Industrial Engineering Standards in Europe
- industry needs versus education

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ABSTRACT
This paper describes and discusses the project 'Industrial Engineering Standards in Europe' (IESE). The project is funded by the EU Leonardo da Vinci Partnership program with partners from universities and organizations offering engineering education and continuing education in the field of industrial engineering.

There are two main objectives in the project. The first is to use the European Qualification Framework (EQF) as a benchmark against the National Qualification Framework (NQF) of the partner countries and the Industrial Engineering educations offered by the partner institutions. What seemed to be a relatively straightforward task showed to be more complicated. Iceland, the Netherlands and Denmark have adopted the EQF approach with 8 levels - BSc, MSc and PhD as the top three levels. Ireland has adjusted to their national educational system with 10 levels, Germany is still discussing their NQF and Sweden has decided not to adjust to the EQF for the moment.

The second objective in the project is to conduct a survey among industries employing industrial engineering in order to investigate a possible gap between the educational programs and the needs of the industry for competences in the field of industrial engineering. A survey has been carried out in Ireland, the Netherlands and in Iceland and the results are indicating gaps in various topics.

Keywords
Industrial engineering, gap analysis, continuing engineering education

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1. INTRODUCTION
This paper, which is the second of two, describes some of the results of a European Leonardo funded project 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, Netherlands and Sweden

The project is now in its closing phase and the work 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 is now showing results. Before we discuss the outcomes of the second objectives, we will briefly introduce the field of Industrial Engineering.

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.

2. INDUSTRIAL ENGINEERING

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*

2.1 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).*

2.2 New areas of IE application

In the last 10 - 15 years 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".

2.3 Industrial Engineering Standards in Europe

As our project objective 1, see [1], we proposed to use the European Qualifications Framework (EQF) 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 EQF and recommendations for next steps in achieving 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 which are currently being delivered in the partner countries. According to the model the areas that form the core topics of industrial engineering are, IE Base, Operations Research, Human Factors Engineering, Management Systems and Manufacturing Systems Engineering.

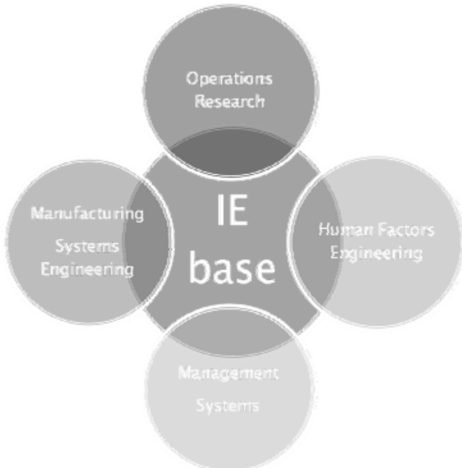

Diagram 1: Venn diagram – ILO Standard for Industrial Engineering Educational Model, see [3]

2.4 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 modelling, 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 fulfil 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*

3. EXTENDED MODEL OF IE EDUCATION

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.

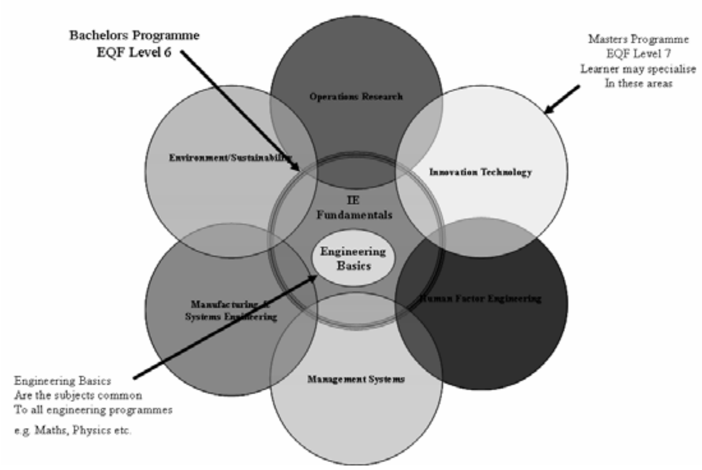

Diagram 2. Venn diagram, IESE standard educational model

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*

4. 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 1: Summary of ECTS credits (%) per subject for education in IE

	IRE	DK	SE	IS	NL	DE	Avg
Engineering Basics	22	40	37	34	6	0	**23**
IE Fundamemtals	15	13	13	2	19	10	**12**
Operations Research	0	13	8	20	5	0	**8**
Management Systems	25	3	15	20	40	29	**22**
Innovation & Technology	0	13	0	4	0	12	**5**
Environment/Sustaniabil.	19	0	8	2	0	0	**5**
Manufacturing Systems	17	12	15	16	30	49	**23**
Human Factors Engineer.	2	6	4	2	0	0	**2**

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 for the programs are based on different total number of ECTS credits and also, it should be kept in mind the differences between the legal status of the institutions, offering of fulltime or continuing education and the pedagogical approach of each institution. But still the diversities are striking. Looking at the average (right column) of the Table 1 it is clear that 3 sub-group categories (Engineering Basic, Manufacturing Systems and Management Systems) are superior to the rest.

The Engineering Basics covers up till 40% of the curriculum at the public partner organizations whereas the private partner organizations teach only 0% till 6% of Basic Engineering to their students because in the Netherlands and Germany the students enter the private programmes when they have already had the basic mathematics, physics and statistics. Management Systems come out with an average of 22 % however the diversity among the partner organizations range form 3 % till 40 % of curricilum and Manufacturing Systems have an average of 23% with a diversity from 12 % till 49% of the curricilum. The tendency is that the private organizations teach more Management Systems and Manufacturing Systems that the public partners. IE Fundamentals are more equally taught in all the partner countries.

The Human Factors Engineering is one of the areas that form the ILO - Standard for Industrial Engineering Educational Model (diagram1) but it has become clear that Human Factors Engineering has a very low priority in all of the partner countries. During our analyses it became apparent that the ILO model currently in use does not adequately represent the curriculum being taught of today's industrial engineering educational programmes and therefore two sub-categories were added; the Innovation & Technology and the Environment & Sustaniability. They both show an average of 5% of curricilum in our analyses but again diversities are found within the partner courtries. It appears that either Innovation & Technology or Environment & Sustainability are taught as the diversity range from 0 % till 19 %.

The second objective of this project is to conduct a survey among industries employing industrial engineers in order to investigate a possible gap between the educational programmes and the needs of the industry for competences in the field of industrial engineering. A survey has been carried out in Ireland, the Netherlands and in Iceland and the results are indicating gaps in various subjects.

The survey has been answered by approximately 50 companies in each country and the respondents percentages have been more than 35 % in each country. The survey consists of 19 questions of which 5 are background information questions about the company. The companies are asked to rank the importance of the 8 different sub-categories of the IESE standard educational model and to benchmark the subject related to each sub-category against each other.

A reference syllabus was to be composed on basis of the results shown in Table 1. A syllabus for benchmarking and assessing industry needs against educational programme specifications in Europe but the data for composing a reference syllabus was not sufficient as we only carried out surveys in 3 countries. However the survey from the individual countries benchmarking industry needs against national educational programme show to what extent the curriculum taught are in line with the industry needs.

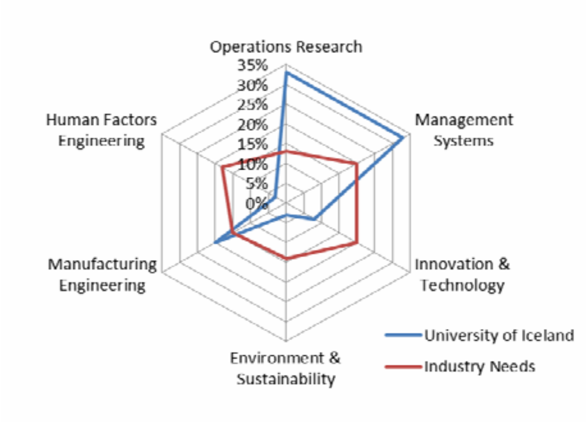

Diagram 3. Syllabus of IE at University of Iceland and the Industry Needs in Iceland

The results from Iceland could indicate that the curriculum should contain more ECTS on Human Factors Engineering, Innovation & Technology and Environment & Sustainability and teach less ECTS in Operations Research and Management Systems.

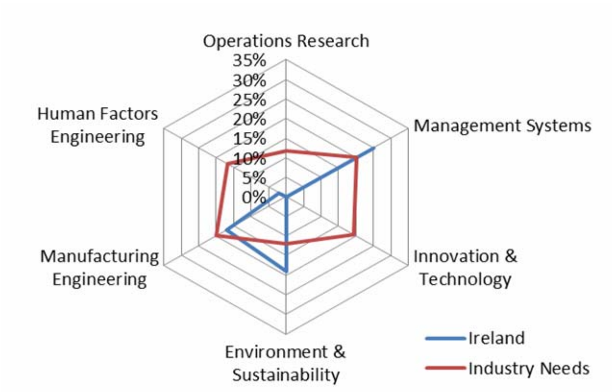

Diagram 4. Syllabus of IE at the Institute for Industrial Engineering and the Industry Needs in Ireland

The results from Ireland also shows that the alignment between the Institute for Industrial Engineering curriculum and industry needs are not a total match and again especially the Human Factors Engineering is under-represented in the curriculum.

5. DISCUSSION

The first question to arise is whether the analysis is showing the right picture. Further analysis of the results from Iceland validates the shape of the gap and leaves the interpretation to further discussion.

The gap analysis should be discussed from at least two perspectives: seen from the industry point of view and seen from the educational institutions point of view. And maybe even more interesting the joint perspective of the two.

5.1 The industry perspective

The competition between manufacturers of today's products has reached a level which has never been seen before in history. Globalization of markets has increased tremendously leaving every company to be very sharp on its competences concerning not only the core activities of manufacturing but also concerning the positioning in the market and amongst competitors. Therefore any company will inevitably focus on obtaining the skills and competences that they expect will improve their position in the market. A relevant question to raise is whether the needs for competences stated by the companies in this survey can be seen as the real needs or as a search for the magic stick to keep the competitors behind.

One should on the other hand not neglect the statements from the industry. The driving forces of competition are at least to some extent the renewal of methods and technologies in combination with the skills and competences of the workforce. These forces are moving with a much faster speed than research based development and will therefore point out directions for future research of the higher education institutions like universities.

A recent survey of graduates [5] (faculties: Humanities, Social Sciences and Engineering & Science) from Aalborg University, Denmark (AAU) and the companies employing them is likewise showing a gap between the industry needs and the competences of the employees graduated from AAU. The needs are identified in a broad sense to be 'more knowledge of how a company works' and 'more understanding of running a business', and not very specific to the type of job. On the other hand the companies are quite satisfied with the fact that the graduates from AAU possesses the general academic skills that enables them to acquire the knowledge they need for solving the problems and tasks of the company.

5.2 The perspective of the educational institutions

Higher Education Institutions serves several purposes to the society, research and education being the strongest. Candidates must be educated to obtain skills and competences to maintain the jobs of a modern society on a long term basis. In the fields of engineering the education will develop continuously to match the needs of the industry but will as all academic educations also target the general qualifications of the professional field.

It could be seen as a law of nature that the HEI always will be delayed in fulfilling the actual need of competences in industry but indeed there are a lot of reasons for this gap:

- *Staff members seem to engage candidates with same professional profile*
- *Priority of research is rising*
- *'Publish or perish' policy is very strong*
- *Changing study regulations and obtaining national accreditation is very time consuming*

6. CONCLUSION

A joint perspective of industry and education on the competence gap might be a more fruitful approach and accessible path to respond to the competence gap.

A better match between needs of the industry and the competences acquired by education can be obtained by establishing a more continuous dialogue between industry and HEI concerning the situation. It seems like HEI with strong capacities within certain technologies will also have a strong local industry utilizing the strength of research at the university.

The gap analysis also reveals a market for continuing professional development in the field of industrial engineering. All engineering jobs of today are depending on strong and specific competences and on a close relation to research in the many professional areas of industrial engineering. It is obvious that engineering consulting companies will offer services based on their experience and knowledge. But HEI like universities could and should offer continuing education far more tailor-made and targeting the industry needs than it is done at the institutions of the partners.

A joint venture of establishing departments for continuing education at the HEI's might create the ideal model for a provider of up-to-date competences to the industry being able to forecast the needs and to be a platform of collaboration between teachers and researchers from HEI and management and engineers in the companies.

7. REFERENCES

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