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DIGITALIZATION CHALLENGES FOR INDUSTRIAL MANAGEMENT EDUCATION IN EUROPE

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A critical mass of Knowledge Workers (KWs) is required to fill the gap between the ever-increasing deficit between demand and offer in the field of Industrial Engineering and Management (IE&M) in Europe. This paper aims at identify weaknesses in combining organizational methodologies for the production of goods and services and new digital technologies in the implementation of the so-called Industry 4.0 (I4.0) paradigm. The main objective is to identify innovative characteristics and paradigms able to close the existing gap in IE&M, creating new curricula for university students and industry workforce and eventually contributing to reduce the shortage of KWs in the manufacturing sector. In this context an European initiative named IE3 under the Erasmus + program will be introduced.

Keywords: industrial management education; digitalization; Body of Knowledge

RETOS QUE LA DIGITALIZACIÓN INDUCE EN LA EDUCACIÓN EUROPEA SOBRE GESTIÓN INDUSTRIAL

Se requiere una masa crítica de trabajadores del conocimiento (KW) para llenar el déficit cada vez mayor entre la demanda y la oferta en el campo de la Ingeniería y Gestión Industrial (IE&M) en Europa. Este artículo tiene como objetivo identificar las debilidades en la combinación de metodologías organizacionales para la producción de bienes y servicios y nuevas tecnologías digitales en la implementación del llamado paradigma Industria 4.0 (I4.0). El objetivo principal es identificar características innovadoras y paradigmas capaces de cerrar la brecha existente en IE&M, creando nuevos planes de estudio para estudiantes universitarios y la fuerza laboral de la industria y, finalmente, contribuyendo a reducir la escasez de KW en el sector manufacturero. En este contexto, se presentará una iniciativa europea llamada IE3 dentro del programa Erasmus +.

Palabras clave: industrial management education; digitalization; Body of Knowledge

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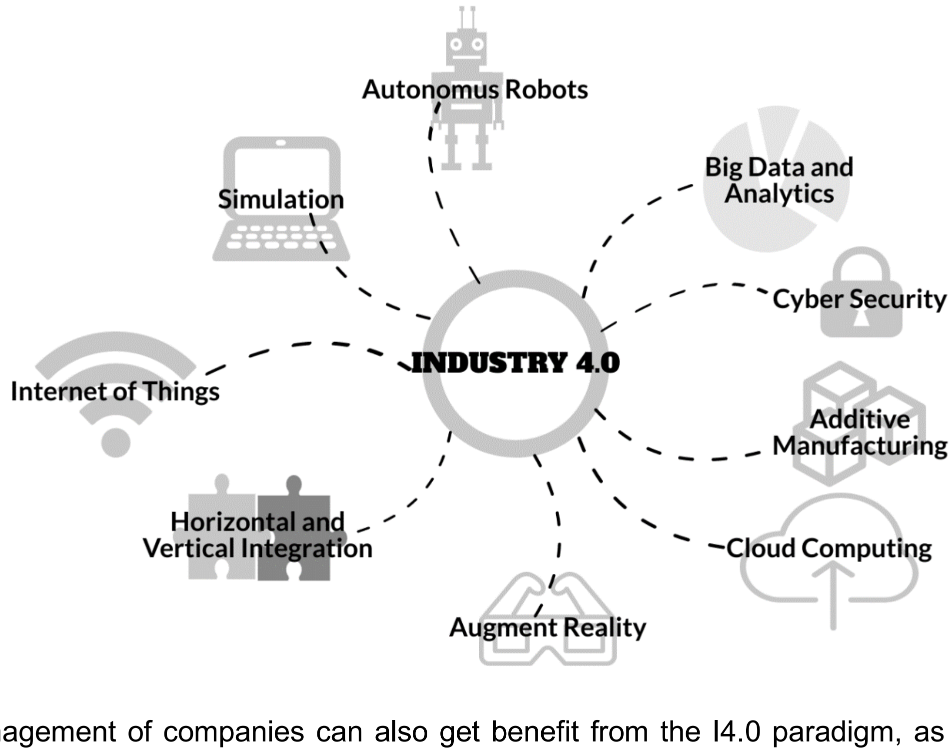
1. Introduction

Both rapid social changes and paradigms evolution require, more than ever before, a faster adaptation of people in terms of mindset, knowledge, and skills. Such social changes include, but are not limited to, the increasing service orientation of society, where instead of willing to have goods, people want to get the benefit from their usage. The old dichotomy between product and service evolved towards a service–product continuum, where the organization at least extends the product to the combination of product and service that delivers value in use, i.e., a Product-Service System (PSS) (Leseure et al. 2010). PSS is defined as a system of products, services, supporting networks, and infrastructure configured to satisfy customers' needs, and have a lower environmental impact than traditional business models (Frank et al. 2019).

To play in such turmoil environment, organizations need to introduce innovation in their context, to adding value to their processes, including the manufacturing ones. One of the well-known context to drive through is the Industry 4.0 (I4.0) paradigm. In this approach, the essential tools are the industrial internet of things (IIoT), the cyber-physical systems (CPS), with concepts like digital twins, and maker culture. In this way, the I4.0 facilitates that systems of industrial automation become connected with highly advanced IT technology, enabling new methods of work, with higher productivity (Kiel et al. 2017). However, I4.0 goes further than just specific tools, and it accounts for the digital coordination of different assets on the shop floor (see Figure 1). Indeed, even more now than I4.0, the advantages come from a deeper digital transformation of the industries, connecting not only the production assets but translating it to the products and services given to the customers (Xu, Xu, and Li 2018).

Figure 1: The nine pillars for I4.0.



The management of companies can also get benefit from the I4.0 paradigm, as SMEs find themselves ill-equipped to face these new possibilities regarding their production planning and control functions and often limit themselves to the adoption of Cloud Computing and the Internet of Things. Likewise, Small and Medium Enterprises (SMEs) seem to have adopted

Industry 4.0 concepts only for monitoring industrial processes, and there is still a significant lack of real applications in the field of production planning (Moeuf et al. 2017).

To address all the technical and managerial challenges that such ongoing transformation requires to increase the so-called knowledge workers (KWs). A critical mass of Ws is required to fill the gap between the ever-increasing deficit between demand and offer in the field of Industrial Engineering and Management (IE&M) in Europe. To provide answers to this problem will require to combine organizational methodologies for the production of goods and services and new digital technologies in the implementation, addressing the I4.0 paradigm. It will require to design and test innovative courses (both classes and e-learning modules) in IE&M, creating new curricula for university students and industry workforce and eventually contributing to reducing the shortage of KWs in the manufacturing sector.

This paper aims to identify innovative characteristics and paradigms able to close the existing gap in IE&M, creating new curricula for KWs in the manufacturing sector. In this context, a European initiative named IE3 under the Erasmus + program will be introduced.

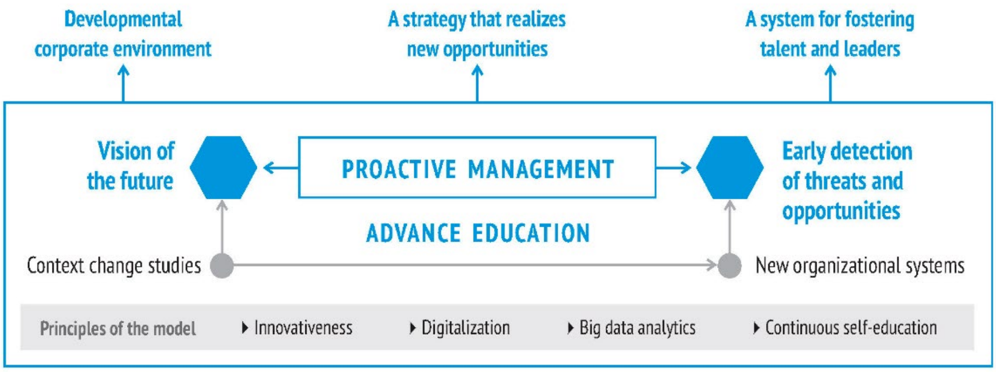
2. Literature Review

Requirements and objectives for KWs, no matter at what organizational level they will be, are turning no linear, with unclear outcomes and even more risky than ever before, as it can be seen in Gitelman, et al. (2019), Chea et al. (2019), and Ordieres-Meré et al. (2020).

There is an extensive list of contributions related to regional challenges that different countries face because of the difficulties raised by these new requirements, like Chik et al. (2019), and Anwar et al. (2018).

In Gitelman et al. (2019) the focus is to identify requirements for generating new educational programs aimed to develop competences for all the life-cycle of industrial integrated systems, including to set up a conceptual framework addressing the features of management education looking to meet the challenges. The authors introduce a taxonomy for management, providing targeted function for each of the elements in the taxonomy. They added a proactive management concept, linking expected outcomes with education and technologies (see Figure 2).

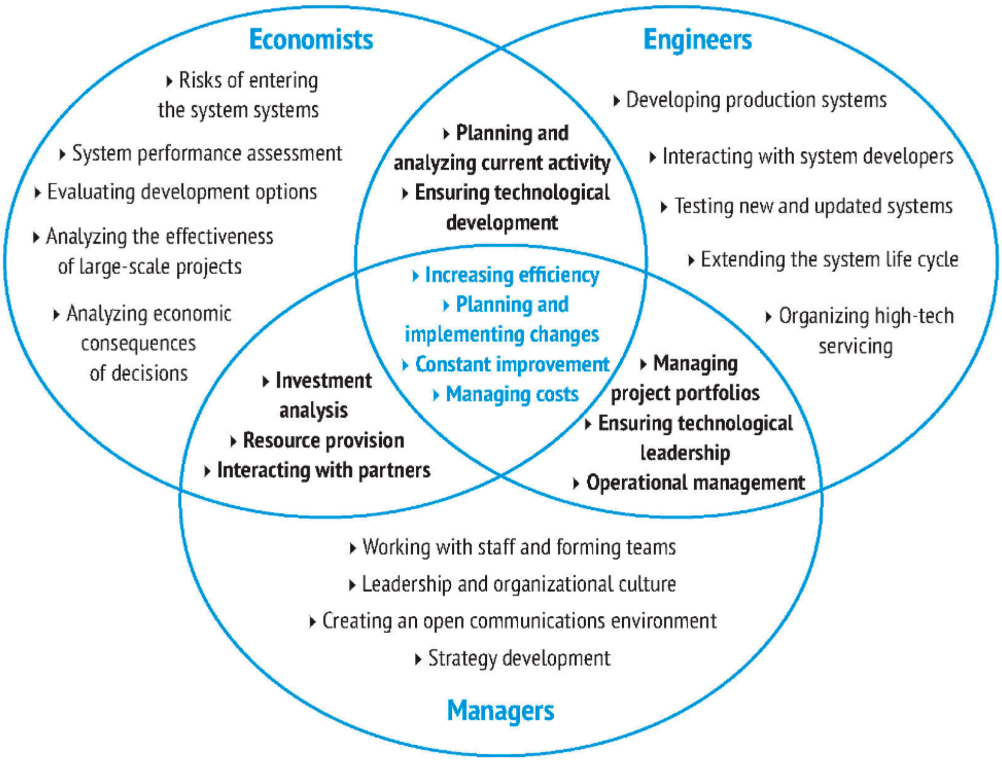
Figure 2: Management model focused on advanced education. Source (Gitelman et al, 2019)



A significant outcome from this work is that they come up with a proposal for competences to be further emphasized, as shown in Figure 3. The competence set was organized by considering Economics, Engineering, and Management, as well as their intersections to be the significant families.

As in other fields of knowledge, the proposal of Education 4.0 (E4.0) appeared as formulated in Chea et al. (2019), where the main identified characteristics were Anytime, Anywhere, Personalised Learning, and Flexible Discovery. The authors proposed the possible branches, areas, fields to be further developed. At the same time, they advise implementors must development of all of them in a leveraged way because just choosing some of them will not deliver the expected benefits. It is relevant, as the identification covers not only technical fields (background, Ace delivery, Pedagogy, etc.) but also managerial ones (sustainability, challenges, research & innovation, etc.), and implementation policies (Evaluation, Governance, etc).

Figure 3: Proposal for competences to be emphasized. Source (Gitelman et al., 2019)



There are some authors such as Schuster et al. (2016), focusing on specific methodological aspects, and highlighting that improvements are needed as well in the context of the educational development process. They ask for transformations from purely document-based management systems to complex virtual learning environments, with more interactive and collaborative components. They report experiences with Minecraft® environments as a way to increase engagement attributes. Other authors explore the contribution of more immersive strategies (Janssen et al. 2016).

There are contributions about quality measures for the newly implemented educational models, as Ulewicz and Sethanan (2019), where the authors adopt the Kano model, which develops the theory of attractive quality and looks to identify the relationship between the degree of sufficiency and customer satisfaction with a quality attribute. It establishes five levels of perceived quality (Attractive quality attributes, One-dimensional quality attributes, Must-be quality attributes, Indifferent quality attributes, and Reverse quality attributes).

In addition to the proposal addressing management dimensions, or methodological delivery related aspects, there are authors proposing adoption of competence models (Prifti et al. 2017), after combining different methodologies like literature review and focus groups. The competence concept has several interpretations, starting from McClelland (1973) view “Competencies are underlying characteristics of people and indicate ways of behaving or thinking, generalizing across situations, and enduring for a reasonably long period of time". Therefore, McClelland proposed competency as a way of testing proficiency in occupational environments when it comes to performing certain activities. However, he became frustrated because of the overutilization of aptitude testing to measure academic success, while ignoring life success (Harper 2018).

It is possible to find authors proposing the utilization of tools able to be applied in the I4.0 context to the education path and management, like artificial intelligence (Ciolacu et al. 2018). Indeed, authors are promoting the use of chatbot as an assessment technique for identifying training demand is also useful in collecting a variety of information about problems, perceptions, and opinions in the digital age.

The relevant conclusion, inferred from the reviewed literature, is that KWs will need to master connections between technology, economics, social expectations, and human factors. It is the way to imagine increasingly sophisticated services, even before stakeholders demand them, which will bring significant advantage competitive, and that will increase the aggregated value delivered by the KWs.

3. The IE3 project

In the context mentioned above some European partners, mainly four universities supported for local industrial partners, carried out a proposal of design, test, and dissemination of a New Educational Model of Higher Education in Industrial Engineering and Management to contribute in increasing the quality of 2nd level academic curricula in Europe (IE3 2020).

Figure 4: Main structure of the IE3 proposal. Source (IE3 2020)

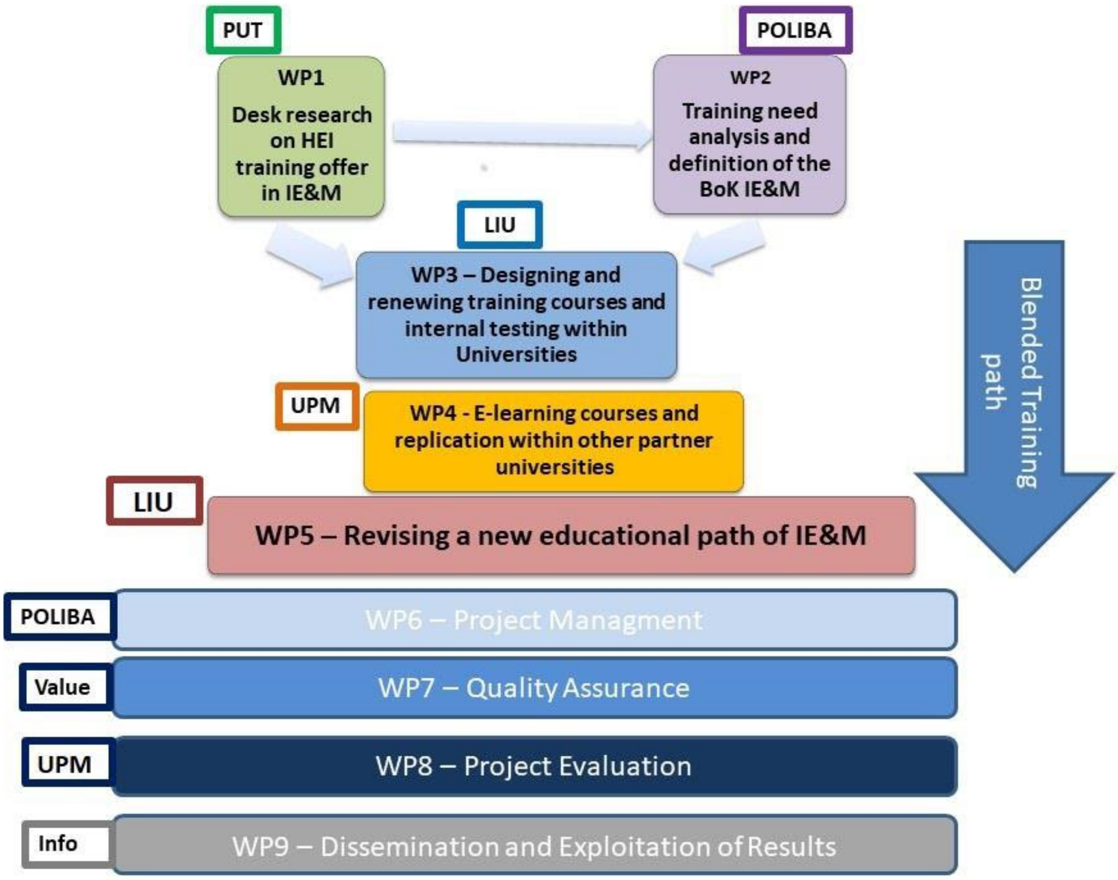
Methods	Main Phases	Outcome
Questionnaires/ surveys/interviews to relevant stakeholders	Need analysis / Gap analysis / Book of Knowledge	Educational offer and new training needs in IE&M **REVISITED**
Traditional learning (development of materials, structuration in classes)	Producing IE&M educational materials and up-to-date training to foster specialized knowledge and intrapreneurship, thus reducing the gap between firms 'demand for KWs and fresh graduates' job hunt	Students' and companies' edu&training needs **ADDRESSED**
Online courses with e-learning modules and materials	Blending the partner experiences within a full course of easy replication; validating, testing and mainstreaming the educational offer and project outcomes	Change in the IE&M specialized educational offer **PURSUED**

In addition to the participant partners, the IE3 project relies on the support provided by the three interesting organizations participating as such and representing the view from different stakeholders. Here it is worth to mention ESTIEM (https://m.estiem.org/), the European

Students of Industrial Engineering and Management association, bringing into the consortium the students' perspective. Also, AIM (http://europe-aim.eu/), bringing into the consortium the academics' perspective, and MadridNetwork (https://www.madridnetwork.org/), providing the companies perspective, as it is an innovation network for different strategic economic sectors in Madrid region.

Figure 5 presents the workpackage (WP) structure as well as the main responsible for each WP. Although currently, the ongoing WP are WP1 and WP2, looking to extract conclusions from both, the existing offer and the demand, the interest of this paper is to anticipate the conceptual approach to select the competence model and the vision to implement it in WP4.

Figure 5: WP structure of the IE3 project. Source (IE3 2020)



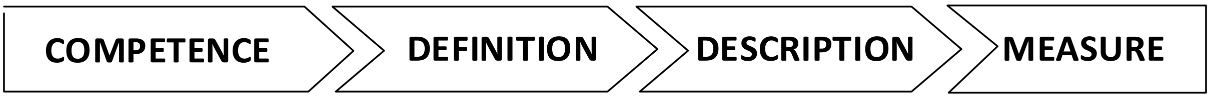
4. Pedagogical model

The term sociotechnical system is applied to describe operations that involve a diverse interaction between humans, machines, and the environmental characteristics of organizational policies (Davis et al. 2014). The developed theory behind is contingent on developing the pedagogical model.

In a similar way that companies evolved their human resource policies from the traditional job-based approach looking for job requirements into a competence-based assign process, higher education entities shifted to a competence-based strategy. In the I4.0 era, organizations need to adopt the competency-based view to help in identifying critical competencies to develop their workforce. To have in place a system able to build people's competence is an essential step looking to meet future market needs.

Scholars have identified two main categories of competences, Individual and organizational competencies. Still, independently from the adopted taxonomy, it is convenient to establish the way competence is understood, which will require, a definition, providing a description, and for how it will be measured Figure 6.

Figure 6: Competence understanding.



The organization of competences in layers helps to build complex capabilities, in a similar way that the WBS does for scope management. *The notion of competency will be a generic skill applied to knowledge in an application domain.* The learner follows two kinds of objectives at the same time - learning specific new knowledge and learning to analyze better what he already knows, helping to restructure knowledge, validate new ideas, and formulate new knowledge. The association between generic skills, seen as generic cognitive processes, and specific knowledge avoids an artificial separation between knowledge and know-how, integrating cognitive and meta-cognitive aspects that must be present together for thoughtful human action and learning (Paquette 2014). The IE3 project adopts the model proposed by this last author.

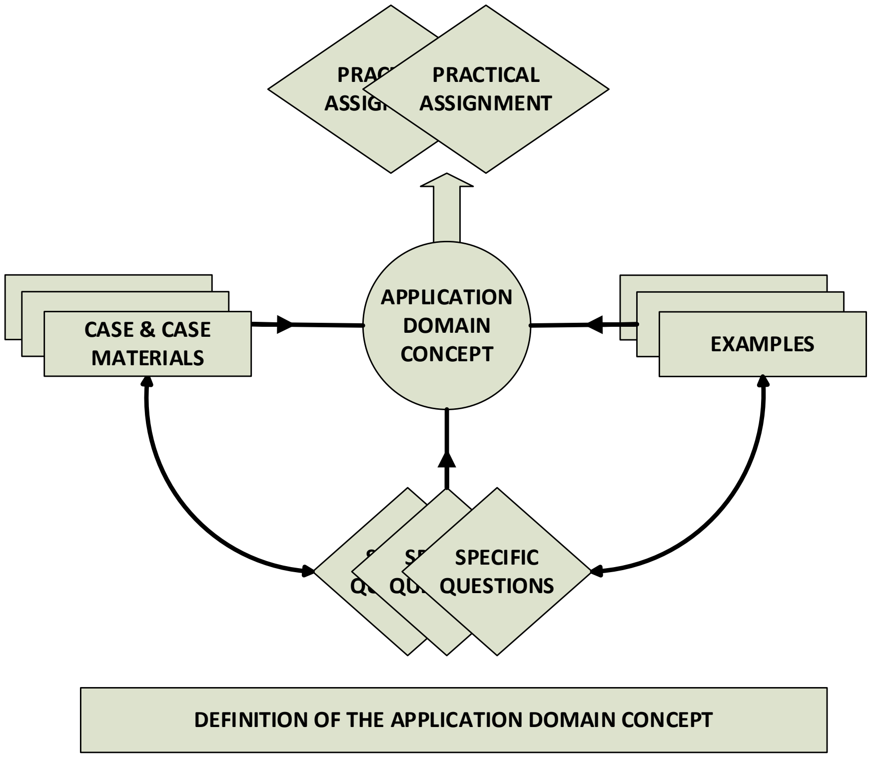
The IE3 will promote the UML model representation for competences into the domain-specific knowledge space to provide the competence description, in addition to its definition.

In practical applications, a set of connected courses constitute one academic program, and a set of related modules build one course. Similarly, a collection of connected competences make one module. Although the hierarchical view is significant, it is much more relevant to analyze the relationship between competences and between application domain concepts. Therefore, careful analysis and understanding of such graph representation also contribute to affirming capabilities. Indeed, reasoning over such knowledge representation, can be potentially helpful. Therefore, the usage of Semantic Web Rule Language (SWRL) needs further investigation.

The approach in the module level for designing or implementing a course of an academic program will be to use the adopted skill process model as a template. The main subprocesses of the meta-process describing the competence will be transformed into learning activities. Then, a second step is to instantiate the template with terms in the application domain. These terms will be defined, described, and their understanding or capability to be performed will be then measured.

Finally, but yet importantly, Figure 7 presents the way to create such application domain knowledge from a practical perspective.

Figure 7: Learning implementation of Application Domain knwoledge.



5. Conclusions

This paper introduced the Erasmus+ funded project IE3, focused on updating the body of knowledge for Industrial engineering and Management at the European scale, trying to address the challenges raised by the I4.0 paradigm.

One key aspect is to accurately identify the existing interactions, because as presented in this paper, there are relevant connections between dimensions and strategies, like servitization of industry, PSS, social willingness, and digital transformation of organizations even further than what I4.0 is looking to deploy.

The main contribution of this paper is to present the method for defining the structural program components, although processes to formally identify gaps between demand and offer are undergoing.

The proposed architecture reaches the competence level and formulates an ontological approach, including a graph-based representation. The derived framework is not just focused on theoretical content, but also it allows the assessment of practical abilities through a comprehensive and transparent configuration.

The contribution of ontologies and SWRL needs further research to calibrate the potential knowledge consolidation effectively brought.

The main limitation is that the current status of the project does not enable to present specific gaps, out of those already know, and related to the excessive theoretical content of courses, as well as the basic content of defined practices, which can jeopardize the competence acquisition.

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References

Anwar, Chairul, Antomi Saregar, Uswatun Hasanah, and Widayanti Widayanti. 2018. “The Effectiveness of Islamic Religious Education in the Universities: The Effects on the Students’ Characters in the Era of Industry 4.0.” *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah* 3 (1): 77–87.

Chea, Chiam Chooi, J Tan, and J Huan. 2019. Higher Education 4.0: The Possibilities and Challenges. *Journal of Social Sciences and Humanities* 5 (2): 81–85.

Chik, Wan Nur Aswannah Wan and Arokiasamy, Lawrence. 2019. Perceived Higher Education Climate of Academics in Malaysian Private Institutions in Industry 4.0 - ProQuest. *Global Business and Management Research* 11 (1): 488–504. https://search.proquest.com/docview/2236129755?pq-origsite=gscholar.

Ciolacu, Monica, Ali Fallah Tehrani, Leon Binder, and Paul Mugur Svasta. 2018. Education 4.0-Artificial Intelligence Assisted Higher Education: Early Recognition System with Machine Learning to Support Students’ Success. In *2018 IEEE 24th International Symposium for Design and Technology in Electronic Packaging(SIITME)*, 23–30.

Davis, Matthew C, Rose Challenger, Dharshana N W Jayewardene, and Chris W Clegg. 2014. Advancing Socio-Technical Systems Thinking: A Call for Bravery. *Applied Ergonomics* 45 (2): 171–80.

Frank, Alejandro G, Glauco H S Mendes, Néstor F Ayala, and Antonio Ghezzi. 2019. Servitization and Industry 4.0 Convergence in the Digital Transformation of Product Firms: A Business Model Innovation Perspective. *Technological Forecasting and Social Change* 141: 341–51.

Gitelman, Lazar, Mikhail Kozhevnikov, and Olga Ryzhuk. 2019. Advance Management Education for Power-Engineering and Industry of the Future. *Sustainability* 11 (21): 5930.

Harper, Donta S. 2018. Competency-Based Learning for Organizational Managers. In *Enhancing Education Through Open Degree Programs and Prior Learning Assessment*, 66–84. IGI Global.

IE3, Consortium. 2020. THE PROJECT – Ie3. 2020. https://ie3.eu/the-project/.

Janssen, Daniela, Christian Tummel, Anja Richert, and Ingrid Isenhardt. 2016. Virtual Environments in Higher Education--Immersion as a Key Construct for Learning 4.0. *International Journal of Advanced Corporate Learning (IJAC)* 9 (2): 20–26.

Kiel, Daniel, Julian M Müller, Christian Arnold, and Kai-Ingo Voigt. 2017. Sustainable Industrial Value Creation: Benefits and Challenges of Industry 4.0. *International Journal of Innovation Management* 21 (08): 1740015.

Leseure, M, M Hudson-Smith, Veronica Martinez, Marko Bastl, Jennifer Kingston, and Stephen Evans. 2010. Challenges in Transforming Manufacturing Organisations into Product-Service Providers. *Journal of Manufacturing Technology Management*.

McClelland, David C. 1973. Testing for Competence Rather than for ‘Intelligence.’ *American Psychologist* 28 (1): 1–14. https://doi.org/10.1037/h0034092.

Moeuf, Alexandre, Robert Pellerin, Samir Lamouri, Simon Tamayo-Giraldo, and Rodolphe Barbaray. 2017. The Industrial Management of {SMEs} in the Era of Industry 4.0.

International Journal of Production Research 56 (3): 1118–36. https://doi.org/10.1080/00207543.2017.1372647.

Ordieres-Meré, Joaquín, Tomás Prieto Remón, and Jesús Rubio. 2020. Digitalization: An Opportunity for Contributing to Sustainability from Knowledge Creation. *Sustainability* 12 (4): 1460.

Paquette, Gilbert. 2014. A Competency-Based Ontology for Learning Design Repositories. *International Journal of Advanced Computer Science and Applications* 5 (1): 55–62.

Prifti, Loina, Marlene Knigge, Harald Kienegger, and Helmut Krcmar. 2017. A Competency Model for" Industrie 4.0" Employees. In *Wirtschaftsinformatik Conference*, 46–60.

Schuster, Katharina, Kerstin Groß, Rene Vossen, Anja Richert, and Sabina Jeschke. 2016. Preparing for Industry 4.0--Collaborative Virtual Learning Environments in Engineering Education. In *Engineering Education 4.0*, 477–87. Springer.

Ulewicz, Robert, and Kanchana Sethanan. 2019. Quality of Educational Services--Industry 4.0 Requirements. *Kvaliteta Obrazovnih Usluga-Zahtjevi* 4: 137–49.

Xu, Li Da, Eric L Xu, and Ling Li. 2018. Industry 4.0: State of the Art and Future Trends. *International Journal of Production Research* 56 (8): 2941–62.

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