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INDUSTRIAL EDUCATION ECO-SYSTEM – AN APPROACH TO ENABLE THE TRANSFER BETWEEN SCIENCE, EDUCATION, AND INDUSTRY

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ABSTRACT

The manufacturing industry is constantly facing multiple trends and challenges – globally and locally. Technologies, like Artificial Intelligence (AI) or Machine Learning are key enablers for companies to increase the ability to react and adapt. No matter if those technologies are part of products for end-consumers, or part of machines which produce the products for the end-consumers – those technologies need to be innovated, designed, produced, maintained, serviced, and recycled. For all those activities people with the right skillset are key.

This paper presents an approach of an industrial eco-system and provides industry-leading-practices. This eco-system allows people in different phases of their educational life to continue their learning path. Moreover, multiple partners in science, education and industry bring their input and opportunities into this eco-system. And one of the key benefits for all participants is the transfer of latest knowledge and technology into the industry.

The presented industrial eco-system is an open and flexible network of multiple partners on the one side, and on the other side a constant commitment and line-organisation. For many industrial companies this is an innovative concept to ensure the transfer in both directions: from science and education into industry – but also getting feedback and open topics from industry back to science and education. By this, the presented approach can be considered relevant for representatives from universities, institutes, and industry.

Keywords: Industrial eco-system, transfer, knowledge and technology transfer

1 INTRODUCTION & MOTIVATION

Engineering and Product Design Education from a global, industrial perspective has the purpose: to educate the next generation of engineers for successful products and services.

Today, the Engineering and Product Design Education typically is performed at universities, research institutes or educational institutions. Very often the foundation of this education is based on traditional subjects like mechanical engineering, electrical engineering, or software engineering. Interdisciplinary subjects are getting more and more relevant, like Systems Engineering. This education today is often mainly driven by academics only, with limited interaction with industrial practice and companies.

This educational situation is impacted by mega trends across society and industry. Those megatrends are transforming the society and industry eco-system [1]. By this, products and the related manufacturing systems need to transform as well. – For this reason: also, the Engineering and Product Design Education needs to be transformed (Figure 1).

Since the frequency of change of those trends has been increasing over the last several years, the need and speed of transformation is also increasing. Hence, the Engineering and Product Design Education needs to adapt transformation at the same pace.

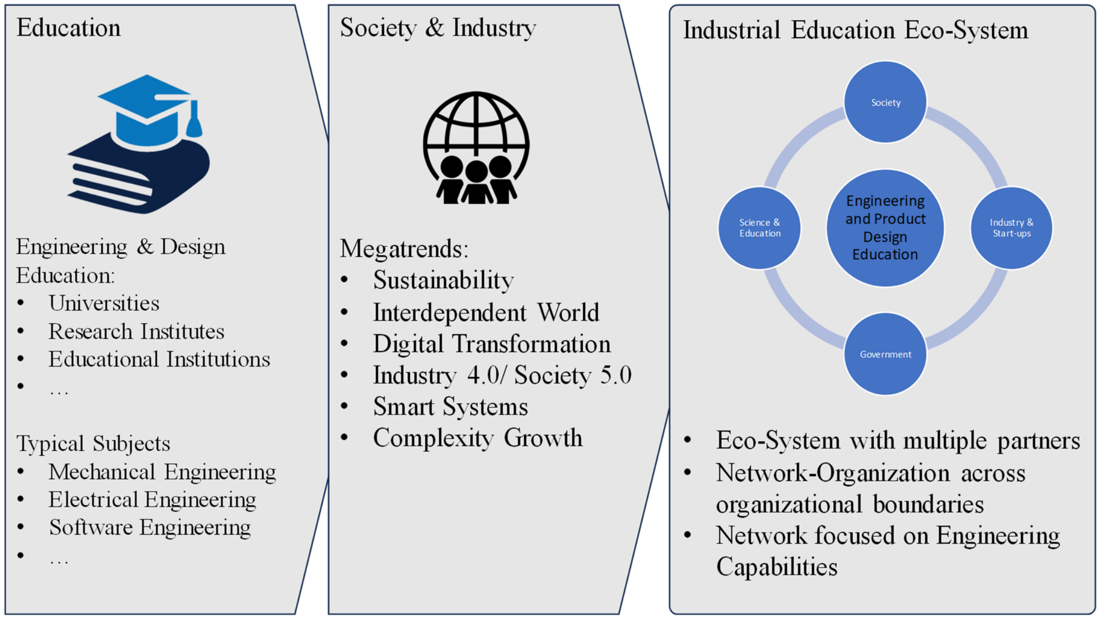

Figure 1. Situation & Motivation of an Industrial Education Eco-System

To address those changes and the increasing complexity, Engineering and Product Design Education needs to operate in an eco-system. This eco-system consists of multiple partner and institutions and should be able to adapt according to the specific situation or context. Since multiple partner and institutions are involved, the eco-system needs to operate as a network organisation.

2 RELATED WORK AND INDUSTRIAL REQUIREMENTS

This paper is based on long experience in industry and educational environments and part of a series of papers reflecting those experience and introducing approaches to bridge existing gaps from science, education, and industry [2] [3].

With focus on Germany and Europe the engineering education at universities is still mainly driven by engineering disciplines like electrical, mechanical or software engineering. Students typically learn specific terms, methodologies, and way of thinking – specific for one of those engineering disciplines. At the same time, the structure and content of lectures very often are not driven by or related to current trends or problems of industry.

When it comes to any kind of technology used in education, very often universities struggle to keep state-of-the-art industrial technology up and running for lectures, laboratories, and research projects. Since those technologies were invented for industrial-daily-operations, those technologies require substantial effort in configuration, installation, operation, and maintenance.

Moreover, based on industrial-daily-operations questions and demands of the industry for further research and education in Engineering and Product Design can be derived. Today, industry is operating in a constantly changing environment with new technologies and products which require new business models [4]. Addressing those questions and demands in a closed loop, is a key success factor for future design education – from an industrial point of view.

3 APPROACHES

The presented approach intends to leverage synergies for science, education, and industry by establishing a permanent network-organisation in the considered company, which allows to establish, orchestrate, and maintain multiple institutions and partners in an Industrial Eco-System.

To unleash those synergies, this approach fosters the collaboration in both ways, as depictured in Figure 2. New topics of innovation need to find their evolution from Science to Education into Industrial Transfer. As well as relevant topics or open questions from Industry need to find their way back into Science and Education.

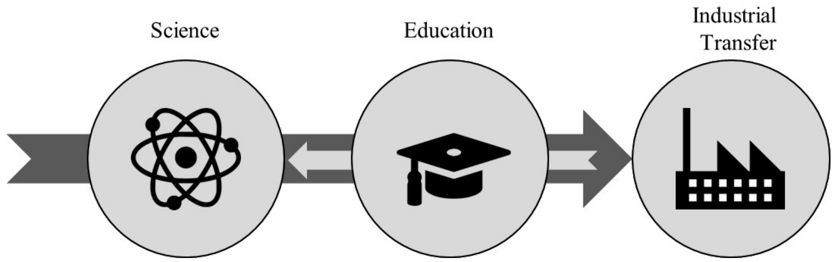

Figure 2. Approach to transfer between Science, Education & Industry

3.1 Frame and Building-blocks

Beside those relevant topics and open questions, the industry can also provide additional elements, which can be leveraged in education (Figure 3).

Industrial Technologies can be a profound platform to enable state-of-the-art Engineering and Product Design Education: from latest versions of assets for digital engineering with multiple design simulation features, to collaboration technologies like Virtual Reality glasses. To increase the learning experience for students, appropriate information and **Industrial Data** needs to exist.

Since those technologies always follow an engineering intend and to not come without engineering processes and methods, the elements of **Industrial Processes & Methods** – as well as **Industrial Use Cases** need to frame the building blocks of Engineering and Product Design Education.

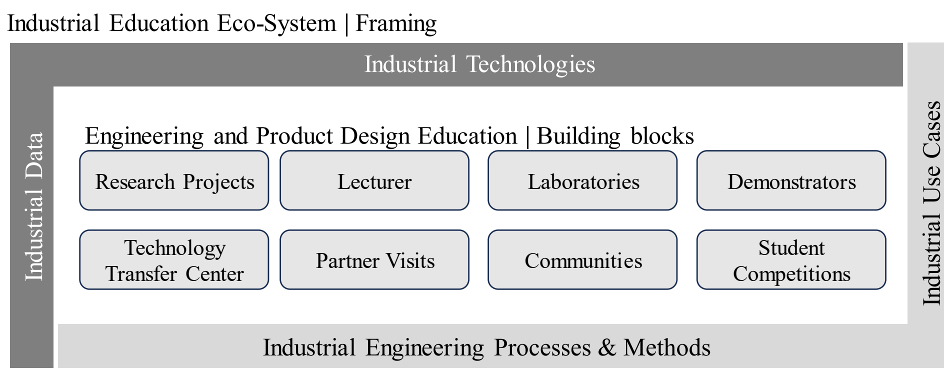

Figure 3. Building blocks of Engineering and Product Design Education in an Industrial Eco-System

The described elements frame the following core building-blocks:

- **Research Projects:** Typically, there are two types of research projects: The first one is industrial research with support of external institutions like universities. The second one is publicly funded research project in a consortium of universities, research institutes and companies.
- **Lecturer:** In lectures at universities or educational institutions representants of dedicated companies can be invited to provide insights and perspectives from industry. Moreover, a permanent lecture-contributions by company representants can be part of the lecture-concept.
- **Laboratories:** Often in combination with ongoing lectures, laboratories are part of the educational schedule. The involved use-cases and technologies can cover industry-specific topics. Furthermore, those laboratories can be extended to facilities or demonstrators of involved companies.
- **Demonstrators:** A sequence of use-cases with relevant technologies involved can be set-up as demos for regular usage. The usage of demonstrators can be across all building blocks of education (see Figure 3). The involved use-cases and technology can be provided and supported by the companies of the eco-system.
- **Technology Transfer Centre:** Multiple demonstrators combined and framed in an educational approach, can be established as Technology Transfer Centre. Those centres can be leveraged in educational building blocks for students and industrial practitioners. This can help to ensure the transformation from Science, Education and Industry very much.

- **Partner Visits:** Partner in the Industrial Eco-System can for example be from other universities, research institutes, government, associations, or industrial companies. Those visits typically happen in both directions – invite for a visit and visit the partner in their location – which very much helps to get a broader perspective during education.
- **Communities:** Based on so called "multi-channel communication" the eco-system needs to have the opportunity to exchange information and to keep each other up to date on new trends and technologies. Publicly available information as a low-barrier entrance helps to share information and to involve more partners in the eco-system.
- **Student Competitions:** There are many established formats of student competitions at universities and educational institutes, such as Hackathons or Formular Student programs. The engagement of the eco-system in those competitions can help to set those activities and events in a more comprehensive context of Engineering and Product Design Education. For example, seeing Formular Student teams engineer their race cars, using CAD and Simulations based on industrial-standard IT solutions.

The main **impact on Design Education** of the presented building blocks is that on the one hand research and innovation topics are constantly brought into engineering education (universities and industrial education). On the other hand, currently existing challenges or research questions are brought up by the industry and find their way back to universities and research institutes.

3.2 Organisational Set-up & Implementation

Company-internal organisations typically are structured in hierarchies and line-organisations. Those line-organisations are needed to structure business operations and responsibilities within companies. At the same time this structure sometimes generates internal boundaries, when topics need to be addressed which require skills and resources across the structure. Alternative organisational structures are partially established in industry which help to bridge those boundaries or silos [5].

Those **network organisations** are part of the approach presented in this paper. A network organisation is centred around functional-oriented groups – called **domains** (Figure 4).

In industrial Research and Development departments, those domains typically are centred around technical and engineering topics: such as Systems Engineering, Lifecycle Management or Sustainability Engineering. Very often those topics are defined to connect existing or traditional topics, disciplines, or technologies. Moreover, domains bring together relevant skills and resources to address a certain task or challenge. Those skills can be distributed in various departments and teams across the line organisation – or even outside of the respective company.

Company-external Networks following a similar intend. Skills and resources of multiple partners or elements of this network are pulled together based on a specific demand or activity. In this approach this network brings together the company with its industrial knowledge and technologies and Universities and Educational Institutions. Moreover, to have a wide perspective on education this network typically also includes governmental institutions, associations, and up-to representatives of society.

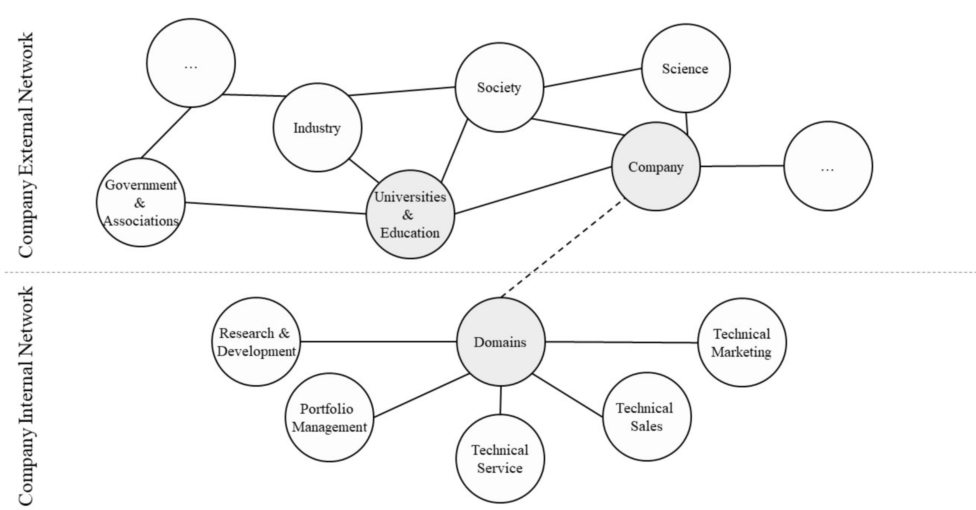

Figure 4. Internal and external network-structure of an Industrial Eco-System

The benefit of such network structures is, that they are more flexible and more dynamic in comparison to the hierarchies. At the same time, establishing a Domain Network Organisation within a company-organisation – in parallel to the well-established and legally required hierarchical structure – allows to constantly drive the Domain Topics – such as Systems Engineering or Sustainability Engineering.

Organisational Implementation of described organisational set-ups typically requires two different strategies in parallel. On the one hand a domain core-team needs to be defined, which gets a high-end education of the respective topic. As an example of Systems Engineering, this team is educated along the certification levels of the International Council of Systems Engineering (INCOSE). This strategy can be described as **"frontloading education"** for the domain core-team, to increase their knowledge in an early phase of the upcoming transformation of the industrial eco-system. On the other hand, the domain focus or domain topic, such as Systems Engineering, need to break down into **"steps of education"** for the respective industrial eco-system. In industrial practice, often those steps are defined along: basic, advanced and leading. In the context of Engineering "basic" could be defined as "Engineering Efficiency" with Product Lifecycle Management (PLM) during the engineering process; while "advanced" could be defined as "Engineering Excellence" with focus on System Lifecycle Management, the "leading" could be defined as "Engineering Innovation" based on technology-enabled system development (Engineering Intelligence). [6]

4 INDUSTRIAL EXAMPLE

The following example shows how the presented approach is used and how it impacts the Engineering and Product Design Education [7]. The engineering of an **industrial machinery context** is in focus. Around this context the entire education concept was developed: Lectures, Laboratories and Research Projects. The set-up of this industrial machinery context is equipped with industrial leading technology for information technology (IT) and operational technology (OT).

Figure 5. Example: integrated education concept for industrial machinery engineering [5]

4.1 Lecture approach

The lecture approach covers multiple perspectives of engineering and integrates those perspective in physical demonstrators and virtual representations (Digital Twins) at the same time.

Product Engineering is one of those perspectives, leveraged in the lecture approach. The simplified electronic device in this context is made of different electrical components such as resisters or switches. With this device the use case is defined, where the industrial machinery needs to replace an electrical component and test the electrical component at the end of the manufacturing line.

Manufacturing Layout Engineering is another perspective where the product use case needs to be operated. In this perspective all components of the industrial machinery need to be engineered.

Manufacturing Process Engineering is also a perspective which needs to be engineered. The production line, high rack excavator or the robot arms need to be programmed to fulfil the required activities in the right sequence and quality.

Students in this lecture learn different perspectives of engineering based on industrial leading information technology and are also able to transfer this to the physical world by applying their engineering results on the physical demonstrator.

4.2 Laboratories and research projects

In addition to the lectures, it is possible to conduct laboratories and research project based on the industrial machinery context. Students are constantly working in small projects to enrich or improve the industrial machinery context. This gives different generations of students a great opportunity to learn from former projects and bring-in innovations to expand the existing set-up. The research projects can be scaled according to the type of project, such as master thesis or publicly funded research projects.

4.3 Demonstrators & Partner Visits

The industrial machinery context can also be leveraged for transfer. In this scenario the machinery with its different use cases can be utilised as demonstrators for students during their education. Moreover, it can be used for knowledge and technology transfer during partner visits with other universities, research institutes or industrial companies. This typically can be a great scenario for new projects or input to further evolve the overall educational approach.

5 SUMMARY AND OUTLOOK

The approach, introduced in this paper, describes how the transfer between science, education and industry can be established and impacts the Engineering and Product Design Education. It is covered under the name "Industrial Eco-System".

The motivation of this approach covers both, educational and industrial demands, as described in the beginning of this paper. The major building-blocks of this approach were introduced. Moreover, the organisational set-up was described which covered the concept of network-organisation, called domains. Finally, an industrial example showed specific impacts on Engineering and Product Design Education with one of the partner education institutes of the eco-system.

In future, this approach will be leveraged with our existing and new partners in the eco-system and will constantly be further developed. Moreover, the focus on transfer will be fostered by new ways of technology transfer centres. This will also help to address the education of employees in industry, which needs to handle the constant change in technologies and engineering methodologies.

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