AC 2008-440: MODULAR, ADAPTABLE AND REUSABLE APPROACH TO THERMAL-FLUIDS: OUTWITTING THE NORMS (MARATHON)

Ivana Milanovic, University of Hartford

Ivana M. Milanovic is an Associate Professor of Mechanical Engineering in the College of Engineering, Technology, and Architecture at the University of Hartford. She received her Ph.D. in Mechanical Engineering from Polytechnic University, NY and M.S. and B.S. from University of Belgrade in Yugoslavia.

Tom Eppes, University of Hartford

Tom A. Eppes is an Associate Professor of Electrical and Computer Engineering in the College of Engineering, Technology, and Architecture at the University of Hartford. He holds Bachelor and Master of Science degrees in Electrical Engineering from Texas A&M University and a Ph.D. in Electrical Engineering from the University of Michigan.

Modular, Adaptable and Reusable Approach to Thermal-Fluids: Outwitting the Norms (MARATHON)

This paper describes the results of a project that implemented modular, adaptable and reusable thermo-fluids laboratories in the undergraduate Mechanical Engineering Technology (MET) Program. MARATHON (Modular, Adaptable and Reusable Approach to Thermal-Fluids Outwitting Norms) successfully engages students in inquiry and learning, gradually building toward intellectual and practical challenges without pre-determined outcomes. For the most part, research and discovery activities did not figure prominently in the MET curriculum. In the past, typical laboratories consisted of a set of exercises with pre-established experimental set up, and instructions. This concept did not foster critical thinking skills because it did not provide students with the opportunity to build experiments and models from scratch, experience difficulties, be resourceful, explore alternatives and make design decisions. Therefore, there was a strong pedagogical need for better practical problem solving skills in the area of thermo-fluids.

MARATHON was created to facilitate development of student problem solving skills in which students become active participants in the process of discovery. To accomplish this, a cluster of interconnected laboratories in the area of thermo-fluids was reconfigured and organized in a pyramidal block-like system. These blocks were: (1) classical experiments, (2) jigsaw experiments, and (3) design of an experiment. This new laboratory structure provides an array of experiences, builds on already existing skills and knowledge, and connects them in a logical way.

MARATHON was first implemented in Fall 2002 and has been used for four academic cycles. The primary benefits have been to expand the students' understanding of the complexity associated with designing and successfully performing an experiment from scratch. Each year at least one project has been featured at the University's undergraduate research colloquium. Laboratory platforms have been provided from other courses to expand the experimental options available to students in MARATHON. Future plans include expanding MARATHON to other programs and disciplines, i.e. analog/digital electronics. Additional laboratory platforms will be developed in the area of computational fluid dynamics (CFD) and virtual LabVIEW-based experiments.

Introduction

The College of Engineering, Technology, and Architecture (CETA) at the University of Hartford has a population of about 800 undergraduate students of which 420 are enrolled in engineering technology (ET) programs. Within CETA, there are three departments that collectively support five four-year ET undergraduate programs. The ongoing challenges we face are:

- More creatively engage students in the laboratory
- More effectively use space, equipment and faculty resources
- Modernize instrumentation and equipment

The Mechanical and Electrical & Computer Engineering Departments are situated in the recently-completed Integrated Science, Engineering, and Technology (ISET) complex. ISET is comprised of two old and one new building. We maintain several special purpose laboratory rooms primarily for undergraduate programs, plus a variety of research facilities that also serve double duty in support of undergraduate programs. While ISET provided newly renovated as well as some additional space, the project did not include major capital equipment purchases or a multi-year plan to refresh the equipment infrastructure.

Moreover, an ABET visit in 2001 found that laboratory equipment for thermo-fluids in the Mechanical Engineering Technology Program (MET) was non-existent. This resulted in the laboratory sections for these courses becoming problem-solving sessions without hands-on laboratory exercises. Consequently, thermo-fluids courses were taught with a theoretical emphasis without the hands-on component normally found in an engineering technology course of study. At the same time, the Electronics Engineering Technology (EET) Program was exploring new ways to expand experiential learning for students taking electronic courses.

Faced with a lack of equipment and insufficient replenishment capital, we took inventory of our current resources, and discovered that there were a number of deficiencies particularly in certain topical areas. To leverage resources, we started having students construct models in the machine shop (thermo-fluids labs) or in other cases, began using virtual experiments that were performed over the Internet (electronics). A distance laboratory system called Advanced Laboratory Test Environment (ALTE) was developed and pilot tested for two years.[1-3] Using ALTE, students were required to perform supplemental experiments over the Internet. However, feedback showed that students strongly preferred to come to the laboratory and enjoyed the hands-on team-based setting it offered. Therefore, we began to view the virtual laboratory as complementary to but not a replacement for the hands-on laboratory.

Hands-on laboratories are not only equipment intensive, but the development of quality experiments is time-consuming to faculty. This responsibility normally falls on the faculty who teach laboratory-based courses and is not shared across the department.[4] A widely held view is that laboratory sections are under-credited for the amount of work and time that is required to teach them. Rather than continuing to pursue a faculty-centric approach, we decided to engage the students in a new learning proposition.

The quest for a better laboratory experience, led us to a more progressive concept called MARATHON (Modular, Adaptable and Reusable Approach to Thermal-Fluids Outwitting Norms). MARATHON is a pyramidal block-like system that employs an unconventional approach to both the design and execution of experiments. With MARATHON, students are challenged to progress through a process of pre-planned labs, open-ended exercises and finally to develop a new experiment from scratch. The laboratory experience steps through three learning blocks: (1) Classical Experiments, (2) Jigsaw Experiments, and (3) the Design of an Experiment (DoE). Each of these blocks is presented to the students sequentially during the course of the semester. This paper describes the structure of each learning block, how it is implemented and interestingly enough how student-designed experiments can be deployed into other courses for re-use.

MARATHON Structure

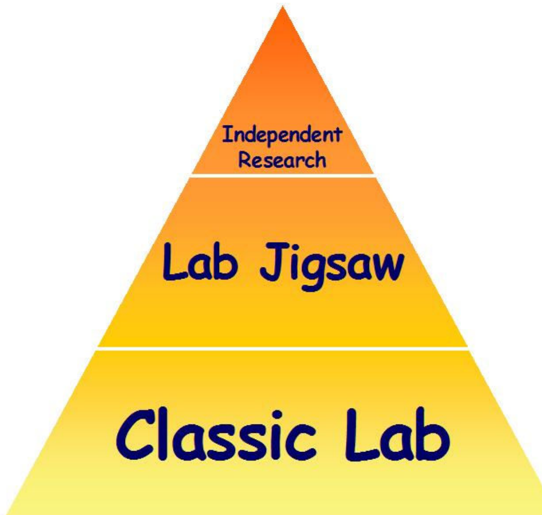
In most undergraduate engineering and technology curricula, design and research experiences are delayed until the capstone/senior design project. This prevailing approach does not properly prepare students for the creative rigors of design-level activity. Typical laboratories preceding the capstone experience consist of a set of exercises with largely pre-set experimental set ups and instructions. Detailed procedures are provided and expected to be followed; outcomes are largely pre-determined with written reports detailing the results obtained.[4-5] Such a concept exposes students to measurement techniques and tools, and enhances their understanding of fundamental laws of the discipline. However, this approach has two drawbacks. First, it requires a significant level of equipment and resources to properly span all course topical areas. Second, it does not foster critical thinking skills, i.e. provide students with the opportunity to build experiments and models from scratch, experience difficulties, be resourceful, explore alternatives and make design decisions.

We are currently using MARATHON in the thermo-fluids laboratories of the MET Program. To date, we have found that students are more engaged in inquiry and learning as they face the intellectual and practical challenges of MARATHON. The components of MARATHON are shown in Table 1 along with their respective activities and outcome assessments.

Component	Activity	Assessment of Outcome
Classical Experiment	Exercises with conventional set up and procedures provided	Written report
Jigsaw Experiment	Experiments with defined objectives but without a complete set of instructions	Written report
Design of an Experiment	Creative exercise in which student teams propose and execute a project within a limited budget and timeframe	Formal oral presentation to judges plus written report

Table 1. MARATHON components, activities and outcome assessment

The components are delivered sequentially beginning with the Classical Experiment. A few of this type of experiment are scheduled to familiarize students with the lab facilities and measurement equipment. Written reports are required and are often the first time students are exposed to American Society of Mechanical Engineers (ASME) technical documentation standards. Building on the first component, a Jigsaw Experiment is then introduced. The Jigsaw is similar to the Classical Experiment since it has defined objectives; however, some instructions are intentionally left out forcing students to synthesize the set up to successfully collect meaningful data. The culmination of MARATHON is the DoE in which teams of students identify, design and perform a relevant experiment of their choosing. In an end-of-the-semester symposium, the design teams deliver formal oral presentations to an audience made up of faculty, students and a panel of judges some of whom are practicing engineers drawn from local industry. Figs. 1 and 2 illustrate the pyramidal structure of MARATHON as well as its overlapping components.



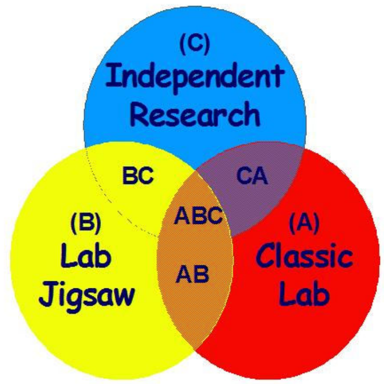


Fig. 1 Lab Pyramid

Fig. 2 Lab Venn Diagram

The learning outcomes of the Classical Experiments are:

- Familiarize students with lab facilities and measurement equipment
- Give students experience in data acquisition, analysis and interpretation of results
- Provide a logical approach to experimental work
- Acquaint students with documentations requirements

These outcomes are generally found in most laboratory courses. However, in MARATHON, they prepare students for more independent work later in the semester. The learning outcomes of the Jigsaw Experiments are:

- Construct models for test purposes
- Describe results through a process of discovery
- Synthesize the experimental set up from the elements provided

The final block is the DoE in which students integrate their prior experiences into an independent research project appropriate for the course and budgeted funds. Students, working in teams of 2 to 4, are provided sufficient time to brainstorm project ideas. The team submits a project proposal that adequately summarizes the purpose of the DoE. An acceptable project must meet the following criteria:

- Relevance to one or more of the course topics
- Scope of effort required
- Originality
- Time and resource constraints

The learning outcomes of the DoE are:

- Ideate and screen concepts down to a single proposal
- Gather and utilize relevant information
- Evaluate specific alternatives within the construct of the experiment
- Synthesize set up and experimental procedures
- Design, build and assemble test fixtures
- Work in a team of 2 to 4 people
- Design and perform an experiment from scratch
- Thoroughly document the DoE in a technical paper
- Deliver a formal oral presentation to a panel of judges

MARATHON integrates an array of laboratory experiences, builds on skills and knowledge already gained, and sequences them such that students gradually learn to perform at more complex levels of experimental design. Furthermore, the DoE block has the potential of feeding ideas and/or modular components into the first two blocks or into other courses.

MARATHON transforms the role of laboratory instructors from one who simply oversees the successful execution of pre-planned experiments to that of a mentor. We have found that MARATHON actually becomes a liberating experience for the faculty since students are challenged to assume a greater responsibility for their learning experience. With MARATHON, the shear quantity of exercises is less; however, abandoning the exclusive use of pre-planned experiment leads to students playing a more active role in seeking and discovering information.

Expanded Benefits

Developing new laboratory experiments complete with fixtures and models is a time consuming process. Too often, an experiment is not updated, or worse yet, retained beyond its useful life. In MARATHON, some DoEs may be adopted by other courses, particularly those that follow in a sequence. For example, new experiments may be generated for use in traditional laboratory courses that do not use the MARATHON approach. For MARATHON-based courses, a supply of new Classical and Jigsaw Experiments may be provided by previous generations of students.

The transplanting of experiments within course bundles can be a powerful change agent within the curriculum. The Lab Reactor diagram of Fig. 3 illustrates how this works in the thermo-fluids area with three complementary sub-disciplines, thermodynamics, fluid mechanics and heat transfer. Each sub-discipline benefits by mutually sourcing experiments from each other thus promoting continuous improvement.

In the past, our experience in capstone project courses has been that many students are not fully equipped to be successful. They often lack creativity, initiative and the ability to develop robust solutions for the problem at hand. A series of MARATHON-oriented courses introduces students to challenging and open-ended problem solving at a much earlier stage in the curriculum. We have found that MARATHON facilitates the integration of knowledge, and is consistent with the notion that traditional boundaries no longer apply. To prepare the next generation to meet the global challenges of the future, MARATHON equips graduates with critical thinking, planning and execution required in real world problem-solving.

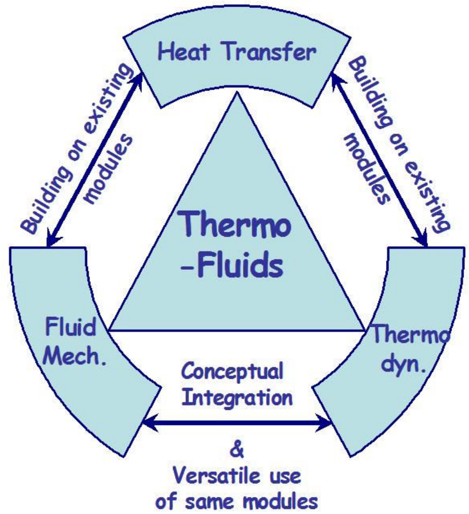


Fig. 3 Lab Reactor

Conclusions

MARATHON was first implemented in Fall 2002 and has been used for four academic cycles in the MET program. We have experienced the full range of benefits and have directly observed the development of skills largely gained by designing and successfully performing an experiment from scratch. Several projects have been featured at the University's undergraduate research colloquium, and MARATHON has exported models and/or experiments to other courses.

Future plans include expanding MARATHON to other programs and disciplines, i.e. analog/digital electronics. As new laboratory platforms are developed in the area of computational fluid dynamics (CFD) and virtual LabVIEW-based experiments, we anticipate that MARATHON will become more widely used in laboratory courses.

References

1. Eppes, T. and Schuyler, P., 'A General-Purpose Distance Lab System,' *International Journal of Modern Engineering*, Vol. 5, No. 2, 2006.

2. Eppes, T. and Schuyler, P., 'A Totally Distance Laboratory Solution for EET/CET Programs,' *American Society of Engineering Education 2006 Conference Proceedings*, Chicago, Illinois.

3. Eppes, T., Schuyler, P. and Oruganti, T., 'Pilot Test Results of a New Distance Laboratory Platform,' *American Society for Engineering Education 2005 Conference Proceedings,* Portland, Oregon.

4. Truax, D. D., 'Improving the Learning Process of Laboratory Instruction,' *American Society for Engineering Education Annual 2004 Conference Proceedings,* Salt Lake City, Utah.

5. Butler, W. M., ‘Introducing Experimental Design in Mechanical Engineering Laboratories,’ *American Society for Engineering Education 2005 Conference Proceedings,* Portland, Oregon.