

# UNVEILING THE GAP

**Pall Jensson**, Professor

Reykjavik University, Iceland

[pallj@ru.is](mailto:pallj@ru.is)

**Ole Rokkjær**, Project Manager

Aalborg University, Denmark

[or@learning.aau.dk](mailto:or@learning.aau.dk)

**Bente Nörgaard**, PhD fellow

Aalborg University, Denmark

[bente@plan.aau.dk](mailto:bente@plan.aau.dk)

## ABSTRACT

This paper describes a project in Europe called Industrial Engineering Standards in Europe (IESE). The project was collaboration between universities and organizations that offer Industrial Engineering (IE) education and/or continuing education in 6 European countries. The project was funded by the EU Leonardo da Vinci Partnership program.

The project had two objectives. The first objective was to use the European Qualification Framework (EQF) as a benchmark against the National Qualification Framework (NQF) of the partner countries and the IE 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.

Analysis of the subject focus for the individual programmes showed a high degree of variation. In the context of CDIO this means that what seems to be a well-known and commonly accepted definition of a discipline like IE is in fact ambiguous. The six partners in the project had highly different interpretations of what is IE.

The second objective in the project was to conduct a survey among industries in order to investigate a possible gap between the educational programs and the needs of the industry. A survey was carried out in Ireland, the Netherlands and in Iceland, keeping in mind the discussion above. The results indicated serious gaps in various topics. In all three countries the industry emphasis was quite different from what the educational institutions were offering. Questions rise about how to assess industry needs, how universities decide what to teach, and how to bridge the gap. Do the university programs simply reflect the expertise of the faculty members? Is there need for increasing emphasis on continuing education? Is life-long education the answer, and has this been addressed by the CDIO community?

## KEYWORDS

Industrial Engineering, Gap Analysis, Continuing Education, European Qualification Framework

## 1. INTRODUCTION

This paper describes some of the results of a European Leonardo funded project called Industrial Engineering Standards in Europe - IESE [1]. The project is collaboration between universities and organizations offering continuing education in 6 European countries: Denmark, Germany, Iceland, Ireland, Netherlands and Sweden. The project had two objectives that will be described later. First we will introduce the field of Industrial Engineering (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 the IIE website [2]:

*"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".*

Others have 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 for example 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 they are supposed to solve. In Europe IE is frequently defined as a field of activity, where the planning and the implementation of complex rationalization schemes are carried out. The required fields of activities (besides a high level of social competence) typically center round technical solutions, work science, work organization, operational topics and juridical questions. The overall targets are to improve the productivity, economic viability or profitability of the company or organization.

In the last 20 year IE in Europe 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 organizations offering post graduate education based on work science and industrial organization. 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.

### 2.1 Areas of IE application

Today IE 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 traditional IE responsibilities in many organizations have been in the areas of

- *Work Measurement (e.g. Cost reduction management)*
- *Materials Handling (e.g. automation / robotics)*

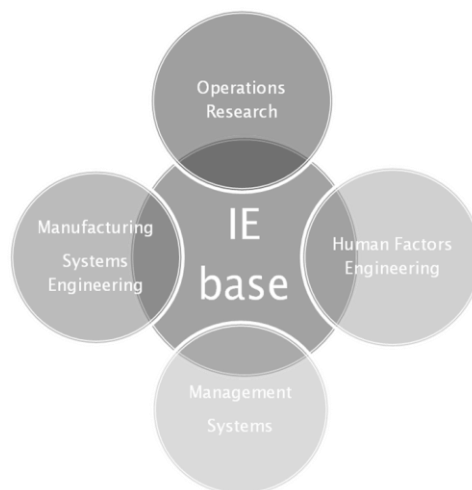
- *Quality Engineering (e.g. TQM – system)*
- *Systems Engineering (e.g. simulation and models)*
- *Process Engineering (e.g. value analysis)*
- *Synchronous Manufacturing (e.g. just –in –time)*
- *Production Planning (e.g. MRP – Materials Requirement Planning)*
- *Customer Satisfaction (e.g. development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

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”.

## 2.2 IE Standards

As our project objective 1 [1] we proposed to use the European Qualifications Framework (EQF), see for example [3], 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 [4]. 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.



**Figure 1: Venn diagram – ILO Standard for IE Educational Model, see [4]**

## 2.3 Description of subject categories for the IE educational model.

### IE Base

IE is basically 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 subjects 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 Operations Research 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

- *Quality Management (TQM)*
- *Project Management*
- *Management Information Systems*
- *Health & Safety Management*
- *Human Resource 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 in 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 (Figure 2 below), which in our opinion better represents the modern understanding of IE core topics. In addition to the original four core subject categories, 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.

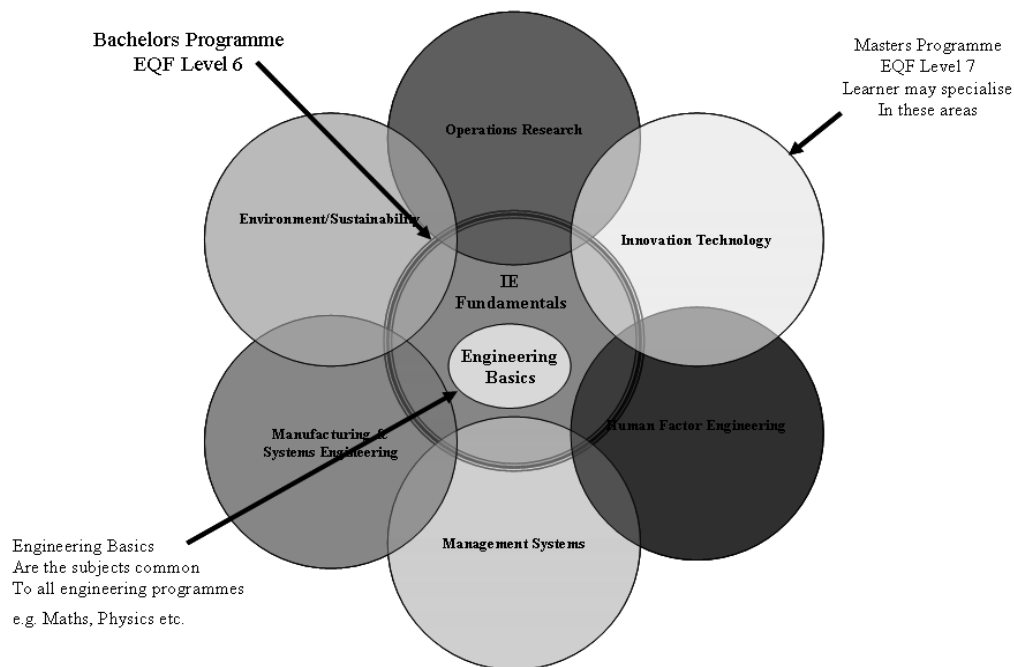


Figure 2. Venn diagram, IESE standard educational model [1]

### **Engineering Basics**

Engineering Basics is a group of engineering subjects and skill sets common to and essential for all engineering disciplines. Examples of these foundational subjects are:

- *Mathematics*
- *Physics*
- *Statistics and Probability Theory*

### **Innovation & Technology**

In the context of IE, Innovation & Technology consists of specific fields of new technology being used for the improvement of integrated systems. - Examples of Innovation & Technology subjects are:

- *Innovation Process & Life Cycle*
- *Information Technology*
- *Manufacturing Technology (discrete, process, etc.)*
- *Nano Technology*
- *Bio Technology*

### **Environment/Sustainability**

This subject category will provide understanding of energy usage, environment and sustainability and the skills in the design and evaluation of environmentally friendly systems. - Examples of Environment/Sustainability are:

- *Environmental Policies and Legislation*
- *Energy Standard EN 16001*
- *Corporate Energy Policies*
- *Energy Management and Auditing*
- *Sustainable Technologies – Wind, wave, solar etc.*
- *Sustainable Technology Integration*
- *Building Management Systems BMS*

## **4. COMPARISON OF IE EDUCATIONAL PROGRAMMES**

The syllabi specifications for all partners' educational programmes were documented and the individual subject categories 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 BSc programme totalling 180 credits and an MSc program totalling additional 120 credits. - It should be noted that only the disciplinary skills were addressed, not the personal or interpersonal skills.

**Table 1: Summary of ECTS credits (%) per subject for education in IE [1]**

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

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 Engineering Basics 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 from 3% till 40% of curriculum. Manufacturing Systems have an average of 23% with a diversity from 12% till 49% of the curriculum. The tendency is that the private organizations teach more Management Systems and Manufacturing Systems than the public partners.

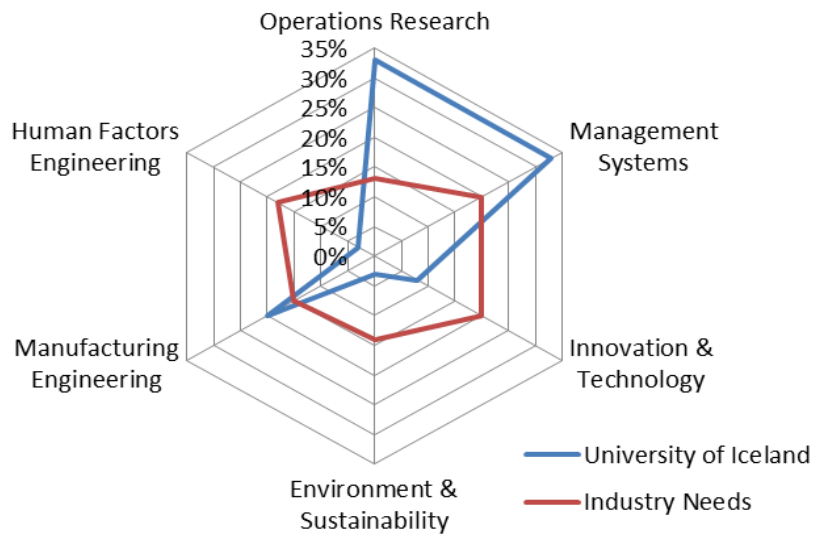
The Human Factors Engineering is one of the areas that form the ILO - Standard for Industrial Engineering Educational Model (Figure 1) but it has become clear that Human Factors Engineering has a very low priority in all of the partner countries. The two new subject categories that were added, the Innovation & Technology and the Environment/Sustainability, show an average of 5% of curriculum in our analysis. Again great diversities are found within the partner countries, a range from 0% till 19%.

## **5. INDUSTRY NEEDS**

The second objective of this project was 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 IE. A survey was carried out in Ireland, the Netherlands and in Iceland. The survey was answered by approximately 50 companies in each country and the responding ratios were over 35% in each country.

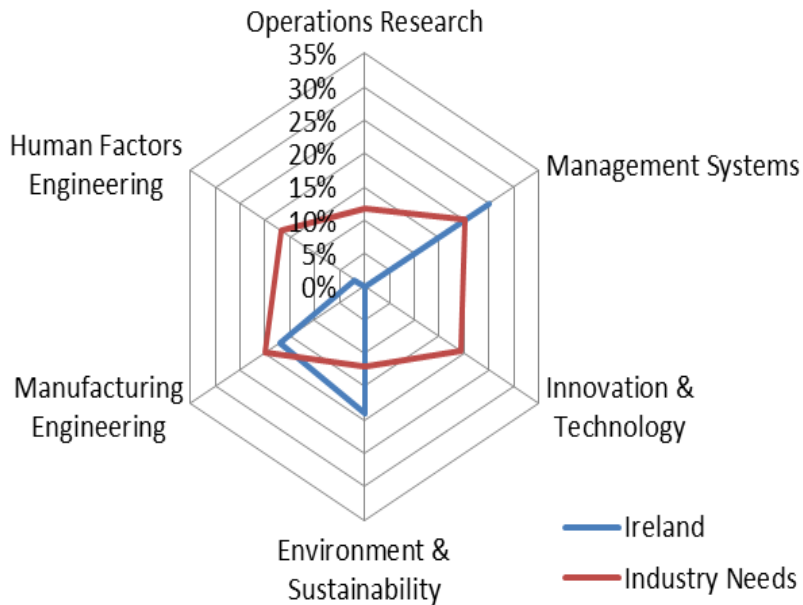
The survey consisted of 19 questions of which 5 were background information questions about the companies. The companies were asked to rank the importance of the 6 different main subject categories of the extended IESE standard educational model (excluding IE Fundamentals and Engineering Basics). Other questions related to sub-categories within each of the 6 main categories as described in sections 2 and 3 of this paper.

The survey from the individual countries benchmarking industry needs against national educational programmes indicate to what extent the curriculum taught are in line with the industry needs.



**Figure 3. Syllabus of IE at UI and the Industry needs in Iceland [1]**

The results from Iceland indicate that the curriculum of the University of Iceland (UI) should contain considerably more ECTS on Human Factors Engineering, Innovation & Technology and Environment/Sustainability and less ECTS in Operations Research and Management Systems.



**Figure 4. Syllabus of IE at the IEE and the Industry Needs in Ireland [1]**



The results from Ireland also show that the alignment between the Institute for Industrial Engineering (IEE) curriculum and industry needs in Ireland are not in match. Again especially the Human Factors Engineering is under-represented in the curriculum, see Figure 4. The same applies to Operations Research and Innovation & Technology. – Results from the Netherlands are not available yet.

It may be noted that the industry needs are in fact very similar both in Iceland and in Ireland. Yet neither of the educational programmes covers these needs. The gap is rather obvious and clear.

## **6. DISCUSSION**

The first part of this research showed that the six partners in the project had highly different interpretations of what Industrial Engineering is in terms of the disciplinary skills that the students should have. In the context of CDIO this means that what seems to be a well-known and commonly accepted definition of a discipline can in fact be ambiguous.

The second part, the gap analysis, can be discussed from at least two perspectives: From the industry point of view and from the educational institutions point of view. And may be even more interestingly the joint perspective of the two, in the spirit of the CDIO philosophy.

### **6.1 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 together with fast technological development 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 present position in the market. A relevant question to ask is whether the needs for competences stated by the companies in this survey can be seen as the real future needs or as a search for the magic stick to keep the today's 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 (HEI) like universities.

### **6.2 The perspective of the educational institutions**

Higher Education Institutions (HEI) serve several purposes to the society, research and education being the most important. Candidates must be educated to obtain skills and competences to serve the needs of a modern society on a long term basis. In the field of engineering the education must develop continuously to match the needs of the industry in a world of rapid technological changes. However general qualifications of the professional field must also be targeted.

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 number of possible reasons for this gap:

- *Faculty members seem to engage candidates with similar professional profile*
- *Priority of research is rising and 'Publish or perish' policy is becoming ever stronger*
- *Changing study regulations and obtaining national accreditation is time consuming*

## 7. CONCLUSION

A joint perspective of industry and education on the competence gap might be a more fruitful approach and an accessible path to respond to the competence gap. A better match between the 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. This is emphasized in Standard 2 of the CDIO implementation methodology, i.e. to get input from the industry stakeholders when determining the learning outcomes.

The gap analysis reveals a market for continuing professional development in the field of engineering. Most engineering jobs of today are depending on strong and specific competences and on a close relation to research. HEI like universities could and should offer continuing education far more tailor-made, targeting the industry needs better than is done today.

A joint venture of establishing departments for continuing education at the HEIs 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. It is proposed that the CDIO community takes this up for a discussion.

When this is written, Reykjavik University is taking the first steps into the CDIO principles, starting with a dialog with industry stakeholders. In this dialog personal and interpersonal skills will be addressed as well as the disciplinary ones. The outcome of that will add to the results of the research presented here.

## 8. REFERENCES

[1] <http://www.iestandards.eu/> , Dec 2010

[2] <http://www.iienet2.org/Details.aspx?id=282>, Dec 2010.

[3] [http://ec.europa.eu/education/lifelong-learning-policy/framework\\_en.htm](http://ec.europa.eu/education/lifelong-learning-policy/framework_en.htm), Dec 2010

[4] Handbook of Industrial Engineering, Edited by Gavriel Salvendy, Institute of Industrial Engineering, John Wiley & Sons Inc New York 1991.

**Páll Jensson**, PhD, Professor of Industrial Engineering at the University of Iceland 1987-2011, after retirement there he joined Reykjavik University in 2011 where he is now a professor and department head of Engineering Management and Financial Engineering. He holds a PhD degree in Industrial Engineering from the Technical University of Denmark 1975. He was employed by IBM 1975-1977 and director of Computing Center at the University of Iceland 1977-1987. Professor Jensson has a long experience of Operational Research and Mathematical Modeling of various economical and technical applications including Profitability Assessment. He has been active in teaching and research in Industrial Engineering since 1977.

**Ole Rokkjær** holds a B.Sc. in Electronics Engineering and a Master in Learning Processes. He is currently project manager and project administrator in Interregional Center for Knowledge and Educational Studies (INCEVIDA) at Department for Learning and Philosophy, Aalborg University, Denmark. For more than 20 years Ole has taken interest in competence development, in practice by teaching, in organizing and coordinating larger Continuing Professional Development projects and by studying and developing models for CPD.

**Bente Nørgaard** is PhD fellow from Aalborg University. Since 1999 Bente has worked within the area of Problem Based Learning (PBL) and continuing engineering education at Aalborg University. She has been involved in several national and international research projects aiming at implementing PBL primarily as an approach for tailor-made continuing education. For the past years, Bente has researched the process of identifying learning objectives in tailor-made continuing education and most recently with a broader perspective on the PBL approach, researched how actors involved in the process organize and coordinate the activities.