MANUFACTURING ENGINEERING EDUCTION ACROSS EUROPE

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Abstract: A comprehensive study was conducted investigating the manufacturing engineering education across several European countries, with the main objective to gather information about the syllabi of both mechanical as well as industrial engineering courses at the undergraduate level (first degree courses) offered by the institutes concerned, and to determine the manufacturing-related content of these courses.
The research revealed that on a Subject Group basis both the maximum (taking into account all optional modules the students can take) and the minimum amount of manufacturing education provision (only considering the compulsory modules) for a particular course varies quite considerably between the institutes concerned. This might pose as a stumbling block to students' mobility/interchangeability. The research also revealed a correlation between the extents of teaching and the research interests.
In addition, it was observed that design- and management-related subject areas are considered 'key' subject areas by many of the institutions involved.

Keywords: Manufacturing education; First degree courses; European Universities.

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1. INTRODUCTION AND SCOPE OF THIS STUDY

The FP6 Innovative Production Machines and Systems (I*PROMS) Network of Excellence was established to address manufacturing research in order to reshape this research area and overcome its current fragmentation. One of its many objectives was to analyse the manufacturing engineering education provided by European Universities, which was done in two phases. During the first phase [I*PROMS, 2008] manufacturing-relevant modules, offered by various institute, all of which were partners within I*PROMS, were identified. Although this allowed ascertaining the total amount of manufacturing modules and topics offered, it was thought that it would be useful to explore in greater detail which individual knowledge/skills was provided.

This second phase study [I*PROMS 2009] attempted to be specific by taking into consideration the manufacturing education provided by considering the contribution to the knowledge/skills required. A particular module may, and often does, contribute to a number of different knowledge/skills. In view of this each academic institute was asked to assess the percentage of effort/time spent on gaining a particular knowledge/skill for those modules which in the first phase had been identified to be relevant to manufacturing. The participating institutes were the Universities of Manchester, Cardiff, Newcastle, Warwick (all UK), Clausthal and Hannover

(Germany), Naples (Italy), Patras (Greece), Sakarya (Turkey), ENIT (France) and Dublin City University (Ireland). Only first degree (undergraduate) programmes in both general/mechanical engineering and industrial/manufacturing engineering were considered.

2. ANALYSIS OF KNOWLEDGE/SKILLS PROVISION

The raw data provided by the individual institutes was 'weighted' by considering the number of credits for each module, and expressed as a percentage of the total degree programme. Both the maximum (taking into account all optional modules the students can take for a particular course) and minimum amounts of manufacturing education provision (only considering the compulsory modules) were considered. Because of the large number of different subjects, considering individual knowledge/skills would have made the analysis somewhat difficult. In view of this the discussion of the data was, in general, undertaken with respect to the following Subject Groups:

(i) Conventional Manufacturing Processes: conventional machining, forming, casting and moulding, joining and assembly.
(ii) Advanced Manufacturing Processes: non-traditional machining, rapid prototyping and reverse engineering and CAD/CAM/CNC technology.
(iii) Precision Engineering: micro/nano technology, quality assurance and inspection.
(iv) Design: drawing interpretation, design/design for manufacture, finite element modelling, rapid prototyping, life cycle engineering, joining processes and assembly.
(v) Process Automation: robotics, automation, instrumentation and sensors.
(vi) Management: lean manufacturing, production organisation and control, materials resource management, cost control, global manufacturing and project management.
(vii) Other: knowledge/skills not directly relevant to I*PROMS core-competencies.

Calculating the maximum amount of educational provision is rather complex, as one cannot only consider the maximum number of optional manufacturing modules a student could take, but has to deal with specific knowledge/skills and not manufacturing as a whole. The degree programmes at Cardiff, Clausthal, Hannover, Manchester, Naples and Sakarya are either compulsory or students can take all the options. However, for some degree programmes a student may only take a limited number of the manufacturing options available. While one could analyse all the different programmes it would be somewhat unwieldy. In view of this a compromise situation was used by assuming that all the optional modules can be taken, but with a reduced credit rating. This led to (i) some knowledge/skills training being included which a particular student may not receive, and (ii) a reduction in the time spent on the knowledge/skills training included, with the actual reduction depending on the number of optional modules.

2.1 General/Mechanical Engineering Degrees

With respect to Subject Groups the maximum and minimum amount of provision is shown in Table 1. It is readily seen that the amount of manufacturing education provision varies significantly between the different degree programmes. The variation in some cases being very large, e.g. Cardiff spends more than eight times the time on process automation than Naples. It should be noted, however, that Naples also offer an Industrial Engineering degree where the time spent on process automation is much higher. With the exception of Patras all the degree programmes spend a significant amount of time on design. Patras, however, has a high

percentage of project work and some of this may well include design. The degree programmes at Warwick include a significant amount of management, although not all of it is relevant to I*PROMS, as the high percentage of time spent on 'other' knowledge/skills reflects.

		Cardiff	Clausthal	Dublin	Manchester	Naples	Newcastle	Patras	Sakarya	Warwick
Conv. Manuf. Processes	Max	1.3	3.6	5	4.7	4	4	3.7	6.7	1.7
	Min	1	2.7	5	3.1	4	0.7	2.6	1.4	1.7
Adv. Manuf. Processes	Max	2.7	1.7	2.6	5.4	4.5	4	2.5	3.1	1.3
	Min	1.9	1.4	2.6	1	4.5	0.5	0.9	1	1.3
Precision Engineering	Max	4	2.2	1.3	4.5	1	4.3	1.2	1.4	4.8
	Min	0.8	1.1	1.3	0.1	1	0.6	0.5	0.1	0.9
Design	Max	9	10.4	8.6	11.8	8.2	8.4	2.4	7.1	13.2
	Min	4.6	7	7.2	9.4	8.2	4.4	1	3.3	8.5
Process Automation	Max	8.8	1.6	4.3	1.9	1	6.9	3	2.7	4.5
	Min	3.3	1.6	2.9	0	1	0	1.2	0	0
Management	Max	8.3	2	9.7	6	6	4.6	3.2	2.6	7.5
	Min	6.9	2	8.5	6	6	0.8	1.2	0.3	3.4
Other	Max	5.6	1.2	3.8	3	7	1.3	4.8	0.9	18.6
	Min	4.4	1.2	3.6	3	7	1.3	0.1	0.3	12.3
Projects etc.	Max	8.3	18.5	2.1	12.5	10	10.4	28.8	0	6.3
	Min	4.2	0	2.1	6.3	0	10.4	0	0	6.3
Non Manufacturing	Max	52	58.8	62.6	50.2	58.3	56.1	50.4	75.5	42.1
	Min	73.9	83	66.8	71.1	68.3	81.1	92.5	93.6	65.6

Table 1 Knowledge/skills provision as percentage of overall course content - General/Mechanical Engineering

While the minimum design provision is generally lower than the maximum, the reduction, in most cases, is not particularly significant, implying that design is seen as a key subject. To a certain extent the same can be said of management, although in this case the reduction is somewhat greater. Considering conventional and advanced manufacturing processes together, the lowest level of provision is at Cardiff, Newcastle, Sakarya and Warwick. However, Newcastle, Sakarya and Warwick also offer Industrial/Manufacturing Engineering degrees which have significantly more training in manufacturing processes (Table 2).

2.2 Industrial/Manufacturing Engineering Degrees

As in the case of General/Mechanical Engineering degrees, the amount of manufacturing education provision varies significantly between the different Industrial/Manufacturing Engineering degree programmes, see Table 2. To a certain extent this is expected since the degree programmes considered vary somewhat in nature. The programmes at Naples and Sakarya being essentially industrial engineering rather than the more mechanical engineering orientated manufacturing programmes at the other institutes. The highest percentage of 'other' knowledge/skills is again at Warwick. The percentage of time spent on conventional and advanced manufacturing processes at Naples is, at first sight, surprisingly low. It should be

noted, however, that the degree at Naples is only of three years duration, thus allowing less time for coverage of certain topics than at other institutes where a significant amount of time is spent on manufacturing in the fourth and, where appropriate, fifth year. It should also be noted that the Naples degree is in industrial/production engineering and it is pertinent to note that they spend more time on manufacturing processes in their mechanical engineering degree.

		Dublin	Hannover	Naples	Newcastle	Sakarya	Warwick
Conv. Manuf. Processes	Max	5	5	3	4.7	6.1	6.1
	Min	5	5	3	4.7	6.1	6.1
Adv. Manuf. Processes	Max	2.6	1.6	1.2	4.6	2	3.6
	Min	2.6	1.6	1.2	4.6	2	3.6
Precision Engineering	Max	1.3	3.3	1.8	3.4	4	6.3
	Min	1.3	3.3	1.8	1.3	4	4.3
Design	Max	8.9	7.6	4.2	8.8	9	11
	Min	7.2	7.6	4.2	7.8	9	10.8
Process Automation	Max	4.3	4.1	3.5	5.9	2.6	4.5
	Min	2.9	4.1	3.5	0	2.6	2.4
Management	Max	9.6	7.5	12.3	4.6	19.5	10.9
	Min	8.5	7.5	12.3	4.6	19.5	7.2
Other	Max	3.8	4.2	12.3	1.3	5.1	19.9
	Min	3.8	4.2	12.3	1.3	5.1	15.5
Projects etc.	Max	2.1	22.1	8.3	16.7	6.7	12.5
	Min	2.1	22.1	0	16.7	0	12.5
Non Manufacturing	Max	62.4	44.6	53.4	50	45	25.2
	Min	66.6	44.6	61.7	59	51.7	37.6

Table 2 Knowledge/skills provision as percentage of overall course content - Industrial/Manufacturing Engineering

In general the amount of time spent on design and management is comparable to that on the General/Mechanical Engineering degrees considered. With respect to management the amount at Sakarya is particularly high but, once again, it should be mentioned that the Sakarya degree is in industrial engineering. On the other hand, the amount of management at Newcastle is somewhat low for a manufacturing degree. However, the Newcastle manufacturing degree is closely linked to their mechanical engineering degree, which also spent less time on management than many of the degree programmes under consideration. Compared to the General/Mechanical Engineering degrees there is little difference between the maximum and minimum provision, since most of the programmes are either compulsory or have few options.

3. CORRELATION BETWEEN RESEARCH INTEREST AND DEGREE PROGRAMME CONTENT

As the previous section revealed, there were significant variations in the type of provision offered. In view of this it was decided to investigate any link between manufacturing education

provision and research interests in more detail. This was done via a spreadsheet asking whether, for a particular knowledge/skill, the institute concerned undertook a high level, medium level, low level or no research at all. The level of research at each institute was quantified using a score of "5" for a high level of research, "3" for a medium level of research, and "1" for a low level of research. Zero was awarded if no research in that particular area was conducted. Whilst analysing the Level-of-Research data, it was observed that there was considerable variation for the various institutes. While it was to be expected that there will be variations in research activity between the different institutes, it should be noted that the 'Levels of Research' were not precisely defined. It is likely, therefore, that some institutes did, for example, consider their research to be of a high level while another institute did consider the same research to be of, for example, medium level.

Since the knowledge/skills provision reported on in Section 2 was undertaken on a percentage basis, i.e. each knowledge/skill provision was expressed as a percentage of the total degree programme, it would appear reasonable to also consider the level of research on a percentage basis. Thus, the Level-of-Research scores for the various Subject Groups were awarded on a 'relative' rather than an 'absolute' basis, see Table 3. In this case the percentage is based on the total knowledge/skills maximum for each Subject Group. The figures in bold on grey background indicate a level of research that was above average within each Subject Group.

	Cardiff	Clausthal	Dublin	Hannover	Manchester	Naples	Newcastle	Patras	Sakarya	Warwick
Conv. Manuf. Processes	45	40	**90**	25	25	80	15	15	**60**	35
Adv. Manuf. Processes	**100**	**60**	**87**	**67**	**73**	**100**	40	**60**	47	**87**
Precision Engineering	**100**	10	20	**100**	30	80	**60**	**60**	30	60
Design	40	**87**	57	50	30	**87**	33	**50**	**67**	67
Process Automation	**87**	33	**100**	**100**	7	**100**	**100**	40	**60**	**100**
Management	27	40	**73**	50	**57**	73	0	**60**	**87**	**90**
Average	67	45	71	65	37	87	41	48	59	73

Table 3 Level-of-Research scores expressed as percentage of Subject Group maximum

3.1 General/Mechanical Engineering Degrees

The Subject Groups' knowledge/skills scores as a percentage of the total degree programme are shown in Table 4, with those Subject Groups having a greater than average Level-of-Research score highlighted in bold on grey background. The table indicates that, in general, those Subject Groups having a greater than average Level-of-Research score have a relatively high knowledge/skill score in relation to the overall average. The main exceptions to this are in Design and Management where it is seen that there are many instances of a high knowledge/skill score even though the Level-of-Research score is below average. It should be noted, however, that these are regarded as 'key' Subject Groups and one would expect significant knowledge/skill provision even without significant research activity. In view of this the average knowledge/skill score without Design and Management as well as the overall average is shown. It is seen that using the average without Design and Management shows an even better correlation between the level of research and knowledge/skill provision.

With respect to the Subject Groups of Conventional Manufacturing Processes, Precision Engineering and Process Automation, all the cases – with the exception of Naples (Process Automation), Patras (Precision Engineering) and Sakarya (Process Automation) – have an above average Level-of-Research score coincide with a relatively high knowledge/skill provision. It should be noted though that precise Level-of-Research data were not available for Patras and it may well be that less research is undertaken in Precision Engineering at Patras than was assumed. Table 4 clearly shows that for Advanced Manufacturing Processes, Manchester and Naples are the only institutes showing a clear correlation between the level of research and knowledge/skills provision. Table 3 shows that Naples has significantly higher Level-of-Research scores than most of the other institutes and it may well be that they interpreted the terms high level and medium level more liberally.

		Cardiff	Clausthal	Dublin	Manchester	Naples	Newcastle	Patras	Sakarya	Warwick
Conv. Manuf. Processes	Max	1.3	3.6	**5**	4.7	4	4	3.7	**6.7**	1.7
	Min	1	2.7	**5**	3.1	4	0.7	2.6	**1.4**	1.7
Adv. Manuf. Processes	Max	**2.7**	**1.7**	**2.6**	**5.4**	**4.5**	4	**2.5**	3.1	**1.3**
	Min	**1.9**	**1.4**	**2.6**	**1**	**4.5**	0.5	**0.9**	1	**1.3**
Precision Engineering	Max	**4**	2.2	1.3	4.5	1	4.3	**1.2**	1.4	4.8
	Min	**0.8**	1.1	1.3	0.1	1	0.6	**0.5**	0.1	0.9
Design	Max	9	**10.4**	8.6	11.8	**8.2**	8.4	**2.4**	**7.1**	13.2
	Min	4.6	**7**	7.2	9.4	**8.2**	4.4	**1**	**3.3**	8.5
Process Automation	Max	**8.8**	1.6	**4.3**	1.9	**1**	**6.9**	3	**2.7**	4.5
	Min	**3.3**	1.6	**2.9**	0	**1**	**6**	0.8	**0**	0
Management	Max	8.3	2	**9.7**	**6**	6	4.6	**3.2**	**2.6**	**7.5**
	Min	6.9	2	**8.5**	**6**	6	0.8	**1.2**	**0.3**	**3.4**
Overall Average	Max	5.7	3.6	5.3	5.7	4.1	5.4	2.7	3.9	5.5
	Min	3.1	2.6	4.6	3.3	4.1	2.2	1.2	1	2.6
Average without Design and Management	Max	4.2	2.3	3.3	4.1	2.6	4.8	2.6	3.5	3.1
	Min	1.8	1.7	3	1.1	2.6	2	1.2	0.6	1

Table 4 Knowledge/skills provision - General/Mechanical Engineering

Considering the minimum amount of manufacturing provision, it is seen that with respect to Conventional Manufacturing Processes and Process Automation the situation is similar to that observed for the maximum amount of manufacturing provision. With respect to Precision Engineering the correlation between level of research and knowledge/skills provision is worse while for Advanced Manufacturing Processes it is better. If, as in the case of maximum provision, Design and Management are neglected, then, with the exception of Dublin (Conventional Manufacturing Processes) and Newcastle (Process Automation) there is a significant reduction in the amount of knowledge/skills provision in those Subject Groups having a high Level-of-Research score. This would suggest that these Subject Groups are not seen as 'key' areas to the same extent as Design and Management. It should be noted, however, that in most cases there is still a reasonable amount of knowledge/skills provision in these Subject Groups, indicating that the various institutes concerned do not, in general, let their research

interests dominate the compulsory element of their degree programmes. There are, however, cases of significant variations in knowledge/skills provision in non 'key' Subject Groups and, as mentioned above, some of these have above average Level-of-Research scores. The suggestion that research interests influence optional rather than compulsory programme content is supported by a consideration of which knowledge/skills tend to contribute to the differences between the maximum and minimum provision in the 'key' Subject Groups of Design and Management.

3.2 Industrial/Manufacturing Engineering Degrees

The situation for Industrial/Mechanical Engineering degrees is reasonably similar to that for General/Mechanical Engineering degrees. The knowledge/skills scores are shown in Table 5, and those Subject Groups that have a greater than average Level-of-Research score are again highlighted in bold on grey background.

		Dublin	Hannover	Naples	Newcastle	Sakarya	Warwick
Conv. Manuf. Processes	Max	**5**	5	3	4.7	**6.1**	6.1
	Min	**5**	5	3	4.7	**6.1**	6.1
Adv. Manuf. Processes	Max	**2.6**	**1.6**	**1.2**	4.7	2	**3.8**
	Min	**2.6**	**1.6**	**1.2**	4.4	2	**3.8**
Precision Engineering	Max	1.3	3.3	1.8	**3.4**	4	6.3
	Min	1.3	3.3	1.8	**1.3**	4	4.3
Design	Max	8.9	7.6	**4.2**	8.8	**9**	11
	Min	7.2	7.6	**4.2**	7.8	**9**	10.8
Process Automation	Max	**4.3**	**4.1**	**3.5**	**5.9**	**2.6**	**4.5**
	Min	**2.9**	**4.1**	**3.5**	**0**	**2.6**	**2.4**
Management	Max	**9.6**	7.5	12.3	4.6	**19.5**	**10.9**
	Min	**8.5**	7.5	12.3	4.6	**19.5**	**7.2**
Overall Average	Max	5.3	4.9	4.3	5.4	7.2	7.1
	Min	4.6	4.9	4.3	3.8	7.2	5.8
Average without Design and Management	Max	3.3	3.5	2.4	4.4	3.7	5.2
	Min	3	3.5	2.4	2.6	3.7	4.2

Table 5 Knowledge/skills provision - Industrial/Manufacturing Engineering

Considering the Subject Groups of Conventional Manufacturing Processes, Precision Engineering and Process Automation, all the cases, with the exception of Newcastle (Precision Engineering) and Sakarya (Process Automation), having an above average Level-of-Research score coincide with relatively high knowledge/skills provision. With respect to the Advanced Manufacturing Processes there is little or no correlation between research activity and knowledge/skills provision. Advanced Manufacturing Processes provision at Naples is particularly low. However, the Naples programme is very much Industrial Engineering orientated and one would therefore expect less coverage of certain technological subjects. It is pertinent to point out in this connection, that there is a high Advanced Manufacturing Processes provision on the Naples Mechanical Engineering degree.

Since the degree programmes at Hannover, Naples and Sakarya are effectively compulsory with

respect to manufacturing provision, there are, obviously, no differences between the maximum and minimum amounts of provision for these institutes. It should be noted, however, that there are many options available at Hannover but data was only available for the relevant compulsory modules and those options offered by only one of University's institutes. The trend at the other three institutes is similar to that observed for the General/Mechanical Engineering degrees, i.e. a tendency towards a reduction in knowledge/skills provision in the non 'key' Subject Groups having above average Level-of-Research scores. This again, with some exceptions, supports the view that the link between research activity and knowledge/skills provision is strongest for the optional modules on offer.

4. CONCLUSIONS

The study highlighted a number of general, non-institute specific, factors which are as follows:

(i) Considerable training in certain knowledge/skills, such as project management, was detected that is not apparent from module titles.

(ii) On a Subject Group basis both the maximum and minimum amount of manufacturing education provision for a particular course varies quite considerably. With regard to student mobility/interchangeability, as proposed by the Bologna declaration [BMWF, 2009], this may be considered as a stumbling block.

(iii) Both design and, to a lesser extent management, are seen as 'key' subject areas by the institutes concerned, as the small reduction from the maximum and minimum amounts of manufacturing education provision indicates.

(iv) Apart from these 'key' Subject Groups, there appears to be a correlation between the amount of knowledge/skills provision and the level of research undertaken. Those Subject Groups having a greater than average Level-of-Research score have a relatively high knowledge/skill score in relation to the overall average for most of the institutions concerned.

5. REFERENCES

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