On Development of a New Manufacturing Engineering Program at Washington State University

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Abstract: *A new Bachelor of Science degree program in Manufacturing Engineering at Washington State University branch campus in Vancouver is described. We discuss industrial participation in curriculum and program development, and review cooperation with community colleges. A planned center for research in semiconductor manufacturing is introduced, and some of the lessons we have learned in starting the new program are discussed. Suggested metrics for outcomes assessments are described.*

INTRODUCTION

Washington State University (WSU) is developing a new branch campus in the southwestern region of the State, to serve the Washington segment of the fast-growing Portland-Vancouver Metropolitan Area. A new curriculum leading to the Bachelor of Science (BS) in Manufacturing Engineering is being introduced on the new campus. In this paper we describe the structure and innovative aspects of the new program, summarize the developmental process, and report on the lessons learned during the development. Growth forecast and future plans for the program are also discussed.

Background

Southwest Washington is growing rapidly: in 1990 Clark County was projected to reach a population of 295,000 by the year 2000. In 1997, however, the population was already well over 300,000 and is growing 4% a year. Manufacturing in the metropolitan region includes companies in nearly every Standard Industrial Classification (SIC), from primary metal production and fabrication of structural shapes to electronics, integrated circuit fabrication, and snack foods. Existing plants are expanding and new plants are opening. In particular, the regional semiconductor industry plans to hire 6600 more engineers and plant workers by the year

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2000 [1, 2]; yet the gap is widening between the number of people needed and the projected number of graduates from area university and community college programs. In response to requests by regional industry, the WSU School of Mechanical and Materials Engineering has introduced a Bachelor of Science program in Manufacturing Engineering on the new Vancouver Campus.

PROGRAM DESCRIPTION

The theme of the new program is *mechanical engineering applied to manufacturing;* the degree differs from industrial engineering primarily through an emphasis on mechanical design and machine controls. The course of study is based on the accredited Mechanical Engineering degree at WSU, but focuses on manufacturing processes and technologies in greater depth to provide the skills needed for advanced manufacturing [3].

Curriculum

The new degree provides an opportunity for WSU to tailor the curriculum in phase with ABET Engineering Criteria 2000 [4] and guidance from manufacturing industry [5-9]. We are following that approach in concert with an Industrial Advisory Board. The curriculum is designed to provide practical training and business skills without compromising solid science and engineering. WSUV will offer upper division courses and electives as listed in Table 1. Technical electives will be specific to particular manufacturing industries. Graduates who choose will be able to gain admission to reputable graduate programs in manufacturing or mechanical engineering. The upper-division design sequence - shown in Figure 1 - will focus on design of manufacturing *processes* or an element of a manufacturing system.

Table 1. Coursework for the BS in Manufacturing Engineering.

[lower division science foundation] 34 cr		
Principles of Chemistry	Chem 105, 106	8 crs
Physics for Scientists & Engineers	Phys 201, 202	8 crs
Calculus; Linear Algebra	Math 171, 172, 220, 273	12 crs
Differential Equations	Math 315	3 crs
Probability and Statistics	Math 360	3 crs
[lower division engineering foundation] 16 cr		
Engineering Graphics	ME 103	3 crs
Innovation in Design	ME 120	2 crs
Statics; Dynamics	CE 211, 212	6 crs
Mechanics of Materials	CE 215	3 crs
C Programming	Cpt S 251	2 crs

[upper division courses in the major] 51 cr

Materials Science	MSE 301	3 crs
Fluid Dynamics	ME 303	3 crs
Intro to Electrical Circuits	EE 304	2 crs
Intro to Microprocessors	EE 305	2 crs
Mfg. Planning & Estimating	ME 325	3 crs
Mfg. Processes I	ME 310	3 crs
Mfg. Processes Lab I	ME 311	1 cr
Mfg. Control Systems (w/lab)	ME 375	3 crs
Systems Design [M]	ME 316	3 crs
Heat Transfer	ME 404	3 crs
Advanced Mfg. Processes	ME 474	3 crs
Mfg. Processes Lab II [M]	ME 410	2 crs
Machine Design	ME 414	3 crs
Design Project	ME 416	3 crs
Engr. Administration	CE 463	3 crs
Mfg. Automation	ME 475	3 crs
Seminar in Manufacturing	ME 400	2 crs
Mfg. Engr. Electives		6 crs

[general education requirements] 27 cr

Introductory Writing	Engl 101	3 crs
World Civ I & II	Gen Ed 110, 111	6 crs
Fundamentals of Macroeconomics	Econ 102	3 crs
Tech & Prof Writing	Engl 402	3 crs
Biological science GER		3 crs
Humanities GER		3 crs
Intercultural studies GER		3 crs
GER Tier III [H] or [S]		3 crs
total credits		128

[Technical electives]

Metrology (w/lab)	ME 3xx (new)	2 or 3 crs
Electronics Assembly	ME 3xx (new)	3 crs
Manufacturing & Operations Design and Strategy	EM 460	3 crs
Robotics	ME 442	3 crs
Computer Integrated Manufacturing	ME 4xx (new)	3 crs
Finite Element Methods in Design	ME 472	3 crs
Computer Aided Design	ME 473	3 crs
Materials Handling	ME 4xx (new)	2 or 3 crs
Quality Control & Reliability Design	EM 480	3 crs
Quality Engineering Using		

Experimental Design	EM 485	3 crs
Internship in Mechanical Industry	ME 495	3 or 6 crs
Industrial Ecology	ME 4xx (new)	2 or 3 crs
Microelectronics Fabrication	EE 478	3 crs
Design for Manufacturability	EM 490	3 crs
Integrated Design	ME 415	3 crs

Abbreviations for Table 1:

ME	Mechanical/ Manufacturing Engineering	CE	Civil Engineering
EE	Electrical Engineering	EM	Engineering Management
MSE	Materials Science & Engineering	GER	General Education Requirement
[M]	Writing in the Major	[H],[S]	Humanities, Social Science

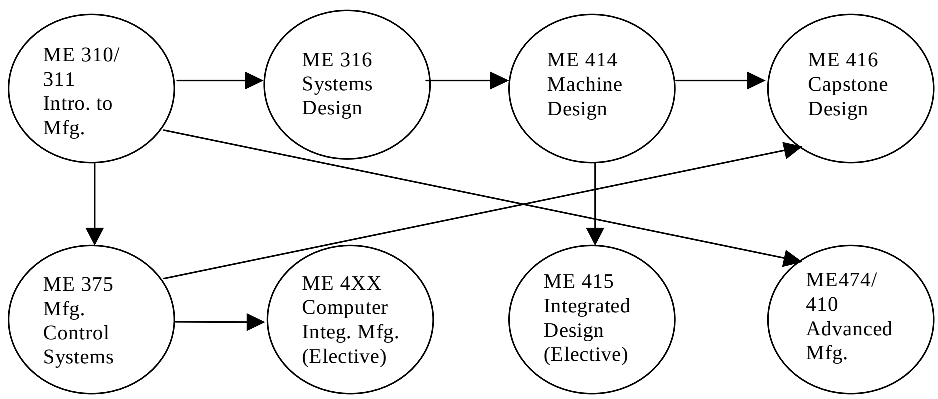

Figure 1. Design Sequence for Manufacturing Engineering.

APPROVAL AND ACCREDITATION

The process for obtaining approval to offer a new degree at the University is formal and incorporates many steps. Final approval was obtained four years after the idea was first conceived and more than a year after submission of the written proposal. The program must be approved by the WSU Academic Offices, Faculty Senate, Provost, and Board of Regents. External academic reviews are also required. Final authority to offer the degree is granted by the Washington State Higher Education Coordinating Board (HECB). While the proposal was going through this process, entering students were certified into Mechanical Engineering. After the first graduating class, accreditation will be sought from the Accreditation Board for Engineering and Technology (ABET).

The new ABET accreditation criteria for engineering programs will be implemented nationwide beginning in 2001. During the three-year phased implementation (1998-99 through 2000-2001), institutions may elect to have their programs evaluated under the current criteria or under new Criteria 2000 which shifts the emphasis from evaluation of the process to evaluation of the product, or *outcomes*. The Society of Manufacturing Engineers (SME) has drafted a supplement to the proposed ABET Criteria 2000 for Manufacturing Engineering programs. The WSUV program is designed to achieve the ABET Engineering Criteria 2000 plus the manufacturing-focused SME objectives [8-9]. A first attempt at allocation of Criteria 2000 requirements among the required upper-division courses is displayed in Figure 2.

Relationship Matrix For ABET Criteria 2000 And SME Supplement		Upper division required courses												GER
		MSE 301	EE 304	ME 325	ME 310 311	ME 303 404	ME 316 414 416	Math 315 360	ME 474 410	EE 305 ME 375 475	ME 400	Econ 102 CE 463	Engl 101 402 **M**	GenEd 110 111 **HS**
SME Proficiencies	a. materials & mfg. processes	•		•	•			•	•					
	b. process, assembly, product engr.						•							
	c. mfg. competitiveness			•								•		
	d. mfg. Systems design			•			•							
	e. laboratory experience				•		•		•	•				
ABET Criteria	a. apply knowledge	•	•	•	•	•	•	•	•	•	•	•	•	•
	b. design & conduct experiments				•		•			•				
	c. design to requirements						•			•	•			
	d. function on interdisciplinary teams				•		•		•	•	•			
	e. define & solve engineering problems			•		•	•				•			
	f. professional & ethical responsibility			•							•			
	g. effective communications						•			•	•		•	
	h. broad education													•
	i. life-long learning commitment													
	j. contemporary issues	•		•					•		•			•
	k. ability to use engineering tools	•	•	•		•	•		•	•				

Figure 2. Allocation of Accreditation Criteria among Upper-Division Courses in the Major.

Our Industrial Advisory Board urged us to teach key non-technical and business skills consistent with lists found in [5-9], without adding to the length of the curriculum. The requested skills include communication (written and oral); the ability to sell ideas to upper management; teamwork; economics and accounting; legal and regulatory environments; human factors; ethics; conceptualization (including sketching); and systems thinking. Our approach is to "weave the non-technical and business skills into the curriculum" by incorporating them into classroom practice. Measurable steps thus far include: team projects with written reports and presentations in Systems Design (ME 316) and Microprocessors (ME 305); systems thinking in ME 316; economics and cost accounting in Engineering Administration (CE 463); planning, estimating, cost-benefit analysis and human factors in Manufacturing Planning and Estimating (ME 325); and preparation of proposals to upper management and encounter with ethical dilemmas in Manufacturing Seminar (ME 400). Additional practice will be gained in the "Writing in the Major" [M] classes and Technical Writing (Engl. 402).

PROGRAM DEVELOPMENT

Courses are being introduced at a rate that would permit a full-time student at the entering junior level to complete the BS degree requirements in four consecutive semesters. Students transfer credits from a community college (primarily Clark and Lower Columbia) to fulfill the science and engineering foundation requirements. The program is projected to serve at least 50 FTE (with 25 students graduating each year) once it reaches full size in its fourth year.

Faculty

Most of the instruction and all of the academic advising for the program will be provided by five tenure-track faculty members of the School of Mechanical and Materials Engineering who will staff the program at Vancouver. Three of these hires are accomplished. The first faculty is an associate professor with experience in industry and program development, who is responsible for local direction of the program on behalf of the Director of the WSU School of Mechanical and Materials Engineering. The second and third are assistant professors with undergraduate teaching experience and specialties in controls, robotics, and design. Additional full-time faculty will be hired in each of the next two years.

The location of WSUV in a manufacturing region also provides a rich source of adjunct faculty. In the first year the two full-time faculty were supplemented by seven adjuncts who were recruited from Hewlett-Packard, Sharp Microelectronics, SEH America, and Portland State University. Six of the adjuncts are engineers and one is a physicist; five hold doctorates and two have MS degrees. In the rapidly changing field of manufacturing, adjuncts from industry help assure that current practice is brought into the classrooms.

Lab building

The Engineering and Life Sciences Laboratory Building for the WSUV campus has gone through pre-design [10] and is scheduled for occupancy in year 2001. The building will include 36,000 assignable square feet (67,000 gross sf), including engineering labs of 10,325 sf, faculty and staff offices and support areas of 6,430 sf, classroom space of 3,000 sf, and study areas, 1,000 sf.

Capital cost of the building is estimated at $30.7M; the allocation for acquisition of manufacturing laboratory equipment is $4M.

Semiconductor device manufacturing

The five year plan for engineering on the campus includes Computer Science and Software Engineering, and a Center of Excellence in Semiconductor Research (CESR). The semiconductor industry attracts particular focus because of WSUV's proximity to the "Silicon Forest" enterprise region. The Center will bring together the university, regional semiconductor manufacturers, and their manufacturing equipment suppliers in a cooperative venture to educate engineers for the regional industry and to perform collaborative research and development on semiconductor and microelectronics manufacturing. The Center is a key addition to the new Manufacturing Engineering program because it will provide opportunity for faculty to conduct research while teaching at the undergraduate level.

Semiconductor and microelectronics manufacturers in Clark County and WSU College of Engineering and Architecture faculty jointly developed the following initial set of objectives for the Center:

1. Create a local source of supply of technically trained workers for the industry;
2. Operate a shared analytical service for product manufacturing diagnostics and quality control;
3. Advance the technology of semiconductor and microelectronics manufacturing.

The planned Center will accomplish all three in a synergistic way, as pictured in Figure 3.

Initial co-location of the Center in the Engineering Laboratory Building will stimulate student involvement with manufacturing diagnostics and research projects as part of their education. Industry has indicated a willingness to donate used manufacturing equipment when they install the next generation in their plants. One company has donated a "Class 100" clean room and HEPA filters. This system, together with other donated equipment is suitable for manufacturing R&D and at the same time will provide a simulated production environment for manufacturing education.

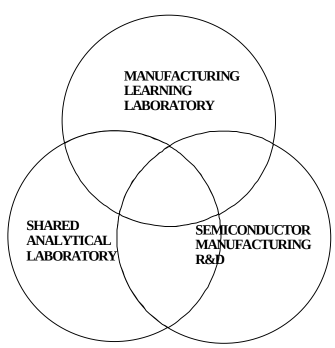

Figure 3: The Three-fold CESR Mission.

SOME LESSONS LEARNED

In this section we describe some of the more successful and innovative approaches that we developed during the early phases of introducing the new engineering degree on a new campus. Our experience is especially unique with respect to WSUV's upper-division-and graduate-only status and its derivative relationship with community colleges.

Starting a program without startup funds

The State Legislature supplies operations money to each WSU campus on a per-FTE basis. Capital is appropriated separately for construction and acquisition, but operational funds for new programs are obtained by reallocation within each campus. Thus new programs - including the B.S. in Manufacturing Engineering - must seek external sources for a significant portion of the non-recurring startup costs. It is not new information to note that engineering education is costly because of its extensive use of laboratories and computers. Moreover, the start-up phase is especially expensive when enrollments are small and infrastructure acquisition is underway. The per-FTE cost for the new program at WSUV in its first year is estimated to be three times the cost of the fourth year, in part because the laboratory building is not yet available. Thus several rather innovative initiatives have been taken to permit the degree program to get underway at the same time the infrastructure is being created. Two approaches to meeting laboratory requirements are described next.

Lab classes without labs

When the new WSUV campus opened in September 1996 it had classrooms and "wet chemistry" laboratories for teaching life sciences (biology, botany, and environmental science); computer laboratories were available for student use and a faculty-only computing laboratory was equipped with high-end PCs. One of the chemistry labs was utilized by the Manufacturing Engineering program during the Fall 1997 semester for ME 316, (Systems Design), where students were required to disassemble and "reverse engineer" some dysfunctional ink-jet printers [11]**.** The work was carried out by teams of three; a tool box with basic hand tools were purchased for student use. In addition to the reverse engineering the students were assigned a design project. In a course like this the project would typically involve manufacture of a prototype device designed by the students using a machine shop. However, since WSUV does not yet have a shop the instructor developed a project whose prototype could be manufactured using items that could be purchased from the local hobby shops, toy stores, etc. The challenge was to design an engineering project that required creativity, engineering analysis, cost little and could be built without a machine shop.

"Introduction to Microprocessors", EE 305, was taught in a classroom with the help of purchased and donated "evaluation boards" [12]. Students were permitted to take the modules home to complete assigned programming projects. The response from the students has been quite favorable, with two significant outcomes. First, the "take-home-lab" approach requires extra effort by the instructor to prepare and debug the exercises in advance; and second, if the students need assistance while working on the exercises at home, the instructor is not there to help. On the other hand, this practice is not qualitatively different from classes in computer programming, where most of the assignments are done at home. The condition of the evaluation boards -and their suitability for subsequent classes - after the semester is not yet known.

Lab classes at Community College
The WSUV campus is approximately six miles from Clark College. Clark has a healthy Engineering Transfer program as mentioned earlier, plus an exceptionally well-equipped Industrial Technology (IT) program. Clark's administration and faculty have welcomed the arrival of WSUV as a win-win and thus have been eager to work with us; for example, by opening Clark IT shops for WSUV engineering laboratory classes. The prototype class was Manufacturing Processes (ME 311), which meets once per week for three hours. Clark IT instructors agreed to participate in the WSU class, to help the WSU adjunct faculty locate materials, set up and troubleshoot manufacturing equipment, and assure access to the facilities. WSU is reimbursing Clark for the extra time spent by the IT instructors. The cooperative effort has gone quite smoothly, despite the fact that Clark is on a quarter system and WSU on semesters. In fact the mixing of engineering and technology education on the Clark campus is helping to publicize the WSUV program.

Packaging the courses for maximum availability
The mission of WSUV is to students within commuting distance of the campus. Only twenty percent of the Fall 1997 class of entering juniors are full-time; the majority are employed full time and taking one to three classes. A poll of students revealed three priorities for scheduling of classes: (1) offer classes in the late afternoon or evening; (2) offer classes early in the mornings if evenings are not available; and (3) group the classes so that students need make only one trip to campus each class day.

Clearly these requirements present scheduling constraints not encountered at a residence campus. The constraints are especially severe when the program is small and only one section of each class can be justified. Nevertheless, the State procedure of funding on an FTE basis places real pressure on maximizing class registrations. The schedule solution for Spring Semester 1998 is shown in Figure 4. A similar schedule was implemented in Fall 1997, and student response has been favorable in spite of some early and some long classroom sessions.

Student academic preparation
Requirements for admission to the program are the same as for Mechanical Engineering at WSU in Pullman. Moreover, students are being certified into Mechanical Engineering until the new degree is approved by the Higher Education Coordinating Board. Nevertheless, the first class of entering juniors displayed a wide variety of academic backgrounds and academic skills. In retrospect, this diversity is not unexpected for a new program and a new campus. In fact, WSU Pullman is reporting a similar experience, although not as pronounced.

The students who have transferred from another four-year institution and enrolled full time are doing well. Transfers from two-year colleges are not doing quite as well, and part-time students, especially those who have been working full time for several years, are struggling the most. The dilemma faced by the new program is how to maximize interest and participation without compromising WSU's academic standards. Insofar as time allows, the faculty have agreed to work one-on-one with the students, and to make it known that the help is available.

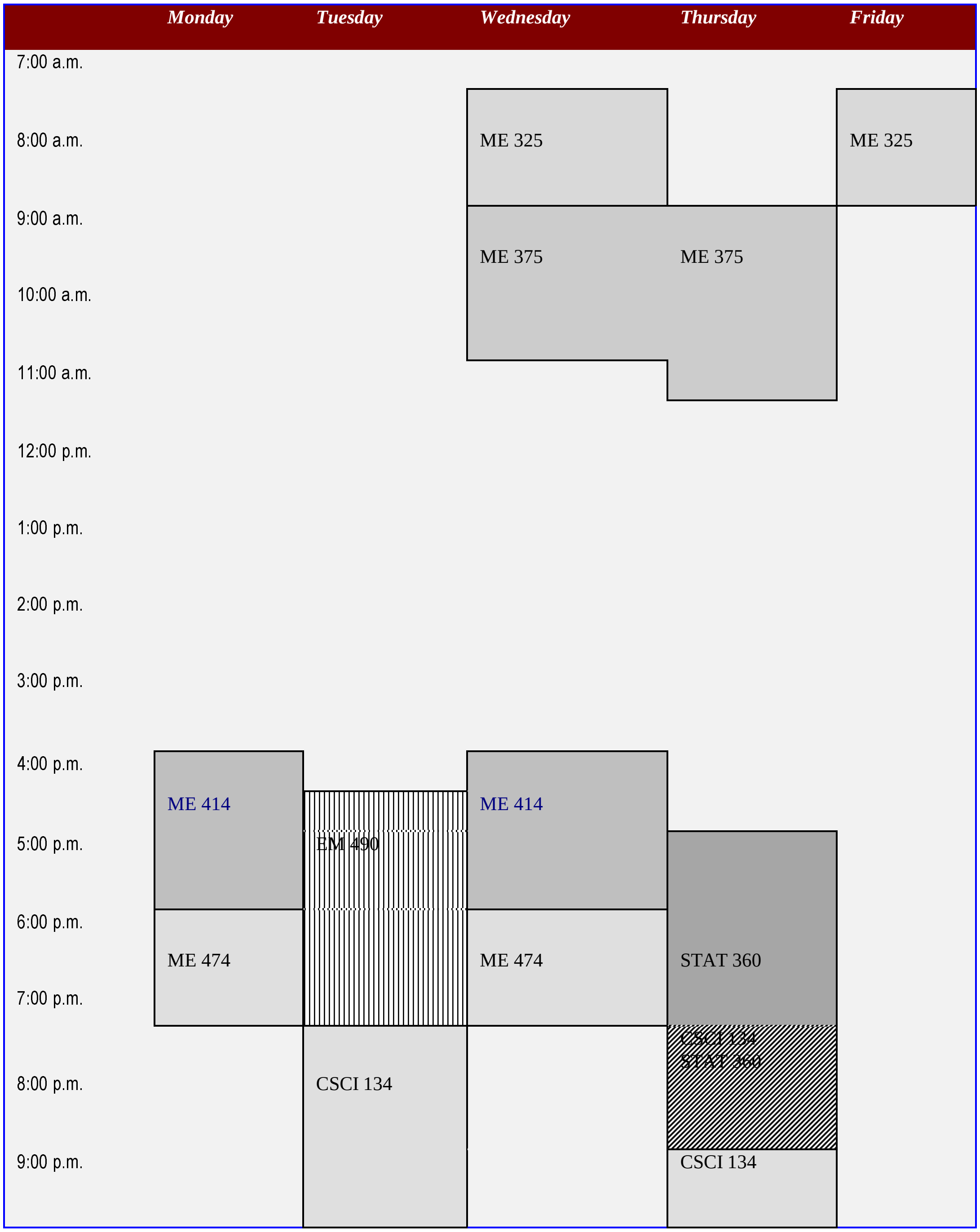

Figure 4. 1998 Spring Semester Course Schedule.

Building relationships with the community
The new program cannot be advertised until it is approved by the HECB. Hence all publicity is word-of-mouth, and each registering student is informed that they are enrolling in mechanical

engineering in WSU with a manufacturing focus area. Nevertheless, the community - including the Portland Metropolitan Area - is quite interested in the new campus and the Manufacturing Engineering program. The faculty cannot support all the invitations to speak at high school, community college, industry, and community (e.g., Rotary) events that are being extended. It is difficult and problematic to decline an invitation, but the "rule-of-thumb" that we are invoking is related to payoff. For example, because WSUV is upper division, our outreach to the high schools can be shared with the community college faculty.

Working with industry

The emerging accreditation criteria call for more than endorsement by industry; they call for documentation of *participation* [8-9]. Clark County industrial firms are embracing these interactions in principle, although undoubtedly some difficulties will emerge as we put agreements into practice. In addition to the Industrial Advisory Board role in curriculum development, several of the new classes are being designed to include in-classroom contributions by industry. Among these are Manufacturing Planning and Estimating (ME 325), where representatives will introduce and demonstrate manufacturing resource planning (MRP) software; Manufacturing Seminar (ME 400), where students will identify and define a capstone design project based upon industry presentations and opportunities for collaboration; and Internship in Manufacturing Industry (ME 495), where faculty and industry engineers jointly supervise a student's learning activity.

All of the companies have been willing to permit employees to serve as adjunct faculty, although the willingness of firms to give the employees time off during the day varies significantly. Several companies have offered to write joint proposals, to make production lines available (within limits) for faculty projects, and to host class tours. A few companies in the semiconductor device manufacturing chain expressed concern over loss of proprietary information to visitors; in these cases the access and projects may have to be limited to faculty and employees who are students.

RETROSPECT AND PROSPECT

In this section we summarize our planned approach to outcomes assessment, and summarize the present report.

Outcomes-based assessment

How will we know when we are on course toward the ABET, SME, and WSU objectives? The WSU College of Engineering and Architecture is developing a Student Outcomes Assessment Plan which delineates four kinds of outcomes assessments for undergraduate engineering education [13]. These assessments will be adopted and tailored for the new program. A brief summary of the four assessment areas follows.

1. *In-class assessments* will be conducted in selected courses such as capstone design, writing-in-the-major [M] courses, lab courses, selected senior course, selected junior course, etc. Assessment tools will consist of tests, projects, reports, activity evaluations, etc. and include instructor assessment report at the end of the course. To guide the assessment activities,

educational objectives and student outcomes will be identified for the program and for specific courses; summary assessments will be made of student performance in regard to meeting the program objectives.

2. *Focus group discussions* will be conducted with representative groups of graduating seniors in each program.
3. *Surveys* will be developed and sent to alumni (e.g. 1 and 5-yr grads). Alumni surveys will be developed by college and programs and administered by the programs; surveys of employers will be developed and administered by the College.
4. *Additional Assessment Activities* will be supplemented by items from the following list: WSU writing portfolio; transcript evaluation; Fundamentals of Engineering (FE) exam results; Professional Engineering (PE) and other licensing results - - such as Certification in Manufacturing from SME; internship and research experiences; and extra-curricular and other program-specific activities.

SUMMARY

A new Bachelor of Science degree program in Manufacturing Engineering program has been introduced at Washington State University branch campus in Vancouver, Washington. The campus is located in the rapidly growing Portland (OR) – Vancouver (WA) Metropolitan Region in which a robust manufacturing sector also resides. The new degree program is best portrayed as *mechanical engineering applied to manufacturing.* Origination and development of the curriculum is described, along with the approach to future accreditation. Industrial participation has been important for curriculum and program development. As an example, WSU and the semiconductor and microelectronics companies are planning to establish a center for research and education in semiconductor manufacturing. The WSU Vancouver campus offers upper-division and graduate classes only, such that cooperative approaches with nearby community colleges are essential. Some of the lessons we have learned in starting the new program are discussed, and preliminary metrics for outcomes assessments are described.

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BIOGRAPHICAL INFORMATION

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