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Some reflections on the methodology of multidisciplinary empirical research conducted within the paradigms: "Education 4.0", "Industry 4.0" and "Society 5.0"

Abstract: The article is an attempt to characterize the methodology of multidisciplinary empirical research, designed and implemented within technical, exact, natural, social, and humanistic sciences. Three paradigms have been characterized: Education 4.0, Industry 4.0, and Society 5.0. The author's attention was drawn to the need for a clear formulation of detailed concepts as well as their content and context. The types of possible empirical research and the methods and techniques used in them were presented, attention was also drawn to the importance of the model used in the research. It was considered necessary to disseminate methodological knowledge for the reliable execution of empirical research, allowing for its repeatability, verification, and evaluation.

Keywords: methodology, multidisciplinarity, paradigm, Education 4.0, Industry 4.0. Society 5.0, post-digital world, model

Introduction

Multiculturalism in the era of globalization is characteristic not only for certain societies of developed countries, e.g., the USA. Canada or Australia, but it is also a result of the migration of Asian or African societies to other regions of the world, including Europe. European society is becoming more and more multicultural because of the migration process of residents not only of other continents, but also of people moving within the European Union countries, e.g. in search for high-quality education (e.g. under ERASMUS plus

programs) and thus obtaining education recognized in many countries or getting a well-paid job. As a result of this process, multicultural student classes, student groups or work teams are formed. Therefore, it becomes necessary to introduce intercultural education in secondary school (Lewowicki, Ogrodzka-Mazur and Szczurek-Boruta, 2000, pp. 21–35). These processes and phenomena are becoming more and more dynamic due to the implementation of new technologies into education, economy, and social systems, especially the Artificial Intelligence, which exponentially causes the development of enterprises and organizations, promotes the emergence of new professions, provides education with new teaching tools, and enables people to communicate faster and more effectively.

For several years, all over the world intensive theoretical studies and empirical research have been conducted under the current scientific paradigms: Education 4.0, Industry 4.0, and Society 5.0. Empirical research, which increasingly has a multidisciplinary character, combines distant (not only scientific) disciplines, but also fields of science. The studies are conducted by multidisciplinary and often multicultural research teams, using the general methodology of sciences or the tools of different sciences and disciplines applied to find an explanation to the issue under study.

The above mentioned paradigms closely correlate and are related to the long-term, dynamic development of digital media, used in many aspects of the modern individual, social and professional group functions, as well as in the functioning of organizations, enterprises, and factories. Problems in today's world have become complicated and complex. The processes of industrialization and urbanization, globalization and liberalization, the spiral development of modern society's digitization, called digital transformation, and everyday life algorithmization have contributed to the synthetic view of economy, not only of individual countries, such as Germany, Japan, or the USA, but also their integrated federations, such as the European Union.

The aim of the study is to characterize multidisciplinary empirical research, designed within the framework of scientific methodology and concerning research problems related to scientific paradigms: Education 4.0, Industry 4.0, and Society 5.0. The study is based on the hermeneutical analysis of the selected theories and examples of multidisciplinary research.

Characteristics of the paradigms: Education 4.0, Industry 4.0, and Society 5.0

The term "paradigm" is treated here as a model theory of fundamental importance for each field of study, which allows researchers in a specific field to adopt assumptions considered to be given facts and focus on solving more specific problems (Kuhn, 1970, pp. 26–28).

Education 4.0

Many of today's children will work in new job types that do not exist yet, with an increased focus on both digital and socio-emotional skills in the coming years. The gap between education and jobs is further widened by limited innovation in learning systems, which were largely designed to mirror factory-style growth models. The Fourth Industrial Revolution has made it imperative that education systems adapt. The Education 4.0 initiative aims to better prepare the next generation of talents through a transformation in primary and secondary education. The initiative will trigger impact through four interconnected interventions: (1) Implementing new measurement mechanisms for Education 4.0 skills; (2) Mainstreaming technology-enhanced Education 4.0 learning experiences; (3) Empowering the Education 4.0 workforce and (4) Setting Education 4.0 country-level standards and priorities (cf. https://www.weforum.org/projects/learning-4–0).

Experts and scientists from many countries believe that these concepts require a change in economic law, as well as the implementation of a reform package concerning: the system of education and modern educational process, the development of social communication, the standardization (including Internet) and development of planning, the implementation of AI in all areas of human activity, while priority is granted to the implementation of education and information programmes.

Industry 4.0 (Economy 4.0)

The concept of Industry 4.0 is not unequivocal, as it includes a number of other concepts related to processes involving the use of new technologies, such as: Internet of Things (IoT) and Industrial Internet of Things (IIoT)), computing clouds (CC), big data analysis (BD), artificial intelligence (AI), as

well as incremental printing (3D printers), Augmented Reality (AR), Collaborative Robots (Cobots), or Cybersecurity. The economy is a social system, a set of cooperative rules within the limits described by law and Economy 4.0 is a concept of an industrial and cultural revolution, stimulated by the development and widespread use of digital media. It includes the processes of automation as well as data processing and exchange, the implementation of various new technologies, allowing the construction of so-called cyber-physical systems and changing the methods of producing goods. This new way of manufacturing is implemented through the digitization of production in which devices and technological systems relate to each other, also via the Internet, and where large sets of production data are analyzed.

The second dimension of the Industry 4.0 concept is related to production management, an organization's activities and to the value creation chain (Prades et al., 2013, pp. 115–122; Benitez et al., 2012, pp. 2432–2441). One can directly talk about the values in the processed data (Oracle, 2020) (as well as about technology evaluation), in which linear processes and traditional pyramids of management systems are transformed into a network of connections and non-linear production. The non-linearity of modern production processes is a reflection of the non-linearity in globalization processes.

The idea of Industry 4.0 (Economy), a term first used during the Hannover Messe in 2011, is a concept developed by German scientists and experts. It has contributed to the European Commission's development of the general concept of EU economic development which takes place until 2050. This idea has been implemented in many developed countries: the USA. Japan, South Korea, Germany (Liao et al., 2017, pp. 3609–3629; Johnson, 2019, pp. 21–23; Ganzari and Errasti, 2016, pp. 119–1128).

Society 5.0

People are functioning today in a society which is most often called the information society, but is also referred to as the knowledge society, civil society, postmodern society, or post-digital society, heading towards the society of the future called society 5.0 or, interchangeably, Super Smart Society. This concept of modern society has been developed by Japanese scientists. In January 2016, the Japanese government adopted the Fifth Science and Technology Basic Plan, which led to the transition from industry 4.0 to society 5.0 (5th Science and Technology Basic Plan 2020; Keidaren – Japan Business Federation 2020 and a UNESCO Science Report, 2020). All aspects of such a so-

ciety, including work in industry, are to be shaped by the latest techniques and technologies which were listed on the previous page. The Japanese define the society 5.0 as a symbol of interpersonal relations focused on the human (a human-centric society). It uses economic progress to solve social problems with the help of the system and technologies that strongly integrate cyberspace with physical, real space. The interpenetration of both real and virtual reality, and therefore embedding cyberspace in the real world, leads to the establishment of augmented reality (AR). The new social order is also called a super-intelligent, creative society or a society of imagination. In the new society 5.0 we are talking about collective intelligence functioning in the web.

The innovative concept of the next social order was a result of Japan's problems related to energy shortages and its import from abroad, limited natural resources and an aging society, therefore the parallels between Japan, Germany and other industrialized countries are becoming visible.

In conclusion, it can be stated that industrial and social transformations result from digital transformation and especially from the introduction to our life of the Artificial Intelligence. It must be remembered that technological and social development must take place simultaneously. When technological development is faster, future social problems will be very difficult to solve.

Selected aspects of the methodology of multidisciplinary research. Multidisciplinarity, interdisciplinarity, and transdisciplinarity

The definitions of terms such as "multidisciplinarity", "interdisciplinarity" or "transdisciplinarity" are vague and not well differentiated. The distinctions between these concepts revolve around the degree of collaboration and cross-fertilization between the disciplines. A multidisciplinary approach means that knowledge of several disciplines is used to a given problem and these disciplines are supplementary to one another in such a way that it is possible to draw clearly cut conclusions, free from being branded as isolated or partial. In multidisciplinary research, several fields are involved in a certain line of inquiry which is specific to a problem or region. Multidisciplinarity also means that a particular problem or an observable phenomenon is considered from different disciplinary viewpoints. This eventually involves a confrontation of different scientific approaches (concepts, models, methods, findings), in the hope that together the multidisciplinary research team will succeed in producing a coherent picture of the relevant problem, its possible explanations and potential solutions (Uiterkamp and Vlek, 2007,

pp. 175–197). It can be defined as a search for knowledge through an objective and systemic method, for an original contribution to the existing stock of knowledge, involving a combination of several disciplines and methods (Molteberg and Bergstrom, 2000).

In an interdisciplinary endeavour, the relevant parts (concepts, models, methods, findings) of different scientific disciplines are merged and neatly integrated. Thus, for example, a natural science model concerning the spreading of air pollution might be coupled with a behavioural science model of using motorized transport; or an economic model of consumer utility maximization might be combined with a psychological model of habit formation and seeking a social status (Uiterkamp and Vlek, 2007, pp. 175–197).

Transdisciplinarity signifies the crossing of boundaries between scientific and non-scientific communities. It represents a set of lively interactions between scientists on the one hand, and representatives of industry, government, and/or civil society on the other. For scientific researchers transdisciplinarity means "reaching out to society" (Uiterkamp and Vleck, 2007, pp. 175–197).

Science aims to describe, explain, and understand natural, technical, exact, social, cultural, and educational phenomena and processes. Since all the sciences, apart from mathematics and logic, are empirical sciences, the methodology of empirical, but at the same time multidisciplinary research will be considered here, because it will apply to such disciplines as: philosophy, sociology, psychology, pedagogy, (inter)cultural studies, linguistics, computer science, automation, cybernetics, robotics, mechatronics, management, economics, production engineering, transport, neurobiology, and physics. Economists for example may focus on cost-effective mechanisms; sociologists on empowering the poor and addressing social inequity; anthropologists on acknowledging local customs, practices, and social structures; psychologists on the attribution of responsibility, or individual relations at work (Karlsson, 2007, pp. 103–126); and development practitioners on relations with the local community (Eyben, 2005, pp. 98–107). Without inclusion of these diverse perspectives, and the interaction of economic, sociological, and anthropological/cultural variables, the risk of confirmation bias becomes, logically enough, elevated (Clements, 2008). All members of a team should be involved in all aspects of the study: design, data collection and analysis. Multidisciplinary research is a learning experience in which the participants also learn from each other.

Model of a phenomenon or a process

Theorists often try to create conceptual systems by developing a model (an ontological, semantic, and syntactic model, which are all related to the concepts present in any particular model, their meaning, mutual relations, environment and context) of the analyzed phenomenon, process, event, or thing (an object). Therefore, in simple terms, the model may be an image of something (e.g. a model of a vehicle, machine, robot, or a team or organization). However, in social sciences, models are symbolic rather than physical. This means that the characteristics of empirical phenomena, including their components and inter – connections, are recreated through the logical ordering of concepts. Therefore, the model in social sciences is the abstract presentation of reality in a way that allows to organize and simplify the view of reality by recreating its basic characteristics (Helmer, 1996, pp. 127–128).

Methods and techniques in multidisciplinary research

A multidisciplinary research project should be developed very carefully and should be repeatedly discussed in the team. Due to the general nature of the research concepts presented in this study, the methodological structure of the project should include the following stages: (a) characteristics of the designed research, its subject and objectives (e.g. theoretical, cognitive and practical ones); (b) research issues; (c) variables and their indicators as well as the hypotheses for nomothetic, quantitative studies, which should be falsified by statistical tests; (d) methods, techniques and research tools used in the studies; (e) characteristics of the research field and the subjects (e.g. people, things, devices, materials, documents, processes, etc.).

Referring to the general methodology of empirical research, it can be concluded that under the Education 4.0, Industry 4.0 (Economy 4.0) and Society 5.0 paradigm, both quantitative and qualitative empirical research can be conducted. The following general methods are used in empirical research: abstraction, analysis and synthesis, induction and deduction, modeling, comparison, experiment, testing, the historical method, and logical scientific cognition. Qualitative research involves, among others, the following detailed methods: monography (e.g. of a multicultural team, organization, enterprise, factory, etc.), case studies (or case-by-case methods), ethnography (such as internet ethnography), action research, and grounded theory. In quantitative research,

the method of a multidisciplinary experiment carried out in the natural functional conditions of the organization (enterprise) is used, yet not exclusively (e.g. to determine the effectiveness of a new production method or cooperation between enterprises, to diagnose a new device performance – e.g. a robot, or work efficiency with the use of AI, to check the effectiveness of a new management method, a specific type of multicultural team cooperation, or of new software, etc.). It is also necessary to use the method of diagnostic survey, which involves an analysis of documents and products of activity (work), a standardized online survey, various types of interviews and observations, as well as tests. The so-called mixed research is most often carried out, e.g. quantitative-qualitative, depending on the form and content of research questions. The research will be largely team-based, usually composed of research engineers, industrial engineers (practitioners), representatives of exact and/or natural sciences, researchers in social sciences and/or humanities, representatives of the government and local authorities. An effective multidisciplinary process is likely to require some "softer" human skills – like teamwork, leadership, tolerance of difference and ambiguity, and selflessness (Fanelli, 2007).

A critical question in an empirical study is sampling (e.g., people, documents, devices, processes, etc.), which may be random (it is then necessary to provide and justify the sampling frame) or purposeful (it is also important to provide justification).

In the phase of research design, it often becomes necessary to construct and analyze a model of a phenomenon or process course, based on a critical analysis of theories describing them and the latest results of empirical research published over the last five years. The model allows researchers to develop the course of the analyzed phenomenon, or at least to indicate the most important variables that determine the course of the explored phenomenon or process. The construction of the model helps researchers to understand difficult questions, and to visualize the probable course of the phenomenon. That is the reason why in many works pertaining to the Industry 4.0 paradigm, researchers construct models of various phenomena or processes to illustrate their course better, to indicate important factors/variables and to demonstrate the obtained changes.

For example, Flavio Tonelli (2016, pp. 122–127) and his colleagues proposed the Manufacturing Value Modeling Methodology and then the analysis of that model with the use of the Value Modeler Tool. This allowed for a comprehensive analysis of the factors creating value in the analyzed organization. In qualitative research, scientists used a critical literature analysis of

the subject, concerning the production of quality and a research area analysis, related to the process of improving the functions of the organization, strategic management, the management of values, management design and management benefits. The authors identified different aspects of creating an added value, the importance of competition, and methods of risk and cost reduction. The goal of the research was to develop what is called a Value Map and is closely related to the features of the analyzed organization, its operating environment and market trends.

A three-step model of diversifying the vision of the cooperation process, strategy and construction of activities was developed by Jaione Ganzarai and Nekane Errasti (2016, pp. 1119–1128) for railway companies under the Industry 4.0 paradigm. The authors think that the dynamic development of this industrial sector creates new opportunities for cooperation between enterprises which have individual development visions, but the vision of cooperation between them is compliant with the analyzed paradigm of effective development.

In his work, Michele Gattullo and colleagues (2019, pp. 276–286) proposed an "innovative" methodology aimed at supporting the authors of technical documentation or the usage of augmented reality (AR) interfaces. The authors applied the conversion of the existing traditional documentation methodology to develop a set of new AR use activities which comply with Industry 4.0 paradigm foundations. The methodology was based on the optimization of the text written in simplified technical English, two-dimensional graphic symbols were introduced, and the content was structured by a combination of Darwin Information Typing Architecture (DITA) and Information Mapping (IM).

Conclusions

Year after year, empirical research, designed and implemented within the discussed paradigms, will appear in the world with growing frequency – starting from simple models of devices and process analyses, through the simulation of phenomena, to the case studies, monographs, and then experiments in multidisciplinary research, in which representatives of various scientific disciplines, practitioners and representatives of governments will take part. One should be carefully prepared for research of that kind. It should be widely proclaimed that cooperation between scientific disciplines, which are much different from one another, or cross-domain cooperation is possible and can

be fruitful, if methodological knowledge is shared earlier and if teams precisely define their ideas and use understandable models, based on the latest, reliable, and repeatable results of scientific research. According to Kazimierz Ajdukiewicz (1983, p. 73), scientific cognition is intersubjectively communicable and intersubjectively controlled. Repetition of research while obtaining similar results (within the margin of error) by researchers or research teams, as well as their objective interpretation, is a confirmation of the legitimacy of the applied theories and models, the reliability of the research and the repeatability of the phenomenon (Polit and Beck, 2006). Without an objective interpretation of research results, breakthroughs in science, its development would be impossible. All in all, in their studies, researchers quantify (measure and evaluate) a phenomenon and establish relations with other phenomena (Vance et al., 2013, pp. 67–75).

Multidisciplinary research offers an opportunity for the international development research community to become more broadly consistent with the key principles in the developmental policy. Linking development policies to multidisciplinary research practice also presents an opportunity to minimize the risk of "confirmation bias" (Easterly, 2006).

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