"Developing Advanced Manufacturing Engineers for European Competitiveness."

Sackett P.J., Nelder G.P. , Skandalakis A.
The CIM Institute, Cranfield University, UK.

This paper reports the results of a pilot study on advanced manufacturing and related postgraduate educational programs in Universities throughout Europe. This study was undertaken on behalf of the European Commission-funded Network of Excellence in Intelligent Control and Integrated Manufacturing Systems. The purpose of the study was to identify the provision and capability provided by the Universities for developing the advanced manufacturing engineers needed to sustain European competitiveness. The study serves as a benchmark of current provision and as a foundation for future initiatives in this field by the ICIMS Network of Excellence.

The methodology used included literature reviews and combined questionnaires with site visits and interviews. Information sought included the level of advanced courses offered, the curriculum models and delivery methods employed together with the underlying rationale for the courses. Analysis of the results reveals areas of emerging consensus about the core curriculum and development trends in advanced manufacturing education.

The paper presents a summary of the data obtained, describes the analytical methods used and gives conclusions. In their recommendations, the authors discuss issues arising from this survey of importance to the future delivery of advanced manufacturing education programs at postgraduate level.

I. Introduction

Manufacturing requires high-quality, professionally qualified, flexible and imaginative management committed to success and capable of managing change (1). Last year the authors undertook a study for the UK Department of Trade and Industry to identify the particular requirements of managing manufacturing change in the Small and Medium sized Manufacturing Enterprise. This highlighted the importance of manufacturing education coupled with enterprise development vision (2). There is a need for manufacturing engineers with an understanding of the integration of people in the manufacturing process, the integration of production activities with the concerns of the whole business from the suppliers to the customers, and the need to engage in continuing professional development, improvement and lifelong learning.

European Institutions that are aware of the need for cross-disciplined manufacturing engineers are beginning to "re-engineer" their academic programs to provide an integration of technological, organisational and human-factors disciplines. Universities and other academic Institutions are required to assess the philosophy of their programs, and the level and spread of expertise offered to the students. The ICIMS-NOE is a group of leading academic Institutions and companies which serves to encourage collaboration in Intelligent Control and Integrated Manufacturing Systems (3). Minimal work has been carried out in identifying requirements and the provision and capability of European Institutions in the fields of Advanced Manufacturing Education, and the Network was asked by the European Commission to undertake a survey focused on postgraduate Manufacturing Education.

II. Objectives

The purpose of this pilot study is to position the European provision and capability in the fields of Advanced Manufacturing Education, and to provide a benchmarking baseline for Universities across Europe. More specifically, the objectives of the survey were:

- The research and articulation of state-of-the-art and international trends in Advanced Manufacturing Education in Europe, and the publishing of its conclusions.
- A database containing detailed, relevant information about the nature, content and procedures of European Programs in Advanced Manufacturing.
- A World Wide Web Site, giving high visibility, while acting as a dissemination medium for interim results

III. Data Collection Process

A brief synopsis of how the survey participants were identified across Europe is given incorporating the techniques used. It includes a summary of how the questionnaire design was realised, and how the data storage system was implemented to support the data collection and analysis processes.

A. Methodology of the Study

The data collection process was through a combination of visits to academic Institutions in Europe and the receipt of the survey questionnaire in hard copy or electronic format. The participants in this pilot study were identified through the ICIMS Network of Excellence Academic Members, the Edition XII Guide to Postgraduate Science 1995/96 (4), the Postgrad 1996 Students Guide (5), and through the CIM Institute's European academic contacts. The main criteria for the selection of the participants were:

- The existence of an advanced manufacturing education or related program, at a postgraduate diploma, masters or equivalent, or doctorate level and
- Academic participants should preferably be established in the wider European Union Area, although participants from other countries are not excluded.

Academic participants were invited to take part in this pilot study, from the following sixteen countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, The Netherlands, Norway, Portugal, Romania, Spain, Sweden and The United Kingdom.

B. Questionnaire Design

The questionnaire was divided into eight sections which are described in Table 1.

	Title	*Description*
Section A	Contact Information	Academic institution information and contact person details.
Section B	Background Information	General information about the academic program.
Section C	Industry's Expectations and Support	Identification of importance of industry's expectations or support.
Section D	Students and Institutional Expectations	Identification of importance of student and institutional expectations from students.
Section E	Influencing Factors from Other Programs	Identification of importance of other existent programs on the same field.
Section F	Influencing Standards	Identification of importance of certain standards.
Section G	Subjects Taught	Analysis of program curriculum.
Section H	Conclusion	Conclusive questions

Table 1: Survey Questionnaire Structure

In sections C through F, the influences on the design of the academic program were established. This was achieved by prompting the user to indicate the importance of several generic influences for the design of the academic program, by giving a rating from one to five according to the keys provided.

The subjects taught in the Advanced Manufacturing Education programs were divided under six generic categories; Manufacturing Processes, Engineering Materials, Engineering Systems and Automation, Product Design, Manufacturing Management, Information Technology. Each participant indicated which subjects were taught as part of their curriculum and the depth of knowledge offered to the students on a one to five scale. The survey questionnaire was also placed on the Internet so academic Institutions could download it or complete it on-line and send it via electronic mail.

C. Data Storage and Analysis.

A relational database was developed to contain all data obtained from the questionnaires, and to avoid conducting data queries manually which would be a complex process considering the large amount of data. A spreadsheet was used to generate a series of Tables and Figures to examine the basic features of single variables, such as the frequency distribution and the mean of individual variables. In addition, a statistical analysis package was used for correlation analyses to determine links between two or more variables.

IV. Study Findings

All the Tables and Figures presented, are based on thirty four participant programs from eleven countries, obtained between the 14th of July 1996 and the 17th of November 1996.

The general findings are presented into four main categories, as follows:

- Background Information
- Objectives of Programs
- Philosophy of Programs
- Program Curricula

A. Background Information

The survey and the data generated provide an insight into the structure and the philosophy of programs in the fields of Advanced Manufacturing Education across Europe. Figure 1 represents the distribution of the participant programs by originating country, while in Figure 2, the distribution by degree type is shown.

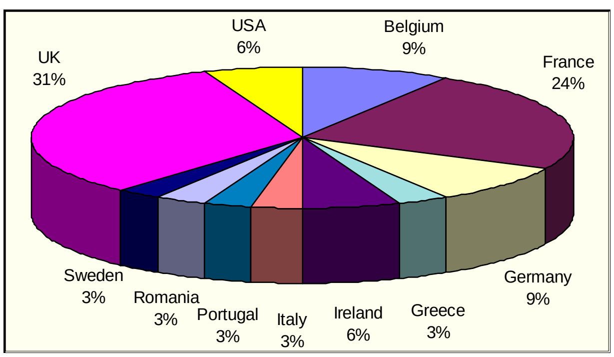

Figure 1: Distribution by Country

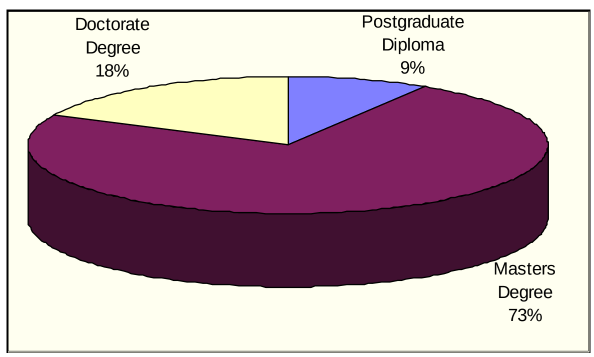

Figure 2: Distribution by Program type

The largest response was obtained from the United Kingdom, covering 31% of the total responses, followed by France with 24%. The majority of the participant programs were masters or equivalent, while only 18% were at a doctorate or equivalent level. The remaining 9% were postgraduate diplomas or related degrees.

B. Objectives of Programs

The five most important objectives of the participant masters or equivalent programs are listed in Table 2.

Program Objective	Percentage of Programs
Education Through Instruction	88 %
Practical Application of Theory	72 %
Development of Industrial Links	60 %
Development of Applied Research	48 %
Technology and Knowledge Transfer to Local Industry	48 %

Table 2 : Objectives of Masters Programs

Most of the participant masters programs educate through instruction. In total 60% of the programs aim to develop links with industry, while almost half of the participants aim to transfer technology and knowledge to local industry. The five most important objectives for doctorate or equivalent programs, are shown in Table 3.

Program Objective	Percentage of Programs
Education Through Research	100 %
Development of Applied Research	80 %
Development of Fundamental Research	40 %
Practical Application of Theory	20 %
Development of Industrial Links	20 %

Table 3 : Objectives of Doctorate Programs

All the doctorate or equivalent degrees aim to educate students through research, and are mainly interested in the development of research both applied and fundamental. In terms of the postgraduate diplomas, all the participant programs were interested in education through instruction and had no other primary objectives.

C. Philosophy of Programs

Influences were identified that could affect the design of an Advanced Manufacturing Education program. These were grouped under six generic categories, comprising of industry's expectations, industry support, students' expectations, institutional expectations of students, other programs' influences and influences from existing standards. The participant programs gave a rating from one to five to indicate the level of importance or effect each of the influences had on their program, and the average values per category are shown in Figure 3.

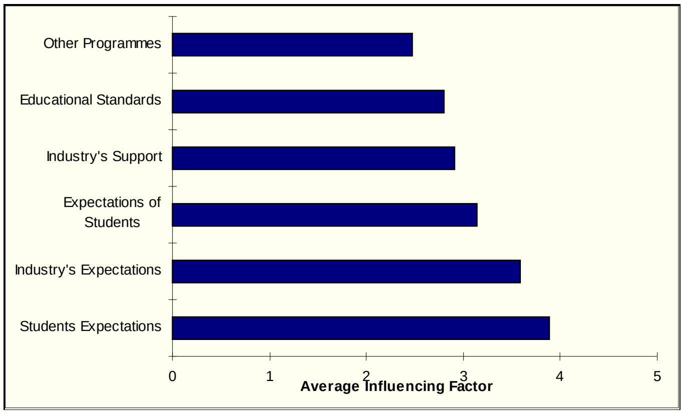

Figure 3: Philosophy of Programs

Academic Institutions place the highest importance on students' expectations, followed closely by industry's expectations. This suggests that these leading academic Institutions are customer driven. In addition, Universities place importance on following existing educational standards when designing a new program, and are scarcely influenced by other advanced manufacturing education programs.

Influence	Influence Factor
Familiarisation with New and Advanced Methodologies	4.5
Multi-Disciplined Students	4.2
Use of New and Advanced Tools	4.1
Students with Technical Expertise	4.0
Find Employment Easy and Fast	3.9

Table 4: The Five Most Important Influences

From Table 4, it can be observed that advanced manufacturing education programs aim to educate multi-disciplined students with sufficient technical expertise who will be capable to employ new and advanced methodologies and tools, which Universities think will eventually lead students into obtaining employment.

D. Program Curricula

In the survey questionnaire, academic Institutions stated which subjects were taught as part of their programs and specified the knowledge expertise gained by the students, on a scale of one to five, with five indicating mastery on a subject. All the subjects were classified under six manufacturing focused categories: Engineering Materials, Manufacturing Processes, Product Design, Manufacturing Management, Engineering Systems, Information Technology.

Figure 4 demonstrates the average depth of knowledge that the participant programs placed on each of the six subject categories.

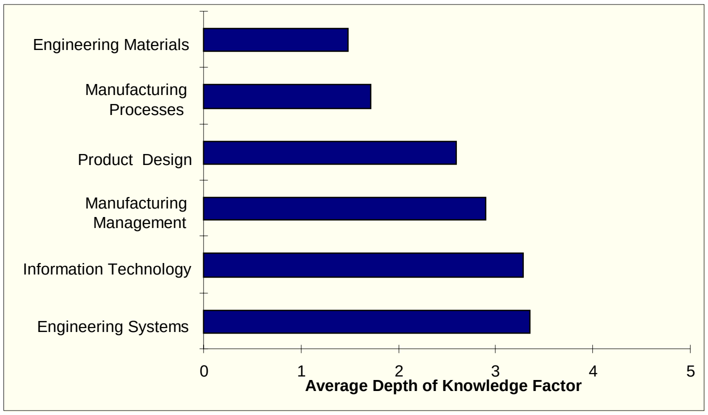

Figure 4: Program Curricula and Depth of Knowledge

From Figure 4, it is observed that the participant programs are specialised in the fields of information systems and engineering systems, and expect their students to be able to perform some level of critical analysis on these areas. In addition, in the areas of manufacturing management and product design students are required to develop an awareness of the basic philosophies. Manufacturing processes and engineering materials have a low average knowledge factor, because they are assumed to be taught at the undergraduate level.

Table 5 shows the subjects with the highest average knowledge factor from each subject category. A knowledge factor greater than 3.5 signifies a high emphasis on educating students to be able to perform a critical analysis on a given subject.

Subject Category	Subject	Knowledge Factor
Engineering Materials	Metals and Alloys	1.7
Manufacturing Processes	Rapid Prototyping	2.1
Product Design	Concurrent Engineering	3.0
Engineering Systems	Automation and Robotics	3.7
Manufacturing Management	Production Planning and Control	3.9
Information Technology	Computer Aided Design	3.7

Table 5 : Most Important Subject from Each Category

The following are the ten subjects with the highest knowledge factor across all six subject categories.

Production Planning and Control, Computer Aided Design, Automation and Robotics, Simulation, Flexible Manufacturing Systems, Manufacturing Cells, Computer Integrated Manufacturing, Just in Time, Total Quality Management and finally Computer Aided Manufacturing.

This can be interpreted as a possible consensus about the most important subjects in Advanced Manufacturing Education .

V. Conclusion

This survey provided an insight into Advanced Manufacturing Education practices in Europe. Initial findings from this survey have been published in the ICIMS-NOE Newsletter, which is widely distributed in Europe, and feedback has been very positive. All the data obtained through the survey questionnaire is already submitted to the ICIMS-Network of Excellence headquarters at the University of Patras, Greece. It is hoped that a further population of the database under the supervision of the Network of Excellence directorate will provide trends and future requirements about Advanced Manufacturing Education programs in Europe.

The study indicated that despite the diverse educational systems across Europe, it has been possible to construct a questionnaire and obtain meaningful data from different countries. We expect this work to continue across Europe, with the development of an Internet based benchmarking tool that will enable academic Institutions to benchmark their programs against trends in the fields or best practices by using the Internet. This tool will provide real time results and comparisons for all participants in the survey, and will be employed to identify best practices amongst different geographical regions and programs.

We believe that it is now appropriate to use a similar model for international Advanced Manufacturing Education program comparison. We have already had enquiries from academic Institutions outside the European Community area, and hope that this survey will go on to include programs from other geographical regions, which will enable a cross-continental comparison of Advanced Manufacturing Education programs.

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