Industrial Engineering Standards in Europe (IESE)

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ABSTRACT:

This paper describes an ongoing project in Europe called Industrial Engineering Standards in Europe (IESE). The project is a collaboration between universities and organizations that offer industrial engineering and continuing education in 6 European countries: Denmark, Germany, Iceland, Ireland, Netherlands and Sweden. As the first objective of our project we proposed to use the European Framework of Qualifications (EFQ) as a benchmark standard, against which we can compare the Industrial Engineering Educational Programme (IEEP) for each participating country.

Analysis of the individual educational programmes has shown that the scope of the programmes needs to be expanded to include additional subject categories and skill sets. The exact parameters of this expansion of the programmes must be determined with reference to current and future “industry needs” as specified in the second objective of this project. Analysis of the subject focus for the individual programmes has shown a high degree of variation.

The project work is now focused on the second objective, i.e. a business needs survey, which will provide a gap analysis of the difference between the educational programmes and the needs of the industry for increased competence in the field of Industrial Engineering. The results of this will be described in a separate paper.

Keywords: Industrial Engineering, IE Education, Standards
1. INTRODUCTION

This paper, which is the first of two, describes an ongoing project in Europe called Industrial Engineering Standards in Europe (IESE), see the webpage of the project [1]. The project is collaboration between universities and organizations that are offering continuing education in 6 European countries: Denmark, Germany, Iceland, Ireland, Netherland and Sweden.

As the first objective of our project we proposed to use the European Framework of Qualifications (EFQ), see [2], as a benchmark standard, against which we can compare the Industrial Engineering Educational Programme (IEEP) for each participating country. This will include a harmonization of the credit transfer system for Industrial Engineering Educational programmes. The deliverable for this objective will be a document comparing individual countries against EFQ and recommendations for next steps in achieve harmonisation.

In order to produce a more appropriate analysis we needed to use a recognised Industrial Engineering (IE) educational programme standard. The standard model for Industrial Engineering Educational Programme currently in common use is prescribed by the International Labour Organisations (ILO), see also [3]. This model has been in use over a number of decades and has been widely accepted as the industry standard across Europe and by many universities in the US. It was decided to use this model as the baseline reference for comparing the Industrial Engineering Educational Programmes currently being delivered by the partner countries. According to this model the areas that form the core topics of Industrial Engineering are, IE Basics, Operations Research, Human Factors Engineering, Management Systems and Manufacturing.

The project work is now focused on the second objective, i.e. a business needs survey or a gap analysis of the difference between the educational programmes and the needs of the industry for increased competence in the field of Industrial Engineering. This work will be described in a separate paper.

Before we discuss the project itself, we begin by looking at the history of IE development. Also we discuss some definitions of IE and areas of application of IE.

2. MILESTONES OF IE DEVELOPMENT

In 1750 B.C. already at the palace of Mari the king of Babylon 20,000 boards made out of clay were found where work design measures like work planning, the calculation of required working days, work descriptions and the fixing of minimum wages were laid down. During the Han dynasty 206 B.C. until 9 AD the people already used muscular strength supported by levers and ramps for moving heavy weights like stones etc.

In the mediaeval times Leonardo da Vinci (1452-1519) further developed work study with regard to studying the motions of humans and also of the hand, muscles etc. He also carried out a time study on periodic physical work. Adam Smith (1723-1790) in his work “An Inquiry into the Nature and Causes of the Wealth of Nations” has written several chapters on the division of labour with the target to increase the productivity and to produce more goods. Karl Marx (1818-1883) later differentiated among economic and social division of labour. He dealt in his work “Work and Rhythm “with the meaning of rhythm with regard to the opportunities to increase production.

Work Science in the 20th century was mainly further developed by F.W. Taylor (analysis of the times which are used for work), F.B. Gilbreth (motion studies and design of workplaces) and Henry Ford (assembly line production). After the two World Wars the Work Science became more popular because of the increasing requirements for analysing problems at the technical and economic interface. Therefore a number of organisations were found in the US (MTM, Work Factor etc.) and Europe (RKW, REFA, VDI etc.), which were involved to further develop methods, train personnel from companies and to provide required consultancy. Industrial Engineering was introduced as a study in the US first. During and following World War II the developments in motion study, time study, optimizing of processes, quality control, remuneration, job evaluation, merit rating, plant layout, materials handling, production control activities, routing and scheduling were the essence of IE activities.

At the same time another development of significance to the IE profession was the emergence of human and organizational behaviour concepts and tools. A wide range of techniques and tools e.g. gain-sharing, socio-technical systems, Delphi surveys, creativity tools were developed to assist the Industrial Engineer. The period from the fifties to the eighties were characterized by a great emphasis in IE on quantitative and computational tools. IE practitioners as “objective” observers focused on hard facts, quantitative and preciseness of measurements.

One major shortcoming in this IE period was that motivational concerns were almost excluded. In the last 30 years Industrial Engineering has developed a lot of techniques/ methods and tools. Because of increasing complexity of the systems and the problems associated with quality, productivity, timeliness, flexibility, customer orientation/ responsiveness and the pressure for cost reduction the IE profession returned after a period of more and more specialization back to its roots “The questioning of assumptions and philosophies about whole systems for producing goods and services and about the modes of reasoning for solving problems”.

Those above selected milestones, which by far are not complete show that people over all periods of time developed methods either to facilitate work by acting in the most ergonomic way or producing goods in the most economical way. At all times they were looking for appropriate solutions for existing problems and therefore numerous methods were developed. While the efforts concentrated at the beginning to find better solutions for technical problems it became clear that behavioural science and later on social science could not be left out.

Today mathematical, physical and social sciences together with the principles and methods of engineering are the basis for Industrial Engineering. The human being has moved into the centre of all reflections. The way of interaction of people, motivation etc. is important for the Industrial Engineer to find sustainable solutions.
3. DEFINITIONS OF IE

The definitions of IE differentiate themselves little as far as the contents are concerned. The official definition by the Institute of Industrial Engineers (IIE) is according to [4]:

"Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems".

The Georgia Institute of Technology and U.S. News and World Report extended the definition to indicate that all sectors and branches can benefit from I.E. methods and tools in order to improve systems by optimizing processes. – In accordance with this, we define IE as,

"The branch of engineering that engages in the study of how to describe, evaluate, design, modify, control and improve the performance of complex systems, viewed over time and within their relative context." The key notion is systems and includes supply chain systems, financial systems, and health systems, among others.

4. THE ROLE OF THE INDUSTRIAL ENGINEER

The tasks of Industrial Engineers are determined by the life cycle of the product or service, the level of interaction and the problems he/she is supposed to solve. In Europe IE is frequently defined as a field of activity, where the planning and the implementation of complex rationalisation schemes are carried out. The required fields of activities (besides a high level of social competence) typically centre round technical solutions, work science, work organisation, operational topics and juridical questions. The overall targets are to improve the productivity, economic viability or profitability of the company or organisation.

In the last 20 year IE has become more and more dominated by university graduates. The gradual integration of IE into the enterprise and as a recognized profession in Europe started mainly with continuing education organisations offering post graduate education based on work science and industrial organisation. These competencies enabled personnel of companies to find appropriate solutions for problems related to production, service or administration processes. Only around 1980 the universities in Europe started to offer degrees in IE. The curricula for a bachelor degree basically cover the following topics:

• Production techniques
• Work science
• Work organization
• Logistics
• Work scheduling
• Cost accounting / cost calculation
• Material logistic
• Production methods
• Work process organization / simulation
• Robotics
• Labour law

5. TRADITIONAL AREAS OF IE APPLICATION

Today Industrial Engineering is concerned in dealing with (production-) systems, in applying methods and in developing / using appropriate tools for existing problems. This means improving systems by applying tools to optimize processes.

The Industrial Engineering responsibilities in many organisations are in the areas of

• Work Measurement (e.g. Cost reduction management)
• Materials Handling (e.g. automation / robotics)
• Quality Engineering (e.g. TQM – system)
• Systems Engineering (e.g. simulation and models)
• Process Engineering (e.g. value analysis)
• Synchronous Manufacturing (e.g. just-in-time)
• Production Planning (e.g. MRP – Materials Requirement Planning)
• Customer Satisfaction (e.g. development of new concepts based on customer needs)
• Human Resources (e.g. Ergonomics)
• Finance (e.g. Project management and justification).

6. NEW AREAS OF IE APPLICATION

In the last 10 -15 year activities in the areas of Environment / Sustainability, Technology and Innovation became more important because of the long –term effects of rapid technological development combined with the pressure for increases in productivity and competitiveness in the world market. A major current influence is the “Green Economy”.

7. SELECTED IE METHODS

It would be impossible within the scope of this paper to go through all the various methods of IE. Therefore only a selection will be mentioned:


As the used methods and applied tools should be tailor-made for the specific problem, there are numerous approaches to find solutions based on IE know how.

A comprehensive production system (e.g. Toyota Production System) is based on a dynamic network of defined organizational principles, methods (e.g. Methods-Time Measurement – MTM) and tools for planning (e.g. MITO - Portfolio tool), operating and continuously improving the processes (Continuous Improvement Process – CIP) The production system serves as a model for the generation of a system of standards for the organization and operation of work systems. The standards used apply to the whole value adding process.
8. **OBJECTIVE 1 OF THE IESE PROJECT**

As our project objective 1, see [1], we proposed to use the European framework of Qualifications (EFQ) as a benchmark standard, against which we can compare the Industrial Engineering Educational Programme (IEEP) for each participating country. In order to produce a more pertinent analysis we needed to include the additional criteria of a recognised IEEP standard. The deliverable for this objective will be a document comparing individual countries against EFQ and recommendations for next steps in achieve harmonisation.

The standard Venn diagram model for IEEP currently in common use is prescribed by the International Labour Organisations (ILO) – diagram 1 below and [3]. This model has been in use over a number of decades and has been widely accepted as the industry standard across Europe and by many universities in the US. It was decided to use this model as the baseline reference for comparing the IEEP’s currently being delivered in the partner countries. According to the model the areas that form the core topics of industrial engineering are, IE Fundamentals, Operations Research, Human Factors Engineering, Management Systems and Manufacturing Systems Engineering.

**Diagram 1: Venn diagram – ILO Standard for Industrial Engineering Educational Model, see [3]**

9. **DEFINITION OF SUBJECT CATEGORIES FOR IE EDUCATIONAL MODEL.**

**IE Base**

Industrial Engineering is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. - Examples of IE base are:

- *Work measurement* (time studies, work data)
- *Processes* (business processes, value chain processes)
- *Workplace evaluation and Design Business*
- *Administration* (costs, losses, profits)
- *Logistics* (production, physical, material handling)
- *Organisation Development* (structure, definition of labour, tasks, responsibility)
- *Planning / Steering* (strategically, tactical, operational)

**Project Management** (project plan, project team, time schedule)
**IT basics** (information structure and use of data)
**Quality Management** (quality systems, performance monitoring)

**Human Factors Engineering**

Human Factors Engineering (HFE) is the discipline of applying what is known about human capabilities and limitations to the design of products, processes, systems, and work environments. It can be applied to the design of all systems having a human interface, including hardware and software. Its application to system design improves ease of use, system performance and reliability, and user satisfaction, while reducing operational errors, operator stress, training requirements, user fatigue, and product liability. HFE is distinctive in being the only discipline that relates humans to technology. - Examples of Human Factors Engineering are:

- *Ergonomics*
- *Human interface engineering*
- *Behavioural science*

**Operations Research**

This is an interdisciplinary branch of applied mathematics and formal science that uses methods such as mathematical modeling, statistics, and algorithms to arrive at optimal or near-optimal solutions to complex problems. – Examples of OR methods are:

- *Optimization Models*
- *Simulation*
- *Network Models*

**Manufacturing Systems Engineering**

Manufacturing Systems Engineering includes engineering assembly and batch production, flexible manufacturing systems, lean production, group technology, job production, kanban, and mass production systems. – Examples of Manufacturing Systems Engineering are:

- *Production Systems*
- *Maintenance Systems*
- *Automation Technology Systems*

**Management Systems**

A management system is the framework of processes and procedures used to ensure that an organization can fulfill all tasks required to achieve its objectives. - Examples of Management Systems

- *General management*
- *Quality management (TQM)*
- *Project management*
- *Management Information Systems*
- *Contract management*
- *Health & safety management*
- *Human resource management*
- *Business Ethics*
- *Cross cultural management*
10. IE EDUCATIONAL MODEL DEVELOPMENT

During the course of our analyses it became apparent that the ILO model currently in use does not adequately represent the curriculum being taught on modern day industrial engineering educational programmes. As a consequence of this finding and the amalgamation of all partners’ educational programmes, a new curriculum model was developed (Diagram 2 below), which in our opinion better represents the modern understanding of industrial engineering core topics. In addition to the original four core subject categories a further two have been added. These topics are Innovation & Technology and Environment/Sustainability. In the interest of clarity the IE Base category was renamed IE Fundamentals with a further sub-group category called Engineering Basics, which contains subjects like mathematics and physics common to all engineering disciplines.

Diagram 2. Venn diagram – IESE standard educational model

Engineering Basics
Engineering Basics are the group of engineering subjects and skill sets common too, and essential for all engineering disciplines. Examples of these foundational subjects are:
- Mathematics
- Physics
- Statistics and Probability Theory

Innovation & Technology
In the context of Industrial Engineering, Innovation & Technology consists of specific fields of new technology being used for the improvement of integrated systems such as information technology, process technology, discrete technology, production technology, etc.). - Examples of Innovation & Technology:
- Innovation process & life cycle
- Speed of technological development
- Information technology
- Manufacturing technology (discrete, process, etc.)
- Nano technology
- Bio technology

Environment/Sustainability
This subject will provide expertise in terms of: energy usage, environmental performance and sustainability and the design and evaluation of building service systems. - Examples of Environment and Sustainability are:
- Policies and Legislation
- Energy Standard EN 16001
- Corporate Energy Policies
- Energy Management and Auditing
- Sustainable Technologies – Wind, wave, solar etc
- Sustainable Technology Integration
- Combined Heat and Power CHP
- Building Management Systems BMS
- Lighting
- HVAC

11. COMPARISON OF IE EDUCATIONAL PROGRAMMES

The syllabi specification for all partners’ educational programmes was documented and the individual subjects were mapped on to the IESE standard model. ECTS credit points were assigned to each subject category and a summary of all the educational programmes was produced, see Table 1 below.

The base metric used in this calculation was; one credit = 25 hours with the overall Bachelors programme totalling 180 credits.

<table>
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<th>Subject</th>
<th>IRE</th>
<th>DK</th>
<th>SW</th>
<th>IS</th>
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<td>OR</td>
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<td>10%</td>
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<td>49%</td>
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</table>

Table 1: Summary of ECTS credits per subject for BSc level education in IE

As can be seen from the table, the educational programmes in the 6 countries are very different. It should be kept in mind that the results are not the same when the MSc level is included.

Also, it becomes clear that Human Factors Engineering has a very low priority in most of the countries.

A Reference Syllabus was created on basis of the results shown in Table 1, which may be helpful in Project Objective 2 as a benchmark in assessing industry needs against educational programme specifications.
12. CONCLUSIONS

Analysis of the individual educational programmes has shown that the scope of the programmes needs to be expanded to include additional subject categories and skill sets. The exact parameters of this expansion of the programmes must be determined with reference to current and future “industry needs” as specified in the second objective of this project.

Analysis of the subject focus for the individual programmes has shown a high degree of variation, particularly in the non-core subjects. A levelling of the subject categories, particularly the core subjects will be undertaken in phase two of the project.

The project work is now focused on the second objective, i.e. a business needs survey to provide a gap analysis of the difference between the educational programmes and the needs of the industry for increased competence in the field of Industrial Engineering.

The very first results, and previous work, indicate that it could be a very difficult matter to have good answers when asking companies about their needs for competence development. Experience from sending out questionnaires to engineering companies in Sweden demonstrated these difficulties. The answers show a very shortsighted perspective on the competence development process.

This is one of the main challenges of the second phase of our project. The results of the second phase will be discussed in a separate paper soon to be published. The progress can be followed on the webpage of the project [1].

REFERENCES


