Hands-on Learning: Two Approaches to Enhance the Undergraduate SMET Curriculum

Lueny Morell, Jorge I. Vélez, Ramón Vásquez, Rosa Buxeda
University of Puerto Rico at Mayagüez
Mayagüez, Puerto Rico 00681-9040
Voice: (787)265-3822; Fax: (787) 833-1190; email: lueny@ece.uprm.edu

Abstract: There are various approaches to integrate hands-on learning into the curriculum. This paper describes two approaches undertaken by the University of Puerto Rico at Mayagüez (UPRM). One is the ***Learning Factory*** implemented by the Manufacturing Engineering Education Partnership (NSF Grant # 98-12928), a program to develop a product realization and manufacturing option in strong collaboration with industry partners that makes use of specially designed laboratory facilities. Another approach is the ***Partnership for Spatial and Computational Research (PaSCoR)***, a program to develop a remote sensing and geographical information systems (RS-GIS) option that integrates undergraduate research in various undergraduate SMET programs (NASA Grant number NCC5-340). Both of these programs aim to strengthen academic programs through the integration of hands-on activities and cooperative learning. They are outcomes-based and student centered, focused on hands-on learning activities provided throughout the student's academic career. The outcomes will be a graduate that is knowledgeable of the science, technology and their applications, and also possesses the necessary skills either to enter graduate school or become a successful professional. The Learning Factory has been successfully implemented at Penn State University, the University of Washington in Seattle and at UPRM. NASA PaSCoR is in its second year of implementation in its goal to integrate research at the undergraduate level in various science, math and engineering/technology (SMET) disciplines.

Both of the programs address issues brought forth by the new engineering education accreditation criteria ABET 2000. Both programs aim at developing values such as diversity, teamwork, global awareness and communication. This paper describes the strategies and major components of these programs, including assessment.

Keywords: curriculum innovation, hands-on learning, active learning, undergraduate education

1. The Need

Higher education: what drives it? Is it the faculty inner world, the publish or perish environment? Are promotion and tenure driving the principal driving forces in higher education? How is our responsibility to respond to our stakeholders' being met? Do we know who are the stakeholders in education? Are we in higher education aware of the our mission, goals and objectives? Are we continuously assessing our performance and outcomes for continuous quality improvement? Are our students really learning in our classrooms? These and many other questions need to be asked and responded if we want our educational endeavor to be pertinent, effective and efficient.

There are multiple stakeholders in education: employers, students, faculty, administration, accreditation bodies, society at large. In order to develop the intellectual capital that will serve as the engine of economic, social and scientific growth for this century, industry, government and universities should and must partner. New educational paradigms must be developed in order to produce the kind of professional that will drive the new economy. These paradigms - diverse and dynamic - should focus not on teaching but rather on learning. Jane E. Milley, senior advisor to the President of Jobs for the Future[1], states that one way to enhance learning takes place in settings that go beyond the traditional classroom, where learning takes place through hands-on activities, application of real life problems and through motivation and engagement of students toward academic achievement. The University of Puerto Rico at Mayagüez has responded to this challenge and with support from two federal grants has developed two programs that use this learning paradigm. These are described henceforth.

[1] Jobs for the Future is a non-profit organization located in Boston Massachusetts, http://www.jff.org

2. Enhancing the Learning Experience through Hands-On Experiences: the University of Puerto Rico at Mayagüez Experience

There are various approaches to integrate hands-on, practice-based learning into the curriculum. The University of Puerto Rico at Mayagüez (UPRM) has developed and implemented two approaches. One is the ***Learning Factory*** implemented by the Manufacturing Engineering Education Partnership (NSF Grant # 98-12928), a program to develop a product realization and manufacturing option in strong collaboration wi th industry partners that makes use of specially designed laboratory facilities. Another approach is the ***Partnership for Spatial and Computational Research (PaSCoR)***, a program to develop a remote sensing and geographical information systems (RS-GIS) option that integrates undergraduate research in various undergraduate SMET programs (NASA Grant number NCC5-340).

3. The Learning Factory

The Learning Factory is a program developed by the the ***Manufacturing Engineering Education Partnership (MEEP,*** a collaboration of three major universities with strong engineering programs (Penn State, University of Washington and University of Puerto Rico at Mayagüez), a government laboratory (Sandia), over 100 industrial partners, and the federal government (which provided funding for the project through the ARPA Technology Reinvestment Program).[2] The overall outcome of the project was the development of the ***Learning Factory***, a new, practice-based curriculum and physical facilities for product realization and manufacturing**.** The major goal of the program was to provide an improved educational experience that emphasizes the interdependency of manufacturing and design in a business environment, thus graduating better engineering professionals exhibiting the knowledge and skills needed to succeed in the highly competitive environment. The desired skills that students develop include communication, teaming, business concerns and project management.[3] The key element in this approach is *active learning*: the combination of curriculum revitalization coordinated with *hands-on experiences.* Thus, the gap is reduced between traditional lecture vs laboratory, academia vs industrial experiences. MEEP curriculum model is depicted in Figure 1.

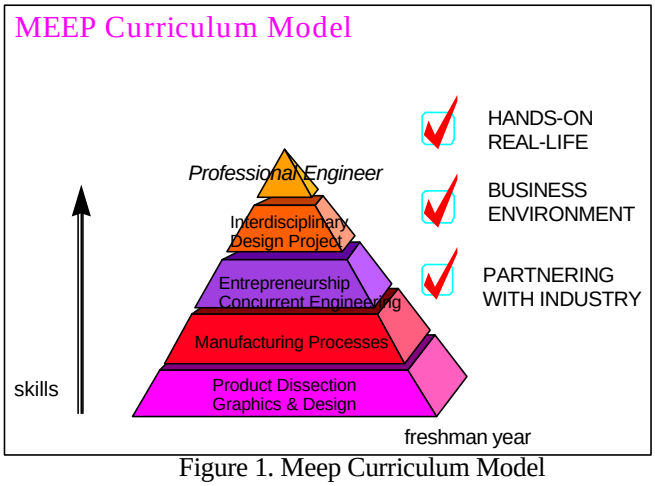

Figure 1. Meep Curriculum Model

[2] ***The Learning Factory - A New Approach to Integrating Design and Manufacturing into the Engineering Curriculum,*** Lamancusa, J. et al, ASEE' s Journal of Engineering Education, April, 1997.
[3] Ibid.

4. **The Partnership for Spatial and Computational Research (PaSCoR)**

Due to the previous success with MEEP, in 1998, the College of Engineering University of Puerto Rico at Mayagüez (UPRM) received a NASA grant, number NCC5-340, to develop the interdisciplinary program called ***Partnership for Spatial and Computational Research (PaSCoR).*** The main goal of this 5-year project is to strengthen academic programs and integrate research at the undergraduate level in various science, math and engineering and technology (SMET) disciplines in the areas of remote sensing and geological information systems (RS/GIS). The program follows the strategy of the ***Learning Factory*** model implemented by the Manufacturing

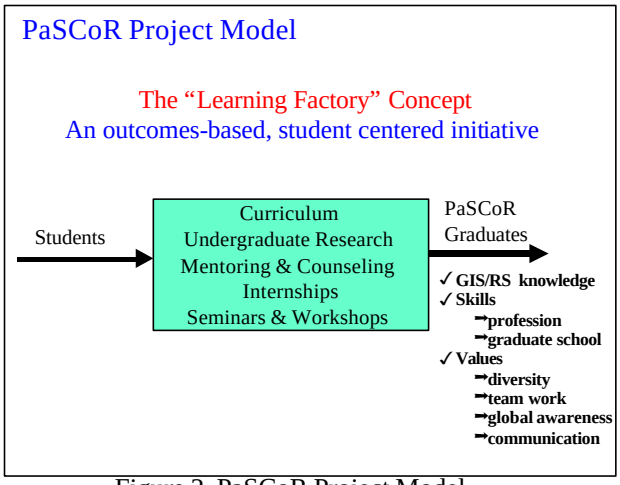

Figure 2. PaSCoR Project Model

Engineering Education Partnership (MEEP)[3,6]. In this case, the PaSCoR program is being developed in response to the need for skilled scientists and engineers in the areas of remote sensing and geographical information systems (RS/GIS). As the Learning Factory, this program is outcomes-based and student centered. Nonetheless, there is a slight variation: the hands-on learning experiences that are integrated into the program come in the form of undergraduate research throughout the student's academic career. ***The aim of PaSCoR is to provide an environment of learning by doing.*** The program is being developed using a process-based approach, as Figure 2 shows. A series of activities are carried out in order to achieve the desired outcome: a graduate that is knowledgeable of the RS/GIS technology and applications who possesses the necessary skills either to enter graduate school or becomes a professional in these areas with success. PaSCoR curriculum model follows MEEP's strategy. It has two main objectives: 1) provide an "*alternative track" or "option*" for undergraduate SMET students in the areas of RS/GIS, global positioning systems (GPS), data visualization, animation and analysis, and other related topics, and 2) integrate research in RS/GIS at the undergraduate level. The RS/GIS track or option will provide students in at least four SMET programs (Electrical Engineering, Geology, Mathematics and Agricultural Sciences) with non-traditional learning experiences in the new courses developed and revised. By doing so, we aim to attract and retain students and provide a focus for preparing students for careers and graduate studies in these areas. This innovative program integrates an undergraduate curriculum with hands-on experience provided by exposure to laboratory activities and undergraduate research that spans the student's college years. Students completing the course and research requirements will receive a certificate in RS/GIS. This strategy provides continuing curriculum contact with students, spans their entire college career, and integrates hands-on learning activities, skills development and industrial collaboration. The RS/GIS alternative track consists of 12 credit-hours (or the equivalent of four 3 credit-hour courses) that students take as electives in their respective programs of study. These courses are complemented with 6 credit-hours of undergraduate research work and a summer internship in their senior year in the abovementioned research areas.

Students can start the program from their freshman year. The process begins in the freshman year with recruitment and awareness, and ends with a formal research experience, which includes a summer internship, as represented in Figure 4. The "process" starts with awareness of the option and recruitment and concludes when the students complete their research requirements and a summer internship.

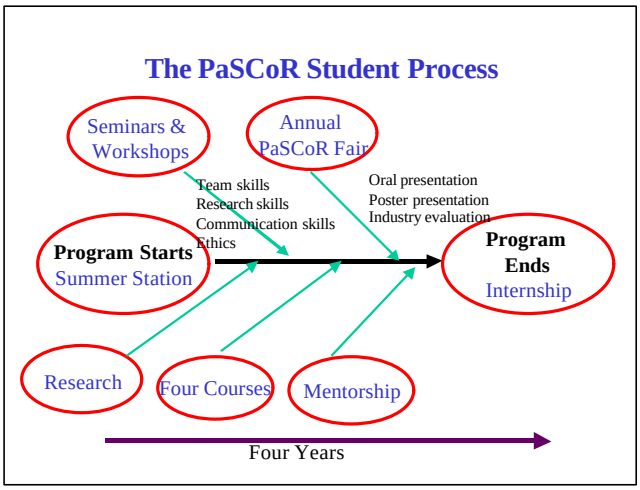

Figure 4. PaSCoR Student Progress

5. Assessment

How do we know if these experiences described above have been successful in enhancing student learning and respond to stakeholders' needs? Both programs have integrated project and student learning outcomes assessment. Major quantitative results of MEEP include the following[4]:

- New minors and formal options in Product Realization and Design/Manufacturing started at each academic partner.
- 1333 students participated in MEEP courses and projects in the (year 2 of the 2-year project).
- 43 faculty participated in curriculum and facilities development.
- Nearly 100 industry partners provided $2.3 million in cash and in-kind services.
- Learning Factory facilities are operational at each academic partner with nearly 15,000 ft^2 of new or remodeled space.
- Curricular materials currently being disseminated to other institutions through workshops, seminars and presentations.

The fundamental reason for MEEP's success was the strong partnership created between the partnership faculty, industry and the students in the development process. As faculty we spent a lot of time listening to each other. The curriculum reform involved 40 faculty across four time zones and representatives from more than 100 industrial partners. These partners, representing both large and small companies, took on the responsibility of assuring that the topics and the focus of the course and program developments were both relevant and germane to the activities the graduates would encounter in both civilian and government (defense) sponsored industries. Faculty have consulted with our industry partners about relevancy of course developments, industry experts have provided lectures on wide range of topics from concurrent engineering, product design, to technology entrepreneurship, and numerous industrially sponsored capstone design projects were successfully completed by our MEEP students. From the assessment data we conclude that there is a high degree of acceptance and satisfaction of the MEEP program by all stakeholders and that the major goals of the project have been met with success. This effort has allowed the partnership to achieve its goals with extraordinary results and has produced the following benefits:

- Superior engineering graduates who are confident in their abilities and well prepared to impact business productivity,
- An engineering educational program based on a balance between design and manufacturing and recognizes the need to relate practice and engineering science through hands-on experience,
- The development of practice-oriented teaching modules transferable through electronic media.

Although the PaSCoR program is still in its development phases, we have feedback from all constituents regarding our success. One hundred percent of students' summer internships mentors agree that students have excellent research skills and would very much hire the student. NASA January 2000 Site Visit team stated in their

[4] *Making a Partnership Work: Outcomes Assessment of MEEP*, Morell, et al, 1997 Frontiers in Education Conference, Utah.

report that this program "...exceeded expectations" and could serve as a national model. Eighty-on percent (81%) of participating students in the 1999 Summer Station Workshop say that the research initiation experience was provoking, stimulating and exciting. All of the students registered in the first course in the program. Almost 50% of the students currently in undergraduate research are considering going to graduate school. Faculty also evaluates the hands-on experience as very valuable: 73% believe that the research experience strengthened the students teamwork and communication skills.

Conclusion

Hands-on and active learning provides undergraduate students with valuable opportunities to acquire not only knowledge but also experience and skills, motivating them for careers and graduate studies much better prepared. The major attributes of these curricula are:

- Interdisciplinary focus, providing students and faculty to exposure to various SMET disciplines
- Balance between knowledge and skills/competency development
- Integrated hands-on, research and laboratory experience, thus learning by doing
- Strong collaboration with industry
- Focused on the needs of tomorrow's workplace for this technology
- Integrates both student performance and outcomes assessment

For more information, please access http://lf.psu.edu, and http://ece.uprm.edu/pascor.

Bibliography

Buxeda, R.J., and Moore, D.A., ***Using Learning Styles Data to Design a Microbiology Course,*** Journal of College Science Teaching, January, 2000, pages 159-164 (in press).
Felder, R.M, ***Reaching the Second Tier - Learning and Teaching Styles in College Science Education,*** Journal of College Science Teaching, 23 (5), 1993, pages 286-290. [http://www2.ncsu.edu/effective_teaching]
Lamancusa, J.S. and J. E. Jorgensen, J.L. Zayas-Castro ***The Learning Factory - A New Approach to Integrating Design and Manufacturing into the Engineering Curriculum,*** Journal of Engineering Education, April 1997.
Morell, L and J.S. Lamancusa, J.L. Zayas, J. Jorgensen ***Making a Partnership Work: Outcomes Assessment of the Manufacturing Engineering Education Partnership Assessment Strategy***, Journal of Engineering Education, Supplement, December, 1998.
Morell, L., and J.S. Lamancusa, J.L. Zayas, J. Jorgensen ***Making a Partnership Work: Outcomes Assessment of the Manufacturing Engineering Education Partnership Assessment Strategy,*** Journal of Engineering Education, Supplement, December, 1998.
Integration of Skills Development Across the Engineering Curriculum, Morell, Lueny, et al, 1995 ASEE Conference Proceedings, Anaheim, CA, June 1995.

file:papers/icee-2000-paper.doc