Collaborative Research: Center for Mobile Hands-On STEM

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Dr. Kathleen Meehan is presently an associate professor in the Bradley Department of Electrical and Computer Engineering at Virginia Tech. Her previous academic positions were at at the University of Denver and West Virginia University. Prior to moving in academia, she was employed at Lytel, Inc., Polaroid Corporation, and Biocontrol Technology. She received her B.S.E.E. from Manhattan College and her M.S. and Ph.D. from the University of Illinois-Urbana/Champaign under the direction of Prof. Nick Holonyak, Jr. Her areas of research include design of optoelectronic materials, devices, and systems; optical spectroscopy; high heat load packaging; and electrical engineering pedagogy.

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Dr. Yacob Astatke completed both his Doctor of Engineering and B.S.E.E. degrees from Morgan State University (MSU) and his M.S.E.E. from Johns Hopkins University. He has been a full time faculty member in the Electrical and Computer Engineering (ECE) department at MSU since August 1994 and currently serves as the associate chair for Undergraduate Studies. Dr. Astatke is the winner of the 2012-2013 American Society for Engineering Education (ASEE) Mid-Atlantic Region Distinguished Teacher

Award. He teaches courses in both analog and digital electronic circuit design and instrumentation, with a focus on wireless communication. He has more than fifteen years experience in the development and delivery of synchronous and asynchronous web-based course supplements for electrical engineering courses. Dr. Astatke played a leading role in the development and implementation of the first completely online undergraduate ECE program in the state of Maryland. He has published over 40 papers and presented his research work at regional, national and international conferences. He also runs several exciting summer camps geared towards middle school, high school, and community college students to expose and increase their interest in pursuing Science Technology Engineering and Mathematics (STEM) fields. Dr. Astatke travels to Ethiopia every summer to provide training and guest lectures related to the use of the mobile laboratory technology and pedagogy to enhance the ECE curriculum at five different universities.

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Dr. Deborah Walter is an associate professor of Electrical and Computer Engineering at Rose-Hulman Institute of Technology. She teaches courses in circuits, electromagnetics, and medical imaging. Before joining academia in 2006, she was at the Computed Tomography Laboratory at GE's Global Research Center for eight years. She worked on several technology development projects in the area of X-ray CT for medical and industrial imaging. She is a named inventor on nine patents. She has been active in the recruitment and retention of women and minorities in engineering and currently PI for an NSF-STEM grant to improve diversity at Rose-Hulman.

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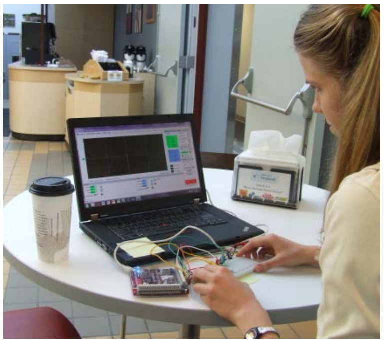
Vision and Goals of the Center for Hands-On STEM

Hands-on activities are an essential part of the learning experience for STEM students to demonstrate theoretical concepts in practice and to connect students with the experimental component of our STEM disciplines. Historically, these activities were relegated to structured experiments conducted during formal lab courses in limited access, centralized laboratories utilizing expensive equipment and requiring extensive support infrastructure. In recent years, the ready availability of portable, low-cost, experimental platforms (e.g. standalone systems like LEGO NXT kits and electronic measurement systems that connect to laptops through USB ports like the Analog Discovery design kit from Digilent and the myDAQ data acquisition device from National Instruments) is making it possible to fundamentally change the educational experience we can deliver to our students. These new tools can help create **a ubiquitous hands-on learning environment** anywhere and anytime: at desks in a traditional classroom, in a dorm room, in a study group setting, at a coffee shop, etc. These small, mobile experiments allow for a new pedagogical model that opens new avenues for inquiry-based learning of fundamental concepts, experimental concepts and skills, and give students experience in system level design and integration.



Imagine mobile hands-on learning activities that involve both the student and the faculty member in the learning process without considerable time or effort by the instructor. And, suppose that there are freely available resources to assist a faculty member, educated under the old lecture system, to introduce hands-on learning modules and rapidly develop his or her own modules using validated procedures. Now, let's consider what would happen if this pedagogical approach is integrated throughout a STEM curriculum so that students see how concepts from one course can be applied in other course to build a system-level understanding of their discipline. Suddenly, we have STEM graduates who know, and appreciate, the complexities of their discipline and who are able go out into the workforce and immediately contribute to product development. Perhaps, a larger percentage of U.S. STEM students will decide to pursue advance degrees and, with the holistic systems-level knowledge gained from hands-on learning, help to sustain and further the Nation's technological and economic leadership and increase the well-being of all. This is the vision that drives the center – the challenge to provide the next generation of STEM professionals with the skill set and motivation needed so that they remain in the field, retain a creative and innovative spirit, and participate in the advancements in STEM and STEM education.

Different constituencies benefit from this new mobile hands-on approach to learning:

Students have the tools immediately available to solve problems on design projects, to participate in design competitions, and to just tinker and follow their own creativity to new areas of discovery. They also bring a more engaged attitude to class and find learning concepts with the mobile equipment to be easier and more accessible than with traditional, high-cost, limited-access and intimidating lab equipment. Students get accustomed to the tools and become comfortable doing things on their own. Online and distance learning students have equal access to hands-on activities as do on-campus students.

Instructors have a new way to facilitate inquiry-based learning through hands-on activities. They can develop course content anywhere and anytime; new ideas for labs, activities, and projects can be easily tried out at home rather than waiting until lab classrooms and technical staff are available. With minimal resources, teachers can easily integrate mobile hands-on activities into their courses, even non-STEM classes, with the result that a wide range of students will be exposed to STEM concepts and be shown how STEM impacts all aspects of life. This process can re-invigorate the instructor's love for teaching.

Institutions will have new options for incorporating practical lab experiences into their curriculum without the need for expensive equipment and dedicated lab space since students own their own equipment. The cost of Mobile Hands-On STEM experiments can be so low that most financial barriers disappear. Disciplines that have traditionally not had any technological component now can add this critical aspect and address real-world problems and applications in exciting areas like biomedical and environmental sensing.

Non-Governmental Organizations that offer successful K-12 STEM activities like FIRST Robotics can now afford the tools to make electrical and computer components equal in value and accessibility to the mechanical and structural components in the eyes of the participants. As the cost of hardware continues to decrease, opportunities abound for informal learning in all disciplines using mobile hardware. Stand-alone kits that utilize low-cost mobile hardware and software can be designed and made available to the Boys and Girls Clubs, Girl Scouts, and other groups to engage all children in STEM activities.

Center Plans

Mobile Hands-On STEM (MOHS) has been implemented and studied in three NSF funded projects: The Mobile Studio Project (RPI, Howard, Rose-Hulman, U Albany); Lab-in-a-Box (Virginia Tech); and TESSAL (Georgia Tech). Application of MOHS pedagogy has expanded at all partner institutions and been successfully transferred to other institutions in the US (e.g. Wisconsin-Madison, Boston University, Morgan State University, Virginia Western, Community College of Rhode Island, etc.) and in other countries (e.g. Ethiopia, Cameroon). In all cases, hands-on learning has been successfully implemented at low cost, with more engaged students and instructors, and hands-on learning implemented in courses that were traditionally only theory based. Although the development and spread of this exciting new approach to STEM education argue for broad application, the documented case for its adoption is not yet at the stage where all STEM educators can fully appreciate its merit. This is due, in part, to the characteristics of the early adopters who tend to be curious and innovative about how students learn within their content; at ease with the technology of electrical and computer engineering; well acquainted with

STEM educational research, etc. As a result, the most effective approach to STEM education is still in question in the broader community and best practice methods of dissemination of MOHS pedagogy to the entire STEM community have not yet been identified.

RPI, as the lead institution, along with Georgia Tech, Virginia Tech, University of Albany, Rose-Hulman Institute of Technology, Howard University, and Morgan State University are pursuing activities that support the following goals:

I. Gather strong evidence of the effectiveness of Mobile Hands-On STEM pedagogy on student learning
II. Develop a pro-active dissemination strategy that will be effective with all of the STEM educational community.

To achieve these goals, we are documenting the evidence already available on mobile hands-on learning, identifying and standardizing the assessment tools utilized by the three main partners (RPI, Georgia Tech, Virginia Tech), developing and implementing new assessment tools that measure student learning as well as ease of adoption by instructors, holding a practitioners' best practices workshop for instructors who currently employ mobile hands-on education to build a community of users to pool expertise, holding focus groups among different constituencies to identify the barriers for wide-spread adoption and how these might be overcome, holding a series of mini workshops to introduce mobile hands-on learning to instructors from these different constituencies, and will pilot a full-scale workshop for new instructors to mobile hands-on learning.

Over the next two years, the center will undertake the following tasks in support of these activities:

1) **Assemble Evidence of Student Learning from Mobile Hands-On Learning**
   Document our model of engineering pedagogy that builds on years of experimentation with and without mobile platforms, which will include a review of what the MHOS team have learned individually. Compile evidence of depth of learning, short- and long-term retention that results from increased enthusiasm as a result of experiences in active learning, confidence building in engineering skills particularly among underrepresented students, and that engaging in active learning and having the equipment readily available stimulates student creativity and inventiveness.
   i. Perform a literature review of relevant information for and empirical evidence on efforts in active hands-on learning. Connect what we have done with work from other disciplines, especially demonstrating that the low-cost, highly accessible, mobile MOHS approach can provide the same type of experiences described in the literature
   ii. Integrate results from focus group/surveys/input from workshop of targeted faculty from a cross-section of 2- and 4-year institutions, from a representative set of STEM disciplines, and follow-on study
   iii. Document the current evidence on the models and assessment in a highly visible journal of pedagogy, which can be used to help convince engineering faculty members to adopt hands-on learning.

iv. Document any open questions or missing evidence that will help engineering faculty members to adopt hands-on learning.
v. Collect and share all high quality supporting information on the MOHS website and provide opportunities for comment by any interested parties.

2) Develop and Implement New Assessment Tools

Initiate a comprehensive concept inventory (theory, practice, synthesis of ideas, and systems integration) and develop assessment techniques that will document the depth of learning, student motivation to participate in their chosen field, and degree of creativity/curiosity that is stimulated by the pedagogy of active hands-on learning.

i. Develop a simple first-cut at a concept inventory for hands-on learning to assist new adopters as they assess the efficacy of MOHS pedagogy.
ii. Tools developed by the U Albany Evaluation Consortium for the Mobile Studio Project and the complementary Mobile Studio Project in Physics will be reviewed, adapted and standardized so that the TESSAL and Lab-in-a-Box projects can be assessed in a consistent manner allowing for integration of results from all existing MOHS projects. In addition to addressing student learning, these tools also have also made it possible to study and understand critical characteristics of instructional staff in the application of MOHS pedagogy.
iii. As new issues are identified, new assessment and evaluation tools will be developed and or existing tools will be modified and applied; this will allow for the identification of developmental patterns of implementation, areas for "just in time" instructional support for faculty as well as students, and broader documentation of impact as the process and products are disseminated across the STEM domain.

3) Determine Barriers and Best Practices to Wide-Spread Adoption

The center plans to utilize a large set of constituency groups from a diverse group of colleges and high schools and STEM disciplines to identify barriers to wide-spread adoption for each of the different groups (such as K-12 teachers, instructors and administrators from 4-year and 2-year higher level institutions including minority-serving schools). We also intend to pool together expertise from these different groups to build best practices and universally accepted templates for how to build mobile hands-on educational modules. We will perform three activities in this task:

i. Host a Practitioner's Workshop of faculty who are leading and fully invested in mobile active learning efforts in 2- and 4-year institutions. The center is soliciting input from faculty who are currently involved in hands-on/active learning to determine where and how they have instituted active learning at their institution and to document what has been developed thus far that has been shown to stimulate deeper learning, based on the use of inexpensive tools to allow a larger community of students to participate. The goal is to: (a) identify successful implementation models, and (b) develop a template for implementation and rubric for assessment that can be disseminated to support adoption of mobile active learning at other institutions.
   1. Collect data during workshop on:
      a. past and current barriers to adopt and sustain active learning in the curricula,
      b. administrative support required to successfully implement hands-on learning,

c. key areas within engineering curricula and within degree progress where students gain significantly by engaging in active learning,
d. instructional materials needed to support independent hands-on learning,
e. missing elements, including equipment, that would support more wide spread adoption,
f. how the job of a faculty member, lecturer, laboratory instructor, GTA, etc. changes with the use of hands-on learning, and
g. determine the audience that must be brought into the decision making process when adopting active hands-on learning.

2. Follow-on focus group/interviews to build a library of case studies.

ii. Hold 10 focus group discussions among different contingencies geographically distributed to determine the barriers and possible remedies for wide-spread adoption among those groups. The focus groups would consist of instructors from 2 year colleges, minority serving colleges, 4 year undergraduate institutions, 4-year institutions that have strong research activities; department heads from a selection of universities; K-12 teachers and administrators.

4) **Workshops on Mobile Hands-On STEM**

The center will hold a series of workshops that concentrate not on getting the faculty to do specific experiments but rather on working with faculty on ways in which they can engage students in active hands-on learning at their institutions.

i. Develop materials for workshops on what mobile hands-on learning is and that provide convincing evidence on the pedagogical advantages of mobile hands-on learning along with evidence of ease of use by instructors and students alike as well as the low cost for schools.
ii. Host 4 mini-workshops associated with conferences. We held a full-day workshop on hands-on learning at the 2012 ASEE conference in San Antonio, TX. We plan to hold two at the upcoming ASEE conferences, with several changes in approach based on feedback from the previous workshop. Since much of the work in the mobile platforms has been in the electrical and computing engineering fields, we plan to hold two workshops at conferences that are outside of this discipline in order to expand the influence of the topic. The likely conferences are a mechanical engineering conference and a physics education conference.
iii. Hold a full-scale (2-day) workshop on Mobile Hands-On STEM that serves as a model for future workshops. This workshop will incorporate all of the developed workshop instructional materials, the results from the Practitioner's Workshop, focus groups, and all other collected and published information. .
iv. Conduct follow-on studies after each workshop to validate the workshop templates and to review and refine the template for implementation.

Past Work

The pedagogical ideas on which the center is based have been addressed by the three projects listed above and have been the subject of many presentation in recent years, especially at this conference. This effort continues during the present conference. The key papers, which also contain many additional references are listed below.

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