Manufacturing Technology Curriculum Research and Development for High Schools and Colleges in Washington State

D. Kim[1], J.T. King[2], T. G. Stoebe[3], I. Cossette[4]
[1]School of Engineering and Computer Science, Washington State University, Vancouver, WA /[2]College of Education, Seattle University, Seattle, WA/ [3]Department of Materials Science and Engineering, University of Washington, Seattle, WA/[4]Edmonds Community College, Edmonds, WA

ABSTRACT

The Puget Sound Consortium for Manufacturing Excellence (PSCME), a three year project funded through the National Science Foundation (NSF), is a regional education-industry partnership aimed at enhancing the connection between manufacturing technology education, student career goals, and private sector demand. The goal of the PSCME has been to develop an enhanced manufacturing curriculum for manufacturing technology programs in high schools and in two-year institutions. PSCME works with high schools and community/technical colleges in Washington State to gather and review existing manufacturing curricula, and to communicate with local industry leaders to clarify regionally developed industry skill standards and curriculum needs. This paper will discuss this deliberate cooperation and the resulting development of a new, modularized curriculum model. Based on the curriculum research, 19 modules were developed: Interpersonal Effectiveness, Introduction to Manufacturing, Safety in Manufacturing, Hazardous Materials, Manufacturing Field Trip, Total Quality Management, Statistical Process Control, Applied Mathematics, Interpreting Technical Drawing, Precision Measurement, Manufacturing Planning, Shop Skills, Job Readiness, Labor in Industry, Career Exploration, Computer Applications, Manufacturing Processes, Technical English as a Second Language, and Manufacturing Internship. These modularized curricula have been introduced to regional high schools and community colleges through a series of training workshops sponsored by the PSCME. Throughout the development process, these modules have been evaluated by students and local high school and college instructors. Feedback from the students and instructor evaluations will be discussed.

1. Introduction

Manufacturing is one of the most important businesses in terms of workforce and economics in Washington (WA) state. Aircraft manufacturing, metal fabrication/machine shop business, and ship building and repair are among the top industry cluster in two or three regions of the state. Statewide, only about 34 percent of all projected job openings

with short to moderate level skill requirements can be met by the completers of vocational/technical programs at WA community and technical colleges [1]. Therefore, there is a need for manufacturing technology programs at the community and technical colleges to provide enhanced education at programs for students. Manufacturing companies are deeply concerned about the shortage of workers with the skills needed to keep pace with technology. According to a fall 1997 survey by the National Association of Manufacturers, 88% of manufacturers report a shortage of qualified workers in at least one job category [2].

Established in 2001, the PSCME is a regional education-industry partnership aimed at enhancing the connection between manufacturing technology education, student career goal, and private sector demand. One of the goals of the PSCME is to develop an enhanced manufacturing curriculum model and teaching materials for the manufacturing technology programs at the 2 year institutions. Many manufacturing related curriculum has been developed [4,5], however there has been no effort to develop modules in manufacturing technology to meet the regional need in manufacturing technology programs. This paper will present the results of research on the content of existing manufacturing curricula. A discussion on the modularized manufacturing technology curriculum will follow. As well, the PSCME has partnered with the Manufacturing Technology Advisory Group (MTAG) in the revision and implementation of curriculum modules. MTAG is a partnership comprised of Washington business, education, government, labor and community to address the emerging technological needs of education and the manufacturing/engineering industry [2]. Throughout the curriculum development process, these modules have been evaluated by students and local high school and college instructors and their evaluations will be discussed.

2. Existing Manufacturing Technology Curriculum Research

Figure 1 shows the overall activities of the PSCME include working with various community and technical colleges in WA State to gather and review the existing curricula. To establish baseline enrollment data, the PSCME program targeted colleges with the State Board of Community and Technical Colleges (SBCTC) Classification of Instructional Program (CIP) code of 480501, which is defined as a machinist or computer aided machining technology program. Baseline colleges include Bates, Bellingham, Clark, Columbia Basin, Lake Washington, Lower Columbia, Renton, and Shoreline. These colleges are located in ethnically and economically diverse areas of the state, which creates an opportunity for the program to impact enrollment of minority students and women. Existing curricula in the machining related programs (CIP 480501) were collected.

The instructors and representatives of these colleges were then interviewed in order to survey their needs and to further identify the existing curricula. From the communication with the instructors, it was found that most existing curricula had been developed based on class textbooks, instructors' preferences (or experiences), existing instructional

modules, departmental history and equipment, and discussion with the program advisory committee. As a consequence, there is no modularized curriculum on manufacturing in WA state, thus making it is possible to have training gaps in the program. There are some disagreements between college instructors regarding the manufacturing technology curriculum. The first disagreement is whether to teach computer aided drafting (CAD) in

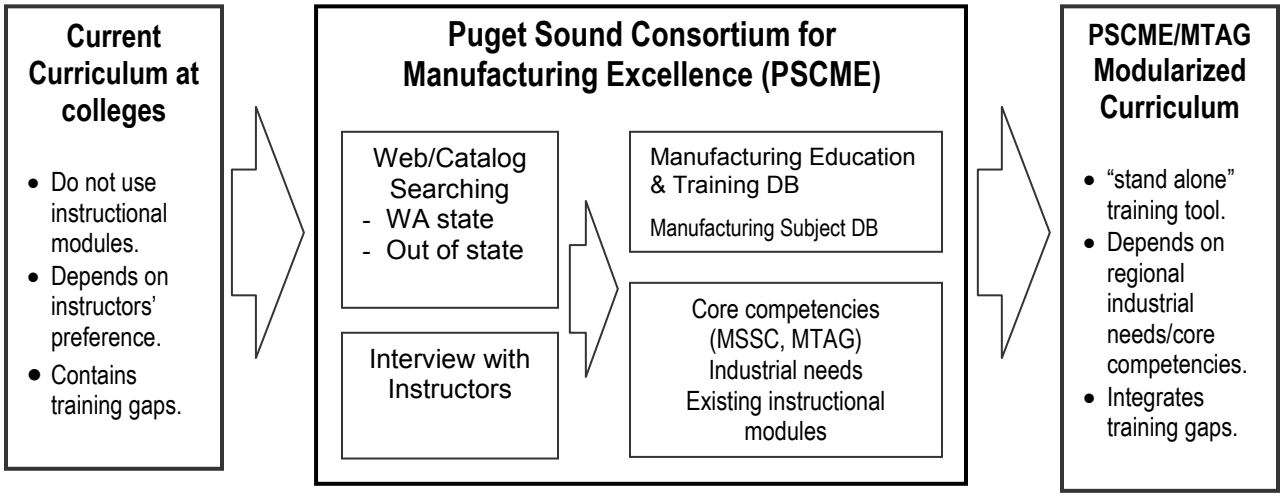

Figure1. Development of PSCME Modularized Curriculum

the machining program. Some instructors think that most machinists will not use CAD in industry, so students do not have to learn CAD. However, other instructors believe that students should learn CAD because machinists should know how drawings are created, and they might work with or go to design/engineering/ drafting departments using CAD. Another disagreement is whether to teach computer aided machining (CAM) software. Some instructors state that there is no need to teach students how to create G-codes (Computer codes which describe tool paths), and to understand G-codes might be enough for students in the machining program. However, many instructors include the CAM classes in the program because machinists should use CAM software to create tool paths and to learn about the concurrent manufacturing environment.

Having reviewed the existing curricula, we then result to identify training gaps and develop a curriculum to meet those specific gaps. Two information databases have been created for all existing curricula to find these specific training gaps: one is a Manufacturing Education and Training Database, and the other is a Manufacturing Subject Database. The Manufacturing Education and Training Database contains all manufacturing subject offerings in each college. The Manufacturing Subject Database includes the subtopics and textbook information on each manufacturing subject. The information databases are posted on the PSCME web site [3]. According to the information databases, each college has several training gaps in their curricula, as shown in Figure 2.

Colleges / Manufacturing Subjects	PSCME Baseline Colleges								Reviewed at the request of SBCTC*		
	Renton	Lake Washington	Shoreline	Clark	Columbia Basin	Bellingham	Bates	Lower Columbia	Clover Park	Green River	Spokane
Shop Safety	■	■	■	■		■	■	■	■	■	■
Measurement	■	■	■		■		■	■	■	■	■
Blueprint	■	■	■	■		■	■		■	■	■
Engineering Math	■	■	■			■	■		■	■	■
Geometric Dimensioning & Tolerancing	■	■	■								
Materials	■	■	■			■					
Bench work (hand tool)	■	■	■	■	■	■	■	■	■	■	■
Manual Lathe	■	■	■	■	■	■	■	■	■	■	■
Manual Mill	■	■	■	■	■	■	■	■	■	■	■
Grinding	■	■			■	■	■	■	■	■	■
Nontraditional Machining (EDM)	■			■							
Computer Aided Drafting					■	■	■		■	■	■
CNC Programming	■	■	■	■	■	■	■	■	■	■	■
CNC Mill	■	■	■	■	■	■	■	■	■	■	■
CNC Lathe	■	■	■		■	■	■	■	■	■	■
Computer Aided Manufacturing	■			■	■	■	■	■	■	■	■
Heat treating	■				■	■	■		■		
Quality Control	■		■			■	■			■	■
Process Planning	■	■					■				
MFG Handbook use	■					■		■	■		
MFG Economics		■									■
MFG Resource management											■
Communication	■										
Workplace Ethics	■						■				
Group dynamics	■					■	■				
Hydraulics						■					
Welding							■				
Co-op	■			■				■	■	■	■

■ Class offered □ Class not offered

*SBCTC: WA State Board for Community and Technical Colleges

Figure 2. Training gaps in the manufacturing program (CIP 480501) in 2001-2002

3. Modularized Manufacturing Technology Curriculum Development

In order to establish a modularized manufacturing technology curriculum, there is a need to benchmark manufacturing technology curricula around US and clarify the training

gaps. First, the existing curricula were evaluated using industry standards, including both the Manufacturing Skills Standards Council (MSSC) and Manufacturing Technology Advisory Group (MTAG) standards as well as existing instructional modules. In addition, the percentage baseline colleges providing each subject were reviewed and compared to available manufacturing technology curricula around US as shown in Figure 3. Based on this, core curricula can be identified and instructional modules can be determined to be

Manufacturing Subject	% Offerings (baseline college)	Skill standards		ATE's			Etc.		Modules
		MTAG	MSSC	WMCC	AIM	SC ATE	MAST	NIMS	
Shop Safety	88%	O	O				O		X
Measurement	75%	O	O	O			O		X
Blueprint	75%	O	O	O			O		X
GD&T	38%						O		
Engineering Math	63%	O			O	O	O		X
Materials	63%	O	O	O	O		O		X
Bench work (hand tool)	88%	O	O	O			O	O	X
Manual Lathe	100%	O	O	O			O	O	X
Manual Mill	100%	O	O	O			O	O	X
Grinding	75%	O	O				O	O	X
Nontraditional Machining	25%	O					O	O	
CAD	38%	O					O		
CNC Program	100%	O	O				O	O	
CNC Mill	100%	O	O				O	O	
CNC Lathe	88%	O	O				O	O	
CAM	75%	O	O				O	O	
Heat Treating	50%	O					O		
Quality Control	50%	O	O	O	O		O		X
Process Planning	38%	O	O	O	O		O		X
MFG Handbook use	38%								
MFG Economics	13%	O	O						
MFG Resource Mgmt.	0%	O	O	O					
Communication	13%	O	O		O	O	O		X
Workplace Ethic	25%	O	O		O		O		X
Group dynamics	25%	O	O		O		O		X
Leaderships	13%		O				O		X
Job Preparation	13%						O		X
Hydraulics	13%								
Welding	13%	O					O		
Internship	38%								X

WMCC: The Wisconsin Manufacturing Curriculum Consortium
AIM: The Advanced Integrated Manufacturing (AIM) Center
SC ATE: The South Carolina Advanced Technological Education Center of Excellence
MAST: The Machine Tool Advanced Skills Technology Program (Texas State Technical College)
NIMS: National Institute for Metalworking Skills, Inc.

X: PSCME/MTAG Modularized Curriculum

Figure 3. Evaluation the existing curricula and the preliminary modularized curriculum establishment

developed. Core curricula were offered by more than 50% of baseline colleges, and both skill standards and instructional modules cover them. Core curricula include Shop safety, Engineering Math, Materials, Blueprint reading, Machining theory and manual machining lab, Measurement and inspection, CAD, CNC machining theory and lab, CAM, and Quality control.

In addition to benchmarking, there is a need to add industrial inputs on the modularized curriculum. The industry representative focus group explored participants' thoughts on the future of manufacturing in WA, qualities needed in the future employees, and curriculum in manufacturing technology programs. The participants anticipate that manufacturing careers of the future will require individuals who are efficient, highly skilled, knowledgeable and experienced with computer technologies, and good communicators/team builders. The participants pointed out that manufacturing technology programs needed to include statistical process control, process planning, and soft skills such as communication and work ethics. There was another input from the PSCME NSF National Visiting Committee (NVC). It was determined that several manufacturing subjects were missing in the existing curricula. Three manufacturing subjects were determined to be training gaps at all baseline colleges. These are

- Manufacturing Processes
- Technical English as Second Language
- Manufacturing Internships

Based upon interviews with instructors in secondary and post-secondary institutions, they do have strong curricula on CAD, CNC machining theory and lab and CAM. This is not surprising because most manufacturing technology instructors used to be CNC machinists in their backgrounds. Also, it was determined that modularized curriculum should include a detailed lesson plan and all supporting resources such as slides (Power Point base), handouts, and skill check or assessment units. The format utilized for the modularized curriculum is: Introduction, Lesson Plan, Class Curriculum, Handouts, Assessment, Module evaluations, Overheads and Resources. Using this format, an instructor can identify module content by reading the Lesson Plan. The Class Curriculum section provides instructors with an overview of topics, content knowledge, and activities for the module. All instructional resources, including PowerPoint Handouts and Overheads, are included so that the curriculum is provided ready for instruction. Skill checks and assessments are interspersed throughout the module so that instructors can monitor and evaluate student progress. This modularized curriculum is made using electronic files to allow for flexibility so pieces of the module can be modified as needed.

Based on this research, the PSCME has partnered with the Manufacturing Technology Advisory Group (MTAG) in the revision and implementation of manufacturing technology modularized curriculum. MTAG has developed 16 modules; Interpersonal Effectiveness, Introduction to Manufacturing, Safety in Manufacturing, Hazardous Materials, Manufacturing Field Trip, Total Quality Management, Statistical Process Control, Applied Mathematics, Interpreting Technical Drawing, Precision Measurement, Manufacturing Planning, Shop Skills, Job Readiness, Labor in Industry, Career

Exploration, Computer Applications. PSCME proceeded to develop three of these instructional modules; Manufacturing Processes, Manufacturing Internship, and Technical English as Second Language (TESL). The technical content for these 19 modules is being developed in accordance with local industry needs and national and state skill standards.

4. Pilot Testing and Evaluation

PSCME/MTAG 19 manufacturing technology modules were pilot tested with high school students and instructors at the Summer Workshop, and with educator interns who participated in the PSCME/MTAG internship. Both high school students and instructors were asked to complete a survey regarding their impressions of the modules and suggestions for learning. The difficulties and effectiveness of the modules were evaluated by students. The teachers evaluated the quality of learning activities and module content, sequence of module activities, alignment of module objectives and contents, readiness of module for instruction, flexibility of module, clarity of module instructions, and module's usefulness. In addition to these questions, students and teachers made suggestions to enhance the modules. Overall, the high school students reported positive impressions of the three modules they experienced. Student reported the objectives were clear and that objectives were met by each modules' end. The high school students also indicated that it was easy to stay focused on the module and the exercise were helpful in learning the material, but they did not find the modules very challenging. Like the student, the instructor reported favorable perceptions of the two modules for which surveys were completed. The educator interns, on the other hand, were less favorable in their ratings of the nine modules reviewed. The educator interns made several suggestions for revisions to improve the modules that they reviewed such as include more activities, subdivided the modules, and address more competencies.

In addition, PSCME/MTAG 19 manufacturing technology modules were pilot tested at selected community/technical colleges and high schools in WA. The program representatives as well as instructors were satisfied with the modules due to their convenience to use in classroom. The instructors felt comfortable about sharing module information with their students. Also, they were positive to being able to choose the modules that fit with their existing curriculum. However, the instructors recommend adding more resources on the modules.

5. Conclusions

The PSCME's 2 year experience of manufacturing technology curriculum research and development for the highschools and community/technical colleges in WA State was described. The existing manufacturing technology curricula were evaluated using the skill standards. Through the survey with consortium and industry partners, the PSCME made recommendations for updating manufacturing technology curriculum. There are some training gaps between local industry needs and manufacturing technology programs. To fill out those gaps, the PSCME partnered with MTAG to develop, revise, and implement manufacturing technology instructional modules. They have been reviewed by

the consortium partners. Overall, the students reported positive impressions of the modules and the instructors also reported favorable perceptions of the modules.

6. Acknowledgment

Partial support for this work was provided by the Puget Sound Consortium for Manufacturing Excellence, NSF Advanced Technology Education Grant 0101582.

7. References

[1] Paul Sommers and Deena Heg, Report for the State Board for Community and Technical Colleges and Workforce Training and Education Coordinating Board, October 2002.
[2] Manufacturing Technology Advisory Group Web Page, http://www.wa-skills.com/html/mfgtech.html.
[3] Puget Sound Consortium for Manufacturing Excellence Web Page, http://www.pscme.org/educators.html
[4] J.C. Swearengen, S. Barnes, S. Coe, C. Reinhardt, K. Subramanian, "Globalization and the Undergraduate Manufacturing Engineering Curriculum," Journal of Engineering Education, April 2002, pp. 255-261.
[5] Bob Lahidji, Jihad Albayyari, "Assessing the competencies in the Manufacturing Engineering Technology programs," Proc. 2002 ASEE Annual Conf. Session 3548, CD-ROM, 8 pages, June 2002.

DAVE (DAE-WOOK) KIM
Dr. Dave (Dae-Wook) Kim is an Assistant Professor of School of Engineering and Computer Science at Washington State University Vancouver. He received his Ph.D. from the University of Washington, Seattle, and his M.S. and B.S. at Sungkyunkwan University, Korea. His teaching and research interests include manufacturing processes, composite materials, and mechanical behavior of engineered materials.

JOHN KING
Mr. John King is a Ph.D candidate in Education at the University of Washington. He teaches curriculum and instruction in the Master in Teaching Program at Seattle University and serves as a curriculum consultant to the Puget Sound Consortium for Manufacturing Excellence.

THOMAS STOEBE
Dr. Tom Stoebe is Professor Emeritus of Materials Science and Engineering at the University of Washington. He serves at PI for the Puget Sound Consortium for Manufacturing Excellence and for the National Resource Center for Materials Technology. He is active in research in the area of radiation detection and optical materials.

MEL COSSETTE
Ms. Mel Cossette, M. Ed., was the Director & Principal Investigator of the Puget Sound Consortium for Manufacturing Excellence, Lake Forest Park, WA, and currently is the Director of Material Science at Edmonds Community College.