Implementing Education Vision in the Context of Industry 4.0

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Abstract. Transformation of the traditional industry through digital technologies shapes the education system, as comprehensive knowledge in the interdisciplinary areas of technologies is required. Amid the challenges of competitive and digital technologies in the advanced manufacturing industry, the universities and industry cooperation is imperative. This study presents the planning and implementation of the educational projects in metrology to create a vision of building the bridge between educational institutes and the industry. The implementation of tele-presence and tele-operation case studies focus on flexibility, efficiency and quality of the processes that does not limit the resources to a location, time difference or facility. Vision in education is of extreme importance in this present time of worldwide international competition in Industry 4.0 that will enable to achieve sustainable environmental friendly goals with contribution to both industry and society.

1. Introduction

Digitalization and deployment of growing technologies in ICT are transforming the machining and the manufacturing industry worldwide. The term "Industry 4.0" was first emerged in 2011 to refer to a new era in industry following a research agenda and recommendations for implementation in 2013 by Acatech - the German Academy of Engineering Sciences [1]. Industry 4.0 includes a higher priority on individualized products, which requires transformations in the designing, manufacturing, and service of industrial systems and products as well as their business models [2]. A long term strategy to dovetail the demand in today's manufacturing industry assures a sustainable development [3]. Besides, the roadmaps and plans be routinely reviewed and updated until a formal iterative process occurs to better explore and understand certain technologies [4].

The industrial and technological key concepts need to be specified and comprehended not only by industry but also, even more importantly by educators and scholars. This goal will be achieved by establishing guidelines, roadmaps, and scientific literature [5]. Moreover, the strategic work will enable to address the guidance of transitioning to new forms of engineering and manufacturing address [6].

The cooperation of international partners in research focusing on providing borderless collective experience, expertise and use of laboratory facilities sets the background of a roadmap towards efficient integration of applications both in academy and in industry [7]. When we talk about the education, sustainability is the key term to overcome the challenges of competitive and digital technologies in the advanced manufacturing industry. The sustainable model of educational improvement is basically based on a methodology of Life Long Learning easy to adapt moreover to other topics with adequate constraints [8].

2. The Scope of Metrology in Advanced Manufacturing Systems

In advanced manufacturing systems there exist close interactions between intelligent design, intelligent metrology and industrial and technological developments. Special points of interest are integrated intelligent management, digitalization, automation, high accuracy, high efficiency, next generation manufacturing and nano/pico metrology.

The production of very precise components goes hand in hand with the development of the necessary metrology, and a wide range of measuring instruments has been devised to cater for the evaluation of surfaces and structures down to the 0.1 nm level. This powerful array of instruments provides a measuring capability in nano- and pico-metrology. In modern metrology it is possible to use instruments capable of creating atomic resolution images of the surfaces of different specimens and 3D measurements as well as scanning of high precision parts. SCM, AFM, STM, Scanning Probe Microscopy (SPM) and high precision CMMs are such advanced measurement technologies.

The needs of the industry for ultra-high precision engineering and workpieces with a surface roughness less than few nanometers call for measurement instrumentation that can be applied reliably in modern production processes, together with international standards defining parameters and tolerances in the nanometer scale. The requirements on the measurement systems and the measurement strategy to determine suitable parameters, time, costing and the guarantee of predetermined process stability by means of measurable and correlated parameters come into focus.

On basis of industry needs, the demands on industrial nanometrology can be subdivided into three major scientific attributes:

- Reliability: Measurement results have to mirror the real surface structure and statistic and systematic errors may be reduced to an absolute minimum.
- Comparability: Measurement results must be comparable when they are measured with different measurement systems of the same kind. Ideally measurement results taken with different systems should be comparable too.
- Reproducibility: Several measurements of the same sample under the same conditions must result in the same results. Changes in measurement conditions must result in comprehensible changes in the measured parameters.

Increasing demands on precision and accuracy of measurement results in manufacturing and metrology is a particular important challenge in industry. Adequate competencies, knowledge and experience are required for sustainable development. As a part this vision, the High Precision Measurement and Nano Metrology Laboratory at the AuM-TU Wien (The Department of Interchangeable Manufacturing and Industrial Metrology / Production Metrology and Quality, Vienna University of Technology) is chosen as a node to create an inter-university network.

As the technology advances rapidly, the qualification of required education has to catch up providing the required knowledge. Otherwise, the classical system of education will be irrelevant for soon future. In order to establish required engineering and technology educational models, one has to consider a methodology based on continuous improvement. This study performs a model and strategically implementation of continuous improvement in education with modern methods of quality management.

2.1. Quality Management in Education
Implementation of quality management in the vision of education offers an advantage in fast developing technological era with defined research and development processes at the universities and institutes. The applicable standards for the quality management in education are used as guidelines as they support three pillars of sustainable development namely economic, social and environmental. They can be listed mainly [9-16]:

- ISO/IEC 19796-1:2005:Information technology - Learning, education and training - Quality management, assurance and metrics - Part 1: General approach. It is a framework to describe, compare, analyze, and implement quality management and quality assurance approaches with the main aspect of Reference Framework for the Description of Quality Approaches (RFDQ).
- ISO/IEC 19796-3:2009: Information technology - Learning, education and training -- Quality management, assurance and metrics - Part 3: Reference methods and metrics. The reference framework for the description of quality approaches (RFDQ) by providing a harmonized description of the methods and metrics required to implement quality management and quality assurance systems for stakeholders designing, developing, or utilizing information technology systems used for learning, education, and training.
- ISO/IEC 40180:2017:Information technology - Quality for learning, education and training - Fundamentals and reference framework. It provides the fundamentals and the reference framework for quality assurance, quality management and quality improvement in IT-enhanced learning, education and training (E-Learning) harmonizing existing approaches, concepts, specifications, terms and definitions related to quality for E-Learning, education and training.
- ISO 29993:2017:Learning services outside formal education - Service requirements. It specifies requirements for learning services outside formal education, including all types of life-long learning (e.g. vocational training and in-company training, either outsourced or in-house) including any learning services provided by a learning service provider (LSP) that are addressed to learners themselves, as well as to sponsors who are acquiring the services on behalf of the learners. The key features of these kinds of services are that the goals of learning are defined and the services are evaluated, and that they involve interaction with the learner. The learning can be face-to-face, mediated by technology, or a combination of both.
- ISO 29990:2010:Learning services for non-formal education and training - Basic requirements for service providers. It specifies basic requirements for providers of learning services in non-formal education and training.
- ISO 21001:2018:Educational organizations - Management systems for educational organizations - Requirements with guidance for use. It specifies requirements for a management system for educational organizations that uses a curriculum to support the development of competence through teaching, learning or research, regardless of the type, size or method of delivery such as professional training departments.
- PAS 1069:2009-07 Learning, Education and Training with special consideration of e-learning - Guideline for the Reference Process Model for Quality Management and Quality Assurance - Planning, Development, Realization and Evaluation of Processes and Offers in Learning, Education and Training.
- PAS 1032-1:2004-02 Learning, education and training focusing on e-learning - Part 1: Reference model for quality management and quality assurance - Planning, development, realization and evaluation of processes and offers in learning, education and training.

The quality system to approach contributes to understanding and managing interrelated processes as a whole and moreover enhances effectiveness and efficiency in education models fulfilling its targets. The quality system approach principle address the requirements through:

- Defining the system objectives
- Establishing, implementing and maintaining the   management system as a set of processes

- Describing the system
- Continual improvement
- Interconnection, interrelation and sequence of   processes
- Maintaining the integrity of the system

Establishing educational models will not only enable adequate qualification but also enable processes to overcome   the challenges for organizations that proceed towards the modern manufacturing environment in such as the hidden costs leading to potential savings. Therefore, the documentation requirement covers the reports to be implemented in the education strategy.

2.2. Applications in Education

The time, cost and expertise for establishing metrology and mechanical laboratories is very high for many small and medium size enterprises. Besides, required expertise and knowledge can't be found in every country. The High Precision Micro and Nano Metrology Laboratory at the AuM-TuWien (The Department of Interchangeable Manufacturing and Industrial Metrology / Production Metrology and Quality, Vienna University of Technology) is chosen as a node in this study to create an inter-university network. A developed platform serves as a practical experience of an intelligent metrology process model, which is also available as educational models to the students on a global scale. An educational concept for the current students taking part in high precision measurement activities and intelligent metrology cycle as the target, research and development process is established at the cooperating universities and institutes. Based on continuous improvement approach from the referenced standards, the experience obtained by integration of the processes will further create a roadmap for future developments.

The cooperation in this study between the local laboratories in Argentina enables the practical applications to develop and create a resource for future connection nodes that is already in the near future plans. The current status of the project focuses on automatic control of the high precision measurement instruments through the network established using a server. The operation requirements of remote control results an increase of the workload of the channel in the network. Hence, the bandwidth limitations generate a reduction speed of the process. To resolve this difficulty; a client server computing technology is used for the control of all the equipment in the laboratory. Establishing a paradigm in the Linux server enabled us to connect to the equipment that is required for further applications. The measurement applications are represented in the Figure 1.
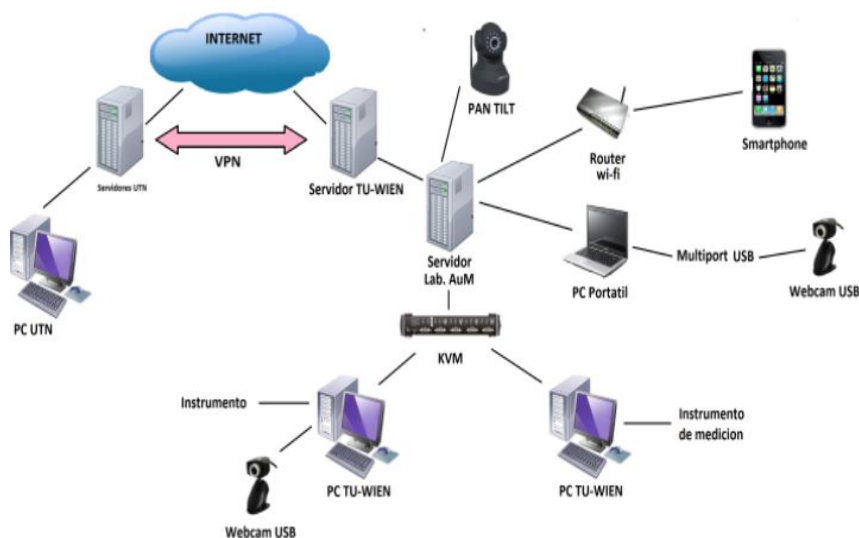

Figure 1. The overview of working environment

The existing status of the inter-university network exhibits good results using also mobile phone technology. The mobile phone technology enables currently to connect to the other nodes (e.g. Buenos Aires) using the Wi-Fi network established in the laboratory environment. The international network for telepresence and teleoperation educational models is represented in Figure 2.

Figure 2. The international network for tele-presence and tele-operation educational models

3. Conclusion and Future Work

Establishing and implementation of educational vision to serve adequate knowledge and expertise throughout generations sustainably will also enable the methods to overcome the challenges of the new era Industry 4.0. The educational models based on flexibility, efficiency and quality will provide the advanced manufacturing industry an advantage in competitive and digital technologies.

The practical approach of this inter-university network project offers collaboration to any industrial or university organization without boundaries. Learning and continuous improvement are the basics of each module of the system. Once the targets are achieved, it is possible to implement the modules in another node using the systematic knowledge obtained throughout this project. Moreover, as the technology develops, improvement will be supported further by means of documentation as a part the quality management system integration.

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