Engaged Interdisciplinary Engineering Design in a Minka House for the Aging

Dr. Brandon S. Field, University of Southern Indiana

Brandon Field teaches in the thermal fluids area of mechanical engineering at the University of Southern Indiana, Evansville.

Dr. Adam Giles Tennant
Mr. David J. Ellert PE, University of Southern Indiana

Dave Ellert teaches freshman engineering problem solving, computer aided drafting and design (CAD) and computer programming. He has a B.S. degree in mechanical engineering from Purdue University. Dave has been on the USI Department of Engineering faculty since 2003.

Dave is a license professional engineer registered in the state of Indiana. Prior to teaching, Dave worked 18 years as a consulting engineer designing HVAC systems for buildings.

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Introduction

A pilot demonstration Minka house has been built on campus in a collaborative project between the Gerontology Department, the Engineering Department, and the MAGIC team. MAGIC is an innovative gerontology care group external to the University which includes medical professionals as well as aging experts; the acronym stands for "Multi-Ability, multi-Generational, Inclusive Communities". The partnership between the MAGIC team and the Gerontology Department was initially brought about through a conference that is sponsored by the Mid-America Institute on Aging and Wellness. At the beginning, discussions and planning meetings for the partnership included many different departments and units throughout campus. In particular, several Engineering faculty produced contributions to the overall project. All of the faculty members contributing to the present article were involved to varying degrees with the initial discussions planning of the overall collaboration.

The Minka house is characterized by a small and efficient floor plan design that is easily accessible, to allow for a longer period of independent living by the residents. The construction is made of modular wood panels that are fabricated using CNC wood tools before being brought to the construction site, to allow for affordable construction but still allow for aspects of customization by the residents. The initial project only included a single home, but the long-term vision is to take advantage of scaled manufacturing and possibly produce a "MAGIC village" of these homes, in proximity to one another and lived in by multi-generational residents.

The partnership between the MAGIC Team and the University provided unique learning opportunities for students. In particular, the engineering students participated in a number of different ways that integrated into courses on campus.

A team of college seniors conducted a manufacturing analysis as a capstone design project. For their project, they developed the design of a flexible work cell that could be used to produce the modular units for multiple houses that would make up the MAGIC village. The work cell would allow rapid production and assembly but still leave some degree of customization options, to be selected by the residents.

The construction site of the house in the middle of campus was easily accessed during and prior to construction; this allowed the students more opportunities than they would have been for a typical building project. A Soil Mechanics class took advantage of this by taking soil samples that were analyzed using the same techniques included in the laboratory portion of the class, but with a tangible application. These results were documented in the format of a geotechnical report, giving the students in the class another true-to-life example of the material being taught. The worksite availability was also used by a Construction Estimation class to give those students a real-life example of crew productivity to observe.

Finally, the proposed MAGIC village of multiple Minka houses is currently being used this semester in a Project Management course that is taught as part of an Engineering Management concentration of an MBA program. This is giving the students a realistic project that will be used to illustrate and reinforce the management principles taught in the class. The project management plan produced by the MBA students could be used in the potential upcoming project MAGIC village.

Manufacturing and Construction

The Minka houses are designed to be manufactured using standard 4' x 8' wood sheets that could ideally be locally sourced at the construction site. The sheets are cut using a CNC wood saw, and then assembled into panels which are then constructed into the actual house. For the single unit, the wood sheets were cut and assembled off-site, and they were transported by truck several hundred miles to the construction site on campus. If an entire "MAGIC village" of these houses were to be put up, a local assembly facility is part of the sustainability vision of the project. It might even be desired to have the wood-working equipment shipped as an entire assembly facility in a shipping container to the construction site, where it can produce the panels from locally sourced supplies. The design of a self-contained collection of wood-working equipment was discussed as a possibility of a student-team design competition, but has not been pursued yet.

Within the Engineering Department, a degree in Advanced Manufacturing is offered, specializing in manufacturing technologies and techniques. A team of three seniors, two Advanced Manufacturing students and one Industrial Engineering student, took for their capstone project the design of a work cell that could easily and economically produce the assemblies for these houses. The team observed the construction site several times throughout the semester in order to identify the sizes of the parts needed, and the construction techniques that were being used to better quantify the needs of the assembly cell. They worked in communication with the off-site collaborators, and experienced all the real-life frustrations with communication lags and misunderstandings. Their analysis included an economic analysis, the floor layout, recommended manufacturing machinery, and their final recommendations included site location if this were to be implemented on campus, including all the relevant safety aspects (most campus locations that were available would be sharing space with instructional labs). The recommendations from their report will be used if the "MAGIC village" phase of the project is implemented in the future.

Some thermal aspects of the Minka house design were considered in a class assignment for a thermodynamics and heat transfer course taught as part of the Advanced Manufacturing curriculum. The peak heating load for the Minka house was computed for different densities of EPS insulation. The results indicated that there was only a minimal difference in heat load, and so the lighter (and therefore cheaper) insulation would be the preferred choice.

Soil Mechanics

This construction site located in the middle of campus was a tremendous opportunity for civil engineering faculty as it allowed a way to make tangible the concepts in class that are taught during lecture. Other larger scale constructions sites on campus tend to be fenced off for safety concerns. This limits access and basic visibility of the site. The model Minka site, although pre-constructed and modular, still requires a solid foundation. To transfer the structural load to the soil below, the design called for auger piles. The design of these auger piles is partially determined by soil conditions on the site and requires a geotechnical report. This soil investigation was performed by a third party geotechnical firm that specializes in this work and produced an investigational geotechnical report.

The faculty member who teaches Soil Mechanics in the Engineering Department had worked collaboratively with university officials and MAGIC team members early on to incorporate the project into CE381. The Soil Mechanics course covers physical and index properties of soil, soil classification, and includes eight laboratory experiments. The course content matches very well with the knowledge needed to produce a geotechnical report such as required at the Minka site. From the faculty members prior experience teaching the course, it was desired to have the lab be a more dynamic and formative experience for the students. To do this, the Soil Mechanics class incorporated the Minka site soil into the laboratory portion of the class. A formative approach was taken to the individual labs that would all come together to produce a summative project of a geotechnical report of the Minka site.

For the first lab and before ground was broken at the Minka sites by the contractor, students collected soil samples at various depths to determine the moisture content of the soil in situ. The students additionally collected soil at a depth of around 3 feet which was later used in subsequent laboratory experiments to determine gradation (size of particles), specific weight, and plasticity of the soil. After ground was broken, the students returned to the Minka site and requested an equipment operator to use an excavator to collect soil which they needed in the lab to perform compaction and permeability testing. The students performed eight detailed geotechnical experiments on the soil that will go into the geotechnical report. They produced various tables and graphs to assist in the visualization of the results.

Wherever possible, coordination was made between the class, the university, MAGIC, and the construction professionals to obtain information such as the plans sets and the physical soil boring to make this project of completing a full geotechnical report strongly resonate with the students as a reality-based experience. Additionally, during the course, a new industry standard software on groundwater seepage was introduced to better prepare the students for the working world. An assignment was made for the students to analyze a fictional ring levee around the Minka home as a flood control feature with the new software.

A traditional lab manual was not used but laboratory instructions from various Departments of Transportation across the country were provided, as this is what the students would be expected to use professionally. Concurrently videos were provided so the students could see sample lab work completed.

The students enjoyed the course and a reversal in a declining course and student evaluation was observed between this most recent offering and the course evaluations from the previous fall, which was rewarding to the faculty member see Table 1.

Table1: Course Evaluation and Student Evaluation for CE381 Soil Mechanics Pre and Post Minka House Project Material Incorporation

	Course Evlauation	Student Evaluation
CE381 (2017)	80%	80%
CE381 (2018)	87%	88%

Course evaluations are an important source of information as individual faculty members assess their teaching effectiveness. Course evaluations are mandated at this university for every course taught. These course evaluations are conducted at the end of each regular class during the two weeks before finals. Two categories of questions are present in the questionnaire. The course evaluations category which seeks to measure instructor effectiveness; the other category student evaluations which seeks to measure the student's view of their self-performance. The values shown in the table are the mean of all the questions in a single category together.

Construction Estimating

The Minka project was not only utilized for the Soil Mechanics class but also in the Civil Engineering course for Construction Estimating, CE301. This course is a study of the characteristics, capabilities, and operating costs of equipment and primarily estimation of construction costs. Typical assignments include quantity takeoffs, pricing of materials, classification of work, labor assignment, overhead calculations, reading specifications, and bidding a fictional project. All care was taken to make the course as realistic as possible by incorporating a project from the US Forestry department to encourage engagement. Unfortunately, the students only had virtual access to this site in the form of pictures, maps, and plan sets. To supplement this project-based learning, an assignment was created that allowed the students to visit the Minka site and observe construction activities.

A significant driver of cost in construction is crew productivity; these numbers give an idea of units per hour that can be performed by a crew of labor and equipment. For example, an excavation crew composed of 1 laborer, 1 operator, and an excavator would be able to dig 50 CY/Hr. These productivity values drive cost as they determine hours worked by labor and equipment utilization. These values can often be roughed in by utilizing estimating manuals. Unfortunately, these cookie cutter production figures tend to produce erroneous cost as productivity often varies significantly by site conditions. An example of this would be the presence of overhead power lines that would slow productivity from the excavator by limiting its full swing. Estimating from personal experience is ultimately the objective of the class and is how senior construction estimators work.

The students were given an assignment that required them to capture a construction activity potentially at the Minka site. The students had to upload a video and several photos and include a description of the activity and identify and document the productivity. The students had to thoroughly describe the labor, equipment, and material to complete this activity. A specific Instagram account was set up for this class to post these findings in an attempt to further motivate the students. The assignment was graded according to a rubric based on if the student fully captured the construction activity in words and pictures. The main purpose besides giving the students an opportunity to see estimating as a dynamic career path was to integrate field conditions into their understanding of estimating which was challenging to coordinate but worked out well. Again, a small but measurable increase was observed in course and student evaluation for the course between this most recent year and the same course the previous year, as shown in Table 2, giving support to this method of engagement for student perceptions and satisfaction.

Table 2: Course Evaluation and Student Evaluation for CE301 Construction Estimating Pre and Post Minka House Project Material Incorporation

	Course Evlauation	Student Evaluation
CE301 (2017)	77%	84%
CE301 (2018)	88%	91%

Project Management

The original Minka site with the university was an exciting project that provided a useful model to prove the construction technique and further the theory of MAGIC. The project led to a further desire for the MAGIC team and the University to work together on the first blended, student/elder, multi-ability, multi-generational, inclusive community.

The goal of creating a MAGIC Village on a future property has earned equity through the model Minka and the cooperative efforts between the external developers and the university students and courses. A preliminary budget and plan has been developed that outlines the knowns related to a Minka Village of 15 houses. Some of the activities that need to occur are: general planning, horizontal site development, and physical construction of the Minka homes. The infancy and scale of this project lends itself to a full-blown project management approach.

It was determined, based on the success with the past student involvement with the MAGIC project, that the graduate course in Principles and Practices of Project Management would be a good fit to incorporate the proposed Magic Village project plans. This course is an examination of the fundamental principles of project management with emphasis in technical enterprises and strongly stresses the role-playing aspect in the class to enable students to develop an understanding of project management concepts and provide opportunities to employ them. The course has recently been moved to an online format due to its use in the online MBA program. This course has over 70 students enrolled in the class.

The course is underway in the Spring semester, and some of the products that will be produced by the students include: a project charter, work breakdown structure, project schedule, detailed budget, risk analysis, and a project management plan. Significant effort has been put into including the MAGIC team in the course and obtaining as much factual information as possible so students can practice the craft of project management. A secondary goal is to potentially produce documentation that could be useful to the MAGIC team and the University for use in the project.

Conclusion

A collaborative effort that took place between the Gerontology Department and Engineering Department has taken form around the construction of a new Minka house that is intended to change the shape of independent living. The efforts of the Engineering Department thus far have resulted in using the project to provide real-life educational opportunities for the students. Some of the work that was performed by the students has been used in the existing project, and much of what was done could be used in the proposed future phase of this project. In addition, there are additional collaborations that have been discussed that would continue the collaboration between the Engineering Department and the rest of the MAGIC team that need to be explored. The ubiquity of material that engineering students can participate in meaningfully means that there are many possibilities of turning collaborative efforts into learning opportunities that fit within the engineering curriculum.