Daniel Waldorf, Cal Poly State University

Dr. Daniel Waldorf is an Associate Professor of Industrial and Manufacturing Engineering at Cal Poly State University in San Luis Obispo. Dr. Waldorf teaches mainly in the manufacturing processes area, including courses in manufacturing process design, tool engineering, computer-aided manufacturing, and quality engineering. His research interests are with machining process modeling and monitoring, especially related to cutting tool wear, vibrations, and advanced tool design. Prior to coming to Cal Poly Dr. Waldorf worked in Chicago as a quality/manufacturing engineer at ATF, Inc., a producer of fasteners and specialty cold-formed products for the automotive industry. He received his Ph.D. in industrial engineering from the University of Illinois at Urbana-Champaign in 1996. Dr. Waldorf is a registered professional manufacturing engineer in California and is a member of ASME, SME, and ASEE.

Sema Alptekin, Cal Poly State University

Sema E. Alptekin is a professor in the Industrial and Manufacturing Engineering Department of California Polytechnic State University - San Luis Obispo (Cal Poly) where she served as Department Chair for six years. She teaches graduate and undergraduate courses in Simulation, Product Design and Development, and Automation. Her research interests include Artificial Intelligence and Soft Computing Systems. She was a visiting scholar at the Berkeley Initiative in Soft Computing Center within the Electrical Engineering and Computer Sciences Department UC Berkeley. Prior to joining Cal Poly, she was a faculty member at the University of Missouri-Rolla and she worked as a member of the Advanced Manufacturing Engineering group of General Motors in Warren, Michigan. She holds a BS and an MS in Mechanical Engineering and a Ph.D. in Industrial Engineering from Istanbul Technical University in Turkey. She is a senior member of ASEE, SME, IIE, and IEEE.

Robert Bjurman, General Motors Global Engineering

Only 92 hours after Bob received his Bachelor of Science Degree in Mechanical Engineering Technology from California Polytechnic University, he began his career with General Motors in Southern California. Bob had many challenging assignments in the vehicle assembly side of the business on the factory floor in Industrial Engineering, Tooling, Production Supervision and Future Production Planning. His manufacturing expertise lead to assignments in vehicle design bringing real world production concerns and processes into the product engineering activity to design in quality and buildability. Bob’s manufacturing and engineering expertise were also applied during an assignment at Hughes Aircraft on the aerospace and defense side of the business improving Trident and Cruise missile guidance system production preceding Desert Storm.

Returning to the vehicle side of the business, Bob was involved from almost day one as the Liaison between the GM Engineering community and the Purchasing activity to introduce a new, aggressive and progressive Globally Integrated Purchasing Process. The quick and successful implementation of this new process delivered the major contribution to the largest industrial turn-a-round in American history. Bob is now functioning as Manager of Global Engineering working to interconnect and maximize the benefits, talents and resources of General Motor’s Engineering Centers around the world. He is also assigned as the Engineering Representative on the Steering Committee for the GM sponsored traveling SPACE Exhibit spaceexhibit.com

Bob eats, sleeps and breaths cars. He is on his 85th vehicle. He designed, built and drove his own racecars professionally for 14 years. Away from business, Bob participates in a prison ministry that travels around the country to spend weekends in jails, prisons and penitentiaries counseling inmates.
Abstract

Manufacturing industries worldwide have undergone dramatic changes in recent years and now demand more from graduating manufacturing engineers. The effects of globalization have forever changed the parameters for success in manufacturing. Our educational institutions must respond to these changes with innovation. That agenda formed the basis for a special SME/CIRP international conference on manufacturing engineering education called “Looking Forward: Innovations in Manufacturing Engineering Education,” held in San Luis Obispo, California, June 22-25, 2005. At the meeting, manufacturing education professionals from around the world came together to share their own innovative ideas and to brainstorm ways to shape the future of manufacturing education so that it best meets the needs of industry. Conference sessions covered educational methods, course and program issues, collaborations, sustainability, and globalization.

The brainstorming took place during a unique, dedicated conference session that occurred near the end of the conference, ensuring that participants had opportunities to meet, exchange ideas, and become comfortable with other attendees prior to brainstorming. The session was formally chaired and hosted by a manufacturing industry representative who motivated the thirty-one session participants to come up with hundreds of ideas for improvement. Ideas were generated to address the future of manufacturing education as it relates to:

- what new technologies or systems need to be covered in the curriculum,
- what changes should be incorporated at both the course and program levels,
- how programs should interact with industrial and professional organizations, and
- what can be done to improve recruiting of new students into the field.

The brainstorming was essentially an open-ended survey that functioned with the advantages of a focus group. The ideas were recorded by the participants and collected from the session. This paper discusses the data collection (i.e., brainstorming) method used and then summarizes and categorizes the ideas generated from the session. In an attempt to capture the collective wisdom shared at the session, the results are compiled to suggest a broad roadmap to guide future change in manufacturing education.

Introduction

As the global economy shifts traditional skill-based manufacturing jobs overseas\(^1\), manufacturing enterprises are deciding whether and how much engineering activity can also be offshored. As enrollment in U.S. engineering schools declines\(^2,3,4\), however, many manufacturers are scrambling to ensure that a capable stream of highly-educated and talented manufacturing engineers is available in the U.S. to develop new opportunities in global markets. While offshore outsourcing of manufacturing jobs is occurring for many engineering tasks\(^5,6,7\), a continuing U.S.
presence for significant manufacturing is expected. New skills may be needed in engineers as they deal with the development of a global production enterprise – particularly manufacturing engineers. According to Hira, “substantive changes in engineering education [are needed] to provide different skills than those of foreign engineers.” American industry is moving more toward requiring potential for leadership, the ability to develop relationships, and creativity in graduates recruited for domestic offices. According to another source, “enormous opportunities are being created for technically skilled graduates capable of understanding and operating in global networks.”

Other efforts to identify needs for future engineers have included industry panels and committee work. In 1999, a panel discussion was convened to discuss globalization and its impact on undergraduate manufacturing engineering curricula. “The Engineer of 2020: Visions of Engineering in the New Century” is a recent report by the National Academy of Engineering that makes an attempt to answer the question, “What will or should engineering be like in 2020?” The follow-up report includes their recommendations to guide educators as they reengineer the education process. The Industry-University-Government Roundtable for Enhancing Engineering Education (IUGREEE) was formed in 1995 to provide an industry voice and an action agenda for reforming engineering education. The recommendations of IUGREEE are outlined in McMasters.

Meanwhile, American engineering schools are having a difficult time convincing prospective students (and their parents and advisors) that they should study engineering, much less the specific fields of manufacturing engineering or manufacturing engineering technology. Enrollment in engineering schools is down all across the country as students have changed directions toward other fields. As a large fraction of the high-wage blue-collar jobs that have for decades formed the basis of our economy are lost, countless media headlines have convinced many prospective students that an education in manufacturing is a waste of time.

Members of both industry and academia are rethinking the roles of manufacturing engineers and the specific education provided at American colleges. Their shared concern is for new graduates that are best prepared and positioned to succeed in the new global manufacturing environment. A need clearly exists to evolve the curricula for manufacturing engineers and to reevaluate current educational strategies. Unfortunately, there are few forums available for experts in the field to come together to talk specifically about how education can evolve for manufacturing engineering.

Several efforts, however, are attempting to provide just such an opportunity. Of course the American Society of Engineering Education (ASEE) hosts an annual conference and publishes the Journal of Engineering Education that include discussion on manufacturing engineering curricula. Several papers on the general subject of curriculum changes have been made recently. In addition, the professional societies such as the Society of Manufacturing Engineers (SME), the American Society of Mechanical Engineers (ASME), the Institute of Electrical and Electronics Engineering (IEEE), and the international production research institute CIRP (Collège International pour la Recherche en Productique) have various groups and publications, that focus on education trends and relations with universities. Most recently
SME and CIRP collaborated to sponsor an entire conference specifically dedicated to issues of manufacturing engineering education\textsuperscript{24}.

The conference, named “Looking Forward: Innovations in Manufacturing Engineering Education”, was held June 22 through 25, 2005, in San Luis Obispo on the California Polytechnic State University (Cal Poly) campus. The international conference was actually the third such SME/CIRP joint event (and the fourth SME event) in the past decade\textsuperscript{25,26,27}. The objective of the event was to help shape the future of manufacturing engineering education by fostering communication among a global set of participants. Sessions were provided for industry and academic participants to discuss trends and innovations related to globalization, sustainability, new technologies, educational methods, the use of product design and teams in curricula, and models of successful collaborations. In addition to the conference transactions\textsuperscript{24} a special issue of SME’s Journal of Manufacturing Systems in 2006 will highlight papers from the conference. As part of the conference, a special brainstorming session was held to generate, share, and document specific ideas for shaping the evolution of manufacturing engineering and manufacturing engineering technology programs in academia.

Previous efforts at soliciting input from a wide array of experts have included surveys and individual interviews. The results of a survey of industry concerning manufacturing curriculum were presented in Todd\textsuperscript{28}. SME’s Manufacturing Education Plan identified critical competency gaps for future manufacturing engineering professionals with input from experts in industry and academia\textsuperscript{19,20,21}. A more general inquiry into the changing needs of industry for all engineering disciplines due to globalization was developed through interviews with high ranking technology executives\textsuperscript{29}. Surveys and individual interviews have tremendous proven value. However, they fail to harness the synergy that can come from a real-time, focused exchange among a group of experts.

The format of the gathering of a diverse array of experts that is the subject to this paper provided a unique opportunity for a direct, collaborative effort to generate and communicate new ideas. Great care was taken in surveying and selecting a brainstorming protocol that would maximize the quality and quantity of the output from the group. Research has shown\textsuperscript{30,31} that a well designed group brainstorming session will result in more and better ideas than can be elicited from the sum of individual efforts. It is a rare event however, for manufacturing engineering experts of diverse backgrounds, to gather and to collaborate in a tightly focused endeavor to address the direction of engineering education. There is a large body of literature devoted to various so-called “group ideation” techniques. Some of the more widely used techniques are: Brainstorming; The Gordon Method; Imagination- Underdeveloped- Resource; The 'Hypothetical Situation' Method; Buzz Session; Reverse Brainstorming; and Slip Writing. More information on these techniques can be found in Roberts\textsuperscript{32}.

The brainstorming method chosen as most appropriate for this conference setting was a hybrid of the total \textit{GoFast!} process refined at General Motors (GM). This process was adopted at GM as part of their \textit{GoFast!} Culture and has proven to be both effective and efficient. The approach used in the special session combined the effectiveness of proven brainstorming techniques with the traditional focus group concept for coming up with a set of recommended actions.
In general, the process involved the following steps:

1) Define Goals: Broad objectives of the session were specified.
2) Collect Ideas: During this phase, the participants were asked to come up with ideas while deferring judgment.
3) Group Ideas: Ideas were grouped according to the objectives that they addressed.
4) Rank Ideas: Participants were asked to review and rank ideas according to perceived value and to vote for the best ideas in each topic area.

Ideas addressing the future of manufacturing education generated from this process are summarized and categorized in the following sections of this paper.

**Methods**

Sessions at the SME/CIRP international conference in San Luis Obispo were designed to promote discussion and idea-generation throughout the three-day event. Participants were particularly encouraged to stay on campus in residence halls and to remain throughout the conference to participate in discussions. An attempt was made to limit the number of papers in each session to provide for ample time for discussion. In addition to regular paper presentations, two of the nine sessions involved formal expert panel discussions (Figure 1). One session was dedicated entirely to parallel poster presentations (Figure 2) with informal discussions at the posters. And the brainstorming session took place on the final day, after most of the participants had been able to get to know each other during session discussions and other planned activities (Figure 3).

![Figure 1: Panel Discussion](image1)
![Figure 2: Poster Discussion](image2)
![Figure 3: Informal Discussion](image3)

Participants at the conference included a broad cross-section of geographical and professional experience. Most of the seventy-five attendees represented U.S. institutions, including large research-oriented schools like Penn State, Michigan, Purdue, Auburn, Arizona State, and Kentucky as well as smaller undergraduate-focused schools such as Ohio Northern, Detroit Mercy, Texas State – San Marcos, and Central Connecticut State. However, participants also attended from Mexico, Canada, Israel, Germany, Norway, and Denmark, and authors represented backgrounds and significant contacts with several other countries (particularly China, Malaysia, Korea, Singapore, Lebanon, Sweden, Spain, and France). Ten attendees represented industry from companies that included Boeing, General Motors, Raytheon, Danly IEM, Mori Seiki, and Haas Automation as well as CADCAM software producers. Members and representatives from SME, CIRP, ASEE, ASME, and the National Center for Manufacturing Education (NCME) were also present. The broad cross-section of individuals added immeasurably to the success of the conference and the effectiveness of the brainstorming session.
The brainstorming session itself (Figure 4) involved a well-defined set of tasks based on a hybrid of the total General Motors GoFast! brainstorming activity, itself derived from the “Workout Process” shared by Jack Welsh at General Electric. The session was chaired by one of the current authors (a General Motors employee and Cal Poly Mechanical Engineering Technology graduate). The ideas for improvement in manufacturing engineering education were then generated by the session attendees after a summary of a national survey of current academic programs was presented by Hugh Jack of Grand Valley State University. Fifteen minutes of individual (silent) brainstorming (Figure 5) was initiated by asking what ideas could bring improvement in four topic areas:

- The relationship between academia and professional organizations
- Academic issues outside of traditional technical areas of manufacturing engineering
- Academic issues directly related to the technical areas of manufacturing engineering
- Other issues (e.g., image building and marketing)

The individual ideas were all recorded on Post-It® Notes and stuck to the walls according to the topic area addressed. Session participants then formed into teams by voluntarily selecting one of the four topic areas on which to work. Forty-five minutes were then spent reviewing the ideas, identifying common (composite) ideas, and determining logical categories for the ideas. Each participant was then given two green sticker “dots” with which to vote for his or her two most valuable of all the individual ideas in their topic area (10 minutes allowed). After a general discussion of the outcomes, the conference chair collected all of the documented ideas, categories, and green dot votes to summarize the results in this paper.

The collected raw data from the brainstorming session includes approximately 260 documented ideas from 31 conference participants. These participants, as a subset of the larger group of conference attendees, included mostly (about 90%) academics and represented institutions in 5 countries (about 15% from outside US). Roughly half were from major research-oriented schools. Many of the ideas they came up with could be grouped together to form composite ideas that were generally supported by more than one participant. Presented here are the most popular composite ideas, categorized as being directed towards industry/professional societies, academic programs (i.e., curricular issues), or academic departments (i.e., program issues). Popularity is roughly measured by assigning a score to each composite idea: one point for each participant that came up with that same idea plus two points for each “green dot.” For example, if seven participants each came up with the same basic idea and the idea eventually received two
green dots, the composite idea earned a score of 11. The remaining ideas, supported by just one or two participants, are listed separately in the Appendix.

A. Ideas and suggestions for manufacturing industry and professional societies

By far the two most popular ideas in this category (points in parentheses) are:

- **Promote positive image of field of manufacturing engineering (22)**
  Although there were a number of specific ways mentioned that a positive image of the field could be promoted, it is suggested that this effort should be the top priority for professional societies (primarily SME). A visible national (or international) advertising campaign is recommended as media outreach to highlight the positive impacts of manufacturing (and shift media focus off of auto/truck industry layoffs or other negative corporate examples). Community/helping/medical efforts, affordable new technologies, rapid prototyping (i.e. Star Trek technology), new businesses/industries/jobs and other positive effects of manufacturing should be the focus. The campaign may involve traditional advertising or other outreach projects such as a kids television show (like Bob the Builder) or Lego League or robotics competitions. Several professional organizations (National Association of Manufacturers, National Council for Advanced Manufacturing, industry groups, academic groups, etc.) should work together on this.

- **Sponsor more conferences and meetings on manufacturing engineering education (17)**
  It is recommended that the series of conferences focusing specifically on manufacturing engineering education be continued. It is hoped that the SME Manufacturing Education and Research Community (as well as CIRP and the Council of Manufacturing Engineering Chairs COMEC) can play a larger role in putting on these future events. An international representation is preferred.

Several other key ideas in this category (mainly directed towards SME) received support by a number of participants:

- **Establish a Manufacturing Assistance/Research center (12)**
  It is strongly suggested that SME and/or other professional societies prioritize the construction and maintenance of a central web-based infrastructure for sharing a wide variety of information related to manufacturing and education. The materials could include databases of published papers, videos, research models or research activities, case studies, “best practices” studies, listings of co-ops/internships, seminar notices, industrial projects for courses, marketing or recruiting materials, or other educational materials or resources.

- **Ensure more successful Manufacturing Engineering or Manufacturing Engineering Technology departments at top universities (8)**
  It is suggested that SME or other professional groups partner with top industry representatives to financially sponsor/support/start-up more Manufacturing Engineering or Manufacturing Engineering Technology programs or departments at top-tier universities (including highly visible research universities) such as Ohio State, Illinois, Purdue, or Michigan. It is generally hoped that more support and help is given to these or to existing ABET-accredited programs to ensure their success and survival. SME should give more effort to surveying, tracking, and reporting the status and health of existing programs.
• Professional groups or societies should reorganize or collaborate more (8)
SME should collaborate and establish closer relationships with ASME, IIE, ASEE, ASQ, or other societies to achieve common goals for manufacturing. Some aspects of these groups may even combine to be more efficient. It is also suggested that a new society of manufacturing engineering educators (perhaps IMEE – the Institute of Manufacturing Engineering Educators) could be formed to focus solely on education issues.

• Coordinate international chapters/networks to give US university students “globalization” experiences (8)
Getting current students more globalization experience is generally thought to be in the interest of all involved. Industry or professional organizations are encourage to help in this effort to whatever extent they can, e.g., funding for students to travel abroad, networks of opportunities for projects/internships, and incentives for achieving globalization experience in the form of scholarship and contest criteria.

• Offer more support to local chapters/activities that generate industry/university interaction (6)
More exposure of students to industry is also desired. It is thought that a good way to achieve this is to have professional organizations put forth more effort in sharing opportunities, needs, trends, stories, etc. with universities. SME can provide more support and get more involved in local activities (and student chapters) to assist in establishing better industry-academic relationships and, for example, encouraging more student participation in SME senior chapter activities.

• Sponsor more student competitions and class projects based on real industrial problems (4)
Students need project and problem-solving experience, and it is suggested that industry and professional societies concentrate academic efforts on increasing this kind of experience. Student competitions, industry-sponsored class activity, and class projects with real industry-supplied problems will help to achieve this.

As stated above, additional ideas for manufacturing industry and professional societies are listed in the Appendix.

B. Ideas and suggestions for academic programs (curricular issues)

Although some of the suggestions for academic programs concerned the overall curriculum structure, most dealt with specific topics and skills that needed to be added or improved in the students’ learning experience. The top seven composite ideas (and corresponding number of points) are:

• Teach Globalization issues (19)
Manufacturing Engineering and Manufacturing Engineering Technology programs should introduce more concepts and activities geared towards giving students a better understanding of global issues in manufacturing and a stronger ability to relate to others in their role as leaders of global processing. To that end, it is suggested that students develop more awareness of world cultures by listening to the news, reading the newspaper, reading current books and magazines, and then discussing some in class. Students should learn more about geography and social issues of other cultures. Students should understand technical issues like exchange rates and import/export regulations and
management. Students should read “The World is Flat” or other book that gives a modern perspective of global changes and influences on business and manufacturing. Above all, it is recommended that students (in college and also K-12) be encouraged or required to learn more foreign language skills (e.g., Mandarin, Spanish).

- **Use Project-based activities for learning (19)**
  Students learn necessary manufacturing engineering skills best when participating in projects, especially when the project is a real, industry-supplied problem carrying real-world constraints. It is strongly encouraged to get industry representatives actively involved in the students’ efforts at solving the problem. Faculty should learn how to utilize industry projects for education and reconsider how to structure a curriculum considering such time-consuming and sometimes unpredictable experiences.

- **Improve Communications skills (18)**
  The ability to communicate with a wide variety of professionals is increasing critical for today’s manufacturing engineering graduates. Students must have the ability to write clearly and succinctly to explain ideas and propose projects. They should get practice making effective oral and visual presentations and utilizing computer graphics. Students should learn to teach others and to easily convey technical ideas. Faculty should maintain consistent standards for these and implement throughout the curriculum.

- **Continue updating/exposure to new technologies (15)**
  Students must constantly be exposed to new technologies that they can bring to future problem-solving efforts. Especially mentioned as important were information systems and databases, nano/MEMS technology, CAD/CAM/CAE/CIM software, automation/robotics, and e-business tools. Summer training institutes for faculty are one way to update knowledge in these areas.

- **Introduce Interdisciplinary learning (13)**
  It is recommended that students develop skills for direct interaction and communication with individuals from a variety of fields. Manufacturing engineering students need more contact with others from business (management, economics, marketing), scientific (e.g., life sciences), art, communications, and design (including other engineering fields) programs. Courses and projects are encouraged that force these interdisciplinary experiences.

- **Ensure Teaming skills (10)**
  Today’s graduates must be able to lead, function on, and contribute meaningfully to teams used for product development, problem solving, or other efforts. They must anticipate the need to function on teams of geographically dispersed individuals, especially using virtual means to communicate. Course activities that promote leadership, interpersonal skills, and other aspects of teamwork are encouraged.

- **Increase exposure to Business principles (10)**
  Manufacturing engineering graduates should be closer to the business function of a company and should be prepared for this in their education. They should be exposed to principles of marketing, business strategy, cost estimating and accounting, and business economics. They should also be exposed to entrepreneurial concepts such as intellectual property and start-up business models.

Several other ideas were generated with considerable levels of support from session attendees and deserve added attention.
• Make sure students have Lean/Six-Sigma skills and knowledge (9)
  It is suggested that the modern concepts of lean manufacturing and “six-sigma” quality
  and productivity programs should be more pervasive in the manufacturing engineering
  curriculum.

• Introduce Systems Engineering concepts (9)
  Students should understand the basic tools and methods of systems engineering and
  integration. They should understand project management, logistics and supply chain
  management, and ERP systems. They should especially understand the life-cycle design
  constraints related to manufacturability, reliability, maintainability, etc.

• Improve student Processing and Materials knowledge (9)
  Students must understand material processing methods, especially processes that go
  beyond the tradition of metals processing. Polymers processing, rapid prototyping, and
  processing of electronics materials are very important. It is suggested that students be
  prepared for process planning irregardless of the type of material to be used. Knowledge
  of modern materials (such as smart materials) properties are critical.

• Introduce Sustainability issues (7)
  It is suggested that the total product life-cycle be constantly considered during product
  development activities, including processing considerations, side effects during use, and
  product disposal. Green manufacturing concepts and design for sustainability issues are
  key.

• Teach Ethics (6)
  It is recommended that professional and personal ethics be a regular part of the
  curriculum so that students consider the impacts and responsibilities of manufacturing
  engineering.

• Provide direct interaction with industry (5)
  Students will gain necessary perspective and understanding by being exposed to industry
  professionals through tours and visits, SME/industry meetings, guest speakers in the
  classroom, and industry participation on projects.

• Consider a Product-centered curriculum (5)
  A suggestion is made to change the focus (or even the name) of manufacturing
  engineering curricula to one of product design and development rather than on material
  processing. The entire curriculum can be designed around the idea of product
  development and the manufacturing engineer’s role.

• Provide hands-on experience (4)
  Since learning by doing has long been recognized as an effective strategy, programs
  should continue to strive to provide as many opportunities as possible to get hands-on
  experience with manufacturing issues, including equipment operation. Some even
  recommend activities such as automotive disassembly/assembly or repair as a useful
  exercise.

• Establish Curricular integration (4)
  It is recommended that the curriculum have a unifying theme that ties classes together. A
  “learning factory,” a product development experience, or other major project may serve
  as an appropriate tool.

Additional ideas for academic programs are documented in the Appendix.
C. Ideas and suggestions for academic departments (program issues)

The brainstorming ideas generated for academic departments mainly deal with recruiting and the encouragement (or requirement) of key extra-curricular experiences for undergraduates. The four main composite ideas (and points) include:

- **Help to improve the attractiveness of the field to prospective students (26)**
  Department should place a high priority on outreach and attempting to influence the image of manufacturing engineering to prospective students. Among the many ideas are to: encourage current students to go to high schools to promote the field; focus on attracting diversity (especially including females and Hispanics); assist in forming Manufacturing Engineering or Manufacturing Engineering Technology programs at large universities; dress like professionals; participate in community activities and charitable causes; offer workshops to K-12 students; stress the “helping” nature or other positive, empowering aspects of the field; publicize success stories; bring more challenging, high-tech projects into the curriculum; and more closely tie the teaching of math and science with manufacturing engineering.

- **Provide for overseas experiences (14)**
  Manufacturing engineering departments are strongly advised to devise ways to help their students gain some global perspective by experiencing some aspect of their profession outside of the U.S. The experiences could include exchanges with overseas universities, foreign internships or visits, or even web-based communications with students or industry representatives outside of the U.S. Strong ties are needed with global partners to enable such efforts.

- **Promote Co-op and internship activities (12)**
  Academic departments should foster and enable co-operative work and internships as much as possible. A generally active and productive industry relations effort is needed to make this happen.

- **Consider alternative program options (5)**
  Among the suggested programmatic changes are to change Manufacturing Engineering from an independent major to a minor or a subfield of Mechanical Engineering and to change the name to Production or Product Engineering.

Although the ideas and suggestions collected in all three categories during the brainstorming session form a very useful template for improvement in the field of manufacturing engineering, many of the ideas were not necessarily new or innovative. Many of the composite ideas are a direct reflection of the ideas that the Accreditation Board for Engineering and Technology (ABET) have been prescribing in their assessment criteria for engineering programs overall. Calls for improvements in the teaching of communication skills, project and teaming skills, multidisciplinary experiences, modern tools and technologies, ethics, business principles, materials/process knowledge, and even product, process, and system design are all quite consistent with ABET. However, although ABET prescribes a “broad education” to understand the impacts of the field in a global environment, the ideas and suggestions presented here seem to go beyond the recommendations in ABET, especially in reference to globalization, sustainability, and lean manufacturing issues. Furthermore, the relative ranking or prioritization that can be inferred from the data here helps to solve a problem that has always been missing from the ABET criteria. Finally, the suggestions for a program or department to consider
integrated curricula, a product development focus, and a more concentrated effort to achieve direct industrial interaction and experience all go beyond the basic tenets of the EAC.

The data are also consistent with the list of “Competency Gaps” compiled by SME, which was determined largely from industrial sources. Many of the needs are the same – business skills, communications skills, systems knowledge, process/materials knowledge, teamwork skills, design knowledge, co-op/internship and hands-on experiences, even international perspective is listed. The prioritization in the SME lists focuses on communication skills, business skills, hands-on process experience, and systems engineering (including project and supply chain management) skills as being the most important gaps, while the data here suggests that global perspective, staying abreast of new technologies, and interdisciplinary teaming experience are the most important. Furthermore, the idea that project-based learning is the best approach is a very high priority as presented here, and was perhaps overlooked in the SME surveys. The concepts of sustainability, ethics, curriculum integration, and a product-centered curriculum are also novel to the current data and probably reflect the academic perspective of most of the participants.

The data presented here offers unique suggestions for industry, professional societies, and academic administration (departments). In some ways this may be the most useful aspect of the brainstorming session, as it offers a counter-perspective to the ABET and SME documents as to the steps needed to improve education that must be taken by those outside of academic programs. The focus is on improvement of the manufacturing engineer’s image (through promotion), the need for a regular education conference, providing resources and infrastructure for co-ops/internships, overseas experiences, course projects, and other needs, and helping to ensure that manufacturing engineering programs are established at more top-name universities.

**Conclusion**

A manufacturing engineering education conference was held in June 2005 in order to gather together many of the international experts in the field for a discussion on innovations, trends, and a recommended course of action for the future. The conference included useful sessions on product design, sustainability, globalization, educational methods, collaborations, teamwork, and new technologies. Papers from the sessions are available in a proceedings published by SME. A key session at the conference included a brainstorming activity designed to elicit ideas and suggestions for helping to ensure a successful future of the field. The suggestions targeted industry, professional groups, and academic institutions.

The brainstorming session yielded a large number of valuable ideas, both individually and as composite concepts. Key recommendations for professional groups and industry included ideas for promoting the image of manufacturing engineering, establishing resources or activities that can help universities, and initiating more academic programs in the field. Curricular recommendations for academic programs focused on ensuring an understanding of globalization issues, the use of interdisciplinary team-based projects for learning, and improved education in communication skills, new technologies, and business skills. Academics administrations are encouraged to prioritize outreach in the field as well as establish an infrastructure that aids students in finding cop-ops/internships and overseas learning experiences.
As a result of the effort, it can be concluded that:

- The brainstorming approach utilized here led to a large number of valuable ideas and suggestions for various audiences,
- To remain successful, the field of manufacturing engineering education must keep up with the rapid pace of technological change and globalization,
- Many of the competency gaps or key curricular issues addressed by SME and ABET are still valid issues to be worked on in manufacturing education programs, especially communication skills and interdisciplinary teaming skills,
- Academic programs will do best to place serious emphasis on teaching via industry-driven project-oriented activities that offer hands-on experience and direct contact with industry professionals,
- There is no substitute for an overseas exchange or other type of co-op/internship in adding crucial value to a student’s manufacturing engineering education, and
- Professional groups can help educational efforts most by fostering a strong image of the field and providing key resources for assisting universities in the efforts described above.

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References

Appendix

Additional suggestions and ideas from conference brainstorming session made by individual participants:

A. Ideas and suggestions for manufacturing industry and professional societies

- “SME should strongly embrace innovation and manufacturing research. Academics must make a strong case for industrial/applied research in their institutions.”
- “SME and CIRP represent too many categories and needs.”
- “More dialogue and coordination is needed between SME technical groups and research activities (NAMRC, Journals).”
- ‘More promotion is needed of the SME publication scheme.”

B. Ideas and suggestions for academic programs (curricular issues)

- “Students need more structured problem-solving skills (A3 process, brainstorming methods, fishbone diagrams, etc.).”
- “Students need training on Problem Definition throughout manufacturing engineering topics.”
- “Programs should resist the trend of reducing # of credit hours resulting from external pressures.”
- “Manufacturing engineering students need factory-level simulation to handle production details/uncertainties.”
- “Curriculum content should be learner-driven to help students establish a sense of ownership and self-confidence with their field.”
- “Rather than catering courses to modern ‘buzz-words,’ programs should focus on establishing a long-term foundation of knowledge.”
- “Basic science courses (physics, math, statistics) need to be improved.”
- “Students should learn to sketch by hand before utilizing CAD.”
- “Programs should reconsider the appropriateness of certain course names.”