Education in Engineering Management for the Environment

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Abstract. Manufacturing engineering is now moving into the digital era, otherwise known as Industry 4.0. The next paradigm shift that is fast approaching and this is the era of personalisation and customisation, known as Industry 5.0. To facilitate this personalisation of products, human and technology must work together seamlessly in a manner where the best of both is leveraged. Human centred systems are at the heart of this revolution. One of the most important enablers of this change is the education of our technologists, our university degrees and post graduate programmes must embed this expertise into their core modules. This contribution looks the educational aspects of the MSc in Engineering Management in the Technical University of Vienna Austria (TUWien) as an example of education which has evolved to facilitate emerging trends. An introduction and a short history of this executive postgraduate MSc is presented, as it is a long established and well know programme which dates back to 1995.

Keywords: Education · Technology · Human factors · Ethics · Cost oriented Automation (COA) Human Centered Systems · Environment

1 Introduction

Modern manufacturing environments are evolving rapidly as new technologies are developed. As part of a European Union publication Breque et al. in 2021 describe future developments of Industry 5.0 as "*a forward-looking exercise, a way of framing how European industry and emerging societal trends and needs will co-exist. As such, Industry 5.0 complements and extends the hallmark features of Industry 4.0. It emphasises aspects that will be deciding factors in placing industry in future European society; these factors are not just economic or technological in nature, but also have important environmental and social dimensions.*"[1] They emphasise that going forward the technological frameworks of highest importance will be (i) Individualised human-machine-interaction; (ii) Bioinspired technologies and smart materials; (iii) Digital twins and simulation; (iv) Data transmission, storage and analysis technologies; (v) Artificial Intelligence; (vi) Technologies for energy efficiency, renewables, storage and autonomy.

As a result of these changes the engineering environment has become more challenging than before. With today's increased technical complexity and competitive pressures,

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engineering managers must confront new highly technical problems and manage complex tasks. To manage effectively in such a dynamic and often unstructured environment, managers must understand the interaction of technical, organizational and behavioural variables in order to form a productive engineering team [2].

According to Mills and Treagust in 2003 *"engineering and management practices have to deal with uncertainty, with incomplete and contradicting information from an organization's environment."* In addition, continuous technological and organizational changes in the workplace impose challenges to the individual. However, the prevailing mode of teaching is similar to the teaching practices of the 1950's, with large classes and single discipline, lecture-based courses. Hence, recent developments show a slow change towards student-centred learning such as problem-based and project-based learning [3].

Fischer in 2004 and Kopacek et al. in 2013 described the following key dimensions of educational competence:

1. Technical Competence: the individual has sufficient subject knowledge and can plan and organise so as to achieve maximum results.
2. Administrative Competence: the individual has a range of business knowledge, can follow rules, procedures and guidelines set out by the organisation and can perform to the expected standards set out by the organisation.
3. Ethical Competence: The individual has moral standards which guide them in their decision making activities in the work environment.
4. Productive Competence: The individual is efficient and capable of producing desirable results. Productive competence particularly focuses upon the capability of the professional to continuously develop their knowledge and skills.
5. Personal competence: The individual can manage time, possesses necessary 'people skills', time management, communications and conflict management skills to operate effectively in the working environment [4, 5].

2 Human Centered Systems and Mechatronics

Kopacek in 2019 stated that industry 4.0 combines production methods with state-of-the-art information and communication technology. The driving force behind this development is the rapidly increasing digitization of the economy and society, and the result, manufacturing and the work environment are irreversibly changing exponentially. In the tradition of the steam engine, the production line, electronics and information technology, smart factories are now determining the fourth industrial revolution. The technological foundation is provided by intelligent, digitally networked systems that will make largely self-managing production processes possible [6].

The focus of Europe is now on the implementation of strategic concepts. With a strong technical foundation, the challenge in Europe is to balance the opportunities of digitalisation in industrial value creation with the needs of a human-centric world of employment. Europe sees Industry 4.0 and 5.0 as a socio-technological challenge. Reclaiming industrial competitiveness is critical in manufacturing as well as the preservation of sustainable careers. Breque et al. state that *"there a consensus on the need to*

better integrate social and environmental European priorities into technological innovation and to shift the focus from individual technologies to a systemic approach." [1].

A framework of the emerging Industry 5.0 can be seen in Fig. 1 as proposed by Doyle-Kent in 2021 [7]. The importance of education leading this field cannot be underestimated, and an interdisciplinary approach combining the technological, social ethical, industrial, environmental and management aspects is required going forward to enable graduates not just to survive but to flourish in their future careers.

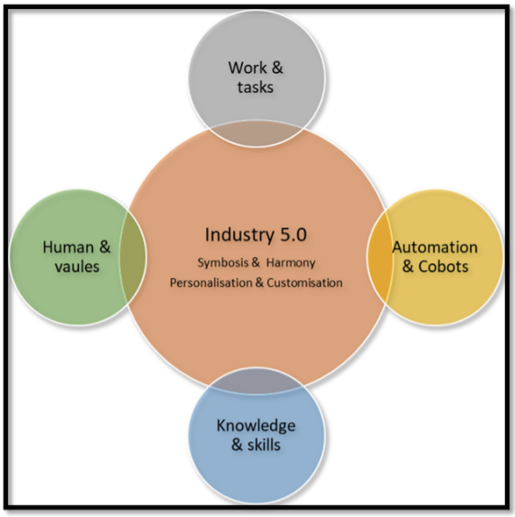

Fig. 1. Conceptual framework illustrating Industry 5.0 [7]

Additionally an Industry 5.0 definition has been put forward by Doyle-Kent so that researchers can easily conceptualisation this paradigm shift that is fast approaching. *"Industry 5.0 is the human-centered industrial revolution which consolidates the agile, data driven digital tools of Industry 4.0 and synchronises them with highly trained humans working with collaborative technology resulting in innovative, personalised, customised, high value, environmentally optimized, high quality products with a lot size one."* [7].

3 Engineering Management at TU Wien

In the past, the areas of engineering and management were regarded as two very different and unrelated disciplines. Trained technical experts undertook the process and technical aspects of engineering, whilst a different type of person altogether, often with an unrelated background and experience, oversaw the management of an engineering business or technical processes. Because of the evolution of the manufacturing industry new skills and new approaches are required by staff because the hi-tech processes and

systems need to be operated with maximum efficiency and effectiveness. The need for a new kind of manager has been heightened by the new international nature of most businesses. There is an increasing demand from customers to deal with people familiar with the technical aspects of a product and who are also experts in business management and customer relationships [8].

The teaching methods and the materials are equally important in modern education. Giving the student exposure to real life problems that can concretise the theory and in Engineering Management both what and how are given equal importance. Internationally distinguished experts are members of this highly acclaimed faculty, either through their sound interdisciplinary scientific knowledge or their extensive practical experience in the field of engineering management.

The program is customized for small and medium-sized enterprises as well as for as departments of large companies facing a growing and increasingly competitive market. It is designed to prepare graduates from technical and economic universities for leadership roles in technological, corporate and national affairs.

The part-time master's program is characterized by its internationality. Lecturers are affiliated to universities and industrial enterprises in nine countries like USA and numerous European Countries and seek to communicate technical, economic and juridical skills in an interdisciplinary way. By cross-linking theory, practice and case studies in a targeted manner, this knowledge can then be implemented directly in the companies and businesses of the participants.

The main goal of the above design was to develop a curriculum which would enable graduates to be conversant with business issues, and appreciate these in the context of the implementation of "new "technologies [9].

MSc Engineering management students can access the TUWien Pilotfactory which was designed to bring students into a real-life learning environment. This facilitates the technical and social education of the students and is based on the concept of the 'digital twin' in manufacturing [10]. It uses scenario-based learning (SBL) is rooted in situated learning and cognition theory [11, 12]. Situated learning theory claims that learning is most effective when it takes place in its natural context where the acquired knowledge is going to be used. Thus, knowledge can be transformed to competencies of action. Cobb similarly states that learning is effective when it constantly shifts between "thinking" – a process of abstract conceptualization, "feeling" – largely based on experiences, "watching" – a process of observation and reflection and "doing" – an active stage of experimentation [13].

4 MSc in Engineering Management – A Closer Look

4.1 The History

The first idea for a postgraduate, executive Engineering Management MSc program at TU Wien came up in 1992 as a cooperation with the Oakland University in Rochester (MI). The main goal has been to educate managers for SME's as well as Department Heads of large companies from the producing industry [8].

After some discussions and visits a general cooperation agreement between Oakland University and TU Wien was signed on January 25, 1995 in the Rectors office of TU Wien. The main points were:

- An international faculty,
- A two week stay at Oakland University with lectures and company visits
- Participants receive a MSc degree in Engineering Management from Oakland University as well as a certificate from TU Wien.

On October 20, 1995 the first program was launched with 11 participants in Austria. The following programs (until 2005) took place in different locations in Lower Austria and Vienna. Since 2007 this program has been running under the framework of the Continuing Education Center (CEC) of TUWien with TUWien lecturers but without an agreement with Oakland University.

4.2 Facts and Figures

The highlights of our program are summarised in the following table:

Table 1. MSc in Engineering Management TUWien highlights

More than 25 years' experience, more than 200 graduates
Master of Science Degree of TU Wien
Executive program – number of participants limited
International Faculty – Universities and Industry
International participants – up until now from more than 41 different countries
Part time – 13 weekend modules (Friday to Tuesday)
According to the Bologna Convention
Teaching is in English only
Contents are modernized continuously
Evening lectures which are delivered by distinguished guest speakers
Company visits
Alumni Club
Regular Club meetings for Networking
Graduate profile: approximately 2/3 are in (high) management positions, 1/3 have founded their own companies

4.3 Modules Taught in 2020–2021

Module A - Production Management

Probability and Statistics
Production Systems
Systems Engineering
Project Management & Logistics
Technology
Company Visits

Module B - Engineering Informatics

IT & Management
IT & Production

Module C - Business Management

Accounting
Financing
Marketing
Operations Management
Management Information Systems
International Law
Human Factors

Module D - Master's Thesis

Master's Thesis

The Master's Thesis is an important part of the postgraduate program. It consolidates and integrates what has been learned and establishes a vital link between theory and practice. Students are encouraged to choose a specific and practical problem from their occupational activity and to solve it by the acquired knowledge. A supervisor, who has the role of a mentor, will advise and support throughout the whole process. Some parts of finished theses are published in scientific journals and/or presented on scientific events.

5 Msc in Engineering Management and the Environment

One of the main goals of this program is to give the participants a deeper insight in an "Environment friendly Management." Most of these topics are addressed in the lectures on Technology. Examples or areas that are taught and discussed are as follows:

"End of Life – (EoL) Management".
"Resource Efficiency".

"Heating, Ventilating, Air Conditioning (HVAC)".
"Domotics".
"Smart Cities".
"Bionics".
"Transport of the future".

Furthermore MSc Theses are written in these research areas and some are, or will be, presented at International Scientific Events and also published in Scientific Journals.

6 Summary and Outlook

As the working environment changes so must our educational offering to both undergraduates and post graduate students. The MSc in Engineering Management in TU Wien has a long standing history of educational excellence aimed at both Austrian and international students over a number of decades.

One of our main goals is to adapt the contents of the lectures according to the newest developments from program to program. According to the international developments in the future we have to add some additional items related to the environment. This will take priority over the coming years as the program evolves and adapts.

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