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University Partnerships with Industry and Government*

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Cooperation between the university, industry, government and the community can help achieve the primary missions of the university while better meeting the needs of its stakeholders. This paper demonstrates the value of integrating activities of the university into the broader society by describing several areas of collaborative activities among The University of Tennessee, Eastman Chemical Co., Sentech, the Oak Ridge National Laboratory, and what is now INVISTA.

Keywords: Partnerships; community; conceptual design; collaboration; industry

INTRODUCTION

UNIVERSITIES' PRIMARY MISSIONS are to provide education, research and public service. Two very visible objectives are to educate the next generation of citizens and to further human knowledge; thus, teaching and research. However, universities must not be viewed only in these narrow contexts. For a University to survive it must attract students and it must obtain adequate funding. Students demand that their education be effective, interesting, useful, and sufficient to qualify them for future employment. The intellectual and physical resources of a university, when applied to research, can also yield significant revenue. Too often the full potential of a university is not realized because it operates as a standalone institution. Active cooperation between the university and industry, government and community can help achieve the primary objectives of the university while better meeting the needs of its students and society. This paper demonstrates the value of integrating the university into the broader civil and economic society by describing several areas of collaborative activities among The University of Tennessee (UT), Eastman Chemical Co., Sentech, the Oak Ridge National Laboratory, and what is now INVISTA.

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These activities have proved to be very important to the missions of all of these partners although they do not necessarily fit the expected role of the university. The activities could be classified as education, research or public service, but in reality it is where all three themes are integrated that university, students, industry and society most benefit. 'It is good for engineers to be reminded now and again that their work, even when motivated directly by the prosaic needs of running a business, can nevertheless produce splendid results in the public interest' (Samuel C. Florman). It is hoped that this discussion will foster thinking about designing similar collaborative education and research activities useful to society.

PHILOSOPHY OF PARTNERSHIPS AND COLLABORATIVE ACTIVITIES

The cooperative activities described in this paper are characterized by:

- improving the quality of student education by making sure the curriculum is current and applicable to real-world issues, varying the pedagogical format, and offering students increased exposure to future employment opportunities;
- using university/student research and student projects to improve the green engineering aspects (efficiency, quality, cost, and/or cleanliness of industrial processes), thus improving the

competitiveness of local business and strengthening the economy while obtaining increased revenue for the university;

- focusing on green engineering technology areas that benefit society, such as energy efficiency, pollution reduction, waste management, and hazardous material clean-up. While there is no standard formula for such collaborative activities, the successful ones recognize the varied motivations of the participants—university, professors, students, industry, society—and make sure that every party benefits.

Industry's role is usually self-evident:

- sponsoring research;
- benefiting from university/student activities;
- helping to better educate rising students;
- offering employment to university graduates.

Government—national, regional and local—tends to be most concerned with:

- economic development (job creation and improved industrial competitiveness);
- environmental protection;
- safety.

As the 'surrogate' for societal interests, government benefits from these partnerships. Government is also an essential benefactor; it provides funding and, through the National Laboratories, expertise and facilities.

The paper describes four collaborative activities:

1. The Capstone Engineering Program, involving the University of Tennessee and the government-industry team of Eastman Chemical, Oak Ridge National Laboratory, and what is now INVISTA, has student teams applying their education to real industrial problems.
2. Applied university research may benefit an entire industry, but individual companies may not have the resources or the objectivity to sponsor it. This is properly government's role, and the University of Tennessee's nitrohydrolysis research is one such program.
3. The Industrial Assessment Center program, sponsored by the US Department of Energy, uses student teams to improve the efficiency and cleanliness of local industrial processes. This program has been successfully adapted to East European technical universities as part of an overall curriculum enhancement activity.
4. A continuing education experience including a workshop focused on assisting a new Russian business, SATIS Ltd., a joint venture partnership of VNIEF and Avangard. The workshop was entitled Business Partnerships: Critical Issues, hosted by the University of Tennessee and the Oak Ridge National Laboratory with support from US Department of Energy. The workshop participants were principals of SATIS Ltd., who proceeded to apply their new techniques in marketing their products in a series of meetings with USA and European firms.

Continuing interaction between the university and local industry is essential to identify opportunities for mutually beneficial cooperation. One way the University of Tennessee accomplishes this is by encouraging lectureship exchanges. Industry professionals often provide mentoring for on-campus projects, including research. Mentors and speakers from industry frequently speak at departmental seminars and provide lectures for various courses. Conversely, professors and graduate students provide lectures for industries through participation in national meetings and consulting to industrial facilities. The programs described in this paper did not appear spontaneously; they grew from relationships built and ideas generated as a result of interactions among university (students, faculty and administration), business, government and community personnel.

CAPSTONE ENGINEERING PROGRAM

The capstone design activities use authentic industrial projects as a teaching mechanism. The Capstone Engineering Program in UT's Chemical Engineering Department (ChE) has completed 54 projects involving 238 students in the period 1989 to 2006; it is one of several such departmental efforts at UT, bringing together students, faculty and practicing engineers to work on authentic industrial projects [1, 2, 3]. Continuing support of UT–ChE Capstone Education efforts is provided by Eastman Chemical Company, the Oak Ridge National Laboratory and what is now INVISTA. Capstone projects in UT ChE have completed studies on far-ranging topics, including control of leachate materials from a hazardous waste repository, recovery/control of NOx and organics from a process offgas stream, treatment/reuse of sludge from biological wastewater treatment reactors, reduction of emissions from pesticide production, recovery of and reuse of materials in purge streams from various processes, future systems for the production of HCN and optimization of fluid delivery systems. It is similar to programs at other universities that regard the real-world solution of engineering projects as important learning activities [4]. It provides engineering students a realistic capstone conclusion to their undergraduate education under the direction of faculty and industrial 'coaches'. While there are some variations at UT from department to department, the program involves at least a 2-semester program, some instructor-led elements, with transition to an industry-provided project for each team of 4 to 6 students.

Teams of students work on carefully selected industrially-sponsored projects. These projects require application of sound concepts of scientific and engineering principles, teamwork and project management to accomplish their goals. Protection of the sponsoring industries' confidential information is assured.

The Capstone Engineering Program in Chemical Engineering proceeds through some typical steps leading to a conceptual design study or to the development of a prototype. For a conceptual design study leading to preliminary process/product synthesis and evaluation a typical pathway is:

- feasibility study
- narrowing the field of alternatives
- preliminary design report and presentation
- flowsheet development
- estimation of capital and operating costs
- selection of most promising alternative(s)
- final report and presentation.

The deliverable of this activity in Chemical Engineering is a final report with recommendations. The deliverable may be different in other departments where the capstone design project leads to the development of a prototype. The function of the faculty and industrial coaches is to provide the necessary conditions and support for a student process design team to function effectively.

Important benefits of the Capstone Design Program are:

- valuable interaction with interdisciplinary student design teams working on projects that are important to the participating company;
- access to faculty who have expertise in technical areas related to specific projects;
- significantly improving the education of the next generation of engineers;
- visibility in identifying and recruiting new engineers.

Currently, in the Department of Chemical Engineering at UT there is some variation in our industrially-sponsored capstone design activities, depending largely on the discipline and level of industrial funding. In general these projects focus on process synthesis in response to an authentic industrial need. If the industry fully funds a project team, then they usually insist on confidentiality. Other situations are negotiable, with some projects having no confidentiality concerns. In general, the student team should and usually does utilize a more extensive set of metrics than economics.

An illustrative example of project deliverables comes from an early project on reduction of gaseous emissions from granular pesticide production [5]. The fundamental phenomena may be illustrated as:

$$\text{Raw Clay} + \text{CBA} + \text{AI} \rightarrow \text{Granular Pesticide}$$

where CBA is the chemical binding agent for the active ingredient, and AI is the active ingredient.

The production facility had recently been modified to so that increased air inleakage into the process and discharge were required. After the modification, unacceptable rates of CBA discharge were observed. The objective of the student team was to reduce CBA emissions by 98% while maintaining sound waste management practices. The waste management options selected and a classification of treatment or pollution prevention (P2) are:

1. Soil bed oxidation/biofiltration (treatment).
2. Aqueous absorption (treatment).
3. Condensation (P2).
4. Adsorption with activated carbon (treatment).
5. Adsorption with raw clay feed (P2).
6. Incineration (treatment).

The project proceeded with the annualized costs for the conceptual processes obtained as presented below. (Annualized costs contain depreciation as an expense and are normalized. TER = Thermal Energy Recovery.)

- soil bed oxidation/biofiltration (0.02);
- aqueous absorption (0.43);
- condensation (0.74);
- adsorption with activated carbon (2.74);
- adsorption with raw clay feed (1.00);
- incineration: 0 % TER (1.89); 35% TER (1.41); 95% TER (0.95).

The recommendation was to proceed with further study of the soil bed oxidation/biofiltration and adsorption by raw clay options. The industrial partner proceeded to acquire pilot plant data for the soil bed operation and to obtain experimental isotherm data for CBA loading on raw clay; both options were proven viable but economics prevailed and the option installed at the plant was the soil bed option, which has worked well for over 10 years.

The value of the Capstone Engineering Program to industry may be seen in the continued involvement by original industry sponsors that now spans several years. Jerry Johnson, a former program participant, White House Fellow, and currently Vice-President of Banc of America Securities in New York, cites the value of the program for students in teaching and emphasizing:

- the value team work and collaboration;
- development of a 'business-plan' approach to problem solving;
- the opportunity to work with large high profile chemical companies.

GOVERNMENT-SPONSORED APPLIED RESEARCH

The utilization of excess biosolids from wastewater treatment is an example of government-sponsored research organized as a capstone design project. A UT student team reviewed the basic data and relevant technology; this review included tours of the local (Knoxville Utilities Board) wastewater treatment facility and a local composting facility utilizing excess biosolids. Several approaches were considered and screened to provide the most likely set of useful technologies. Flowsheets were developed and capital investment and operating costs determined for the leading technologies. The technology selected for recommendation was one not well developed, Nitrohydrolysis. (Nitrohydrolysis involves the nitric acid catalyzed hydrolysis of the biosolids to several products, including acetic acid.) The team's recommendations were provided in a final report and oral briefings. For their work the team was given credit for the senior design course. This story does not end here, however, as UT has continued research and development activities associated with the possible commercialization of the technology utilizing federally-supported grants with 'in-kind' contributions from industrial partners.

The Nitrohydrolysis process had widespread usability and has recently been the recipient of a combined industry–US Department of Energy grant. Funds to begin the research and development (R&D) were provided by the Department of Energy's Energy Efficiency/Renewable Energy (EE/RE) State Partnership program and involved a partnership between UT and ORNL with industry providing 'in-kind' support. The work has been continued with funding from a grant from the State of Tennessee Water Resources Research Center and continued industrial in-kind support. This R&D for nitrohydrolysis has been the subject of a number of publications [6–9] and was the basis for a Ph.D. dissertation presented by Larry Perkins in 2004.

INDUSTRIAL ASSESSMENT CENTER (IAC) PROGRAM

The University of Tennessee provided the pilot work in 1975 for the US Department of Energy's (DOE) Industrial Assessment Center (IAC) program and developed the strategy that guides this program. For its 25-year life the UT IAC provided approximately 700 assessments and numerous special projects [10]. Nationally, the IAC is a component of the National Energy Strategy and also addresses the issues of waste reduction and productivity improvements for small and medium sized manufacturing firms. Assessments are performed at no cost to the manufacturer by teams of faculty and students from engineering schools at participating universities. Twenty-six (26) universities operated IACs. An industrial assessment is an in-depth assessment of a plant site, its facilities, services and manufacturing operations and involves a thorough examination of potential product improvements and cost savings from energy efficiency, industrial process and environmental remediation technologies. Assessments are performed by teams of engineering faculty and students from the participating universities. Students are compensated for their work and receive no academic course credit for their participation.

The assessment begins with a university-based IAC team conducting a survey of the plant, followed by a one or two-day site visit, taking engineering measurements as a basis for assessment recommendations. The team then performs a detailed analysis for specific recommendations with related estimates of costs, performance and payback times. Within 60 days a confidential report detailing the analysis, findings and recommendations of the team is returned to the plant. In two to six months, follow-up phone calls are placed to the plant manager to verify recommendations that will be implemented.

Recommendations from industrial assessments have averaged about $42,000 in potential annual savings for each manufacturer. As a result of performing these assessments, upper class and graduate engineering students receive unique hands-on assessment training and gain knowledge of industrial process systems, plant systems, and energy systems, This results in both more motivated and experienced students who are more employable. The participating manufacturer interacts personally with the students, sometimes extending employment offers after graduation. Faculty have developed ideas for research from their studies of manufacturing processes and have taught courses using experiences gained through their auditing work.

APPLYING IAC TO EASTERN EUROPEAN UNIVERSITIES

A fruitful activity in curriculum development was carried out as a partnership between a local engineering company and UT. This was a US Agency for International Development (USAID) activity in 1996–1999 focusing on Czech, Polish and Slovak technical universities with objectives to strengthen their curricula in energy efficiency and environmental protection. A major challenge of this effort was that East European universities traditionally relied almost completely on a lecture format for classes, while USA universities had integrated other types of presentations and interactive exercises into their courses in order to increase pedagogical effectiveness and retain student interest.

Another complicating factor was that in the post-communist economics, concepts of economic assessment, net present value, environmental regulation, externalized costs were only just beginning to be introduced. The project team found that to effectively convey these ideas, and have the students apply them in the context of making industry more economically efficient and profitable, a radically different teaching approach was needed. Thus, in addition to curriculum development, the UT professors had to introduce their European counterparts to improved pedagogical techniques, such as use of case studies, interactive exercises and participatory lecture formats. An indicator of the effectiveness of this activity was whether the European instructors would actually implement the material and teaching methods in pre- and post-graduate courses on energy and environment. This task was carried out by UT professors in partnership with the Alliance of Universities for Democracy (AUDEM, an organization of over 110 USA, British, Russian and Central and East European Universities).

Initially, three Czech universities participated: Czech Technical University in Prague, Technical University of Ostrava and Technical University of Liberec. The project consisted of initial planning meetings with the Czech universities, an intensive interactive week-long workshop for all three universities, a visit of Czech professors to the US, sample energy/environmental assessments carried out at each Czech university using the US Industrial Assessment Center (IAC) methodology, and concluding on-site visits to the Czech universities for implementation support by the American staff. In addition to curriculum and pedagogy improvements, it was hoped that the universities would establish a similar IAC in the Czech Republic. Admittedly this was an ambitious goal, as there was no potential for government sponsorship in the Czech Republic similar to the USA DOE's support for the IAC.

The Czech universities felt the project was very useful in modernizing curriculum and pedagogical techniques. Czech Technical University established an Energy Assessment Center modeled after the US ones, but funded by the university and private industry (since there was no Czech government funding available).

From a human-interest perspective, the following account by a UT professor describes his observations during the final visit to the Technical University of Ostrava [11]:

> Prof. Leos Pchalek described his own experience and excitement caused by immediate inclusion of new material and new teaching techniques in two of his classes upon return to Ostrava after the April, 1997 visit in Tennessee. He explained that he had decided not to incorporate new ideas since it was too late in the semester. On his first day back in class, a student asked what his impressions were about industry in America. His lecture that day was on control systems. He decided on the spot to elaborate his lecture with a verbal case study from his visit to the steam plant at Opryland Hotel in Nashville, Tennessee. As Prof. Pchalek told his story, you could sense he was remembering the feeling he had in class that day. His first example led to spontaneous use of a second and then a third, integrating his East Tennessee experiences between dissertations about theory. He said he lost track of time and when he noticed, he had run 2½ hours for a two-hour class. He was stunned that the students had not reminded him of the time as they usually would. He told us that normally the students were so bored that he dismissed class after 75 or 90 minutes of a 120-minute class. Several students told him how much they had enjoyed the class and asked 'would you do that again for the next lecture?' He did, but the next lecture ran to almost three hours before he realized the time. Again, the students did not complain. He said he really prepared a new approach for the next several lectures and incorporated an interactive experiment designed to encourage questions and, he hoped, leading to a discussion with his students rather than the traditional lectureonly mode so common in Central and Eastern Europe. Prof. Pchalek described the result just two classes later; there had been a discussion between him and the students, and even among the students in the class, again stimulated by pedagogical encouragement learned during this project. He said this had been the first time in his teaching career that students actually took part in class; he saw them participate in their own learning.

Following the Czech experience, a similar program was implemented with four Polish universities, using staff from UT and Prof. Karel Kabele of Czech Technical University. The four Polish technical universities involved were Warsaw University of Technology (PW), Silesian University of Technology (PS), Krakow Academy of Mining and Metallurgy (AGH), and Krakow Polytechnic University (PK). The Slovak Technical University of Kosice also participated.

The project was 'kicked off' at the 1997 AUDEM annual meeting in Warsaw and the results were announced at the 1998 annual meeting in Nitra, Slovak Republic. As a result of this activity, two of the Polish universities created Energy/Environmental Assessment Centers, one added an endowed chair in Energy Efficiency, and all revised their curricula as a result of the project [12]. AGH has incorporated the materials in its Fuels and Energy Program and has established a chair in Energy Efficiency. PW expanded an existing industrial process laboratory center to become an IAC, offering energy and environmental audits to small and medium sized industrial enterprises. PS also established an Assessment Center. PK improved their pedagogical techniques and course materials. They plan to establish an Assessment Center, and have conducted at least three energy/environmental audits since the USAID activity ended. In addition to enhanced and updated curricula in numerous courses, PW, the largest technical university in Poland, immediately added five new courses:

- Law and economics in environmental engineering, Part I
- Law and economics in environmental engineering, Part II
- Methods of energy effectiveness analysis
- Economics of municipal enterprises
- Hydrotechnics and water reservoirs (this water resource management course, at PW's Institute of Land and Water Engineering, used materials supplied by Tennessee Valley Authority during the Polish professors' trip to the USA.

COLLABORATIVE CONTINUING-EDUCATION EXPERIENCE FOR RUSSIAN ENTREPRENEURS

The Chemical Engineering Department at The University of Tennessee and the Nuclear Science and Technology Division at Oak Ridge National Laboratory (ORNL) hosted a workshop entitled 'Critical Issues for Business Partnerships' in June, 2002, for visiting Russian Entrepreneurs. The four Russian participants are four of the six partners of a new start-up company, SATIS, Ltd. of Sarov, Russia. SATIS will market equipment and services to the safeguards and security industries, with special early market emphasis on the nuclear industry needs.

The workshop was led by UT and ORNL professionals and was sponsored by a US Department of Energy Nuclear Cities Initiatives (NCI) project, NCI-32-ORS-SA. The DOE NCI program is chartered to support and establish redirection of employees from the Russian weapons-grade nuclear programs to peaceful, civilian employment. SATIS partners are comprised of individuals from two Russian Ministry of Atomic Energy nuclear facilities (All-Russian Scientific and Technical Research Institute, VNIIEF, and Avangard of Sarov). These two sites are similar in mission to DOE's Los Alamos Nuclear Laboratory of New Mexico and PANTEX facility of Texas.

The workshop featured interactive sessions:

- joint USA–Russian ventures;
- tools for business opportunity assessment;
- business strategies;
- corporate quality goals and ISO 9000;
- cultural aspects of business;
- marketing strategies.

The workshop was deemed a success, as the partners readily demonstrated the capability to acquire new skills, knowledge and to fully engage the presenters on the various topics. Another positive feature of the workshop was the marketing strategy, a presentation and a 'role playing' exercise for learning how to greet people and how to draw interest to one's product and/or services.

After the workshop, the Russian group participated in marketing activity at the 43rd Annual Meeting of the Institute of Nuclear Materials Management, June 23–26, 2002, in Orlando, Florida. SATIS shared an Exhibitor's Booth with a United States firm, MRO Software, Inc. SATIS had previously signed on as an Authorized Reseller of MRO products. The SATIS partners displayed their newly-acquired knowledge by first assembling the booth display items and then interfacing with attendees throughout the meeting sessions. Through their efforts and with John Randolph's support, they were able to identify possible future customers and to identify two new US business partners, Canberra of Albuquerque, New Mexico, and RAMSafe of Oak Ridge, Tennessee.

CONCLUSIONS

Several types of collaboration projects between universities, national laboratories, government and industry are presented. It is hoped that they demonstrate the value of partnerships between universities, government and industry in education, research and public service. Universities are a tremendous national resource, and their value is magnified as they interact with other organizations. The authors hope these examples have relevant application to society.

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