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Special issue on 'transdisciplinary approaches to digital manufacturing for industry 4.0'

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## Editorial

### Special Issue on “Transdisciplinary approaches to digital manufacturing for Industry 4.0”

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Margherita Peruzzini<sup>a\*</sup>, Nel Wognum<sup>b</sup>, Cees Bil<sup>c</sup>, Josip Stjepandić<sup>d</sup>

<sup>a</sup>University of Modena and Reggio Emilia, Modena, Italy

<sup>b</sup>Delft University of Technology, Delft, The Netherlands

<sup>c</sup>Royal Melbourne Institute of Technology Melbourne, Australia

<sup>d</sup>PROSTEP AG, Darmstadt, Germany

\*Corresponding author: [margherita.peruzzini@unimore.it](mailto:margherita.peruzzini@unimore.it)

#### Biographical notes:

Margherita Peruzzini is Associate Professor at the Department of Engineering "Enzo Ferrari", University of Modena and Reggio Emilia, and works in the research groups of Methods and Tools for Industrial Engineering. She co-founded the X-in-the-Loop Simulation Lab ([www.xilab.unimore.it](http://www.xilab.unimore.it)) and she is part of the inter-department Lab (INTERMECH MO.RE.) that works on advanced mechanics for industrial applications. Her topics of research are: Digital Manufacturing, Virtual prototyping, Human-Centered Design, User Experience. She is part of the Board and Conference Coordinator of the International Society of Transdisciplinary Engineering (ISTE) <https://intsoctransde.org>. She is author of more than 130 publications.

Nel Wognum is a guest researcher at Technical University of Delft. She graduated in Medical Informatics in 1986 and received a PhD in Knowledge Systems in 1990. Since 1996, she has been involved in research in concurrent engineering and cross-organisation (supply-chain) collaboration in Technical University of Twente and in Wageningen University in The Netherlands. She is General Secretary of the International Society of Transdisciplinary Engineering (ISTE).

Cees Bil is Professor in Aerospace Systems Design at RMIT University in Melbourne, Australia, with a MS and PhD in Aerospace Engineering from Delft University of Technology in the Netherlands. He has worked in academia for about 30 years in teaching and research in aerospace design, dynamics and control, flight mechanics, unmanned air vehicles and ATM. More recently he is involved in knowledge-management, aerospace operations, lifecycle costing and sustainment. He is a member of the RAeS Australian Division Council and ICAS Programme Committee, AIAA Director Region VII and President of the International Society of Transdisciplinary Engineering (ISTE).

Josip Stjepandić is the head of business unit 3D Product Creation at PROSTEP AG. He is the author of various scientific articles and publications in the field of

The concept of Industry 4.0 (I4.0) outlines the vision of a smart factory characterised by the complete networking of all production parts and processes, consisting of real time control via cyber-physical systems, increased use of robots, intelligent and adaptable production systems, which should contribute to greater productivity through resource efficiency. Convergence of production and interaction, work and communication requires increasingly transdisciplinary competencies for creating a smart factory, which is economically successful and competitive. These competencies consist, among others, of divers expert knowledge, flexibility, and creativity for moving toward I4.0.

I4.0 is not just about machines, but also about people. The Internet of things, data and services are merging the physical and digital world. This is where people now move and work. Workers inside this new factory model are the bearers of this knowledge and the drivers of innovation. Modern factories should not only pay special attention to agile processes and sustainability, but also to social and human aspects. They should support sustainable development, resource-efficient production systems, innovation and a successful economy, and active participatory and collaborative processes. They should also anticipate and counterbalance the impact of technologies on human beings and societies.

Transdisciplinary Engineering (TE) is an emerging field that extends and evolves engineering approaches by transcending the technical disciplines. TE is an applied science field combining natural sciences, applied sciences, social sciences and humanities to achieve a higher level of comprehension and awareness of the context in which industrial products, processes, systems, and services will be implemented and experienced by users (Borsato et al., 2016). Research in TE also incorporates social science methodologies to acquire the necessary knowledge about users and context. TE is inherently aimed at solving ill-defined, socially relevant problems (Wognum et al., 2018). Many researchers have studied transdisciplinary processes and have tried to understand the essentials of transdisciplinarity.

Numerous engineering problems can be characterised as ill-defined and socially relevant, too. Although transdisciplinary engineering cannot widely be found in the literature yet, a transdisciplinary approach is deemed relevant for many complex engineering problems. An overview of the literature on research into transdisciplinary processes and their relevance in engineering domains has been recently published (Wognum et al., 2019).

Achieving an I4.0 environment is a complex problem. It is characterized by the need to create a vertical networking of smart production systems, such as smart factories and smart products, and the networking of smart logistics, production and marketing and smart services, with a strong needs-oriented, individualised and customer-specific production operation. In addition, strong horizontal integration by means of a new generation of global value-creation networks is needed, including integration of business partners and customers, and new business and cooperation models across countries and continents. Moreover, I4.0 is founded on acceleration through advanced technologies that will transform the manufacturing production. More specifically, isolated, optimised machines and/or cells will be aligned in a network to achieve a fully integrated, automated, and optimised production flow, leading to greater efficiencies and changing traditional

production relationships between suppliers, producers, and customers, as well as between human and machine.

The practical goals of a transdisciplinary approach to the design of manufacturing systems in a I4.0 context are related to avoiding loss and misuse in data exchange (Engelmann et al., 2018) and to achieve its potential benefits. IoTs and CPSs involve a high amount of data and information, but they have to be properly managed to improve human-machine interaction and properly monitored (Schmitt et al., 2018). They need to control the adaptive behaviours of both machines and interfaces (Beisheim et al., 2018). As a consequence, adopting a transdisciplinary approach not only requires inclusion of human factors in system design to be more efficient, adaptive, flexible and sustainable, and to manage the growing complexity of systems that are hard to manage and maintain (Peruzzini and Pellicciari, 2017), but also the collaboration between people with different scientific and practical background. An essential property of TE processes is, that they cannot be performed by one person, nor by one discipline alone.

In designing I4.0 environments it is important to realize that machines are becoming more and more digitised and technologically more advanced. They require more experience but also higher mental abilities, requiring continuous education. These trends can be divergent, and only the inclusion of people from different disciplines (technical as well as social) as well as people from practice in the design of industrial systems can overcome the currently increasingly higher demands due to changes in working conditions, new technologies, and new demands on workers (e.g., higher flexibility, extended knowledge, polyvalence) (Toomingas and Kilbom, 2007).

Different methodologies are required to bridge the gaps between technical and social sciences. They will bring the needed intelligence into the shop floor required to provide factories with flexible and adaptive behaviours (e.g., self-steering or continuous improvement teams). Next to different methodologies, technologies, like digital manufacturing help engineers and technicians to anticipate critical conditions and to envisage possible solutions. To include people from practice, a human-centred design approach could be adopted, which allows to correlate the workers' needs and the system features at different levels (considering the users, the context, the machine, and the interface) and to test the designed adaptability with virtual prototypes. A similar approach can be used to preserve cultural heritage (Xie, 2018).

In the context of I4.0, transdisciplinary-engineering methods can be successfully applied to solve complex problems linked to digital manufacturing (Rauch et al., 2018). This issue incorporates examples and applications of transdisciplinary approaches including digital knowledge management, Virtual Training, X-in-the-Loop Virtual Prototyping, Ontology-based models, Smart Maintenance, collaborative practices, and methods to include human factors and ergonomics, and pay attention to legal restrictions.

This special issue includes invited papers selected from contributions to the 25<sup>th</sup> International Conference on Transdisciplinary Engineering held in Modena, Italy, on 3-6 July 2018 (Peruzzini et al., 2018).

The authors come from traditional industrial countries, such as Italy in Europe and Brazil in America, but also numerous new emerging countries, such as China and India, to demonstrate that the attention to transdisciplinary engineering is widespread all over the world and represents a new topic of discussion shared among Industry and Academia.

In this issue six papers are included.

The first paper entitled "A review of the barriers, impacts and basic requirements for Industry 4.0" by Da Silva et al. presents an intrinsic scientific contribution to deploy I4.0

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in companies, by an extensive literature review based on empirical studies to give empirical evidences of I4.0 adoption. As result, it reports the main barriers, such as lack of financial resources and lack of infrastructure, and the most challenging impacts, such as relocation of people in the labour market, and benefits, respectively. It also provides a set of technological and managerial requirements for I4.0 implementation.

The second paper entitled “Using Taguchi and Neural Network Approaches in the Optimum Design of Product Development Process” by Ming-Chyuan et al. uses Taguchi method and neural networks for robust product design to help designers search for an optimum combination of variable characteristic values for a given product design problem. Data resulting from Taguchi experimental design are forwarded to the back-propagation network training process for algorithm simulation to predict the most suitable combination of variable characteristic values. The recommended combination of variable characteristic values is represented in a 3D form. The paper is multi-disciplinary characterized by the merge between artificial intelligence approach and engineering design issues. Experimental results indicate that the proposed procedures could enhance the efficiency of product design efforts.

The third paper entitled “Environment interaction model-driven smart products through-life design framework” by Zhang et al. proposes a high-profile design framework for guiding environment interaction model-driven smart products through-life design in the smart factory. It consists of a generic environment interaction model that help mapping out the interaction requirements between the smart product and other interaction elements, a smart product design process model, and a design strategy of smart products through-life design. Transdisciplinarity in this case is represented by the concept of smart product, which merges technical and social functions, and usually combines internal interactions with physical products and external interactions with the surrounding informational environment.

The fourth paper entitled “A Transdisciplinary Digital Approach for Tractor’s Human-Centered Design” by Peruzzini et al. focuses on the inclusion of users into the design process by the adoption of new tools to directly collected the users’ feedback for design optimization. In particular, it proposes a mixed reality set-up where humans are monitored and digitalized to easily evaluate the human-machine interaction, according to the I4.0 context. Such an approach is defined as transdisciplinary since it promotes collaboration within the design team and push to look at technical design issues by a human perspective, with the goal to early detect design criticalities and improve the overall system design. Industrial use cases have been developed to demonstrate the validity of the proposed approach; results have demonstrated potential improvements, in terms of time saving for design review and workers’ training, reduction of physical prototypes for design validation, reduction of late design and engineering changes, reduction of ergonomic issues, and global positive impact on time-to-market.

The fifth paper entitled “Systems Evaluation Methodology to attend the Digital Projects Requirements for Industry 4.0” by Ramos et al. presents an evaluation methodology between legacy and local systems, using multi-criteria decision making analysis methods, in order to verify if both attend the specifications of the organization’s digital transformation for industry 4.0. The model has been demonstrated through an automotive company case study in Brazil which have satellite plants in South America (Colombia) with local systems that need enhancing for implementation for I4.0 projects.

The sixth paper entitled “The Role Of Crowdsourcing In Industry 4.0: A Systematic Literature Review” by Vianna et al. presents an approach that seeks to identify the role of

crowdsourcing within the scope of Industry 4.0, starting from a literary review on scientific articles and discussing the role of crowdsourcing to support the implementation of smart technologies for Industry 4.0. The review identified a set of five categories of crowdsourcing application in Industry 4.0: product development; innovation; provision of data and information for manufacturing; crowd-sensing; and problem solving/troubleshooting. The study was also able to explore the relationship among Industry 4.0 factors and Internet of Things, Intelligent Production Systems, Big Data and Cloud Computing.

Finally, we would like to thank all the reviewers who gave their significant comments and suggestions for improving the published papers in this special issue. Thank you all the contributors to make the publication of this special issue. Special thanks should be given to Prof. Stephen T. Newman, editor-in-chief of the International Journal of Computer Integrated Manufacturing, and Dr. Aydin Nassehi, managing editor, who gave their great support.

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