage payments are used to build still more Habitat houses.

While some academic institutions, colleges, and universities have developed habitual links to Habitat for Humanity, most are through student organizations and clubs rather than Departments or Programs and perhaps fail to capitalize on the potential academic value. The scope envisioned by this project where the Habitat mission is tied to a specific course is apparently unique. This project introduces students to construction materials and practices essentially in a methodology generally consistent with a project based learning approach with the students working in teams to execute real-world constructive endeavors involving planning and building a home.

It is widely held that project based learning contains two essential components: (1) a driving question or problem that serves to organize and drive activities, which taken as a whole amounts to a meaningful project; and (2) a culminating product(s) that meaningfully addresses the driving question.¹² Project based learning is associated with some distinctive benefits when compared to learning solely from textbooks including a deeper knowledge of subject matter, increased self-direction and motivation, improved research and problem-solving skills, and understanding how classroom learning connects to jobs and careers.¹³ This research project would work directly with local operational centers located in Charlotte, Concord, Davidson, and Matthews.

Methods and the Concept of Operations

The end-state of this aggressive research project envisions a successful implementation of the guided-inquiry module protocols as well as the deployment of student teams to Habitat for Humanity job-sites at both the University of North Carolina at Charlotte Campus and at other campuses offering similar academic programs and courses. These freshman classes targeted for this effort are an ideal place to excite students about their engineering majors and expose them to real world engineering experiences. As depicted in Figure 1, "Two-Year Operational Timeline," this project is executed in three successive phases going from classroom guided-inquiry module development and "Habitat" exercise planning to an implementation and sustainment spanning multiple campuses.

Phase I: Guided-inquiry Module Development, "Habitat for Humanity" Exercise Planning, Concept Validation and Module Assessment and Refinement

Planning and developing appropriate guided-inquiry modules directly support concept validation operations involving implementation of the project in both the Construction Methods course (Fall Semester, 2011) and the Materials course (Spring Semester, 2011 & 2012). During the concept validation process, one “control” section will be maintained with the instructor using standard, traditional techniques of instruction or lecture; the guided-inquiry approach will be implemented in a second section run in parallel with the control section.

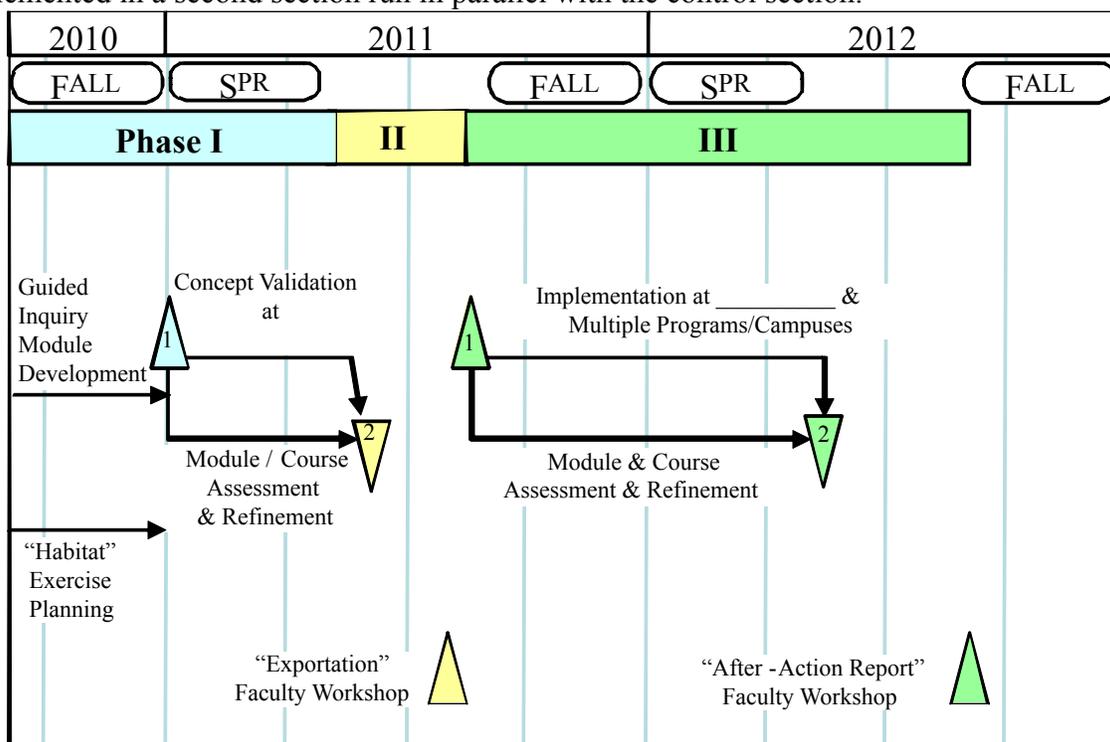


Figure 1: Two-Year Operational Timeline

During the Materials course, the section selected for implementation of the guided-inquiry modules will also provide a source for groups of students to comprise the Habitat workforce. The 3-hour labs included with the Materials course provide the infrastructure for planning, organizing, and implementing the Habitat program. With approximately 25 students per lab, a single lab section will be selected and deployed in total to a job-site once during the semester during a single regularly scheduled lab period.

Assessment will occur throughout the semester and will provide timely opportunities for improving the process application during execution as well as supporting comprehensive evaluation of the project. Students will be assessed in accordance with the evaluation plan. Phase I evaluation will also include a comparative analysis of assessment data comparing the “control” sections with the implemented sections to validate the concept and establish a basis for refining the guided-inquiry modules, the Habitat exercise, and the course itself if needed.

Phase II: Engaging the Academic Community -- Recruiting Other Programs and Campuses

The Project materials (modules, assessment questionnaires and other tools, evaluation results, and lessons learned) developed, implemented, and refined during Phase I will be presented during a Workshop held at the University of North Carolina at Charlotte for a small group of carefully selected faculty from Community Colleges and Universities with similar construction methods and materials courses. Course materials will be packaged to support immediate implementation at participant home institutions after any modifications required to conform to respective semester schedules and individual course learning objectives. Faculty attendees will be provided a stipend for attending with the intent to enlist their participation during Phase III.

Phase III: Project Exportation Off-Campus and Sustained Implementation at the University of North Carolina at Charlotte

In addition to continued implementation at the University of North Carolina at Charlotte, Community Colleges and Universities who participated in the first Workshop will be enrolled to participate in the project during Phase III. The research team will support these external faculties in addressing and resolving issues concerning module/Habitat development and implementation as well as student/Project assessment activities. A second Faculty workshop will be held late in Phase III to afford a comprehensive after-action review of the activities from all campuses. Assessment/evaluation results from the implementation efforts will be shared. Participants will also receive a stipend for attendance at this workshop but will be expected to provide formal written individual course assessment reports (ICAR) documenting their project analysis. Written interim reports will be expected 45 days after the conclusion of each semester where the project was successfully implemented; a final report for external institutions will be within 65 days of the conclusion of the final semester where the final semester.

Important Project Features

Quality, Relevance, and Impact

The overall purpose and goal of this project is to transform a conventional course sequence in construction methods and materials and to engage students in an off-campus construction experience to keenly supplement classroom instruction and personal experience with real, hands-on construction tasks. This project will set the conditions to compel students to be responsible for their own learning in the classroom and will demonstrate the utility of integrating Habitat for Humanity into a targeted freshman course in engineering materials. Historically, the first-year students enrolled in this course typically have very little or no professional experience in construction. This relatively low cost venture involving Habitat has potentially highly significant benefits in reinforcing learning objectives from the classroom.

The courses identified in this project have a forecasted enrollment for 2011 of approximately 100 students each. However, the impact of the project will extend far beyond the targeted courses: first, in perhaps an indirect routing, as incoming freshmen secure a firm

mastery as well as some direct construction experience from Habitat, future follow-on courses should be favorably influenced by inheriting better, more prepared students; secondly, as the project is designed as an outreach initiative to be “exported” to other college and university campuses, these benefits will be quickly spread to other academic programs in the STEM community.

Student Focus

This project’s student focus is paramount to its success and has a clear relation to affecting learning – both in the classroom and on the job site. The project is expected to accomplish the following objectives:

- **Increase Student Learning:** Students will be responsible for and engaged in learning, turning a passive listening exercise into an active, participatory exercise where the students learn by doing.
- **Increase Student Engagement:** With the instructor facilitating in the classroom rather than lecturing and Habitat providing construction opportunities, this initiative will increase student engagement by providing many with their first hands-on experience with construction techniques and procedures; it will also provide an opportunity for them to witness how their chosen field can benefit and engage the community.
- **Enhance Faculty-Student Interaction:** By integrating faculty into the Habitat program working side-by-side on-site with students, the faculty-student interaction will be further enhanced through the required cooperative efforts to jointly comply with Habitat for Humanity’s building expectations.
- **Improve Student Cooperation:** The project will improve cooperation among students as they serve on teams during classroom exercises to master learning objectives and on construction teams dedicated to collectively construct a specific feature of a home. Essentially, teamwork will be critical for success.
- **Promote Active Learning:** This project features classroom pedagogy and hands-on learning that directly promotes active learning. Led by seasoned Habitat mentors as well as University faculty, students will learn by doing as active participants in a real-world constructive endeavor.
- **Improve Student Performance of Course Learning Objectives:** As the project engages students to actually employ the tools and materials of the construction industry in constructing homes, their mastery of stipulated course learning objectives should be enhanced and show improvement.
- **Aid Academic Community Building:** As the project commences Phase II with the Workshop for Community academic partners, a dialogue and sharing of ideas, resources, and policies, procedures, and technique will provide a basis for a working, long-term relationship that will synergistically benefit participants as well as our collective understanding of STEM learning.

Use of and Contribution to Knowledge about STEM Education

As the literature review indicates, other disciplines outside traditional STEM areas (such as Chemistry) have recently successfully implemented the guided-inquiry methodology. Application of this approach to active learning will demonstrate a common thread with some students outside of STEM that has not been previously established or even extensively investigated. Further, successful implementation will perhaps validate the premise that students if given the chance can quite successfully and with reliability take more responsibility for their own education. By the same analysis, this project may conclude that the traditional STEM instructional approach of a professor lecturing from the platform in the front of the classroom can no longer be viewed as the default, acceptable mode of interaction with students. This research should provide some credence to the supposition that STEM students excel when confronted with an active-learning, engaging mode of instruction and when they are a key player.

STEM Education Community-Building

This project is specifically designed to interact not only with the Educational community but also with the local community as well. Beyond the educational benefits, the University of North Carolina at Charlotte should also benefit from this project as an outreach initiative to the local community. Through the Office of Educational Outreach (OEO), the University already works in conjunction with numerous groups, departments, and professionals in an effort to reach out and connect to the community. These activities typically target “teachers, middle and secondary students, counselors, administrators, and other community stakeholders that are committed to strengthening the local infrastructure of education, i.e., curriculum, pedagogy, networking, resources, etc.”¹⁴ The project envisioned by this research would provide another link through community service and good will and would positively reflect the University’s commitment to being a vital member of the region.

Sustainability

After the developmental work is accomplished, sustaining the paradigm for both the continuation of the classroom active-learning model as well as maintaining ties with Habitat organizations is considered an extremely low cost proposition with large potential benefits. It is anticipated that this will become a long term commitment.

Expected Measureable Outcomes

The project goals and objectives noted above translate into the following measureable outcomes. These outcomes will be employed to track progress during the project based on both objective and subjective measures noted later in the Project Evaluation Plan.

- **Increase Student Learning:** Objective measures such as specific graded events during the semester will be employed to measure student performance which will be

comparatively evaluated against previous semesters as well as during Phase I, against the control group.

- **Increase Student Engagement:** Participation and student engagement will be assessed through student surveys, direct observation by the instructor, and interviews with third parties, that is, the Habitat administrators and job foremen.
- **Enhance Faculty-Student Interaction:** Project impacts on faculty-student interaction will be measured through student surveys and interviews.
- **Improve Student Cooperation:** Student cooperation will be assessed through student surveys, direct observation by the instructor, and interviews with third parties, that is, the Habitat administrators and job foremen.
- **Promote Active Learning:** Student preference for active-learning methodology will be assessed through student surveys and will be directly inferred by Phase I comparisons between project participants and the control group.
- **Improve Student Performance of Learning Objectives:** Collective measures of individual graded events will be documented to indicate student performance in terms of the course learning objectives.
- **Aid Academic Community Building:** Questionnaires and post-interviews will measure the benefits and relative strength of working relationships, the benefits from sharing academic initiatives, and plans for future collaboration.

Project Evaluation

External assessment of this project will be provided through the Center for Education Measurement and Evaluation (CEME)¹⁵ from the University of North Carolina at Charlotte. CEME routinely serves research efforts both internally and externally to the University to assess both quantitative and qualitative performance criteria. The investigators for this project will also conduct a highly structured assessment project to document progress in terms of the project objectives. Assessment and evaluation activities will be structured to assess each of the specific objectives noted earlier including the course learning objectives.

Table 1: Assessment Tool Application Matrix

*Note: Questions for Interviews and Surveys may change based on targeted population.

Assessment Tool Supporting Project Objective Evaluation		Guided-inquiry Module Implementation	Habitat Participation	Instructor Workshop
Graded Homework/Exercises		Yes	Yes	
Exam Problems		Yes		
Interviews	Student*	Yes	Yes	
	Faculty/Instructor* (UNCC)	Yes	Yes	Yes
	3 rd Party* (Non-UNCC)		Yes	Yes
Survey (Pre-Event)			Yes	
Survey (Post-Event)	Student*	Yes	Yes	
	Faculty/Instructor* (UNCC)	Yes	Yes	Yes
	3 rd Party* (Non-UNCC)			Yes

The project evaluation will be based on both survey data and objective assessment data collected before, during, and after each semester when the project has been implemented in the classroom. As shown on Table 3, a variety of tools will be employed at key target of opportunity to solicit, capture, and analysis performance data. The collective sum of all applicable assessment and evaluations for each course during either Phase I (Validation) or Phase III (Implementation) will collated in a form Independent Course Assessment Report (ICAR) which comprises a significant deliverable from the research effort. Classroom performance will be tracked with objective data (graded homework, exercises, and exam problems) augmented with subjective data resulting from Pre- and Post-Surveys and interviews. Student data and perceptions will be complimented with input from faculty through surveys and interviews as well. The Habitat mission will also be deliberately measured as shown in figure 1.

Before

All students enrolled in the course will complete surveys designed to identify their level of knowledge and experience at the beginning of the semester. Commensurate with the Habitat program, students will be further assessed during interviews. Information collected will document past experience and current level of knowledge on applicable learning outcomes and develop profiles for the student populations. During Phase I, these profiles will also be measured against descriptive statistics for the student groups who are pursuing the traditional “lecture-mode” of instruction.

During

At the job-side, faculty observers will document any Habitat related on-the-job training and instruction and the demonstrated skills displayed by the students. These skills may include technical as well as functional expectations regarding oral communication and team performance. Further, during the classroom instruction, periodic feedback will be gathered from the students concerning their perceptions of the effectiveness of the project and the Habitat experience in promoting the project objectives.

After

Student participants will perform an after-action review through surveys as well as selected exit interviews. The participants will be tracked collectively as they complete the course and assessed on their respective mastery of the course learning objectives in light of their job site excursion. Particularly during Phase I, their performance will be measured against course standards as well as against the “control group” – that is, those students who did not participate in the Habitat mission or the guided program of study – to determine if any statistically significant differences in outcome mastery can be determined and if so whether it could be reasonably tied to the experience gained through this project.

Habitat Personnel

Persons representing the work accomplished at the Habitat worksites will also be surveyed/interviewed to capture their assessment of the project and to document any noted benefits, outcomes, or shortfalls.

Work in Progress

This NSF, Division of EEC sponsored project initiated in September 1, 2010. Since then, several tasks were accomplished as summarized below:

1. Forming Research Team – A strong research team consisting of two faculty members and one Ed.D candidate was formed to complete the aforementioned research agenda. Although this research involves engineering education, a graduate student with expertise in service-based learning from the College of Education was recruited to share specific expertise to evaluate the effectiveness of the self-learning modules in enhancing student performance. The Center of Educational Measurement and Evaluation also committed to share their expertise in student performance assessment and evaluation.
2. Module Development – In the course on construction materials addressed in this paper, the modules are currently a work in progress, being developed for each of the six primary topics comprising the major blocks of instruction for the course: aggregates, concrete, asphalt, metals, wood, and masonry. These blocks typically cover about two weeks of

classroom instruction for each topic. The instructional methodology shared by the six blocks of instruction included:

- Preliminary Quizzes to measure initial knowledge levels and mastery
- Facilitation of Guided Inquiry Modules for the Block of Instruction
- Post Quizzes at the conclusion of the Block of Instruction to measure student learning and mastery of associate learning objectives.

The Guided Inquiry Modules stand independent from each other and address each separate block of instruction. Students submit completed Modules for grading prior to the Post Quizzes. Module are assessed and returned to students for use in preparing for future graded events. The modules share a common format and generally include:

- Background information on the topic
 - Learning Objectives.
 - Active In-Class Exercises.
 - Demonstrations and Examples.
 - Homework problems and solutions.
3. Habitat for Humanity Coordination – Three local affiliates for the Habitat for Humanity were contacted for student participation during the spring semester. Based on the home building project schedule collected from each affiliate representing different counties within the state, a master schedule was created that allowed students to sign up for participation that fits their schedule. Participation in the Habitat for Humanity project will occur on Saturday and each session on the site will be supervised by one of the research PIs.

Conclusion

This relatively low cost venture works to deliberately advance discovery and understanding of the utility of a newly emerging classroom teaching and learning paradigm coupled with integration of a real world, hands-on opportunity to apply fundamentals of construction methods and materials. To accomplish this objective, the project promotes effective, engaging teaching, trains faculty in innovative techniques for active-learning, and gauges success primarily by evaluating student learning. However, the significance does not stop with student learning but rather extends to the University as well as to the community – both academic and civil.

- Student Learning:** Perhaps the most significant result of this project will be the transformation of these freshman level courses from a passive mechanism of professor lectures to an active-learning environment where the students play a key role in mastering course objectives. The students targeted by this project will directly benefit from applied educational pedagogy developed previously from earlier funded CCLI research. Further, this project will document a low cost solution to a recognized need – how can students, predominately right out of high school receive experience in order to make learning less abstract and more relevant? The Habitat operation gives the students a tremendous opportunity to gain first-hand knowledge of materials, methods, techniques, and procedures employed to produce a constructed facility. Led by seasoned Habitat mentors as well as University faculty, students will learn by doing as active participants in a real-world constructive endeavor. Further, by integrating faculty into the program working side-by-side on-site with students, faculty-student interaction will be enhanced through the required cooperative efforts to jointly comply with Habitat for Humanity’s building expectations. The team projects in the classroom coupled with the Habitat experience will also improve cooperation among students as they serve on construction teams dedicated to collectively construct a specific feature of a home. Ultimately, these results will collectively serve to engage students to actually employ the tools and materials of the construction industry in constructing homes; their mastery of course learning objectives and project outcomes should be enhanced and show measurable improvement.
- University public relations and community outreach:** By actively engaging students in a worthwhile, charitable endeavor such as Habitat for Humanity, the University of North Carolina at Charlotte directly benefits by demonstrating its commitment to the surrounding community. Through the Office of Educational Outreach (OEO), the University already works in conjunction with numerous groups, departments, and professionals in an effort to reach out and connect to the community. This outreach initiative will certainly provide increased student engagement for many with their first hands-on experience with construction techniques and procedures; but it will also provide an opportunity for them to witness how their chosen field can benefit the community. The project envisioned by this research would provide yet another link through community service and good will and would positively reflect the University’s commitment to being a vital member of the Charlotte region. Additionally, this opportunity stands to benefit a family in need who is destined to reside in the facility the students will help build.
- The Academic Community:** Integrating other members of the academic community in a vital key to the success of this project. With successful partnering with other academic programs, even with this relatively small application, the tenet can be demonstrated that the pedagogy is exportable and these same results can be achieved in new programs. Initially, this effort is limited to schools with similar curricula and courses, but certainly success on this relatively small scale should open additional routes to other disciplines within engineering technology as well as STEM. The coordination and sharing of the

project particulars supports dialogue and brainstorming on future innovations that can implement new initiatives or build on older, successful programs. The academic community collectively will benefit for the insights and lessons learned gleaned from this local experience. In this manner, the project should stimulate and support the development and dissemination of even newer shared research and educational platforms.

- **Integration of Research and Education:** The project provides a number of excellent opportunities for undergraduate research and education as we seek better ways to apply pedagogy and produce educated people for the society we serve. Applying fundamentals developed through previously funded research in other disciplines, this project integrates new, active learning techniques to engage students in a dynamic, highly effective manner. It also provides students with hands-on experience in real-world constructive ventures, applying materials and methods previously studied in the abstract.

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