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PARTNERSHIP FOR SUCCESS IN ENGINEERING EDUCATION

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ABSTRACT

This paper deals with the value of corporate partnership in the development of a program in Manufacturing Information Engineering at San Jose State University (SJSU), known as 2+2+2. The program has been developed in partnership with several high schools, three community colleges and six high-tech industrial companies in Silicon Valley. The curriculum has been carefully articulated to enable students to move seamlessly from high school to community college to university. Participating companies play an important role in defining competency gaps, developing case studies, placing students in internships, and developing state of the art laboratories. Competency gaps serve as a driver to curriculum development. One objective of the program has been to enhance diversity and encourage underrepresented minorities to pursue careers in engineering by presenting them with a seamless pathway early on in their education process. The paper will also provide answers to such questions as: How to develop a stable pipeline of students? What is the role of industry in program development? What are the significant achievements of the 2+2+2 program after three years of implementation? What are the lessons learned and the most significant outcomes?

Partnership and Student Success

The 2+2+2 program was designed in 1999 to provide a career pathway for students interested in engineering with an emphasis on manufacturing information systems. The program was developed in partnership with three high school districts (East-Side, Campbell and Sequoia), three community colleges (San Jose, Mission and Foothill-DeAnza) and six high-tech companies in Silicon Valley (Applied Materials, Hewlett-Packard, IBM, Intel, Lockheed-Martin, and Rockwell Automation/Allen-Bradley). In addition, two community organizations (Workforce Silicon Valley, and Workplace Learning Center) have participated in recruiting and providing internships to students.

Program Description

This program facilitates the creation and delivery of a carefully designed curriculum which enables students of diverse educational backgrounds, to move seamlessly from high school, to community college program, to university, Figure (1). Students can choose to join the workforce at any stage of the program. By successfully articulating educational programs, refining curricula, delivering faculty enhancement workshops, and offering students a valuable industry experience, the program aims to establish itself as a national model.

Figure (1)

The program begins with the last two years of high school where students can follow a specified course of study to earn a Certificate in Information Technology (CIT) with college/university course credits for articulated courses. At the community college level students follow a pre-engineering program equivalent to the first two years of engineering at San Jose State University. They may also choose to join the workforce by selecting an Associate of Science degree in manufacturing information systems technology (MIST). From there, students can go to the workforce or transfer to San Jose State University's College of Engineering. At San Jose State University the final two years of the pathway leads to a B.S. degree in Software & Information Engineering with a concentration in Manufacturing Information Systems Engineering (MISE) [1]. The program tracks are designed to provide seamless transitions among curricula.

Target Population

San Jose State University and its partner educational institutions all service a diverse population of students. This program aims at tapping into that diversity and encouraging more underrepresented students to pursue careers in engineering by presenting them with a pathway beginning early in their educational process. Special attention is given to development of alternative modes of instructional delivery, collaborative learning and multimedia technologies. These strategies enhance learning opportunities for English as a-second-language (ELD) students, minorities, women and persons with disabilities.
Figure (2) shows a breakdown by ethnicity of students at our target institutions.

As high-tech jobs increase throughout Silicon Valley it is extremely important that we focus our recruitment efforts on students from a variety of cultural and socioeconomic backgrounds while they are still in high school. San Jose State University, DeAnza

Community College and Evergreen Valley College engage in recruitment of these high school students by directly visiting the high school classes and by holding site-visits and open houses on their respective campuses. On October 2002, SJSU organized a "Show Case for Learning" that attracted over 3,500 visitors; many were students from feeder schools.

Institution	Asian, Filipino, Pacific Isl.	Hispanic	Caucasian	African American	Other
Yerba Buena H.S.	45.14	42.83	6.12	4.40	1.51
Silver Creek H.S.	47.29	31.66	13.38	6.18	1.49
Sequoia H.S.	5	55	36	4	0
DeAnza C.C.	37.1	11.2	35.3	3.8	12.6
Evergreen C.C.	46	26	16	6	6
SJSU Engineering	60	8.6	17	4	10.4

Figure (2): Percentage of student by ethnic group [2-7]

Industry Role

Participating companies have played a key role by defining customer requirements that impacted curriculum, providing case studies, offering faculty and student internships, developing state of the art laboratories, designing industry-based team projects, and committing to matching funds from funding agencies such as NSF and SME.

The successful partnership between local schools on one side and industry on the other has led to the success of the 2+2+2 program. Our consortium of schools has been an invaluable connection for getting faculty and administrators from different schools together to look at how the curriculum at each educational level builds to the next. Through intensive discussions we have been able to identify target courses for articulation and develop a process for implementing changes. In the areas where the educational programs fail to match up, we were able to provide resources for course refinement and program enhancement.

Our industry partners also played a key role in defining the competency gaps that they felt needed to be addressed throughout the educational pathway of a student. By working together we are finding ways to infuse these competency skills into curricula at every level. Figure (3) lists the 10 competency gaps that our partnership has identified. These competency gaps served as a driver to curriculum development.

Program Driver, Competency Gaps

- Good communication, team work and interpersonal skills
- High ethical standards and appreciation of diversity
- Ability to think critically and creatively
- Good grasp of mathematics, natural sciences, engineering sciences and analytical skills
- A foundation in materials, processes and statistics
- A good understanding of the application of information technology into design and manufacturing
- A product focus with a multidisciplinary systems perspective
- An understanding of quality, reliability and design for manufacturability
- Business and project management skills
- A drive to learn continuously and to impact knowledge to others

Figure (3)

Companies like Rockwell Automation/Allen-Bradley have helped strengthen the curriculum by providing equipment and software for a state of the art manufacturing lab at San Jose State University. Additionally, other companies like Lockheed-Martin Missiles & Space have provided strong support for our internship program. Students at every level are given opportunities to work in industry and get hands on experience with the concepts they learn in the classroom.
To strengthen the internship program, we have formed a partnership with Workforce Silicon Valley, an organization developed to spearhead the school to career movement in Santa Clara County. Their Bay Scholar's program offers hundreds of internship opportunities for high school and community college students. By co-enrolling our students in both the 2+2+2 program and the Bay Scholar's program we have greatly increased the number of work experience opportunities for students in the engineering pathway. Workforce Silicon Valley also shares their expertise in issues such as articulation and internship development.

Both Workforce Silicon Valley and the Workplace Learning Resource Center at Mission College help in administering the assessment piece of our program. Students are tested with Work-Keys, a group of assessment tests designed to focus on important workplace skills. These test scores are used by the 2+2+2 program and Workforce Silicon Valley to identify areas where students need additional instruction and more hands on experience. This knowledge is used to design faculty development workshops and to create a feedback loop, informing teachers and potential employers where the students' strengths and weaknesses lie.

Software Engineering
Manufacturing Information Systems Concentration

FRESHMAN YEAR: 33 Units

Fall	**Units**	**Spring**	**Units**
Math 30 Calculus 1	3	Math 31 Calculus II	4
Chem 11A Chemistry	5	Phys 70 Mechanics	4
Engr 10 Engineering Design	3	Engr 20 Design/Graphics	2
Engl 1A English	3	English 1B English	3
Oral Communications	3	Human Understanding/Develp	3
Total	**17**		**16**

SOPHOMORE YEAR: 30 Units

Fall	**Units**	**Spring**	**Units**
Math 32 Calculus III	3	Math 133A Ordinary D/E	3
Phys 71 Electricity & Mag.	4	EE 98 Electric Circuits	3
American Studies 1A	6	CmpE 46 Structured Prg/Design	3
Human performance	2	American Studies 1B	6
Total	**15**		**15**

JUNIOR YEAR: 33 Units

Fall	**Units**	**Spring**	**Units**
CmpE 124 Digital Logic	3	CmpE 138 Database Sys. Design	3
Engr 125 Software Eng I/ISE	3	Engr 135 Obj Oriented Analy/Des.	3
ISE 130 Statistics for Engineers	3	CmpE 130 File Processing	
3			
Engr 126 Alg/Data Str/CmpE 126	3	Engr 131 Computer Ntwks/CmpE148	3
CmpE 120 Computer Org/Arch	3	CmpE 142 Operating Systems	3
Engr 100 W – Writing skills	3		
Total	**18**		**15**

SENIOR YEAR: 34 Units

Fall	**Units**	**Spring**	**Units**
CmpE 150 Software Engr. II	3	Engr 164 Comp/human Interaction	3
Engr 146 Information Engineering	3	Engr 195B Senior Project II	3
Engr 195A Senior Project I	1	ME 109 or MatE 153	3
ME 136 Design for Manufacturing	3	Advanced General Education	3
ISE 140 Operations Planning/Control	3	ISE 115 Comp Integrated Mfg	3
Advanced General Education	3	ISE 167 Systems Simulation	3
Total	**16**		**18**

Figure (4) Curriculum

Curriculum

The curriculum has been designed with participation from all partners to include three major components:

1. General education component
2. Math, science, engineering science and information technology component
3. Manufacturing engineering component

Students from high schools are expected to have the necessary preparation to handle freshman courses in the curriculum, especially math, science and computer skills. Community college students are expected to have completed General Education courses in addition to the math and basic science courses. An introductory course in Information Technology was integrated into the curricula offered at participating high schools and community colleges.

Manufacturing Engineering courses have been taught at SJSU as application courses for Information Technology, using IT concepts learned previously in the curriculum. These courses were designed to emphasize large-scale system integration.

Yerba Buena High School in East Side Union District, has served as our model for curriculum and articulation issues with other high schools. Yerba Buena has an Engineering Magnet program that has been in existence for eleven years. They offer students a strong program in math and science with a selection of pre-engineering courses that focus on problem solving through the use of hands-on collaborative projects. Students take courses in the processes of technology, engineering graphics/design, and electronics concepts, as well as developing a senior engineering project. Many of the students in this program are eligible to attend a California State University when they graduate. They can feed directly into San Jose State University or choose a community college, such as Evergreen Valley or De Anza, that offers a pre-engineering transfer program.

Silver Creek High School, also in the East Side Union High School District, offers a slightly different type of feeder program through their East Side Electronics Academy. This program targets at-risk students by offering them hands-on courses in electronics. This program is supported by Hewlett-Packard who helps provide internship experiences for every junior student enrolled in the academy. Most of these students will continue on to Evergreen Valley community college before transferring to SJSU.
Sequoia High School in the Sequoia Union High School District offers an electronics academy and an information technology academy. Students have the option of taking courses in electronics, CAD/design, or a series of courses in Cisco Networking. The students in these programs represent a range of skills and will feed into local community colleges or San Jose State University.

The middle part of the 2+2+2 pathway focuses on programs at Evergreen Valley College

and De Anza Community College. Both of these community colleges offer pre-engineering programs that prepare students to transfer directly into junior year at San Jose State University. For students interested in earning an A.S. degree and exiting to the workforce, these schools offer related programs in manufacturing technology, and computer information technology.
Students who continue the pathway through to a four-year degree at San Jose State University will follow a curriculum in Software & Information Engineering. Within this major, Manufacturing Information Systems is offered as an area of concentration. To specialize in this field students will take courses in computer integrated manufacturing, computer aided manufacturing, modeling and simulation, and manufacturing processes. After completing this program students are prepared to design software and to architect network protocol for manufacturing automation. Figure 4 shows the four year curriculum at SJSU. 2+2+2 students move seamlessly through the curriculum from partner schools. Industry involvement in this strenuous process served to insure that current faculty skills were added to and/or updated in regard to new technology and/or other areas of professional development. Rockwell Industries provided monthly on-site training for faculty and students that served to heighten faculty awareness of current and ever changing trends in industry. The alliance with industry has accelerated faculty knowledge of contemporary team building techniques and state-of-the-art manufacturing technologies. Curriculum assessment led faculty to incorporate case studies derived from industry into the classroom experience. The benefit to the engineering student is the creation of a classroom environment that incorporates and applies real world problem solving techniques

Articulation

After looking at how the programs and curriculum are aligned at our participating educational institutions, the 2+2+2 program identified two courses, Introduction to Engineering and Introduction to CAD/Design, to target for articulation throughout the three levels. By setting up articulation agreements at each of the schools we were able to streamline students' education. Instead of repeating courses and topics covered in high school, students are able to earn college/university credit for their work. The Introduction to Engineering course is currently being offered at San Jose State University, Evergreen Valley College, De Anza Community College and Yerba Buena High School. All lower division courses offered at SJSU have also been articulated with community colleges.
The process of articulation was modeled after a format developed by Workforce Silicon Valley [8]. The Workforce Silicon Valley format was designed to standardize articulations between high schools and community colleges. San Jose State is the first university to start participating in this process. Ultimately, one set of articulation forms establish a link between topics covered in high schools to courses taught at either community colleges or San Jose State University.

The articulation form for each course sets out the course goals and objectives that must be met by schools participating in the articulation process. Figure (5) shows the goals and objectives for "Introduction to Engineering" course.

Goal 1	**Educate students about the engineering profession and expose them to several engineering disciplines through problem solving for the purpose of providing information to assist them in their choice of major.**
Goal 2	**Give students a basic understanding of engineering methods, including experimentation, data analysis, and computer skills.**
Goal 3	**Introduce students to engineering design through a variety of projects.**
Goal 4	**Provide opportunities for students to practice communication and team skills.**
Goal 5	**Provide support in academic success strategies, and personal / professional development.**

Figure (5): Course goals for Introduction to Engineering Course

Through meetings between faculty at the university and instructors from Yerba Buena, each course objective was discussed and high school courses were identified where the same objective was covered. Yerba Buena then added their corresponding courses and course objectives alongside the San Jose State column. This process allowed the high school teachers to identify areas in their curriculum where projects needed to be added or the level of difficulty needed to be increased. It also showed faculty from San Jose State some areas where the high school has a stronger curriculum and opened communication about adding some of the high school material to the University course. This same process has been replicated with the community colleges for the transfer of other courses. Once a set of courses from a community college has been adapted to match the articulated course objectives, students were able to earn university credits.
To administer the academic units we have established criteria at the high school for students to earn a Certificate in Technology. Students who complete the required courses and projects at their high school are able to submit their certificate to the records office at any of the three colleges they choose to attend and have their course credits added to their transcripts.

Laboratory Development

An important feature of the project has been the development of state-of-the-art laboratories to support all segments of the project.
Modern manufacturing processes and operations, in particular, demand a body of knowledge and skills that are often quite different from those found in traditional Engineering programs. The use of information technology by advanced manufacturing companies is pervasive; the focus is on designing, implementing, operating, and maintaining systems consisting of networks of computers, manufacturing equipment, and input-output techniques and protocols. The integration required in these systems has been a major focal issue of our program.
Rockwell Automation (Allen-Bradley) has taken the lead in the development of two

integral laboratories. These laboratories were carefully designed to support different levels of the Manufacturing Information Systems program including curricula in high schools, community colleges and San Jose State University. Figure (6) shows the main components of the Manufacturing Information Systems Laboratory.

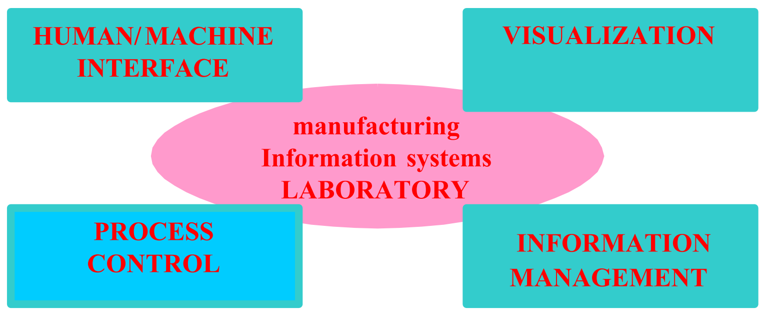

Figure (6) Main Components of the Manufacturing Information Systems Laboratory

One laboratory has been dedicated to Flexible Manufacturing Systems. This laboratory consists of three arm robots, one conveyor system, one disk stacker, and one CNC milling machine. These machines are organized in a cluster using the Rockwell automation architecture. The other laboratory has been dedicated to "Component-Based Enterprise Software". This laboratory is designed for the development, testing and maintenance methodology for Component-Based Distributed Software. The students are exposed to emerging technologies in manufacturing integration and are able to develop a flexible middle-layer using for an efficient agile manufacturing. These laboratories are currently housed in the College of Engineering at San Jose State University and are available to participating community colleges and high schools.

Internship Program

In order to truly meet industry need for a well-rounded and well-prepared workforce, a strong academic curriculum needs to be reinforced with opportunities to put learned skills into action. The internship component of the 2+2+2 program focuses on making this happen. The program provides students with hands-on learning experiences that will help them develop an enthusiasm for engineering, as well as valuable skills for working in industry. SME has developed a list of fourteen competency gaps frequently found in new employees. Finding ways to help bridge these competency gaps is part of our internship program's mission.

Students at every level are recruited for potential industry internships. At the high school and community college levels, students are co-enrolled in Workforce Silicon Valley's Bay Scholar's program. This allows for a greater selection of internship openings. Workforce Silicon Valley provides free information materials for interns and site supervisors in order to help strengthen the learning potential of each intern. They also provide an internship database, which houses our available positions and student profiles. In addition, San Jose State students are placed in internships through the SJSU Career Center's Cooperative Education Program.

In our first year, eighteen high school students went through the application process for internships. San Jose State University provided resume writing and interviewing skills workshops for the students after school. All of the students had the opportunity to interview with representatives from industry sponsors. Lockheed-Martin Missiles & Space participated in placing students for summer internships. This proved to be an outstanding experience for both the students and Lockheed employees. Students had the opportunity to rotate through four different divisions in the manufacturing department and to attend various staff planning meetings. This was consistent with our program goal to have students learn about each company's corporate culture and to be exposed to all aspects of the industry. Each intern was paid a stipend by the sponsoring company. In our second year we increased the internship program to include community college students and were able to provide 23 paid internships.

All of the internship development was handled by a full time intern/program coordinator. The coordinator is responsible for recruiting students from the participating schools, providing career preparation workshops, and interfacing with employers to develop internship positions that are appropriate for students at each educational level. High school internships place a heavy emphasis on mentoring and job shadowing with opportunities to work on small hands-on projects. Community college and University internships place a greater emphasis on hands-on use of skills and encourage increased responsibility over time.

Workshops

Three workshops entitled "Competencies for Success" were offered and attended by 102 students from participating schools. All instructors were either adjunct professors from sponsoring companies or faculty with extensive industrial experience.

The objective of the three workshops was to expose students to important competencies that enable them to succeed in the workplace.

At the end of the workshops, each student who successfully completed the workshops received an Achievement Certificate and a scholarship.

Following is a brief description of each workshop:

First Workshop: Technical Communication

Engineers must communicate through technical writing that is direct, convincing, and accurate. The goals of this workshop are for the participants to:

- Develop an awareness of the need for communication skills in engineering
- Learn how to use special technical writing techniques
- Develop skill competencies needed for individual effectiveness
- Be introduced to standards, methods, and other tools useful in the workplace
- Analyze readers and supply them with appropriate information

Participants are presented tips on:
- Getting started in technical writing
- Conquering writer's block

Industry models and examples are presented on:
- Lab Reports
- Progress Reports
- Technical Instructions
- Environmental Impact Reports
- Formal and Informal reports
- Business correspondence

Second Workshop: **Achieving Engineering Success**

Today's technical organizations achieve maximum success by integrating skilled engineers into effective project teams. Success in engineering is determined by both the technical skills and the ability to function in a project-team environment.
This workshop introduces key elements that are necessary for a successful professional engineering career. The workshop includes both lecture and hands-on participation in covering the following topics:
- Project Management Fundamentals
- Personal Leadership Styles
- Effective Teaming Methods
- Learning Styles

Third Workshop: **Manufacturing Automation & Machine Intelligence Project**

This workshop is designed to allow students to work in teams on programming, building and testing a mobile robot. The workshop includes the following elements:
- Introduction to machine intelligence and automation
- Basic components: soft ware algorithm, processor, sensors and actuators
- A factory automation example
- Theory of operation of a mobile robot and its components
- Construction and testing of a mobile robot, group activity
- Motion planning and programming competition, group activity

Results from these Workshops demonstrated the consistent ability of the 2+2+2 Program to attract equal numbers of males and females and underrepresented groups. In addition, our learning styles survey consistently demonstrated that the most effective approach to teaching this targeted population is by an active/visual approach.

Program Accomplishments and Lessons Learned

The project has succeeded in integrating the study of Manufacturing Engineering with the study of Information Technology. The component of Information Technology provides the Science and Technology base for students. The Manufacturing component was designed with six courses at the last two years as an application area for Information Technology. This has been a unique experiment that showed how to integrate Information Technology with Manufacturing Engineering.

Another contribution has been in attracting a large number of diverse students to the field of Manufacturing Engineering. Most Manufacturing curricula across the country are struggling to attract students.

The concept of a 2+2+2 succeeded in increasing student's awareness at the high school level to the exciting field of manufacturing and the joy of creating useful products.

The project resulted in an excellent model for curriculum innovation based on direct input from industry to curriculum, student, faculty, and laboratory development. Such input was instrumental in developing effective strategies to identify and address competency gaps. Industry saw the value of participating because of the desperate need for graduates with attributes that meet their needs. They saw a direct link between the participant and their company's productivity, and have viewed this participation as an investment in the future of their respective companies.

The internship component was an invaluable aid to education. We noticed that students who incorporated their academic knowledge into an industrial experience have accelerated their learning process by understanding the relationships between concepts and applications. Those students became more interested in the field of Manufacturing Engineering and were eager to know more about what Manufacturing Engineers do. By separating them from the classroom, students were given the opportunity to learn in a concentrated, fast paced, strictly outcome-based environment

Our numerous discussions about articulation, curriculum and internship issues have helped to break down some of the cultural barriers between different educational levels and between education and industry. Effective channels of communication have helped streamline students' education and provide a strong curriculum that builds sequentially and incorporates both technical and non-technical work skills.

Because of the fact that articulation and curriculum development require a great deal of communication, they can be very time consuming. In our experience this has turned out to be time well spent. We have avoided many of the typical miscommunications between schools that would have undermined our goals. Through team spirit, we were able to see how each decision we made impacted the other partners' programs and hence, found solutions that worked for everyone and ultimately improved the pathway for students.

The most difficult task for this project has been in building a strong partnership with industry and keeping industry representatives involved with the program. We have succeeded to a great extent in involving industry in curriculum development and student development activities. We did not, however, achieve the same level of success in involving industry with faculty development

The major contributions outside the discipline of Manufacturing Engineering can be summarized in the following points:

a. This project has demonstrated that the concept of a 2+2+2 program is an excellent approach to recruiting and retaining minority students into any technical program.

b. The 2+2+2 program is considered as the best solution to the problem of academic remediation. The problem of remediation is a serious one in California. More than 60% of students admitted to the California State University system are in need of some form of remediation to remove deficiencies in their academic preparation. A 2+2+2 program offers an effective solution to the problem. Academic institutions working together from high school to universities can effectively eliminate the need for remediation.

c. The success of the program in attracting high school students to the field of Manufacturing Engineering suggests that the same approach could be used effectively to attract students to other disciplines, such as Materials, Industrial and Aerospace Engineering that suffer from low enrollment because of lack of access to high school students.

d. The experience gained from working collaboratively with high schools, community colleges, and universities on program articulation is invaluable and can be helpful to any discipline other than Manufacturing Engineering.

e. This project has overcome many of the challenges of working with industry on curriculum development. There is no doubt that the lessons learned could be used in the curriculum development of any other discipline. The main contribution of this program has been in preparing underrepresented groups of students for rewarding and highly paid careers in Silicon Valley. Many of these students were at risk because of lack of focus and guidance. Our culturally and socio-economically diverse student population demanded that we provide a model of education that ensures success and prepares a broad base of students for jobs in Information Technology in Silicon Valley.

SUMMARY OF SIGNIFICANT RESULTS

Following are the most significant outcomes of the project:

1. Enhanced chances for student success and eliminated the need for remediation
2. Successfully developed a partnership where industry played a key role in program development and implementation
3. Attracted 187 students to the field of manufacturing engineering with 37% from underrepresented groups
4. Developed effective ways to address competency gaps
5. Established effective communication channels among different academic institutions that bridged cultural barriers and focused on student success
6. Established a model for replication by other institutions across the country
7. The success of the 2+2+2 concept can certainly be extended to disciplines other than manufacturing engineering

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BIOGRAPHICAL SKETCH

Dr. Nabil A. Ibrahim joined SJSU in 1990 where he served as professor, Associate Dean of Engineering and is currently the Associate Vice President for Graduate Studies and Research. He earned his Ph.D. from McMaster University and served as professor of Mechanical and Manufacturing Engineering at the University of Manitoba and Bradley University. His research interests include Design for Manufacturability, Materials Engineering, Advanced Composites, Fracture Mechanics, Quality Engineering and Curriculum Innovation. He has produced 24 publications, 30 conference articles and holds two US Patents. He has received significant grant awards and contracts from federal, state and industry sources and built successful partnerships with the corporate community in Silicon Valley and other regions of the country.