Learning Factory at UPRM: Ten Years of Impact

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Abstract *— In 1994, NSF sponsored the Manufacturing Engineering Education Partnership (MEEP) a coalition of three institutions (University of Puerto Rico - Mayagüez, Penn State University and the University of Washington) and Sandia National Laboratories and industry) to develop an undergraduate product realization/manufacturing engineering option the partners called the* ***Learning Factory****, an outcomes-based undergraduate curriculum integrated to laboratory facilities and industry partnership. The Learning Factory was successfully institutionalized at the three partner institutions by 1997. The UPRM Faculty team was composed of Dr. José L. Zayas-Castro (now IE Department Chair at University of South Florida; Dr. Jorge I. Vélez-Arocho, now Chancellor of University of Puerto Rico at Mayagüez, Dr. Agustín Rullán, Professor of Industrial Engineering, UPRM; Dr. Miguel Torres, Professor, Mechanical Engineering, UPRM; and Lueny Morell, now Director of University Relations for Latin America for HP Labs, Hewlett Packard Company). This document summarizes the impact the program has had at the University of Puerto Rico-Mayagüez (UPRM), its faculty, students and partners. But its impact has gone far beyond the borders of Mayagüez and of Puerto Rico, examples of which are detailed.*

Index terms *— engineering education, curriculum innovation, accreditation*

BACKGROUND

The University of Puerto Rico at Mayagüez (UPRM) is one of the 11 campuses of the University of Puerto Rico System. The UPR System is a public institution, which was created by the Puerto Rico Legislative Assembly on March 12, 1903. It collectively enrolls about 67,000 students. The Mayagüez Campus (UPRM) is a land grant institution that began in 1911 with the College of Agricultural Sciences. Subsequently, other colleges were added as follows: College of Engineering (1913), College of Arts & Sciences (1943), and the College of Business (1970). The student body consists of about 11,000 undergraduate and 970 graduate students. The College of Engineering counts on an undergraduate enrollment of 4458 students, of which, 36 percent are females, which is one of the highest in engineering among U.S. institutions. This enrollment results in UPRM as ranking 15th nationally in terms of the number of undergraduate degrees awarded (695) during 2000-2001 [1]. The mission and vision statements of the College of Engineering strategic plan call for preparing "the best professionals in engineering" and "a strong education in engineering." This commitment to excellence is reflected in the college's philosophy "to provide a firm educational foundation [2]. The College of Engineering comprises six academic units or departments, which are: Electrical & Computer Engineering, Mechanical Engineering, Industrial Engineering, Chemical Engineering, Civil Engineering & Surveying, and General Engineering. These collectively offer seven undergraduate degree programs, of which, six are in engineering with a separate program in surveying. All of the six undergraduate degree programs in Electrical, Computer, Mechanical, Industrial, Civil, and Chemical Engineering are accredited by the Accreditation Board for Engineering and Technology (ABET). The undergraduate degree programs at UPRM are of five-year duration as opposed to four years at most U.S. institutions. This provides both breadth and depth, along with ample opportunities for summer internships, undergraduate research, exchange programs, and a strong cooperative education program in partnership with industry. Approximately 27 percent of all undergraduate engineering students avail themselves of this cooperative education industry experience with bulk of the students, about 45 percent, coming from Mechanical and Chemical Engineering programs.

In 1994, NSF sponsored the Manufacturing Engineering Education Partnership (MEEP) a coalition of three institutions (UPR-Mayagüez, Penn State University and the University of Washington) and Sandia National Laboratories and industry) to develop an undergraduate product realization/manufacturing engineering option the partners called the Learning Factory, an outcomes-based undergraduate curriculum integrated to laboratory facilities and industry partnership. The Learning Factory was successfully institutionalized at the three partner institutions by 1997. The UPRM Faculty team was composed of Dr. José L. Zayas-Castro (now IE Department Chair at University of South Florida; Dr. Jorge I. Vélez-Arocho, now Chancellor of University of Puerto Rico at Mayagüez, Dr. Agustín Rullán, Professor of Industrial Engineering, UPRM; Dr. Miguel Torres, Professor, Mechanical Engineering, UPRM; and Lueny Morell, now Director of University Relations for Latin America for HP labs, Hewlett Packard Company). This document summarizes the impact the program has had at the University of Puerto Rico-Mayagüez (UPRM), its faculty, students and partners. But its impact has gone far beyond the borders of Mayagüez and of Puerto Rico, examples of which are detailed below.

UPRM COURSES, CURRICULUM AND LEARNING FACILITIES

One of the most significant impacts this program had was on participating faculty. The program seeded a change in attitude that encompassed how they view teaching and learning, to how to go about course development and assessing outcomes. Faculty shifted its view on education from a faculty-centered activity to a student-centered activity, focusing on developing a program that had as a primary goal effective student learning. This, of course affected faculty teaching. The new paradigm catalyzed a different way of designing/developing courses and programs. It called for involving all stakeholders (students, industry, faculty, administrators) in the design phases, having to reach a consensus in defining the graduating engineer skills, his/her competencies and values, as well as the desired learning outcomes. It also called to enhance the learning experience, thus courses had to include hands on activities, industry projects and other non-traditional experiences which emphasize skills development, like teamwork, ethics and effective communication. Students had to learn not only to solve a problem in teams, but also define and characterize the problem, to build a prototype, write a business proposal and make effective presentations. Last but not least, besides delivering content and knowledge in non-traditional way, faculty needed to integrate student learning and program outcomes assessment, something they were not used to.

The 'seed' that was planted through the Learning Factory program germinated and expanded through the Campus promoting innovation of engineering and science education, some examples of which are listed below.

Product Dissection Course: as a result of Dr. Miguel Torres leadership and teaching effectiveness, this course is now a requirement of all students in the ME Department.

Technology Based Entrepreneurship Course: this course, which was designed among the three schools under the leadership of Dr. Jorge I. Vélez, have been taught uninterrupted since it was created in 1994 in the Business School, now a favorite among engineering and business students, some of them taking learning to the next step and developing their own tech businesses. In addition, this course has served as model for two (2) EPSCoR proposals to expand its product design methodology into other areas.

Learning Factory Facilities: UPRM laboratory facilities, managed by MEEP principal Dr. Agustín Rullán and located in the Industrial Engineering Department, have evolved significantly with industry support, most particularly from Hewlett Packard. UPRM is a strategic partner for the company, providing support of UPRM education and research activities for over 20 years (98% of the local manufacturing plant engineers are alumni). In December 2002, HP upgraded the LF facilities to a real-life state of the art Surface Mount Technology (SMT) manufacturing line, donating more that $2.4 Million in equipment with partners. The $2.4 Million SMT production line which includes $400K donation from Solectron, Puerto Rico Storage and Distribution, Fuji America, and Precision PCB Products will offer services to local companies in the electronics manufacturing sector. HP University Relations matched the grant with two high performance server clusters.

The facility is now known as the ***UPRM Model Factory***, since it aims at providing students with an exemplary manufacturing experience in terms of quality, delivery, continuous improvement, and productivity. Students begin their experience by attending a Printed Circuit Assembly course (IE 4050), which recruits students in their third or fourth year

(UPRM has five-year engineering programs). These students will then be recruited to work in the Factory for pay and credit. After the experience, students are expected to participate in summer and Coop internships at companies in the electronics sector.

During summer 2003, students worked at Hewlett Packard and Solectron and became certified in surface mount technology (SMT) processes. This past fall, the Factory performed a successful qualification run using a Smart Modular Technologies (HP subcontractor) product. In the near future the Factory should start a daily printed circuit assembly activity for one or more local customers. The line is also being targeted for prototype runs from local electronics sector companies as well as new product being developed by interdisciplinary teams as part of a Concurrent Engineering course (IE 4810).

The UPRM Model Factory initiative is part of the Puerto Rico TechnoEconomic Corridor (www.prteconline.com) effort led by HP in Puerto Rico.

IMPACT ON OTHER PROGRAMS AT UPRM: REMOTE SENSING/GIS & BIOTECHNOLOGY

The Learning Factory curriculum has served as model and benchmark to design and implement other multidisciplinary programs at UPRM. Most notably are the Remote Sensing/GIS and Industrial Biotechnology programs.

In 1998, NASA granted UPRM $2.5 Million for the development of a multidisciplinary option on remote sensing and GIS called Partnership for Spatial and Computational Research (PaSCoR) following the Learning Factory model. PI for this project was Lueny Morell, with Jorge I. Vélez (now Chancellor of UPRM) as strategic planning leader and member of the curriculum team. The program, its students and faculty have received numerous recognitions, which merited a visit to UPRM by the new NASA assistant director Dr. Adena Loston last October 2003. The goals of PaSCoR (www.ece.uprm.edu/pascor) is to strengthen science and engineering academic programs, integrating research at the undergraduate level in various science, math and engineering/technology (SMET) disciplines, developing SMET graduate that is knowledgeable of the technology and applications of remote sensing (RS) and geographical information systems (GIS), and, possesses the necessary skills either to enter graduate school or becomes a professional in these areas with success. The program also aims at developing values such as diversity, teamwork, global awareness and communication.

In 2001 the Industrial Biotechnology Program (http://www.uprm.edu/bind/?biotech%20program)at UPRM was re-engineered to follow the Learning Factory model, an initiative led by its new director and NASA PaSCoR faculty, Dr. Rosa Buxeda. The program has a strong industry board with representatives for major biotech companies in the island, investors and government officials. As part of the hands-on learning experiences, undergraduate students are required to spend a summer internship. One of the most significant outcomes of this program is the placement of almost 50% of its graduates in graduate school. As a result of the program's success, two biotech giants, Amgen and Eli Lilly, have made UPRM investments in the thousands of dollars to establish the Biotech Learning Center.

Both of these programs have integrated critical elements in the Learning Factory success story, namely, strategic planning, outcomes assessment, faculty team development (the "Fogawi" tribe), thus ensuring stakeholders' ownership of process through a common vision and mission.

In addition, the recent approved $35Million NSF project to re-vamp SMET teacher preparation program in Puerto Rico, ALACima, has as primary consultant UPRM Chancellor Jorge I. Vélez, who will lead efforts of adapting the Learnign Factory model to this initiative.

THE LEARNING FACTORY, OUTCOMES ASSESSMENT AND QUALITY ASSURANCE

Ever since the approval of the new Accreditation Board for Engineering and Technology (ABET) Engineering Criteria (EC 2000) by the Board of Directors of ABET on November 2, 1996, and its mandatory application as of Fall 2001, educational institutions across the United States have had to assess and evaluate their undergraduate engineering programs from a different perspective. That is, ABET EC 2000 was designed to employ the philosophy and practice of continuous quality improvement to engineering programs. Engineering Criteria 2000 call for each engineering program to identify its

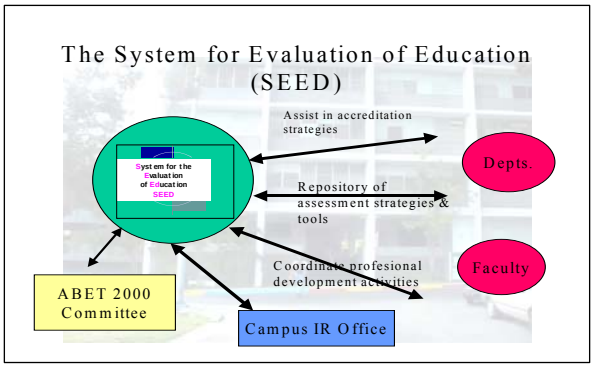
constituencies and, based upon their feedback, to formulate the services that each program will provide. The first step is the development of program educational objectives – statements describing expected achievements of graduates in the early years of their careers after graduation as a result of their educational preparation. Usually, educational objectives are expectations of graduates' performance after they have left the school and been in the workforce for three to five years. Subsequently, the second step requires the more specific definition of program outcomes – skills, knowledge and behavior that would be expected of students at the time of their graduation. All this requires considerable time and effort, not only to clearly define the program educational objectives and program outcomes, but also to develop proper and continuous assessment methods and tools, the documentation, the processes, and the necessary culture and philosophy changes that would be introduced as a consequence of the cyclical processes.

UPRM's College of Engineering ABET 2000 accreditation strategy (www.abet.uprm.edu) was based on the Learning Factory experience. The strategy, led up to 2002 by Lueny Morell, then special assistant to the Dean of Engineering, incorporated the outcomes assessment plan and assessment tools developed by MEEP and PaSCoR. The College of Engineering realized the significance of EC 2000 early on and undertook planning and organizational steps fully four years prior to the actual site visit. Comments shared by Dr. Anand Sharma (who succeeded Lueny leading UPRM's accreditation efforts) at the ICEE 2003 conference in Valencia, Spain: "Among the steps taken to ensure accreditation under the new criteria, the following are noteworthy: While this would generally be the case with external drivers such as industry, or ABET, or Middle States Association, we, at the University of Puerto Rico at Mayagüez, had had some experience related with assessment in earlier educational projects, such as MEEP (Manufacturing Engineering Education Partnership) Learning Factory (funded by NSF, 1994) and PaSCoR (Partnership for Spatial and Computational Research), which was funded by NASA in 1998".

In order to institutionalize this assessment process as part of the various courses, the College of Engineering established a physical office called System for the Evaluation of Education (SEED) in mid-year 2001, with the goal of developing assessing strategies for the undergraduate engineering programs. In addition, the Faculty involved industry and employers stakeholders in its process, carrying on "mock accreditation visits" where industry members provided input about the programs. ABET Committee organized a series of one-day workshops in mid-year 2001 that led to the development of assessment tools and strategies package. This was adopted for common use by all programs with each one at liberty to modify or be selective about the recommended methods or tools. The package contained an outcomes assessment matrix, an assessment strategies matrix, and various assessment forms for integrating ethics, oral and written reports, teamwork, peer evaluation, course/project evaluations, exit survey, alumni survey, employer survey, and internships, the vast majority of these developed under MEEP and PaSCoR.

All six of our undergraduate programs were evaluated during November 2002. ABET accreditation visit team comments: "The institution's systematic and innovative effort to introduce the culture of outcomes-based assessment to the College of Engineering community is especially noteworthy [3]."

As a result of these experiences, UPRM under the leadership of Chancellor Vélez and Dr. Sharma will expand this quality assurance and outcomes assessment efforts at the institution-wide level.



THE LEARNING FACTORY IMPACT IN US AND LATIN AMERICA SCHOOLS

University of Missouri and University of South Florida: One of MEEP's co-PI's Dr. José Luis Zayas-Castro moved to the University of Missouri-Columbia (MU) in 1999. His leadership at this school and later as IMSE Department Chair in the University of South Florida, Tampa, has proven extraordinary. During fall of 1999 Dr. Zayas-Castro developed an effort based on the MEEP experience. This initiative was named Entrepreneurial Manufacturing Innovation Learning Experience, EMILE (www.missouri.edu/~emile/). EMILE teamed faculty and students from the Colleges of Engineering and Business in

MU. Drs. Thomas J. Crowe (current Director of EMILE), Cathleen Burns, Luis Occena, Douglass Moesel and Mary Beth Marrs worked with Dr. Zayas-Castro in obtaining a grant from NSF to initiate EMILE. A sequence of three team-taught courses were designed and implemented. Today various companies and entrepreneurs are supporting EMILE and there is a significant collaboration with the College of Nursing.

In fall 2002 Dr. Zayas-Castro began as Professor and Chair of Industrial & Management Systems Engineering (IMSE) at the University of South Florida (USF). Based on the previous experiences, he redesigned IMSE's Capstone Design Course, integrating an entrepreneurial focus and motivating students to work in teams to develop small manufacturing enterprises. In 2003 he partnered with the Rehabilitation Engineering Program from Mechanical Engineering to use the product concepts/prototypes of ME students to induce students to go through the whole enterprise cycle, from product idea to market analysis to product redesign to production planning to financial feasibility. The students have rated the course as the most comprehensive experience in their undergraduate studies. In addition Dr. Zayas-Castro is working with existing initiatives at USF's Center for Entrepreneurship to stimulate students to develop and incubate high-tech companies.

Latin America: As early as in 1997 while the MEEP project was coming to an end, the UPRM team knew that it had to disseminate this model program with other faculty and institutions. Thus in 1998 UPRM received two dissemination grants from NSF's Engineering Education Action Agenda and Raytheon Company, which were later matched by Microsoft Research and more recently by Hewlett Packard. More than 35 ½ day, 1 day or 1.5 workshops have been offered nationally and internationally to hundreds of faculty and deans many who have adopted or aapted this model program to some extent. The workshops (http://www.ece.uprm.edu/lfw/) provide attendees to go through the steps that helped MMEP and PaSCoR partnerships develop their programs. Outcomes assessment and accreditation strategies are also shared. Some of the sites where this workshop has been offered include:1998 & 199 Frontiers in Education Conferences,1999, 2000 ASEE Conferences, 2000 SUCCEED-GATEWAY conference in Greensboro, NC, UTEP, Tennessee State University, Southern University, North Carolina A&T, 1999 ICEE Conference, Texas A&M - Prairie View, Polytechnic University - Puerto Rico, University of P.R. at Bayamón, Worcester Polytechnic Institute, 2000 ADMI Conference, Hampton University, VA, University of Chile; Pontifical Catholic University of Chile; University of Buenos Aires, Universidad Tecnológica Nacional, Argentina, and Universidade Estadual de Campinas, Brazil.

The impact the program has had in some of these sites has been outstanding, the most noteworthy example being Chile, where the Engineering Deans Council decided to sponsor workshops to more than 130 participants nationwide, resulting in curricular reform supported by government grants and in which the UPRM workshop leaders are assisting faculty at the Universidad Federico Santa Maria in Valparaiso, Chile, Universidad de Bio-Bio, Chile, and more recently at the Universidad de la Frontera, Chile in their implementation efforts.

CONCLUSION AND ACKNOWLEDGEMENTS

It's been 10 years since NSF had the vision of investing in the Manufacturing Engineering Education Partnership and the University of Puerto Rico at Mayagüez. Many students and faculty have benefited from the Learning Factory. But little did those involved suspected the culture change, innovation and impact this program has brought to this Hispanic serving institution, to Puerto Rico and beyond. We are truly thankful to all those that in one way or another have sponsored and supported this and all related programs that emerged since MEEP, especially, NSF, NASA, administrators, faculty, students and industry.

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