Living Learning Labs
A Component of the University of Alabama’s
Engineering Math Advancement Program

by

Dr. Karen Boykin¹, Ph.D., J.D., Ms. Sandy Wood², M.S., Celina Bochis³, M.S., Dr. Semih Olcmen⁴, Ph.D.

Abstract

The University of Alabama through sponsorship by the National Science Foundation’s Science Technology Engineering and Mathematics (STEM) Office implemented a summer bridge program entitled Engineering Math Advancement Program (E-MAP) incorporating Living Learning Laboratories developed by each of the engineering disciplines. In this paper the E-MAP is summarized and importance of introducing students to experimental, hand-on research at an early level is discussed. Paper also outlines the expected roles of a mentor to ensure the success of students. The impact of the hands-on experience on the student learning is given.

I. Introduction

The University of Alabama through sponsorship by the National Science Foundation’s Science Technology Engineering and Mathematics (STEM) Office implemented a summer bridge program entitled Engineering Math Advancement Program incorporating Living Learning Laboratories developed by each of the engineering disciplines. EMAP plays on five important learning principles that are geared toward ensuring that knowledge is retained and not just memorized. In addition to EMAP’s math component, students are encouraged to develop their skills through the interdisciplinary Living Learning Laboratory hands-on experiences, problem solving teaming exercises, and by interaction with other engineers and instructors. Students are introduced to fundamental engineering concepts, with a mathematical basis, in each of the engineering disciplines in the College of Engineering.

I.A. Need:

Freshman level courses engage students in the engineering design and problem solving processes, but without the necessary “practical” experience, the connection between theory and practice is often missed. This leads to a break in the education process. To prevent this rift, engineering faculty at the University of Alabama developed Living Learning Laboratories, exposing students not only to their own disciplines, but to every discipline taught in the College of Engineering (COE). The labs enable entry-level students to receive immediate exposure to the issues and problems that interdisciplinary engineering professionals confront on an everyday basis. This is a necessary step to ensure that the student gains the information needed in order to decide the path of engineering that best suits their individuality. The laboratories have been established in a manner to encourage the faculty teaching them to conduct experiments when possible that will enhance and reinforce the math theories being taught with the use of visual imagery to bring the concepts of mathematics to life.

Science and engineering students’ involvement in practical (laboratory) work enforces their understanding of the theories of science (Scanlon et al., 2004). This also fits with the different learning styles incorporated into the learning experience proposed. This is the primary reason for the inclusion of the

¹ E-MAP Program Coordinator
² Freshman Engineering Program Instructor
³ Ph.D. student, Civil, Construction, and Environmental Engineering Department
⁴ Associate Professor, Aerospace Engineering and Mechanics Department, AIAA Associate Fellow
laboratory component to the E-MAP. Similar programs have been shown to be a very effective mechanism in other disciplines to further the interest and student’s knowledge of an area (Benson et al., 1996). Teaming and integration of ideas to solve problems is a key component that is necessary in the science field. The goal of the “living lab is to provide snap-shots of this experience to the students in as close of fit as possible to the “importance of mathematics” theme.

Specifically, the problems and needs that the E-MAP curriculum addresses are:

1. There is no “ramp-up” program for students entering the engineering program in need of additional mathematics instruction to become engineering calculus ready.
2. Students that develop a lack of vision, motivation, and excitement for the engineering profession among entering freshmen often loose enthusiasm while struggling through early preparatory and fundamental core math and science classes.
3. Students can become disenfranchised from the learning process due to the formal college structured class format. This can be intimidating, particularly those students from smaller or rural high school systems.

I.B. Rationale:

The dropout rate for students in Engineering at UA is slightly over 33%. This is a serious problem as many capable students are leaving the engineering field for a variety of reasons. Some of the contributing factors in student dropout, identified by studies in this area, are: natural ability, as measured by high school GPA, ACT/SAT scores; the quality of high school education (Tinto, 1975; Tinto, 1987); and, personal characteristics such as race, gender, financial background, personal motivation, and student involvement. All these things have been correlated to student retention rates (Tinto, 1975; Tinto, 1987; Boulton-Lewis et al., 2000). It has also been established that a positive faculty interaction with students will directly benefit retention rates (Pascarella and Terenzini, 1979). Further documented strategies that have been effective in disciplines outside of Engineering are supplemental instruction (Etter et al., 2001) and university based counseling services (Wilson et al., 1997).

II. Program Overview

The goal of EMAP is to provide the basic environment leading to the retention of students in the college of engineering. To accomplish this goal, the summer E-MAP curriculum has three objectives addressing each of the three problems identified above. The first objective is to improve math skills of incoming students. Supplemental instruction has been shown to lead to improved GPA and retention in other disciplines (Etter et al., 2001). The second objective is to provide hands-on experiences that increase motivation in both math and engineering as a career and thereby increase the motivation level within students. Increasing motivation has been shown to increase the chances of retention (Tinto, 1975). Finally, the third objective is to present the subject matter in an informal, interactive, and interdisciplinary atmosphere so there is a better chance for learning to occur. According to the law of readiness (US Navy, 1992), students learn best when they are physically, mentally, and emotionally ready to learn.

II.A. Math Component:

The E-MAP program is a revised version of the Math 112, 113 and math 115 accommodating a 4 day per week, 3 hour per day combined formal and informal class setting. Any student scoring 300 or above (pre-calculus algebra) on the math placement test is eligible to participate. The first week of the program is dedicated to assessing individual students math skills using the NSF sponsored Assessment and Learning in Knowledge Spaces (ALEKS) software developed jointly by the University of New York and University of California. (Cosyn, 2005)
II.B. Living Lab Component:

The living lab is based on the seven areas of engineering at UA. Two days during each of the five summer weeks are devoted to on-campus laboratories. There are two primary objectives of the laboratories: exposing students to the practical side of each engineering discipline and using math skills in an engineering setting. The first objective is achieved by giving engineering “broad-picture” engineering problems and illustration of the thought process behind each step of engineering analysis and design and teaching them how to break large, complicated projects down into small manageable pieces. The second emphasis, practicing math skills in engineering, is enhanced by exposing students to “data-gathering” experiments in each laboratory. The data gathered is useful for examining, explaining, or simplified derivation of engineering theory.

The goal of the laboratory program in addition to applying math theories learned in E-MAP is to provide a hands-on environment to teach team work as well as exposure for the student to the practical side of each engineering discipline. As a result, students experience research and education in action as part of the field of engineering. Each department is provided a vehicle here to highlight current research that will increase the level of excitement of students entering the discipline. This is an opportunity to the departments to immerse the students in the “hands-on” work within each field to aid the student in deciding career selection and development.

III. Introducing Students to Research

Research is a process by which students can discover or create new knowledge about the world in which they live. Students who are introduced to research are permitted to design projects that provide quantitative data through experimentation followed by analysis and application of that data. "Scientists try to understand how nature works; engineers create things that never were." Engineers should be encouraged to ask: "How can I make this better?"; “What are my design criteria?”; “What does past research explain about what has been done before?”; and “What does testing tell me?” (Society for Science and the Public, 2008).

III.A. Inherent "Knowledge Gap":

The Knowledge Gap Theory was proposed by Phillip Tichenor and his associates at the University of Minnesota in the mid 1970s. They believed that the increase of information from new media sources in society is not evenly acquired by every member of society: people with higher socioeconomic status tend to have better ability to acquire information (Weng, S.C. 2000). This digital divide leads to a division of two groups: one better-educated and information rich, and the other with lower education and information poor, who know less. Lower socio-economic status (SES) people, defined partly by educational level, have little or no knowledge about public affairs issues, are disconnected from news events and important new discoveries, and usually aren’t concerned about their lack of knowledge. "The greatest challenge facing new engineering graduates is in finding the best way to reduce the "knowledge gap" between what students have been taught academically and what they actually need to be able to do once they begin to work," said David Checkel, Professor of Mechanical Engineering at University of Alberta in Edmonton. Hands-on and inquiry based demonstrations where knowledge is applied can be valuable for this purpose.

III.B. Concepts Can Be Over Their Head:

Engineering faculty often report difficulties with student learning of concepts and skills associated with the solution of typical basic mechanics problems. For example, basic mechanics problems involving force and moment equilibrium remains a difficult area for a significant number of students, even in later years of their degree. Researchers have broken down three theories for difficulties in understanding engineering concepts:

1. Academic history: Insufficient math and physics preparation
3. Lack of Contextual Understanding: Students do not have a basis for engineering problems. Research findings more often today suggest that rather than adopting a deficit model of students based on their variable prior training in math and physics, it might be more productive to target specific gaps in basic skills (i.e., use and manipulation of equations), or to support learning in problem areas of the analysis process and to orient the teaching approach for introductory mechanics to those gaps (Dwight and Carew, 2009).

III.C. Must Relate New Concepts to Concepts They Understand:

The question remains, how do you relate new concepts to concepts students will understand? This may vary based on focus area, however, visualization and application can be powerful aids in understanding engineering concepts. It is envisaged both students and faculty will benefit in classrooms of the future where more visualization and application techniques will be used. In the fields of electrical and computer engineering, high-quality computer graphics have allowed the visualization of complex scientific and engineering concepts (Close, 2009). In the University of Alabama’s EMAP Program, Dr. Harold Stern, faculty leader for the Electrical Engineering Living Lab, uses this concept learning by taking simple tasks in electrical engineering for student learning through visualization. The purpose of the lab is to help students gain a more intuitive understanding of the sine function and to see how it is applied in everyday life. Many basic music and speech sounds are composed of sums of sine and cosine functions. Sounds are tested breaking them into a series of sines and cosines allowing speaker identification and speech recognition. Knowledge of sines and cosines is used to remove background noise from poor speech recordings, making the recordings more understandable. Finally, the knowledge of sines and cosines is used to analyze vibration from a machine to determine wear and to diagnose which part within the machine is starting to wear out. Students are shown applications of and reasons why sine waves important to audio engineers who record and analyze music and speech, to wireless systems engineers who design cell phones, to programmers who create speech recognition programs, speech-to-text programs, to forensic analysts, like the CSI forensic scientists, who analyze speech characteristics to identify a particular speaker, to reliability engineers, and to many other seemingly unrelated types of engineers (Stern, 2006).

III.D. Need to Develop Base Understanding:

“Learning is enhanced when it is built on student’s prior knowledge and experiences allowing learners to link what they already know to new information to be learned” (Roth, 1990). References note that it would be excellent if our technical institutes and universities would educate students in basics of engineering, followed up by training in a set of good practices (Jacobson, 2009). The lack of preparedness of graduates for professional careers with well rounded skills is a complaint raised by practitioners (Karunasekera, 2007). In addition to introducing students to Living Labs, the EMAP Program at UA involves student based industry learning. Similar to activities at the University of Melborn, where undergraduate students work on a project with industry during their final year, EMAP students are provided real-life engineering experience. While the project begins the process for in preparing students for work with industry, observations in both cases are that attention must be paid to the breadth of skill understanding needed to succeed as practitioners and the importance of building upon the basis of concepts learned. (Karunasekera, 2007). Engineering disciplines are based on theoretical foundations used as a basis to form a deeper understanding, a body of rules, design patterns, implementation procedures and engineering processes. However, the consequent application of many of the results of research in formal theoretical methods into practice is still missing. To complicate matters, each engineering discipline has and needs its own theoretical and mathematical foundation like other engineering disciplines. The next step must, therefore, be to increase the experimentation and the transfer of these theoretical results to engineering. To bring theory to practice, well-understood application scenarios are needed for proposed formal methods. If we want to bring formal methods and theoretical foundations closer to practice, we need a clear idea of the skills of people that are going to apply these methods. In addition, we need competent and open-minded partners in industrial applications both among the development engineers and their clients. We have to rethink the way we carry out research in
engineering to make sure that the feedback process between theory and practice is improved. We are at an exciting stage with technological advances, particularly in software engineering and formal methods. Most of the theoretical work required for the foundations has been done. What is needed is an experimentation, integration and application (Broy, 1999). Through classrooms, applied laboratories, and partnerships, EMAP faculty and staff are beginning their work as part of this process.

III.E. Should be Engaging and Interesting:

“To teach is to engage students in learning... the aim of teaching is not only to transmit information, but also to transform students from passive recipients of other people's knowledge into active constructors of their own and others’ knowledge” (Christensen, 1991). According to Dr. Dan Roth, Professor of Engineering, University of Illinois, and well published author of models addressing how to engage students, learning should include three components: (1) Active Learning involving students in doing and thinking about the things they are doing; (2) Constructiveness where students are encouraged to use active techniques (experiments, real-world problem solving) to create more knowledge, reflect on, and talk about their understanding; and (3) Hands-on and learning in which students experience powerful ideas. The desired outcome: students actively and thoughtfully engaged in their studies.

III.F. Competing for Time:

Further complicating the need to keep engineering students both engaged and interested, is the competition for their time. How can teachers and mentors find the time and place to know and connect with students among extant demands such as staying current with knowledge, advances in technology, and changing student demographics? Similarly, for students, are competing demands, such as keeping pace with teachers’ knowledge and learning while at the same finding time for the increasing number of extracurricular activities or possibly employment to pay tuition, housing, and meals? (Diekelmann, 2003). Priorities and expectations must be set with the students at the beginning of their time with instructors. As a part of EMAP, students are provided a Study Skills series of lectures covering topics of time management, test preparation, and general college life information. At this time, open dialog is used to obtain feedback from students as to their priorities and where engineering studies fit.

III.G. Cannot be Discouraging Unless Student is Highly Internally Motivated

There are many factors that can work to discourage students pursuing engineering degrees: the level of mathematics knowledge, the average number of years for graduation compared to other degree programs, the pay rate compared to careers such as attorneys or business majors, and the study load required for most students. Under the EMAP curriculum, the interim space between high school and college is “bridged” with a program designed to optimize communication in the classroom and presented at the level most suited to the students. Communication includes open discussion of these issues. Students are made aware that engineering may not be for everyone. Characteristics of engineers are covered in EMAP along with Myers Briggs Testing, LASSI testing, and Math Science Inventory testing. Students are asked to complete the LASSI and Math Science Inventory tests prior to entering EMAP, and then provided Myers Briggs upon leaving and entering their fist freshman semester. This provides time for students to consider their own personalities.

IV. Becoming a Research Mentor

Academic development of a student is enhanced if the student is also engaged in active research throughout their studies with a mentor. The mentor's duties would include interacting with the student, personally welcome them to the profession, guide them in their studies, give them a broad understanding of the field with different examples, and direct them in the areas that are of interest to the student by referring them to books, research articles, and then actively interact with the student in the details of a topic of
interest. The disciplined research develops skills additional to the ones taught in class, such as writing and presenting their research and using the research tools.

Mentoring for research requires a mentor not only to be a good communicator but also a good listener, enabling her/him to read the needs of the student and match them with the needs of the research. These conditions may change from day to day according to the daily progress of the research or according to the emotional conditions of both the mentor and the student. A mentor is required to be able to address personal as well as motivational issues a student may have. Mentoring for research requirements differ depending on the level of the student. For example while the graduate students want to be more independent, produce results and present them in their discretion, undergraduate students need guidance in understanding the material as well as interpreting the results.

Under the context of the EMAP program the students are exposed briefly to the ongoing research in different engineering fields and to the research tools while they are improving their math skills. They become familiar with the laboratories within the university and develop a better understanding of the different fields. Enough exposure to positive engineering scenarios motivates students to find an area of study where they are comfortable. Through EMAP, students are improving math skills, and exposed to experienced professional engineers and real-life projects to build both self-esteem, a sense of pride and belonging in the profession, and ease them comfortably into the college environment. Example Living Laboratory work in students analyze data of calculated air flow around an aircraft wing and produced plots to display stream lines, velocity contours, and pressure contours around the airfoil. "Engineering students are engaged because they can create something recognizable out of a mass of data. In the process, they learn how to manipulate array structures and use MATLAB visualization capabilities," notes Craig. Motivation is the process of prompting a person to learn (Maslow, 1943).

IV.A. Must Relate First to Student Personally

An excerpt taken from Carla Alderman, a 2006 English undergraduate student recipient of the Leslie and Patrick Ballard Scholarship spoke of her experience talking with one of her mentor teachers: 'When asked how he came to be such an effective teacher, Larry laughed and said, "I have sat in that chair. I know what it's like to be in that audience." Because of this common ground, Larry believes that students and professors are "colleagues" and should share a mutual trust. "I think a lot of professors don't trust their students. This distrust recycles itself and creates a negative environment for everyone." (Alderman, 2004).

While it may not always be possible, there are benefits to relating to students individually. EMAP places students in groups of 30 or fewer with one instructor and two mentors for more one-on-one time. Emphasis is placed in two areas: first relating to students to cover materials, and second on finding out about the students themselves. Although it was the original design for EMAP to have small class sizes, teacher evaluators of the program, asked for more individualized student skill attention. High school physics and mathematics teachers recommended assessing individual student skills. The ALEKS software has assisted instructors for this purpose. Time spent connecting with the students learning aspects, is also provided during class mentoring, hands-on and teaming exercises, as well as industrial trips and social events.

IV.B. Student Should Want to Emulate (Follow) You

According to Upwardly Mobile, Inc., 2009, the best way to find the success path that’s right for you is to emulate, model and mimic the behaviors of people you admire. Superficial career assessments tell you that you’ll be a good engineer, doctor or entrepreneur and give you memorable talking points for social chatter. But the best way to get inspired, get focused and get results. EMAP has been very fortunate during the five years of operation through NSF support to involve some of the best faculty and instructors from the University of Alabama. The faculty was hand selected as those who have demonstrated a strong interest in student learning both inside and outside of the classroom. Faculty and instructors from each of the engineering disciplines possess dynamic personalities and serve as strong role models, providing the students
with opportunities early on to select mentors in their fields of interest. Although faculty are provided a small stipend of $1,000 each to work with students both during the summer and fall EMAP programs, their involvement has been more of a passion for helping students prepare themselves for upper level coursework and following careers. One common characteristic learned from polling instructors was that you must keep a positive outlook for yourself and your students. Be prepared you may not get through to every student, but the effort is worth your time when you can see the outcomes for those students where a connection and impact was made.

V. Presenting Research Ideas Through Demonstrations

E-MAP Living Lab focuses on exposing the students to the application of math concepts in different engineering areas and additionally acts as an introduction to the application of the math concepts in community related projects. Through the E-Map program students are exposed to math that is also commonly used in research. As an example, one of the living labs held in UA is the demonstration of the θ-β-Mach relation, commonly used in the study of the oblique shocks in Aerospace Engineering. In this lab a 17° wedge is placed in a supersonic tunnel and the tunnel is run at preset Mach number not known by the students. During the run schlieren pictures are obtained.

Students arriving to the lab are first introduced to the working principles of supersonic tunnels. First, the components of the supersonic tunnel are briefly explained. A basic description of the area variation with the Mach number is given to demonstrate that the Mach number can only increase after the flow passes though the throat section, where the flow reaches Mach=1, and that the area downstream of the throat needs to increase to achieve supersonic flows. Next the components of the schlieren system are explained, to introduce the students to the fact that the density variations within supersonic flows can be actually visualized to see the shock waves. Next the tunnel is run and the pictures obtained with a camera are downloaded to a PC and printed.

The students are next taken to a class room and are explained that a relation exists between the θ, β and the Mach number of the flow. Thus the students are first exposed to the equation governing the relation, and the difficulties associated using such an equation. Next the θ-β-Mach chart is given and the students are instructed to how to read such charts, and are next requested to find the Mach number using the chart. The pictures obtained previously are then used to calculate the Mach number of the flow.

This lab, given as an example, served the multiple needs that were aimed by the E-MAP program. Exposing the students to the working principles of a supersonic tunnel motivated the students to learn, since the working principle is against the common intuition that a flow would speed up once it flows through a narrow section of a duct. The introduction of the θ-β-Mach relation exposed the students to a math problem. Reading values from the θ-β-Mach chart allowed the students to focus on how to use graphs. Reading the tunnel Mach number and finding the correct tunnel Mach number gave the students a sense of complete relation between the lab experiments and the math behind it in a hands-on fashion.

E-MAP Living Labs were combined with a societal benefit component that introduced students to participation as “team engineers” on real-world projects sponsored by the West Alabama Chamber of Commerce’s Environmental Task Force. The Figure 1 Example of living labs and the other parts of E-MAP program.
“Chamber Project” addressed how to research a project, how to work as part of an engineering team, and the thought process in tackling an engineering problem. Teams of students taking the same lab were asked to take the elements of math and science from their lab experiments, field trips, and interviews with practicing engineers to investigate engineering aspects of design related to a proposed subject (example: water theme park). Figure 1 is an example of how the living labs can be integrated into the other parts of the program. Those kinds of projects are meant to be challenging and fun, to exercise students’ imagination, creativity, and maturing engineering skills. The Chamber members were extremely impressed with the student’s presentations and their interaction with local engineers. Also, students enjoyed projects rating them overall with an average of 3.0/4.0.

VI. Impact

At the end of the E-MAP program students were asked to rate their hands-on laboratory experiences by giving a grade for the lab teacher, a grade that indicated how well prepared they were for the math involved in the lab, and an overall grade for the lab itself. Their rating provided insight for which examples were more successful and enjoyable. Figure 2 shows the overall grade (base of 4.0) for the eight labs offered from 2005 to 2008 summer programs. The higher-rated labs received positive feedback often related to the ‘hands-on’ quality of the lab and the instructor’s teaching qualities and knowledge of the subject. The most common negative student comments about the lower-rated labs seemed to be related to lack of time to properly understand was going on in the lab and not enough ‘hands-on’ participation.

Also, in E-MAP students experience the interrelationship between mathematics and engineering. Math is the language of science. Engineers apply scientific principles to real-world projects. This concept is presented to the students in four ways during the program:

• “hands-on” laboratory experiments in several engineering disciplines;
• interactions with practicing engineers;
• field trips to installations where engineers work;
• the application of some basic design and math principles learned

Figure 2. Overall grade for the eight E-MAP labs
VII. Conclusions

The outcome of this EMAP program will be felt at three levels: The student level where the program benefit will be: An increased understanding of math and improved math skills upon entering the first freshman semester of college; A better understanding of the different engineering disciplines and career choices available to the student, giving them better direction and guidance in choosing a curriculum; an improved chance of completing college within four years; and motivation toward achieving an engineering degree; and Early exposure to college life and the skills necessary to learn in the college environment. The college level: Elevated level of classroom instruction tailored to a higher level of math understanding; Increased number of COE graduate; A clearer understanding of educational barriers and methods to improve learning; Publication of institutionalized activities and outcomes as a result of the project. The societal level: The field of STEM disciplines will be enhanced because more graduating engineers will have a firmer grasp on engineering fundamentals in math. Program data for the past four years of operation are currently being assessed. Outcomes will be published soon. For those interested, they may contact the authors and view process at the EMAP website: http://emap.ua.edu.
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