Towards Digital Knowledge Transfer in Small and Medium-Sized Manufacturing Enterprises

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Abstract. This paper gives an insight into the project "Education 4.0 for SMEs". Small and Medium-sized Enterprises (SME) in the high-technology sector of lightweight-construction are implementing more and more digitization processes for their industrial settings. These processes strongly depend on internal knowledge transfer. We consult these SMEs to find out which kinds of digital learning technologies and pedagogical concepts are useful for their in-company education and training. Besides featuring well-known learning technologies such as wikis, videos and webinars, novel learning methods based on mixed-reality will be developed and tested.

Keywords: Knowledge Transfer · Learning Technologies · Education Tools and Methods · SME.

1 Introduction

More and more branches of industry have started using lightweight construction materials consisting of carbon fibre reinforced plastic (CFRP) over the last years. Often referred to as "black gold", carbon composites are known for their special physical features, including being extremely light, and as such have gained influence in industry as well as research. The specific composition of the material makes an application in well-established areas of use (such as the sports sector, construction of airplanes etc.) [3, p. 9] possible, as well as providing innovative potential for a variety of products that are only at the start of market penetration [7, p. 30]. Apart from the ongoing development of composites, digitization

is the second large challenge that composite companies are facing today, especially Small and Medium-sized Enterprises (SME), that abound in the composite sector. On the one hand, they need to implement digitization processes in their industrial setting, the result of which is referred to as "Industry 4.0" [2] in Germany. On the other hand, the challenge of digitization is closely connected with meeting the customers' needs for digitizing complete value-adding networks typical of the composites branch. As production cycles become shorter and shorter and technical innovations abound, plant construction and the development of new machines have to comply with ambitious requirements aiming at both high efficiency and flexibility.

Employees have to keep abreast of these developments, but often lack the necessary IT skills. According to a study by the Centre for European Economic Research (ZEW) about "Digitization in medium-sized companies, its status quo, recent developments and challenges" [6], only one in five companies has a comprehensive digitization strategy. The largest obstacles are the lack of IT skills (67%), reservations about data protection and data security (62%) as well as high costs (59%).

Thus, as Industry 4.0 projects are implemented, the staff need to aquire different and new qualifications and skills (e.g., in specific software, IT technologies, or machines), but also concerning skills in interdisciplinary cooperation. A study by the German Economic Institute [8] shows that 85% of enterprises in Germany invest in their employees' further education and training. To this end, enterprises offer classical ways of training like seminars, but increasingly also use informal formats that allow their employees individual on-the-job training, be it supported by digital media or in the form of information meetings. However, a majority of employees does not feel well prepared for digitization, as 72% claim to lack the time for further trainings on digitization issues and 59% say that their employer does not offer any further training on said topic according to the German Association for IT, Telecommunications and New Media [5].

This situation is the starting point of the project on "Education 4.0 for SMEs". It aims at finding out more about possible support of SMEs in their digitization challenges in terms of knowledge transfer. In a high-technology sector such as the composite sector, it is essential to collect a company's knowledge of specific software, IT technologies, or machines and to share this knowledge among its employees. Hence, the main objective of the project is to research and develop organizational and technical solutions to support SMEs in the composite sector by introducing or improving digital knowledge transfer in order to prepare them for the challenges of "Digitization" and "Industry 4.0". To achieve this, we are working with selected SMEs from the composite sector association Carbon Composites e.V. (CCeV) which is also a project partner.

This paper, after sketching the research question in section 2, outlines the approach of the project, dividing it into an organizational and a technological dimension (cf. Sect. 3). Due to the close connection of digital learning and knowledge transfer, not only to the skills but also attitudes of the learners themselves, it is paramount to include reflections on the motivational design relevant to the

project's proceeding (cf. Sect. 4) before giving an outlook of the conclusion in section 5.

2 Research Question

SMEs within the lightweight construction sector mostly focus on developing their production processes, but this development highly depends on their employees' know-how. Demographic change, the lack of skilled workers and a growing importance of knowledge-intensive ways of production as a consequence of the current digitization process [1] even add to this dependency, besides knowledge management, the project addresses (digital) training and education processes in SMEs, which are often neither well defined nor efficient. Discussing these difficulties with a group of SMEs, our project focuses on the following research question:

"How can SMEs be supported in digitization challenges through digital knowledge transfer and learning offers so that they can integrate these digital learning processes into their day-to-day work as easily as possible?"

Based on this research question, we have defined three research interests, which are sketched in the next three sections.

2.1 Type of Training: General vs. Specific Knowledge

A first focus of our research interest lies on the type of training. Therefore, the project aims at assessing which digital tools or strategies perform best within certain contexts and for which types of knowledge. One context includes trainees during their vocational training, which is based on a dual system in Germany. This means that trainees attend vocational schools, where they are provided with general knowledge about their future jobs. At the same time, they work in a company, where they acquire more specific knowledge, e.g., containing company specific information. This differentiation in general and specific knowledge can be mirrored for other further education opportunities within the company.

Thus, in a context of on-the-job training, for example, education media for generic topics could be developed and shared with other companies, making use of the network of composites companies we address during the term of our project. Possible topics might be safety requirements, machine operation descriptions, or – on a meta level – digital tools themselves as a support for digital learning (see Sect. 3.2).

2.2 Type of Trainee: From Consumers to Producers

A second part of our research question can be seen as addressing the role of the learner, which goes hand in hand with certain learning strategies or methods. While in the area of knowledge management it is common to self-document know-how, it is unusual for employees to develop learning media. This might be the case due to the lack of tools that can be used without special educational skills. However, young people in vocational training today are used to producing

presentations, blogging, writing and commenting within social media and even creating graphics and charts. Also a lot of people working in the training sector of SMEs are used to develop simple kinds of learning materials like operational sequence descriptions as text or graphics. All these people are able to describe detailed facts in a face-to-face situation.

So, why not use a camera to produce a video? It will not look like a perfectly produced video with a professional speaker, special cuts, or be perfectly illuminated. But it will fit perfectly in internal training scenarios; and meanwhile smartphones provide adequate video quality. Moreover, using mixed reality (MR) technology it is possible to record motion sequences and annotate them with context-sensitive information in 3D. In this way, for example, an operational sequence can be shown in 3D, e.g., how to set up a machine. Starting from this sample of digital methods, the project will explore in which ways and how effectively employees develop, use and react to which measures.

2.3 Type of Devices: Office vs. Shop Floor Environments

A sustainable implementation of digital strategies of learning and knowledge transfer in SMEs of the composite sector entails specific challenges. A fundamental distinction between such companies and typical office workplaces is that access to IT equipment is not granted in factory buildings. Especially in the composite sector, dusts of composite material would destroy standard computer equipment within a short period. Therefore we are discussing with SMEs within our project-network how to support learners and media producers – on average there are two PCs available for a whole manufacturing department (on the basis of interviews with our project partner SMEs).

Since media affinity of learners is important for deciding which kinds of media should be offered, for example in an e-learning course, we want to develop a study on the media affinity of employees in the composite sector. This study should recommend which kind of media is efficient in which use case based on demographic as well as social or cognitive factors, for example age, affiliation to a specific department, or one's level of experience.

3 Approach

Based on the main objective of the "Education 4.0 for SME" project, i.e., to support SMEs in their digital knowledge transfer, the project implements four measures in close collaboration with the selected SMEs of the German composite networks CCeV. This is shown in Fig. 1. These measures are evaluated and best-practices are condensed. Within the network, every SME shall have access to a broad base of tools, best practices and support about digital knowledge transfer. On a supraregional level synergies and cooperation structures between SMEs are initiated.

Starting with the determination of requirements within SMEs, individual concepts and solutions for digital learning are developed. In order to provide

innovative solutions, the project also includes demonstrations of digital learning technologies such as mixed reality scenarios, webinars or videos. Lastly, in order to improve the implementation of specific tools and strategies, the project supports the collaborating SMEs in this phase in line with demand. Exemplary content will include safety instructions and the set up of machinery. Aiming at sustainable solutions, the project focuses on helping enterprises develop and implement digital knowledge transfer themselves. In concrete terms, SMEs should be supported to integrate digital media into their own training and personnel development strategies.

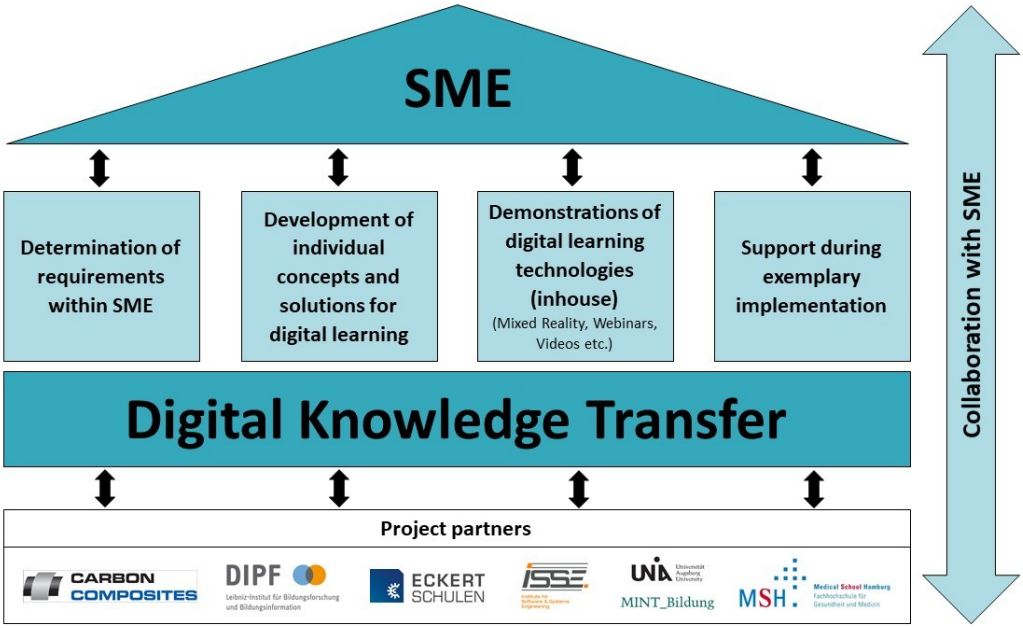

Fig. 1. Approach of the "Education 4.0 for SMEs" project.

By the close cooperation with individual SMEs, we aim at achieving some general insight into possibilities and challenges of digital knowledge transfer in a high-technology sector such as the composite sector. We expect that these insights will have an organizational (cf. Sect. 3.1) as well as a technological dimension (cf. Sect. 3.2).

3.1 Organizational Dimension

On the organizational dimension, the topics of concrete learning modules include specific solutions for requirements identified in a respective analysis, such as digitization of existing strategies of knowledge transfer. Here, organizational factors such as the structure of the company with respect to its different departments and existing strategies of knowledge transfer are at the center of interest in order to explore the effectiveness and sustainability of the chosen strategies. This includes personal factors, such as gender, age, cultural background, or level of experience. Through a mobile learning studio provided by our project, SMEs

can use required technical infrastructure within the company to develop and evaluate different knowledge transfer and learning strategies. Moreover, employees will be qualified to create their own learning modules based on their specific knowledge and their point of view.

3.2 Technological Dimension

The project will feature a broad range of different digital learning and knowledge management technologies. The SMEs are thus able to test and evaluate different approaches. Moreover, it allows us to compare different technologies for the same content. Thus, best practices can be developed for different categories of content. In addition to well-known digital teaching-learning solutions (such as wikis, podcasts, webinars or video conferencing), novel digital learning infrastructures are used. A mixed-reality (MR) learning environment is being developed for this purpose. This allows users to perform a learning module while interacting with machines. In such a setting, context-sensitive information can be shown directly where it is relevant (e.g., at a button or a lever). With this MR learning environment, employees should be enabled to "record" their typical setup or operation procedures for a machine. As a consequence, they digitize their machine-specific knowledge and make it available to other, less experienced colleagues.

4 Motivational Design

To ensure the objective of achieving progress in embedding digital learning methods into the manufacturing sector, a motivational design is conceptualized. This design will serve the purpose of supporting the processes of self-regulation while performing a learning action. The basis for creating the motivational design is a hierarchic developmental model which consists of three extension levels (see Fig. 2). This gradation does not only help to ensure the productivity of the hereby developed learning system but also enables evaluation at an early stage.

The *Integrated Model of Learning and Action* (German: Integriertes Lern- und Handlungsmodell; ILHM) [4] is used as the theoretical foundation of the model as well as findings from the research of SensoMot (German: Sensorische Erfassung von Motivationsindikatoren zur Steuerung adaptiver Lerninhalte). The levels, more specifically the learning content and the single features, are being developed considering the context of lightweight construction.

The ILHM consists of a motivational phase, an intentional phase and an action phase. All three phases contain several segments, for which oneself needs to be in different affective states. Specific feedback processes, assuming they were successful, will then help to keep a self-regulated learning motivation [4].

The objective – to increase the motivational fit between the needs of the learner and the digital educational offer – can be realized through the user's feedback processes which will allow an adaptation of the presented materials and/or methods. For that purpose, the motivational needs will be integrated into the motivational design, e. g. the need for deciding on a learning content

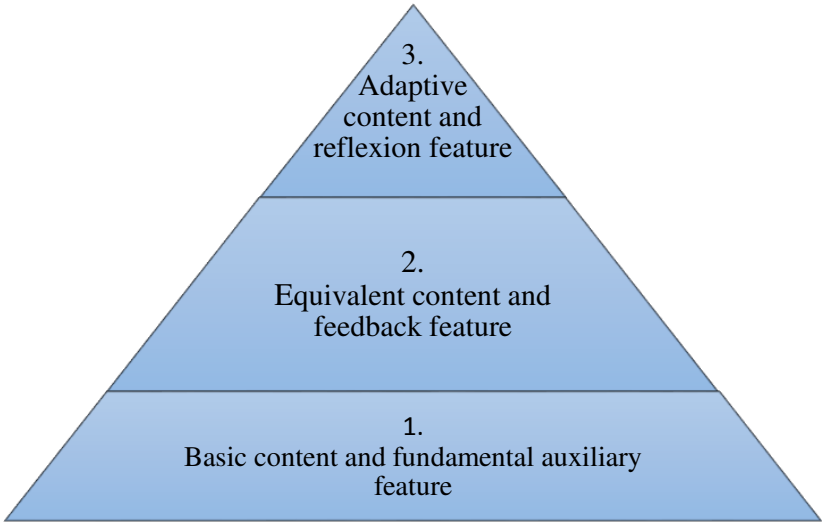

Fig. 2. Hierarchic Developmental Model.

and a strategy autonomously. It is important to consider the segmentation of learning content, multiple learning strategies the user will have access to, as well as accompanying feedback and auxiliary features. Based on the motivational design, motivational indicators will be drawn to then be integrated into the SensoMot project where physiological parameters will be identified and collected. By creating those parameters, it will be possible to automatically match a certain digital learning environment to the motivational needs of the learner. Hence, through the individualization of the learning experience, the motivational design should offer a more profound motivational approach, specifically a higher learning efficiency, a linkage of learning contents and a transferability of those contents, which will result in higher memory capacity for the learned content.

The motivational design should also be applicable to the context of mixed reality (MR), minimizing immersion and therefore decreasing the blocking of a learning experience. Particularly in the manufacturing sector, introducing such a design is of great importance in order to ensure the maximization of successful learning in the context of machine- and target-oriented apprenticeship and training.

5 Conclusion

In this paper, we presented the research question of the "Education 4.0 for SMEs" project and introduced its approach. The SMEs we are targeting are from high-technology sectors – in our special case from the lightweight-construction sector. In a high-technology sector, the employees' knowledge of specific software, technologies or machines are crucial for the success of a company. Hence, the main objective of the project is to research and develop organizational and technical solutions to support SMEs in the composite sector by introducing or improving digital knowledge transfer. For this kind of knowledge, relevant employees must be enabled to create digital learning modules in a few steps. Hence, employees

must be enabled to become producers as opposed to consumers of digital learning solutions. To achieve this, we closely collaborate with selected SMEs from the composite sector association CCeV on an organizational as well as on a technological dimension. From the latter, we consider well-known digital teaching-learning solutions and novel digital mixed-reality learning infrastructures.

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