International Journal of Business and Applied Social Science
E-ISSN: 2469-6501
VOL: 8, ISSUE: 11
November/2022
DOI: http://dx.doi.org/10.33642/ijbass.v8n11p8

Cultural Diversity within Cyber-Physical Systems

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ABSTRACT

In international business, it is widely accepted that the cultural diversity of organizational member's impacts operations. That is why interculturalists have developed approaches to managing this dimension of diversity within and across businesses for decades. When looking at operations in today's international companies, an increasing transformation towards conditions that are often described as Industry 4.0 can be observed. People interact with machines and software in so-called Cyber-Physical Systems (CPS). But the academic discourse regarding this transition mainly focuses on technical issues. The human factors have received limited attention and the role of culture within CPS has been widely neglected so far.

To fill this gap, the paper at hand reviews journal articles and conference proceedings from the disciplines of operations management and business informatics. The findings concerning the role of people in CPS have been aligned with concepts of intercultural management and managing diversity.

It has been found that the application of traditional concepts of describing cultural dimensions and their impact on interaction and cooperation are of limited usefulness when it comes to the integration of machines, software, and people with diverse backgrounds. Contemporary approaches to managing diversity appear more promising. Focusing on individual members instead of particular groups of members can improve the effectiveness and acceptance of CPS.

Keywords: **cultural diversity, intercultural management, cyber-physical system, industry 4.0**

Introduction

Manufacturing has always been subject to change. The way how resources are transformed into goods to satisfy human needs and generate wealth has faced both periods of constant evolution as well as revolutionary progress (Herterich et al., 2015). Mechanization, electrification, division of labor, automation, and robotics have frequently been named as drivers of these past revolutions in manufacturing. The latest disruptive transformation of value creation is driven by the phenomena of digitalization and interconnecting networks. This development is often characterized as the Fourth Industrial Revolution (e.g., Vaidya et al., 2018) and has been labeled as Industry 4.0.

Important key elements of Industry 4.0 environments are so-called Cyber-Physical Systems (CPS) systems that consist of digital and physical components. The physical components are interconnected, monitored, and controlled by embedded software (Davies,2015) which runs the physical systems through actuators. Artificial intelligence increasingly enables these systems to configure themselves, which leads to a growing autonomy of CPS. The multitude of different components results in a high level of complexity in interaction so the interoperability in CPS is regarded as critical (Chen et al., 2008).

This is why until now academic and political discourse as well as the resource allocation for practical applications have focused on technical aspects of CPS integration. But for a successful CPS development and management much more than just coordination aspects of software and mechanical systems has to be considered. Especially human factors demand more attention and have been recognized as a critical factor now (Frazzon et al., 2013). Still, the literature review reveals that the role of people within CPS has mainly been examined with a focus on changes in labor or human-machine interaction (e.g., Dautov et al., 2018; Douibi et al., 2021). In both fields, human beings are mostly conceptualized in a 'standardized' manner. Most studies do not consider diversity. Neither cultural diversity nor other dimensions of human diversity are explicitly addressed.

It is the purpose of this paper to undertake an attempt to close this research gap. The impact of diversity on the development and management of CPS is going to be examined with special regard to cultural diversity.

Materials and Methods

Journal articles and conference proceedings from the disciplines of operations management and business informatics have been reviewed to describe the current state of research regarding the role of people in Cyber-Physical Systems. The findings have been aligned with proven concepts of intercultural management and managing diversity. In conclusion, an approach to adequately address diversity in Industry 4.0 environments has been suggested.

Results

The vast majority of publications in the field of CPS and Industry 4.0 deals with technical issues. The role of people in these settings has long been regarded as a sideline of research. Only recently it has attracted more interest since questions in the

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context of changing job profiles, labor conditions, and forms of interaction between machines and human beings have come into focus. In the technology-centered discourse, human contribution has often been regarded as increasingly replaceable (Huchler, 2016). But this assumption needs to be revised. It has become evident that an increasing differentiation of job profiles can be expected instead. Simple tasks will be substituted to a high degree by more responsible jobs which require high levels of qualification, specialization, and self-initiative. Physical activity profiles will be increasingly supported by robots, which implies human-machine interaction constantly (Hirsch-Kreinsen, 2015). As a result of these findings, some articles pointed out that the term 'Cyber-Physical System' falls short and suggested to use of the term 'Socio-Cyber-Physical Systems' instead (e.g., Fei-Yue, 2010; Liu et al., 2011; Frazzon et al., 2013; Böhle & Huchler, 2017). Nevertheless, the only article that mentions the fact that people differ in terms of cultural backgrounds and mental models is Frazzon et al.'s paper of 2013.

This is surprising since most authors concur in their descriptions of the dynamic environments in which CPS are embedded. See and Kersten (2017) have summarized the drivers most often mentioned in the literature: Digital transformation, complexity, volatility, demographic change, globalization, and change of values require adaptation of the systems to their dynamic environments. In doing so, several dimensions of diversity are addressed. But again, the fact that these drivers may lead to an increased level of diversity among people involved in CPS has not been reflected. Only an indirect approach to the impact of diversity on the development of CPS can be found in a contribution made by the McKinsey Global Institute (2018) to the Tech4Good Summit organized by the French government. The paper says that the development of CPS depends, among other things, on social norms and the social acceptance of the technologies applied (such as artificial intelligence) and that adoption of these technologies "will continue to vary significantly across countries and sectors because of differences in the above factors" (McKinsey Global Institute, 2018, p. 3). So, cultural phenomena lead to the differentiation of behaviors and patterns of adaptation.

When aligning these thoughts with concepts from the field of intercultural management, several touch points can be identified. In terms of acceptance, natural language processing is often perceived as a breakthrough for human-machine interaction. Arthur (2017) points out that it is possible "to talk to a computer as we would to another human being" (Arthur, 2017, p. 3). But what about the fact that people follow very different communication patterns? A classic example of examining these different patterns from an intercultural point of view is Hall's (1989) description of role perception in intercultural encounters. Depending on their cultural backgrounds, some people ascribe the responsibility for successful communication to the speaker, others to the listener. In the first case, perception is driven by the assumption that the content of communication has not been well explicated. In the latter case, someone may have the perception that the listener failed to interpret what was said correctly. When communication partners follow different assumptions, misunderstandings are likely. But how should the computer behave? How to interpret the received content and how combine it with additional impressions such as facial expressions? Which expectations of the human interaction partners have to be met so that the interaction with the CPS is accepted by the person who interacts?

The example of allocating different communication patterns to different groups of people reflects a tradition in intercultural management that analyses and describes cultures based on certain dimensions. The well-known approaches of Hall (1959), Kluckhohn and Strodtbeck (1961), Triandis (1972), Hofstede (1980), and Trompenaars (1993) all stand in this tradition. Good knowledge of the target culture should enable people to more effectively interact with counterparts from this culture. But since today's workforces are extremely multicultural and multifaceted, focusing on certain cultural standards is of limited usage. This is why contemporary approaches to managing diversity emphasize the importance of turning towards individual organization members instead of addressing entire groups (Thomas & Ely, 1996; Lauring, 2013; Phillips, 2014).

Applied to Industry 4.0 environments this makes a fundamental shift. Standardization is the orthodoxy of operations management and business informatics. Implementing and sticking to standards is the modus operandi for managing technical problems which stem from a multitude of algorithms and interfaces. However, these problems are far from being solved (Herterich et al., 2015) and now human factors create additional problems in developing and running CPS. Acknowledging this broadens the scope of the subject and increases complexity. Accepting that a differentiated or even an individual approach to addressing people within CPS is mandatory to successfully run these often globally connected networks. It is a huge step beyond what operations managers and computer scientists have dealt with in the past.

Discussion

The creation and interconnection of CPS is the cutting edge of operations management in international business. The value creation potential is widely regarded as immense, just like the challenges posed by it. Until now the main focus of both scientific discourse and practical application has been put on technical problems, although it becomes more and more evident that a concept that helps to analyze the challenges from more than a purely technical point of view, can contribute to making CPS more effective and useable. Nevertheless, the fact that people differ in their behaviors, perceptions, values, and communication patterns and the knowledge that these differences have an impact on people's level of acceptance of CPS and their way of interacting with them, is widely neglected.

Since CPS cannot operate without human contributions, the involvement of people directly affects the outcomes of the systems. From an operations management's point of view, clues on how to address people's diversity to optimize the effectiveness of CPS would be beneficial. But, as seen in this

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paper, conventional approaches to managing people with diverse cultural backgrounds fall short in Industry 4.0 environments. On the one hand, it is the nature of CPS that geographic boundaries are of nearly no relevance to them (Böhle & Huchler, 2017). On the other hand, people draw cultural inputs from a multitude of settings and influences. How these inputs are processed and used varies, too?

The occurrence of CPS is not limited to the field of global manufacturing. Even small, local suppliers can implement CPS and benefit from the interconnection with systems owned by their customers next door. In such a setting the people involved could stem from a relatively homogeneous cultural background. But in the majority of cases components in different locations and across large distances are integrated into a network. People from different origins, living in different regions and under different conditions, become elements and managers of these systems. They bring in a multitude of experiences, use them in different ways, and show different behaviors in their interaction with CPS (Scheible,2015). Some of these experiences result in explicit knowledge, but much of the experiential knowledge remains implicit (Polanyi, 1985). It is this implicit knowledge that enables human beings to flexibly adapt their actions to the varying requirements of a situation, without much reflection and planning (Huchler, 2016).

The point is that it is impossible to identify any principles or laws to determine which experiential knowledge leads to a certain attitude towards and behavior within Cyber-Physical Systems. When it comes to the above-mentioned "clues", one can only recommend that managers turn to the individual. The here-cited article by Thomas and Ely (1996) can be regarded as the foundation of an up-to-date approach to managing diversity in general. The authors have described a fundamental shift in handling diversity in organizational contexts. Individual support of organization members, appreciation, and exploitation of individual contributions lead to a win-win situation.

The application of these ideas to Industry 4.0 environments makes sense and seems promising. Nevertheless, this paper is exploratory and the subject needs further conceptualization. The concept of applying a managing diversity approach to deal with the impacts of multiple cultural backgrounds of people involved in CPS is new and has been developed on theoretic considerations only.

To find evidence of how the diversity of people involved in CPS is approached in the disciplines of operations management and business informatics, the latest articles and conference proceedings were used. A systematic literature review was not conducted since the number of available studies meeting the inclusion criteria had simply been too small for a systematic approach.

Conclusion

In conclusion, it can be stated that CPS is complex. Many technical challenges are still unsolved and deserve the attention of practitioners and researchers they receive. However, the cultural diversity of people who are involved in CPS needs to be addressed as well to enable smooth interaction of all elements of the systems.

Though traditional concepts of considering cultural dimensions are of little usage for the management of CPS, contemporary approaches to managing diversity offer valuable clues to operations managers in this context. However, a lot of further research is needed. The appropriateness and the feasibility of the herein-before-suggested concept must be tested and discussed, future studies which examine the human factors in CPS should be reviewed, and last but not least, it should be monitored how human-machine interaction in Industry 4.0 environments will proceed in the future.

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