

International Strategic Alliances to Strengthen Engineering Education: Beyond the Learning Factory

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Abstract

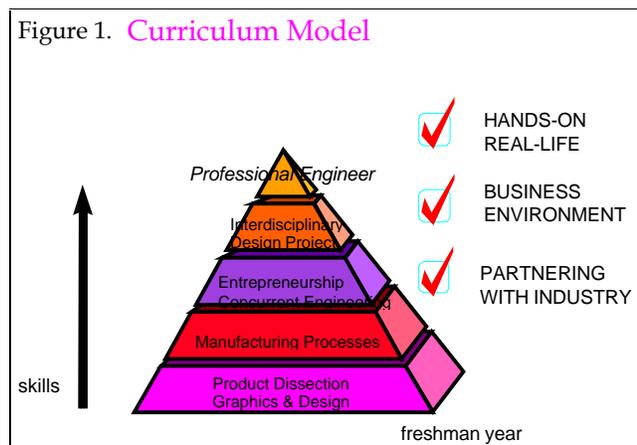
In 1994, NSF awarded three institutions (Penn State, University of Washington and University of Puerto Rico at Mayagüez) and a national laboratory (Sandia National Labs) a grant to develop a novel program focused on product realization/manufacturing engineering. In strong collaboration with industry, this team created and institutionalized the so-called Learning Factory. This successful and nationally recognized program focuses on hands-on, practice based engineering, continuous assessment and industry collaboration. In view of its success and due to its alignment with the new engineering accreditation set by ABET, in 1998 NSF and Raytheon Corporation awarded the University of Puerto Rico at Mayagüez (UPRM) grants to disseminate the program model at national and international forums through workshops. UPRM's Center for Hemispheric Cooperation with its long history of international cooperation in education and research activities, provided the leadership and support for the outreach initiative. Moreover, in 2001, Microsoft Research extends these grants to offer workshops in selected institutions throughout Latin America, with which they are piloting a university relations program. Since then, more than 600 faculty and administrators from US and foreign institutions have participated in workshops to learn and brainstorm about opportunities to adopt or adapt the program. One of the major outcomes of this initiative is the establishment of strategic alliances among participants in different countries.

This paper describes how these international collaborative partnerships have been established and are being nurtured, what have been the benefits so far for each constituent, and what have been the lessons learned. The driving forces (e.g., accreditation activities), the key elements in creating and sustaining successful international alliances, and the outcomes achieved to date will be shared. The paper will present points of view of the different constituents: workshop leaders, sponsors, workshop participants and university administrators. In addition, the paper will explore future collaborative activities among existing partners and opportunities beyond. The experience shows that these types of alliances are paramount to strengthen and foster growth of engineering education in this global economy.

Introduction

The **Learning Factory** is a new practice-based curriculum and physical facilities for product realization developed by the Manufacturing Engineering Education Partnership (MEEP) [1]. MEEP is a partnership between Penn State University, University of Washington, University of Puerto Rico at Mayagüez and Sandia National Laboratories. Funding was provided by the Technology Reinvestment Program, TRP Project # 3018, NSF Award #DMI-9413880. The major goal of this curriculum is to provide an improved educational experience that emphasizes the interdependency of manufacturing and design in a business environment. The educational objectives of this curriculum, i.e., the desired skills which we want our students to develop, were determined in conjunction with an Industry Advisory Board and represent their view of the skills and knowledge which are required of the practicing engineering professional. Among the skills developed in the students are design/synthesis, communication and teamwork. These skills have also been identified by the new ABET Criteria 2000 as of utmost importance.

The partnership developed a series of courses (Figure 1) to augment the typical undergraduate engineering curriculum as well as provide the necessary infrastructure to support hands-on activities in these courses. At each of the schools we implemented the courses and integrated them with existing courses to form minors or options in **Products and Processes Realization**. In this new curriculum, the



Interdisciplinary Capstone Design Course, with “real projects” provided by our industrial partners, form the final test of the students’ ability to function in an emulated industrial environment. Three principal courses were developed as part of the curriculum, which are complemented by a capstone design course:

- **Product Dissection** were students examine the way in which products and machines work: their physical operation, the manner in which they are constructed, and the design and societal considerations that determine the difference between success and failure in the marketplace.
- **Technology-Based Entrepreneurship**: focuses on the starting, financing and managing a new business in a highly competitive and technological based environment (developed in conjunction with the Business School).
- **Concurrent Engineering**: the origin and meaning of the term *concurrent engineering* and discuss its role in modern engineering companies.

Due to the success of this program [2] which has been highlighted in the New York Times [3] awarded Penn State the ASME Curriculum Innovation Award in 1996 and the Boeing Outstanding Educator Award in 1998 and the interest by other institutions in learning how the program addresses the new ABET 2000 criteria, in August 1998 UPRM got NSF Grant # EEC-9812928 to disseminate the Learning Factory program. The major venue was through the offering of four (4) workshops at national engineering education conferences. This grant was complemented by a grant from **Raytheon Company** to offer an additional five (5) workshops during academic year 1998-99 at HBCU's and HSI's and most recently, by **Microsoft Research**,

to sponsor workshops at the leading institutions in four of its (5) Latin American countries where the company is establishing their strategic academic alliances (Argentina, Chile, Brazil, and Mexico).

The Workshops

The *Learning Factory Workshops* (Figure 2) go through the steps that helped MEEP develop this program: from establishing educational objectives to planning (resources, timetable, responsibilities) to curriculum development (courses, integrated laboratory facilities, industry collaboration), and finally to outcomes assessment (designing the assessment strategy, conducting assessment, design of tools, reporting and feedback). Attendees have an opportunity to work on developing an engineering student profile and planning for adopting/adapting the Learning Factory Program at their institutions. Workshop staff involved in this

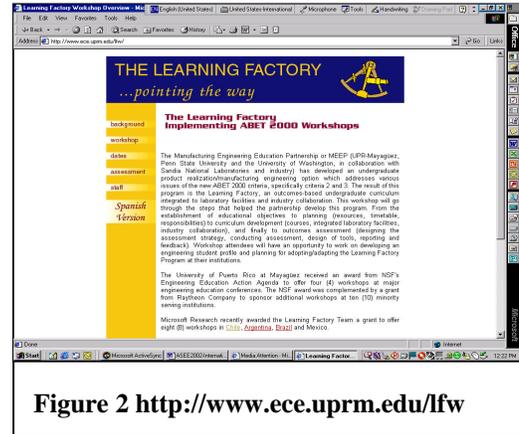


Figure 2 <http://www.ece.uprm.edu/lfw>

project has been instrumental in achieving MEEP goals at UPRM. They are: Lueny Morell, Miguel A. Torres, John Lamancusa, Jorge I. Vélez-Arocho. Lueny Morell is Professor of Chemical Engineering where she has led major educational reform efforts that spread from reform in the classroom to her current role as coordinator of Institutional Research for the UPR system. She led MEEP's project curriculum development at UPRM and the overall project outcomes assessment strategy as well as design UPRM's College of Engineering ABET 2000 Strategy. Lueny was also Director of PR-AMP's Curriculum Innovation Center. Miguel A. Torres is Associate Professor of Mechanical Engineering and has been actively working in the curricular renovation of Mechanical Engineering at UPRM. He developed strategies and tools that have been applied interdisciplinary in the Learning Factory program at UPRM and is leading the ME Department's efforts for accreditation under the new ABET criteria. John Lamancusa is Professor of Mechanical Engineering at Penn State University where he directs the Learning Factory. Jorge I. Vélez-Arocho is Co-Director for the Center of Hemispheric Collaboration, is Professor and former Dean of the College of Business Administration and participates very actively in interdisciplinary educational endeavors at UPRM. He has extensive experience coordinating and facilitating workshops and activities, both national and international.

Between August 1998 and December 2001, a total of twenty-one (21) workshops have been offered to more than 600 participants nationally and internationally. Table 1 summarizes workshop dates, sites and sponsors.

Table 1. Workshops Dates, Sites and Sponsors as of December 2001

DATE	SITE	SPONSOR
1. August 17, 1998	ICEE '98 Brazil	Raytheon, UPRM, NSF
2. September 26, 1999	UPRM	PR-LSAMP Project, NSF
3. October 23-24, 1998	UTEP, El Paso	Raytheon, UPRM, NSF
4. November 4, 1998	FIE '98, Tempe	NSF
5. January 29-30, 1999	Tennessee State University	Raytheon, UPRM, NSF
6. February 19-20, 1999	Southern University, Baton Rouge	Raytheon, UPRM, NSF
7. March 12-13, 1999	Polytechnic, Interamerican and Turabo Universities, Puerto Rico	Raytheon, UPRM, PR-LSAMP, NSF
8. June 20, 1999	ASEE 99, Charlotte	NSF

9. July, 1999	Texas A&M, Prairie View	Raytheon, UPRM
10. August, 1999	ICEE 99, Czech Republic	UPRM
11. November, 1999	FIE 99, San Juan	NSF
12. February 11, 2000	UPR-Bayamón	UPRM, NSF, Raytheon
13. March 6, 2000	Worcester Polytechnic Institute	Raytheon, NSF, UPRM
14. March 28, 2000	SUCCEED-GATEWAY	NSF
15. June 1, 2000	ADMI 2000 Conference	Raytheon, UPRM, NASA
16. July 2000	Istanbul, Turkey	Raytheon
18. July 2001	Universidad de Chile	Microsoft Research
19. July 2001	Catholic University of Chile	Microsoft Research
20. November 2001	Universidad Tecnológica Nacional - Argentina	Microsoft Research
21. November 2001	Universidad de Buenos Aires – Argentina	Microsoft Research

Workshop Assessment

Each workshop is evaluated using an assessment form. Individual workshops' outcomes can be found at the website (<http://ece.uprm.edu/lfw>). Ninety seven percent (97%) of workshop participants expect to put in practice the ideas presented in the workshop. In addition, an external evaluator, Dr. Sharon Derry, from the University of Wisconsin, was asked to assess the workshop:

"...the workshop content and materials focused on valuable and psychologically valid content...Commendable features related to these outcomes include :integration of conceptually oriented content instruction with learning activities representing real-world work; emphasis on teamwork and group dynamics; engaging students in complex, authentic design and analysis; forging coordinated educational efforts between schools and industry; intensive focus on important concepts rather than broad, shallow content coverage; fostering mentor-apprentice interactions, which are potentially more effective and inclusive compared to direct instruction models..... Strongly recommend the workshop to other schools and colleges of engineering. In addition, I believe the workshop may have broader applicability for science, mathematics and technology education in general and could be highly beneficial to faculty beyond schools of engineering".

UPRM, the Microsoft Research Latin American pilot program and international collaborations

One of the most important outcomes achieved by this outreach initiative has been the international collaborative partnerships that are beginning to grow, especially with Latin American universities. Common driving forces (e.g., accreditation activities) and common industry partners (e.g., Microsoft Research) have been key elements in creating and sustaining the newly established international alliances. The next sections summarize viewpoints from the various stakeholders (e.g., workshop leaders, sponsors, and university administrators), as well as some of the outcomes achieved to date and future plans to foster and strengthen engineering education collaboratively.

UPRM has had a long history of international collaboration in both education and research initiatives. The Center for Hemispheric Cooperation in Research and Education in Engineering and Applied Science (CoHemis for short) was founded in 1991 in a hemispheric conference-workshop sponsored by the National Science Foundation. It brought together national science and technology organizations (ONCyT) delegates from 13 countries of the Americas to discuss

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ways to increase hemispheric collaborations in science and technology. Currently, CoHemis maintains relationships with most of the hemisphere's ONCyTs through officially designated liaisons. This center's mission is to promote human resources development, technology assessment, and joint applied research projects and programs with potential benefits for more than one country in the Western Hemisphere aiming to serve the needs of the Americas with the participation of engineering and science researchers faculty and graduate students from the different countries of the hemisphere.

Workshop leaders leveraged on CoHemis' expertise (its co-director, Jorge I. Vélez-Arocho, co-author of this paper, is one of the workshop leaders) and existing collaborative initiatives with several Latin American countries, as well as Microsoft Research's interest in expanding its already successful university program in the US, to organize Learning Factory workshops in selected Latin American institutions.

The voice of the Latin American workshops sponsor: Microsoft Research

There are more than 600 people in the Microsoft Research organization working in more than 40 areas, including speech recognition, user interface research, programming tools and methodologies, operating systems and networking, graphics, natural language processing, and mathematical sciences.

The University Relations organization is positioned within Microsoft Research whose goal is to build world class partnerships with key universities, agencies, industry partners and employees that enhance the teaching and learning experience. One of our goals is to inspire technological innovation in conjunction with establish Microsoft as a leading technology partner for higher education. We were founded in 1996 and have programs in United States, Europe and Asia covering over 200 universities. It is totally funded through Microsoft Research, undergraduate focused with primary concentration in Computer Science, Engineering and Business schools and departments.

Sponsoring the UPRM's Learning Factory was identified very early, as a potential vehicle for making an initial and meaningful contribution to key universities in our latest Caribbean and Latin American program. We picked the Learning Factory for two reasons.

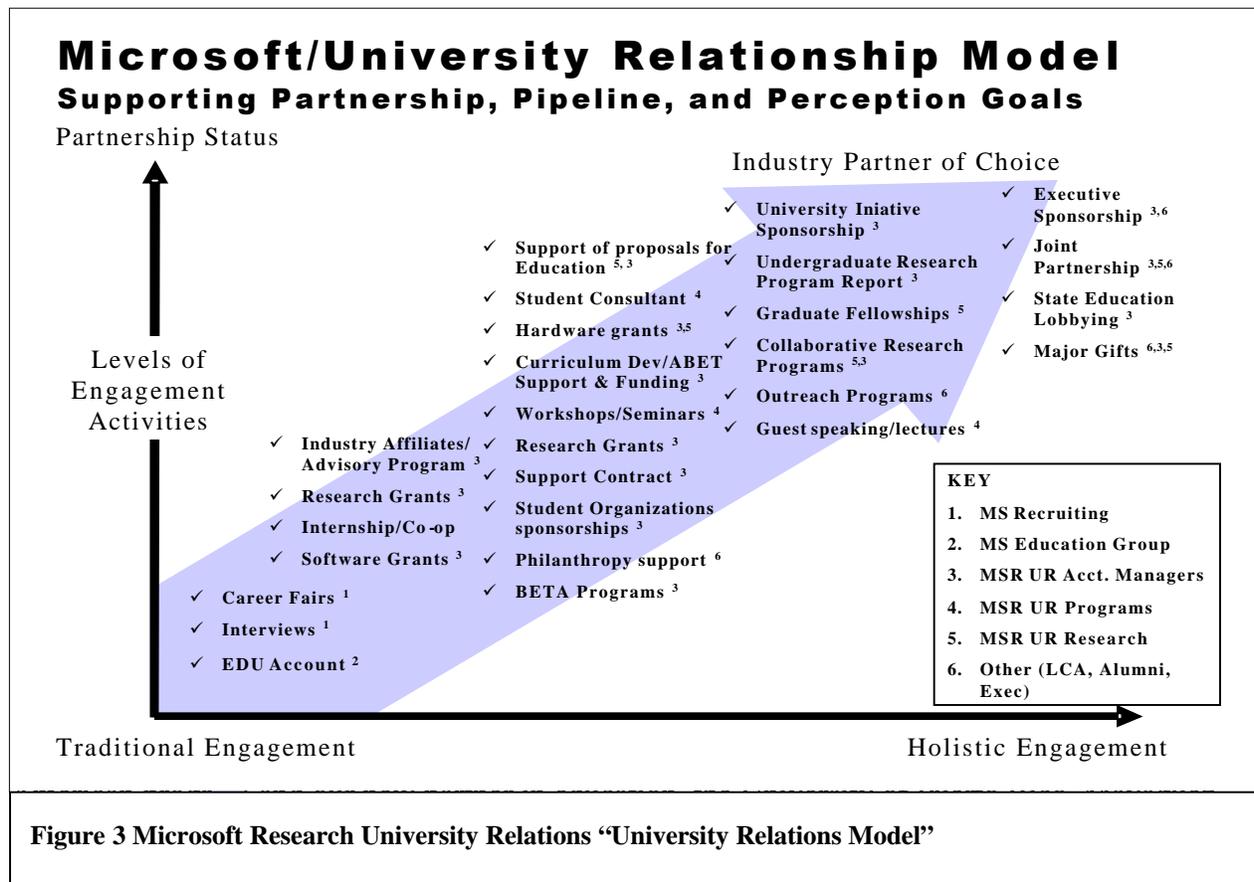
First, it was through the reputation it had established for itself since 1994. It was a solid and proven program with a strong history of collaboration. Additionally, the educational engineering issues that were identified as part of the charter for 'The Learning Factory' workshops we absolutely correct in both assumption and solution.

Second, Microsoft was starting an inaugural program in which we would be making investments in Caribbean and Latin American universities that had strong Engineering schools and departments.

Finally, it was the professional approach and organization within URPM that was identified as a key ingredient. In addition to the excellent leadership from UPRM's College of Engineering, The Center for Hemispheric Cooperation that was mentioned earlier provided the correct

historical backdrop and experience Microsoft needed for our new program. Microsoft had a very strong marketing presence within much of Latin America, with offices in many key cities and most countries. Other than the normal customer relationships, Microsoft did not have an ‘official’ university relationship program in the Caribbean nor Latin America. This was our initial attempt out of Microsoft Research to establish a new program and begin developing new relationships.

The goals and methodologies within University Relations is very long-term by design. We strongly believe that to achieve the honest and valued partnerships with universities there must long-term commitments coupled with a reflective approach in identifying the needs, goals, and problems within each university. As shown by our “University Relationship Model (Figure 3)”, by design we are trying to incorporate activities and engagements that lead to a more ‘holistic’ and long term investment.



Supported by Microsoft Research, a total of four (4) the Learning Factory Workshops have been offered in Latin America in 2001. In July 16-17 it was offered to thirty-five (35) professors from the University of Chile, in July 19-20 to fifty-two (52) professors from thirty-six (36) universities in Chile. The latter was hosted by the Pontifical Catholic University of Chile (PUC-Chile). Dean Aldo Cipriano invited not only the faculty from PUC-Chile but faculty from other universities- in Chile as well. In addition, The Learning Factory Workshop was held at the Universidad

Tecnológica Nacional on November 1-2, 2001. Twenty five (25) professors participated at the Rectorado site in Buenos Aires and more than one hundred (100) were registered and participated at seven (7) other sites in Argentina: La Rioja, Bahia Blanca, La Plata, El Rosario, Resistencia, San Francisco and Tucumán via video conference. Uriel Cukierman, Communications Director for the UTN system helped organize and broadcast this successful workshop. On November 5-6, we conducted the workshop at the Universidad de Buenos Aires. A total of thirty five persons (35) participated. Dean Carlos Raffo and his academic staff supported us and participated in the workshop as well.

The Pontifical Catholic University of Chile: the Dean of Engineering View

The College of Engineering at the Pontifical Catholic University of Chile (PCU-Chile) offers the following engineering specialties: Civil, Chemical, Electrical, Mechanical, Computer, Industrial, Mining and Environmental Engineering. Programs for Master and Doctor of Engineering Sciences are also offered. The number of undergraduate students is 2900 and the number of graduate students is 300 with about 90 full time professors. Teaching and research are considered first priority activities.

The *Learning Factory Workshop* was carried at PUC-Chile in July 2001 with more than 60 faculty from our institution as well as 15 other institutions in Chile. The importance of the ABET accreditation, with its continuous quality improvement process, is very valuable for our institution. The idea of an integrated and multidisciplinary process of teaching has been recognized in our College of Engineering in which Management Engineering is integrated with technological engineering. The approach of the multidisciplinary program on Manufacturing is very consistent with our ideas of engineering. We discovered that we have to reinforce our “hands on” approach to engineering teaching. This workshop, which exposed our faculty to this collaborative program, is a very good way to stay in touch with innovative engineering education programs in the USA. It is a very good way to overcome self reference. It is of utmost importance now that we are in the track for an ABET evaluation visit of some of our engineering programs.

One of PUC-Chile’s strategic objectives is to maintain and enhance international alliances to strengthen engineering education. In our College of Engineering we have followed a long lasting program to send our young faculty to obtain the PhD. degree in North American or European universities; this program has produced strong ties between our faculty and these universities; even more, our engineering education has been greatly influenced by the topics and procedures followed in North America and Europe. Although we believe that relationship with industry is important, in practice our contact with industry has been poor in the past. Our engineering graduates are very well received by industry, but their participation in our engineering education process has been poor. The Learning Factory program provides a model to strengthen this critical relationship with the private sector.

This workshop has provided an opportunity to develop a strategic alliance with UPRM and the other institutions. This alliance will be a very good opportunity to work together in a modern

program in engineering education, to follow the new trends in engineering education in the USA.

National Technological University, Argentina: the Director of Communications view

The National Technological University (NTU) is the only Argentinean University specializing in engineering and has more than 30 campuses distributed throughout our vast country. *The Learning Factory* workshop, offered October 2001, was very instructive and particularly interesting. Its hands-on and practice-based focus validates our institution's study plans which are specifically oriented towards concrete professional practice. The possibility of implementing a model that enables students to achieve a specific professional practice in the framework of their studies is highly positive, and strongly favors the fulfillment of the anticipated goals and objectives of each of the careers in engineering given at the University.

At the present time, our university is immersed in the process of accreditation. Though the accreditation model used in Argentinean universities is basically different to the one proposed by ABET, the topics discussed in the workshop in that area proved to be very useful and valuable to faculty as well as administrators. There is no doubt that alliances with foreign universities constitute a highly positive strategy that would strengthen educational activities. The possibility of team work is always beneficial and allows the incorporation of innovative experiences as the one presented in the workshop. Cooperation and association between the university and the private sector is an important topic for the support of the educational activity, as well as, the need of the industry with respect to graduates. Nevertheless, the scope and objectives of careers in engineering should have academic excellence as its main goal.

We hope that this workshop has been only the beginning of the collaboration with UPRM, and that as the first experiences (in the sense of implementing the concept of *The Learning Factory*) are achieved, mutual cooperation will be enhanced.

Workshop leaders' views: Impact at UPRM

At UPRM the Learning Factory program has had a critical impact on engineering education. One can summarize impact from various angles, which include increased industry collaboration and student career opportunities enhancement as well as facilities development. With funds from NASA, in 1998 this program served as model to develop another successful multi-disciplinary minor at UPRM in remote sensing and geographical information systems [4]. But one of the most important impacts at UPRM has been that this program served as a model for developing the College of Engineering ABET 2000 strategy. Lueny Morell, co-author and LF workshop leader, who led and formulated the College's accreditation strategic plan under the new criteria, used the Learning Factory process-based and outcomes driven model with integrated assessment as key element in the accreditation plan [5,6]. A workshop called "Developing an Outcomes-based Course" based on the Learning Factory course development experiences was offered to all of the College's 160 faculty members as well as 60 Arts & Sciences professors [7].

In 1998, UPRM's Department of Mechanical Engineering became the first department in the School of Engineering to engage in the challenging and pioneering task of revising its twenty-plus-year-old curriculum. Using the material and knowledge gained from our participation in the Learning Factory experience, a team of ME faculty restructured the entire ME curriculum. Not only did the team add and eliminate courses and rearrange the order in which courses are taken, but, more importantly, we integrated hands-on learning experiences into the classroom, incorporated open-ended problems and the teaching of the design method in some of the engineering science courses, and increased student exposure to contemporary issues and ethical considerations. A reduction in the number of credits required for completing the degree made the new curriculum a more efficient system while at the same time satisfying the new ABET accreditation criteria. The new ME curriculum is now being used as a model for developing curricula in other departments of the UPRM School of Engineering.

The collaboration of workshop leaders in international workshops and seminars has provided opportunities both to share knowledge and experience with engineering faculty of different cultural backgrounds and to gain a better understanding of what makes "the engineer" in a wide variety of educational institutions around the world. This understanding has had a direct impact on the way participating faculty teaches engineering and the way engineering curricula evolves. Recent workshops in Chile and Argentina have generated interest among the participants to engage in some very exciting and innovative education experiences. Among those are remote teleconference workshops and seminars, and the coordination of a design course, to be taught among the different institutions, in which faculty members set up multi-national design teams to solve real-life engineering problems.

Conclusions and challenges to maintain and nurture international collaborations

When the National Science Foundation (NSF) granted in 1994 a trio of universities funds to develop and institutionalize the Learning Factory program little it could have foreseen the impact this project would have in our institutions, least in foreign countries. Yet it took a small group of individuals motivated only with the desired to share with many a very successful program that all stakeholders applauded, coupled with a modest amount of funds from both NSF and some visionary companies such as Raytheon and Microsoft Research to disseminate successfully this program during the last three years. Faculty eager to learn and enhance engineering education in various foreign countries have learnt about the Learning Factory outcomes-based curriculum model and have been motivated to consider reforming its education process and some even begin to consider accreditation under ABET 2000 criteria. The seed that has been planted is already extending to other institutions. As a result of the workshop carried at PUC-Chile in the summer of 2001, a group of institutions created a partnership to submit a proposal to bring the proposal to two regions in Chile. Two seminars will be offered in Arica in the north of Chile and Temuco in the south of Chile to bring together faculty from provinces near these two regions in the spring of 2002. Yet maintaining international collaborative activities takes time, resources and creative communication strategies.

Under the sponsorship of Microsoft Research, discussions have begun to formally organize a Latin American institutions group to further share best practices that enhance engineering and science education. In fact, the five countries under the Microsoft Research pilot program have

established a Latin America Advisory Board with the purpose of providing strategic guidance and synergism to the collaborative initiative. Countries are looking for ways to sponsor activities that bring faculty from various countries to share best practices and experiences. The private sector, a most critical stakeholder in engineering and science education plays an important role in providing strategic guidance as well as resources. Engineering and Science foundations like NSF and their counterparts in Latin American countries as well as companies like Raytheon and Microsoft Research should be involved in collaborative activities of this kind.

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Biographical information

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Lueny Morell is a Professor of Chemical Engineering at the University of Puerto Rico at Mayagüez. She also is Director of the Campus R&D Center. She has worked on various SMET curriculum development and assessment projects, among them UPRM's coordinator for the ABET 2000 strategy, NSF- AMP, MEEP and Learning Factory Workshops. Lueny is PI for the NASA grant Partnership for Spatial and Computational Research.

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Professor of Decision Sciences at the School of Business of the University of Puerto Rico – Mayagüez Campus (UPRM). He is a former Dean of the School of Business Administration at UPRM. Currently, he is the Co-Director of the Center for Hemispherical Cooperation (CoHemis) at UPRM and coordinates the Outreach activities for the NASA-sponsored Partnership for Spatial and Computational Research and the NSF-PRECISE.

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A licensed engineer and president of Vector Corp., Dr. Torres holds a Ph.D. from the Massachusetts Institute of Technology and has served as Associate Director of the Mechanical Engineering (ME) at UPRM. Founding member of the Learning Factory, he heads the ME ABET strategy and curriculum revision teams. R&D interests: system dynamics and control of electrical and electromechanical systems, focusing on biomechanics & mechatronics.

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