AC 2008-664: A COMPETENCY GAP IN THE COMPREHENSIVE DESIGN EDUCATION

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Vukica Jovanovic began her academic career in 2001 when she graduated at University of Novi Sad, majoring in Industrial Engineering and Management, Minor in Mechatronics, Robotics and Automation. She was working as Graduate Research and Teaching assistant and lectured various courses at departments of Industrial Engineering, Mechanical Engineering and Mechatronics from 2001 until 2006. She was an active member European organizing committee of student robotic contest Eurobot and chief of Eurobot organizing committee of Serbian student national competition in robotics. In the summer of 2002, she had an internship in the company Gamesa Aeronautica, section Moasa Montajes, Spain where she worked in product distributed environment at manufacturing of aircraft wings and nacelles. After graduating with a Master of Science (M. S.) degree, in area of Industrial Engineering, specialization in Production Systems in 2006, M.S. Jovanovic subsequently continued to work towards her Doctor of Philosophy (PhD) degree at Purdue University, department of Mechanical Engineering Technology. She is currently working as a Graduate Teaching and Research Assistant in Product Lifecycle Management Center of Excellence Laboratory at Purdue University. As a graduate student, she is involved in the following projects: National Science Foundation project: Midwest Coalition for Comprehensive Design Education, Society of Manufacturing Engineers Education Foundation Project: Product Lifecycle Management Curriculum Modules and Workforce Innovation in Regional Economic Development (WIRED) Opportunity Fund for North Central Indiana: Development of Integrated Digital Manufacturing Curriculum. She is a student member of the American Society of Engineering Education, Society of Manufacturing Engineers (SME), Society of Woman Engineers (SWE), and Woman in Technology (WIT). She published two chapters in two textbooks, two journal articles and presented 23 conference papers. Her current research focuses on product lifecycle management and digital manufacturing.

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Dr. Mileta M. Tomovic is W. C. Furnas Professor of Enterprise Excellence, Mechanical Engineering Technology Department, School of Technology, Purdue University. He is Special Assistant to Dean for Advanced Manufacturing, Purdue University Scholar, Director of Digital Enterprise Center and co-director of Purdue University PLM Center of Excellence. He received his B.S. degree in Mechanical Engineering from the University of Belgrade, Yugoslavia, in 1979, M.S. degree in Mechanical Engineering from the Massachusetts Institute of Technology in 1981, and Ph.D. in Mechanical Engineering from the University of Michigan, Ann Arbor in 1991. Dr. Tomovic is recognized nationally and internationally as a leader in mechanical engineering technology education and for his scholarly contributions to the field of design for manufacturability. Dr. Tomovic has fifteen years of teaching experience at Purdue University, with emphasis on teaching manufacturing and design courses, conducting applied research, and engagement with Indiana industry. Dr. Tomovic co-authored one textbook on materials and manufacturing processes, adopted by over 50 national and international institutions of higher education. He has authored or co-authored over 50 papers in journals and conference proceedings. Dr. Tomovic made over 20 invited presentations nationally and internationally on the issues of design optimization and manufacturability. He has co-authored four patents, and over 60 technical reports on practical industrial problems related to product design and manufacturing process improvements. Dr. Tomovic's research interests are in the area of advanced manufacturing, design optimization, collaborative design, product lifecycle management, modeling of rapid prototyping and fast free form fabrication methods, web-based multi-user platform development for industrial tooling and customer-supplier resource management, and deployment and commercialization methodology for highly focused software tools. He has received funding from the Department of Defense, Indiana 21st Century Technology Fund, National Science Foundation, Department of Energy, Purdue Research Foundation, and other sources. Dr. Tomovic has been a PI or Co-PI on several funded competitive grants exceeding $12 million. Dr. Tomovic has been actively involved with local industry through the Technical Assistance Program (TAP). He has assisted over 100 different companies across Indiana on problems related to automation, manufacturing, and product and process design. The estimated value to Indiana industry, resulting from Dr. Tomovic's recommendations, exceed $6 million over the ten years that he has been actively engaged with the TAP. In 2002, Dr. Tomovic received the Republican Gold Medal for Entrepreneurship, in recognition for his contributions to industry and for his entrepreneurship efforts, and also the American Metalcasting Consortium Director's Award for his contributions to the metalcasting field.

A Competency Gap in the Comprehensive Design Education

Abstract

As product design and realization process are changing constantly due to new challenges in the global working environment, highly skilled workers are needed by companies who want to stay competitive. Those engineers need some new skills that are being identified as missing by the Society of Manufacturing Engineers and National Association of Manufacturers. The project named Midwest Coalition for Comprehensive Design Education involves five different colleges which are working on the development of a new program that would bridge the competency gap that currently exists in the education of design and manufacturing engineers. Those institutions are working collaboratively on identification, development and delivery of a new program that will integrate comprehensive design education across associate degree technician and baccalaureate degree technology colleges, in order to increase the skill level in the manufacturing sector. The research related to the core competencies in the advanced manufacturing sector, conducted by Society of Manufacturing Engineers, was the result of complaints that were issued by many industries like automotive, aerospace, electronics and some others. These complaints related to the lack of preparation that future engineers are receiving in colleges and universities in some specific areas that were identified as critical in maintaining innovation in the product design and realization processes for the longer term. The project Midwest Coalition for Comprehensive Design Education has the following objectives: validation of competencies for comprehensive design, development of an interdisciplinary comprehensive design program between partner institutions, development and delivery of educational modules for competitiveness in the global marketplace, development of an educational program in comprehensive design focused on the existing and incumbent workforce, and development of an outreach program for high school students.

Introduction

A core competency is an area of specialized expertise that is the result of harmonizing complex streams of technology and work activity[1]. A competency is the capability to apply or use a set of related knowledge, skills, and abilities required to successfully perform critical work functions or tasks in a defined work setting. The competencies often serve as the basis for skill standards that specify the level of knowledge, skills, and abilities required for success in the workplace as well as potential measurement criteria for assessing competency attainment[2]. Product design, as an integrated profession, covers a wide range, including: engineering (technology, techniques, material and processing), ergonomics (operation, safety, usability), business (marketing, management, planning, corporate identity), aesthetics (form, visualization, style), and even social, environmental, and cultural issues. Design educators and professionals are always concerned with the issue of industrial designers' competencies. However, the quality of graduates is not regarded as up to a level expected by employers[3], and there seems to be a gap between what students learn at school and what they are required to do in practice after graduation[4].

The survey related to the core competencies in the advanced manufacturing sector, conducted by Society of Manufacturing Engineers, raised the central question asked respondents to review the professional and technical competencies that might be required of newly hired community college or university graduates who work in the capacity of manufacturing engineers or manufacturing technologists. Respondents were also asked to rate how well these new graduates met expectations. If the survey respondent rated a competency of a new graduate as “below" or "well below" expectations, they were asked to rate how critical to their organization that competency was. This order is based on how critical to the organization the competency is when it was cited as falling short of expectations. These competency gaps are ranked as follows[5]: business knowledge/skills; project management; supply chain management; specific manufacturing processes; manufacturing process control; manufacturing systems; quality; materials; product/process design; engineering fundamentals; written communication; oral communication/listening; international perspective; problem solving; and teamwork and working effectively with others, as shown in Figure 1.

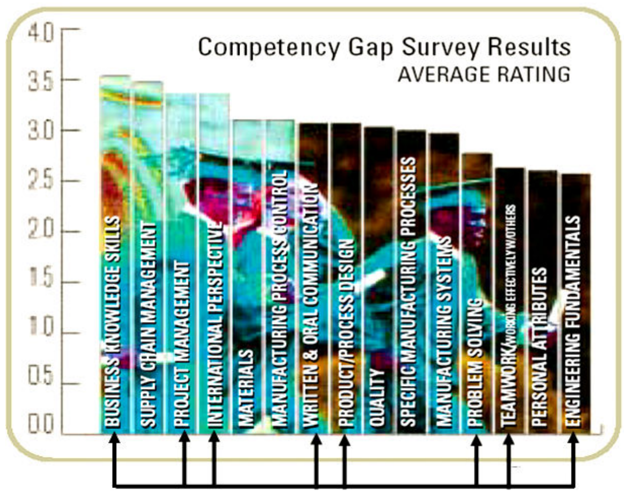

Figure 1: Competency Gap Survey Results: An average rating[5]

The result of this study was that the competency gap occurs in the areas of: business knowledge/skills, project management, specific manufacturing processes, manufacturing process control, manufacturing systems, quality, materials, product/process design, engineering fundamentals, written communication, oral communication/listening, international perspective, problem solving, teamwork/working effectively with others.

Midwest Coalition for Comprehensive Design Education

The partner institutions include a four-year school, Purdue University, and four two-year schools: Sinclair Community College, Fox Valley Technical College, Mott Community College, and Butler County Community College, as shown in Figure 2. They are utilizing and building upon their respective strengths of instructional module development and delivery to traditional and nontraditional student populations. The partner institutions hold regular meetings and videoconferences through which they exchange ideas on novel methods for course development and delivery as well as on the methods for collaboration in course delivery across different programs.

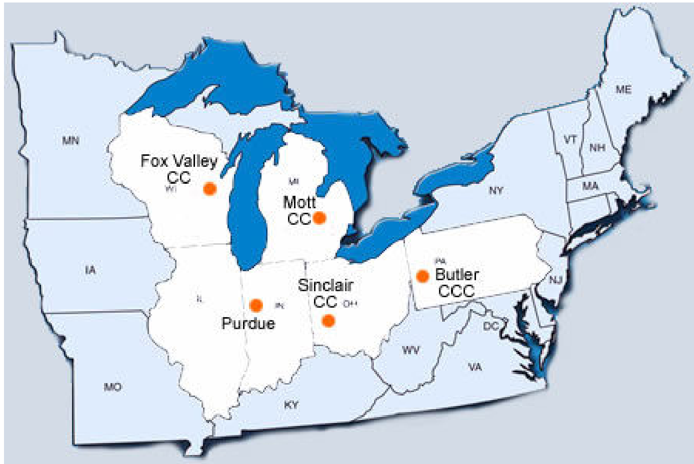

Figure 1: Midwest Coalition for Comprehensive Design Education

One of the first stages of the Midwest Coalition for Comprehensive Design Education project was to determine the competencies that are needed for the area of Product Design and Realization. The first objective of this project was to: establish industry committee with representatives from manufacturers involved with software, aerospace, automotive, appliance, heavy equipment/construction, military, etc. The second objective was to identify competencies for technicians (associate degree graduates) and technologists (baccalaureate degree graduates) with respect to overarching different disciplines. The third objective was to develop assessment instruments to verify student competencies, and finally the field-test instrument. According to the competency gap survey results[5], as shown in Figure 1, competencies were grouped into the following categories, as shown in Figure 3.

Product Design and Realization Core Competencies

- C1.0. Business knowledge and skills
- C2.0. Project management
- C3.0. International perspective
- C4.0. Written and oral communication/listening
- C5.0. Product / process design
- C6.0. Problem solving
- C7.0. Teamwork / working effectively with others
- C8.0. Engineering Fundamentals

Figure 3: Product Design and Realization Core Competencies

C1.0. Business Knowledge / Skills

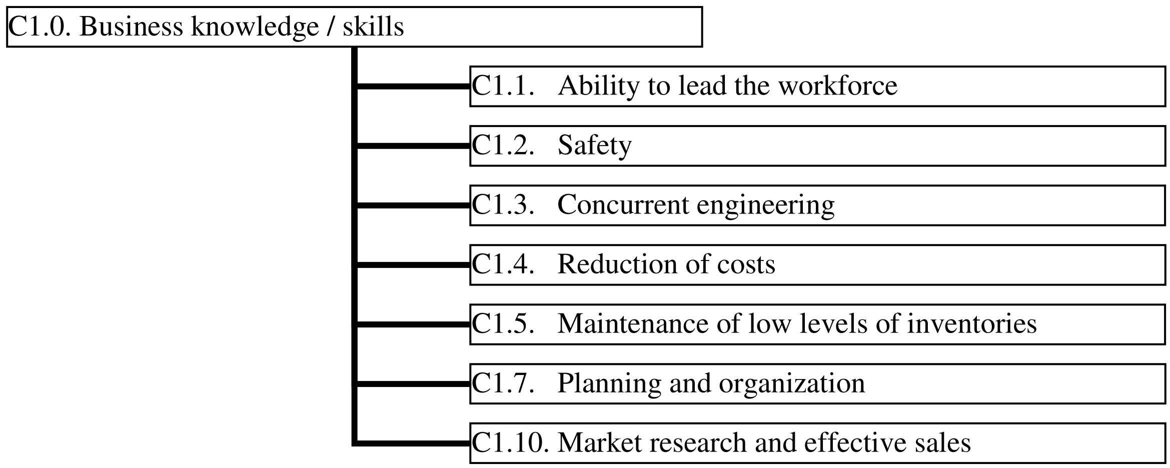

Figure 4: Business knowledge/skills

C2. 0. Project Management

The project manager focuses on the project and the date of its completion. A product realization manager considers that the product line will never end. Product realization has obtained many benefits from the techniques of integrated product teams which work on specific projects oriented to product realization and include members from several different areas and departments. Some of the skills that are common in these teams are initiative, leadership, technical expertise, financial, marketing, and risk management knowledge.

C3. 0. International perspective

Figure 5: International perspective

Working in a global environment requires some new skills for knowledge workers such as: understanding of linguistic diversity of nonverbal dimension of communicating across cultures, and communication over the Internet. International internships and exchange programs could help students immensely to build up those skills. It is also necessary to understand different leadership strategies for organizations engaged in international business, coordination between different time zones, and working around the clock. Communication in such an environment needs the usage of tools such as instant messaging, electronic meeting systems, collaboration product suites, web-based project, desktop conferencing/real-time conferencing, e-learning technologies, and voice over internet protocol, podcasting, etc.

C4. 0. Written and Oral communication/listening

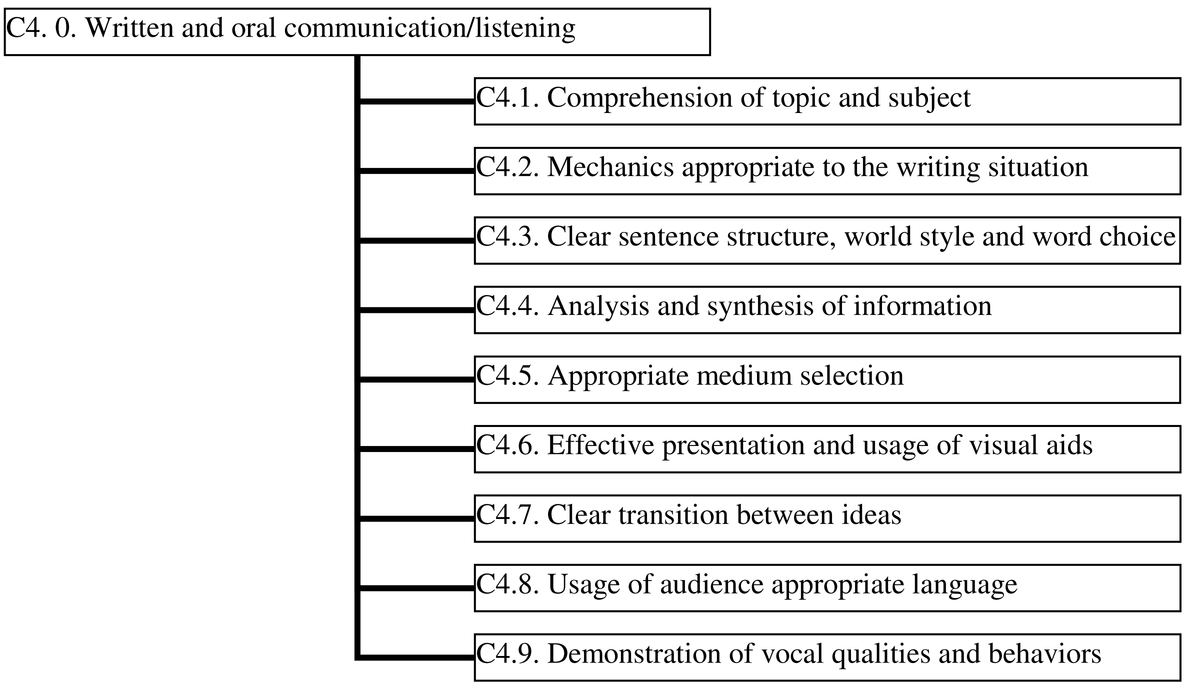

Figure 6: Written & Oral communication/listening

C5. 0. Product/process design

Product/process design competencies have two parts, one related to the product design and the other related to its realization:

5.1. Design for excellence: design for manufacturability, design for reliability, design for cost, design for safety, design for assembly, design for performance, cad systems, sketching /drawing, concurrent engineering, system perspective, design reviews, rapid prototyping skills.

C5.2. Manufacturing processes: used to create or further refine work pieces, such as molding and casting, machining, extruding, stamping, forming, bonding, welding, coating, plating, painting, fabrication, and assembly, manufacturing processes, and materials.

C6. 0. Problem solving

Considered the most complex of all intellectual functions, problem solving has been defined as:

C6.1. Following appropriate problem solving strategy: analyzing causes, identifying alternatives, assessing alternatives and choosing one, implementing the optimal alternative;
C6.2. Critical thinking skills: logical reasoning, analytical thinking, and problem-solving techniques, making and expressing meaningful new connections, thinking of many new and unusual possibilities, and extending and elaborating on alternatives.

C7. 0. Teamwork/working effectively with others

C.7.1. Developing plans in the formation of its purpose;
C.7.2. Training for effective decision-making;
C.7.3. Assessing the performance through effective team oriented problem solving;
C.7.4. Establishing constructive and solid interpersonal relationships;
C.7.5. Treating others with courtesy, tact and respect;
C.7.6. Working effectively with others;
C.7.7. Working to resolve disagreements, attempting to persuade others and reach agreements;
C.7.8. Supporting group decisions;
C.7.9. Facilitating team interaction and maintaining focus on group goals;
C.7.10. Handling differences in work styles effectively while working with coworkers;
C.7.11. Capitalizing on strengths of team members to get work done;
C.7.12. Anticipating potential conflicts and addressing them directly and effectively;
C.7.13. Motivating others to contribute opinions and suggestions;
C.7.14. Demonstrating a personal commitment to group goals;
C.7.15. Demonstrating leadership through teams.

C8.0. Engineering Fundamentals

C8.1. Knowing the engineering problem solving methods and ability to use modern tools to solve problems;
C8.2. Implementing three dimensional spatial visualization skills and creating engineering drawings;
C8.3. Implementing engineering analysis, computational skills, and communication skills;
C8.4. Knowing how to formulate and address open ended design problems;
C8.5. Having a systematic approach to design;
C8.6. Having the ability to consider a variety of issues such as manufacturing, maintenance, quality, environmental issues and related aspects while designing;
C8.7. Using multidisciplinary design principles for solving engineering problems in engineering design.

Product Design and Realization Core Competencies

After the first stage of identification of necessary competencies for a Product Design and Realization program, the project team has created the plan of study that would cover all those necessary competencies. After mapping the competencies that are being covered in existing courses, the following competencies have been identified as missing in colleges that are part of this project:

C.1. Ability to apply mathematical and natural science principles into the product design process;
C.2. Ability to apply fundamental engineering principles for effective solution of practical problems in the product realization process;
C.3. Ability to analyze and develop intelligent electromechanical systems;
C.4. Application relevant technology tools within the product realization environment;
C.5. Development of awareness of the professional and ethical responsibilities for sustainable design, in order to ascertain the impacts of the engineering solution on the global society and environment;
C.6. Ability to work within a multi-disciplinary collaborative product realization team.
C.7. Effective communication by written, oral and visual means;
C.8. Demonstration of commitment to continuous improvement and education through independent experiences;
C.9. Ability to capture customer requirements and generate appropriate design specifications based on market needs and constraints;
C.10. Application of program objectives to collaboratively develop design solutions in a capstone environment;
C.11. Validation of compliance to design specification through prototyping and testing;
C.12. Integration of project management best practices throughout all phases of product design and development.

The following modules will be developed to remove the existing gap in the area in comprehensive Product Design and Realization curriculum, as shown in Fig. 7.

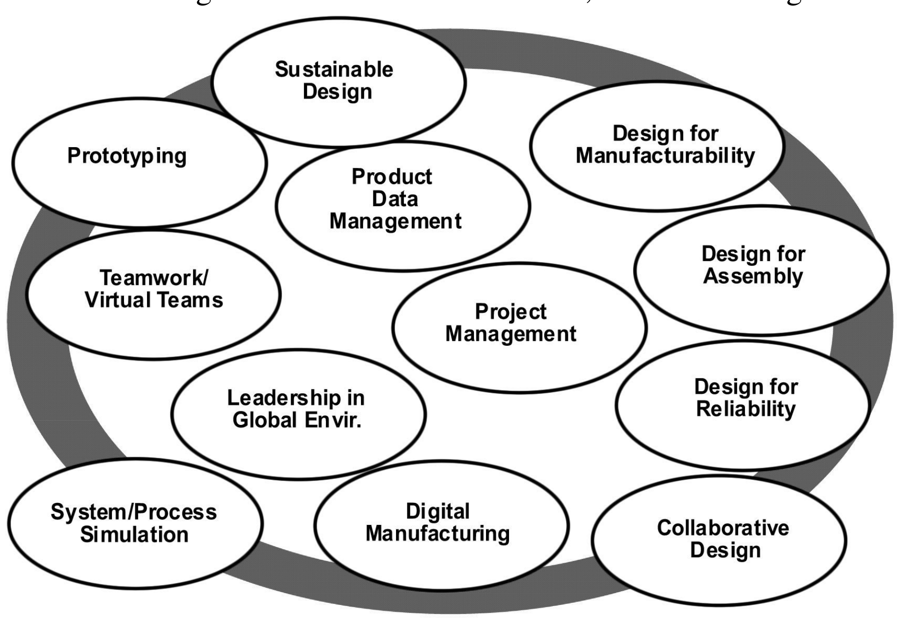

Figure 7: Product Design and Realization courses

Curriculum modules will be developed for the following areas:

Product Engineering
* Design for Manufacturability (Sinclair Community College)
* Design for Assembly (Mott Community College)
* Design for Reliability (Butler County Community College)
* Sustainable Design (Butler County Community College)

Manufacturing Engineering
* Digital Manufacturing (Purdue University)
* Systems/Process Simulation (Mott Community College)
* Prototyping (Fox Valley Community College)

Information Technology
* Collaborative Design (Sinclair Community College)
* Product Data Management (Purdue University)

Business Environment
* Globalization (Purdue University)
* Project Management (Purdue University)
* Teamwork/ Virtual Teams (Fox Valley Community College)

Conclusion

Evaluation of the effectiveness of the project Product Design and Realization program would help students to gain the knowledge and skills listed. It will be established through the development of an interdisciplinary comprehensive design program model. The program would fill in the competency gap identified in first stage of the project for both associate and baccalaureate levels. The teams are currently working on the "adapt and adopt" approach to jointly develop modules that are the equivalent of six, three-credit hour courses. The partnering institutions are developing integrated courses, web-based course and module support materials. All courses are being developed with the respect of the following curriculum design: 1. overview/goal; 2. competencies; 3. pre-activity discussion; 4: learning activity; 5. assignment specifications; 6. post activity discussion; 7. assessment; 8. references. The following stage would integrate comprehensive design curriculum into the existing academic program, workforce training, train the trainer sessions, and reaching pre-college populations.

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