INDUSTRY 4.0 AND SOCIETY 5.0: VISIONS OF A SUSTAINABLE FUTURE

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I. The domain of Industry 4.0: Vision, Strategy and Key Enabling Technologies

Industry 4.0 is generally understood as a vision and strategy as outlined by the German strategy "Industrie 4.0". The architectures and building blocks of the future of smart manufacturing have matured a great deal since 2011 – though some technologies are still emerging slowly, like augmented reality and some may perhaps "never" happen – like fully autonomous, self-adjusting machines (and driverless cars).

The most important characteristic of technology enabling the Industrial Internet of things (aka Industry 4.0) is connectivity, the wired and wireless ability our machines and operators have, in principle in order to exchange data with and without human support – in real time. However, as for the human-centered internet we all know, and increasingly need to both work and play, not least in a pandemic – the massive possible exchange of data and information comes with serious concerns. The most severe is perhaps security and safety – in particular in connection with safety-critical systems and processes involving the cooperation of humans and machines. The Industry Internet Consortium (IIC) has placed "Trustworthiness" as a design criterion for the Industrial Internet of Things, while "Interoperability" is the key motivation and driver for change, not least for efficient (inter-)governmental and enterprise-wide cooperation (ISA², IIC). Recently, Gaia-X in Europe has placed the key concerns of "trust", "interoperability" and "sovereign" data as the motivation for a federated, open platform and architecture for the future of IT infrastructure that enables cloud computing without compromising self-ownership of data.

As an example of the technological challenges involved in realizing "Industry 4.0", consider the requirement of Real-time data exchange – needed for e.g. remote-control over the internet and to enable efficient cyber-physical systems in general. Delays of seconds may be tolerated in human-human communications, as supported by regular TCP/IP-networks, but delays in the milliseconds range may be critical for machine-to-machine data-exchange; real-time data transaction remains in development [1].

Cyber-Physical Systems, and various software/machine learning approaches to "smart systems for manufacturing" such as "Multi-Agent Systems" offer many opportunities for research and development, in particular for research on ICT and computer science skills in smart manufacturing.

A few applications (API's) will find niche-use cases very soon, or are already in place, while others are less mature. For logistics and real-time adaptive planning, automation and machine-to-machine data-exchange will continue to enhance interoperability. Examples include shipping and handling supported by ERP/MES-software to complement best practice "Lean" supply chains. Future manufacturing information systems will likely still have many forms of "human-in-the-loop" decision support and continue to be customer-focused, finding a balance between efficiency, flexibility and customer-as-decision-maker when possible. As such, Tesla is perhaps the prime example of a "Industry 4.0" ready automotive company, in much the same way as the Ford Motor Company become the prime example of a new era of mass-production of complex products in what may be called "Industry 2.0" using the usual taxonomy outlined by "Industrie 4.0". Since the 1960's, low cost and increasingly capable control systems, computers, mobile devices, sensors and actuators based on silicon semiconductors have followed what is generally known as Moore's law. Robotics and flexible automation is still in development and at various levels of "Industry 3.0" (or 3.5) - depending on your point of view, and the level of automation etc. However, consumer-grade ICT has been evolving much faster than IT/OT-systems in manufacturing - hence the vision "Industry 4.0" and strategies to fully exploit IT-capabilities such as "cloud"-based IT infrastructures.

In Europe, the recent "Gaia-X" project initiative places citizens, consumers and SME's in the centre of attention for future smart, sustainable cities and society.

The architecture of Gaia-X is based on the principle of decentralisation. Gaia-X is the result of a multitude of individual platforms that all follow a common standard – the Gaia-X standard. Together, we are developing

a data infrastructure based on the values of openness, transparency, and trust. So, what emerges is not a cloud, but a networked system that links many cloud services providers together. [2]

Gaia-X thus aims to enhance the sharing of (personal) data in a federated cloud environment - while letting the data remain controlled by the individual. The challenge of empowering citizens through education at all levels will have to be tackled through this and similar initiatives.

II. International collaboration within Industry 4.0 Education

The Fourth industrial revolution generates new opportunities for international scientific and technical cooperation. Industry 4.0 processes have covered different branches of the world economy. Many businesses have already started implementing Industry 4.0 technologies (fig.1). According to [3, p. 6], “companies are now experiencing major benefits in terms of lower costs, improved efficiencies, increased yield, mass customization and most importantly new revenue and business models”. Some professional organizations (such as the Association of Industrial Automation of Ukraine [4]) promote the idea of Industry 4.0 at the level of business, government, and education.

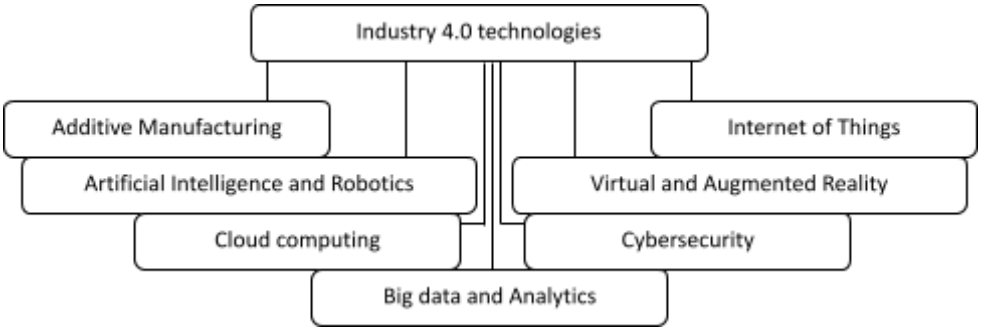

Figure 1. Main Industry 4.0 technologies [3]

Since 2018, a project of collaboration between Norwegian University of Science and Technology (NTNU) and National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute” (KPI) aimed at improving higher education in the field of Industry 4.0 through the exchange of knowledge and experience. The main outcomes of this collaboration are as follows:

1. Developing new educational programmes related to topics of Industry 4.0 and Additive Manufacturing at partner universities, improving these elements of the higher education systems in Norway and Ukraine.
2. Strengthening and expanding the cooperation between the partner institutions with a long-term perspective of writing joint project applications and publications on topics related to the institutions’ focus areas and strategies.
3. The exchange of staff and students, supporting both of the above points as well as intercultural understanding and cooperation.

The project’s inception involved staff from several NTNU and KPI departments, and was built upon good personal and academic relations forged through a strong cooperation since 2010, when NTNU in Gjøvik (then the Gjøvik University College) incorporated sustainability as a central part of its strategy and found KPI a suitable partner for cooperation in this field. A formal project cooperation commenced in 2011 with funding from SIU, the Norwegian Centre for internationalization of education (later DIKU, now HKDIR, the Norwegian Directorate for Higher Education and Skills).

The initial project proposal for the current iteration of our project cooperation emphasized the development of an attractive and effective curriculum for industry 4.0, additive manufacturing and related disciplines, as well as the improvement of pedagogical practices using new technologies, such as a Festo didactic learning factory, which is currently installed at NTNU and used in industry 4.0 education.

The exchange of students from KPI to NTNU, too, was an integral part of this proposal: Indeed, despite the ever-ongoing COVID-19 pandemic, we have been able to complete most of the planned student mobilities. The students’ cross-border activities have contributed to several publications in scientific journals.

In July 2019, a delegation from NTNU visited Kyiv and Ukraine, with site visits at several exciting and innovative Ukrainian manufacturing businesses. This visit strengthened the existing cooperation as well as intercultural familiarity, and an updated Memorandum of Understanding between the two institutions was signed, with the intention of further, expanded cooperation in future projects.

In September 2019, the NTNU-KPI group participated, in cooperation with the INMAN project – an INTPART project involving NTNU, IIT Hyderabad (India) and Waseda University (Japan) – in the NTNU Sustainable and Circular Manufacturing Summer School, with eight participants from KPI joining the event physically and several others online. This resulted, among other things, in the creation of a circular manufacturing MOOC, publicly available through NTNU's panopto system.

The following year, in September 2020, the Eurasia 2020 summer school was organized in Kyiv as an online event, a format mandated by the pandemic, with the topic "Sustainable manufacturing in Industry 4.0: Technologies and solutions", with lecturers from KPI, NTNU, and industry both in the Nordics and in Ukraine. Among the 234 participants were representatives of HEIs, industry and the NGO sector.

III. Future Focus

We believe that the cooperation of universities and the development of education in Industry 4.0 will help create the basis for development towards a "Society 5.0" in both partner countries and beyond. We acknowledge the existence of a significant number of obstacles to the realization of the objectives of cooperation, in particular the existing restrictions due to the pandemic. However, digital collaboration will enable future collaborations with more partners - including a system of "open innovation".

The main expected outputs of the joint KPI-NTNU project are as follows:

1. Further development of the subjects is to be adopted and included in the educational programs (each 7,5 ECTS) at NTNU and KPI: Additive Manufacturing Technologies, Experts in teams, Industry 4.0, Manufacturing Management, Materials and process selection, Product Development and Project work.
2. Exchange of experience and competence in the previously mentioned fields of studies in order to develop new knowledge.
3. Student long- and short-term exchange.
4. Staff short-term exchange.
5. Organizing a summer school with further publication of scientific and/or methodological articles.
6. Recruiting PhD fellows that would work on topics related to the developed courses.

The implementation of these tasks is an important condition for the formation of the intellectual potential of universities, which will contribute to the improvement of the national innovation system. This collaboration in the field of education enables further commercialization of innovations through the integration of education, science, and business, considering the feasibility of Ukraine's integration into the European digital space. The designated goal may be achieved through the implementation of a number of tasks, namely:

- diagnostics of the educational services market and the labour market;
- creation of an innovative educational laboratory using business simulators;
- development and implementation of educational technologies for training a new generation of specialists in the field of economics and management;
- the interdisciplinary and cross-industry transfer of educational technologies.

Summarizing the above, we note that the exchange of experience and knowledge in the field of Industry 4.0 is a necessary condition for strengthening the scientific potential of the university as a leading link in the formation of the intellectual potential of society. The problem of manufacturing enterprises of training and hiring personnel with the necessary knowledge, who will be able to introduce the use of Industry 4.0 and society 5.0 [5] technologies into their business organization models, remains important. The rapid development of technology coupled with the new requirements of a changing market underline the relevance and importance of developments in the direction of Industry 4.0 for business, which open new horizons for international scientific and technological cooperation.

References:

1. Bruckner et al., "An Introduction to OPC UA TSN for Industrial Communication Systems," in Proceedings of the IEEE, vol. 107, no. 6, pp. 1121-1131, June 2019, doi: 10.1109/JPROC.2018.2888703
2. “Gaia-X”: “What is Gaia-X”. Official website: https://www.gaia-x.eu/what-is-gaia-x Accessed 22.02.22
3. Mehta D., Hamke A.K. (2019). In-depth: Industry 4.0 2019: Statista Digital Market Outlook (August, 2019). Statista. 102 p. URL: https://www.statista.com/study/66974/in-depth-industry-40/. Association of Industrial Automation of Ukraine (APPAU). Official website. URL: https://appau.org.ua/en/
4. Association of Industrial Automation of Ukraine (APPAU). Official website. URL: https://appau.org.ua/en/ Accessed 18.02.22
5. Aquilani, B.; Piccarozzi, M.; Abbate, T.; Codini, A. The Role of Open Innovation and Value Co-creation in the Challenging Transition from Industry 4.0 to Society 5.0: Toward a Theoretical Framework. Sustainability 2020, 12, 8943. https://doi.org/10.3390/su12218943
6. Industry IoT consortium: About us. https://www.iiconsortium.org/about-us.htm Accessed 22.02.22
7. ISA²: About. https://ec.europa.eu/isa2/isa2_en Accessed 22.02.22