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TEACHING INDUSTRY 4.0 – PRODUCT DATA MANAGEMENT FOR SMALL AND MEDIUM-SIZED ENTERPRISES

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ABSTRACT
Industry 4.0 is the next step to autonomous products, productions and processes, which have the ability to communicate with each other, collect information about their environment and their influences. Especially Small and Medium Enterprises (SME) are challenged with the implementation of Industry 4.0 because of resource scarcity. Industry 4.0 does not have to be developed completely new, but are based on existing products. However, the expansion to a communicable product generates new product data, which needs to be managed and organized with the use of a Product Data Management (PDM) system. With the workshop "Learning to Handle Product Data! – Product Data Management in the context of Industry 4.0" from the Institute of Product Development of the Leibniz Universität, Hannover participants with different and to the instructor unknown professional backgrounds and expectations learn about the impact of Industry 4.0 on the product development and have the possibility of exchange. The following article presents the course of action and the teaching concept. Afterwards, a participant's exercise is presented, followed by the evaluation of the workshops in 2017.

Keywords: Industry 4.0, Digitalization, Product Data Management, Product Development

1 INTRODUCTION

Industry 4.0 is a term introduced by the German Federal Government on the Hannover Fair in the year 2011. It is often put in touch with a self-organised and networked production and logistics connected by information- and communication technology [1]. With the approach of *Industry 4.0 and more* is not just the storage, saving and converting of information from the production and logistics considered, but also the entire product lifecycle including usage and development phase [2]. The German Federal Government observed that especially small and medium-sized enterprises (SMEs) are challenged with the implementation of Industry 4.0 [3]. For this reason the German Federal Ministry for Economic Affairs and Energy initiated a programme called *Mittelstand Digital*, to inform and qualify SMEs about Industry 4.0 and to provide their employees practical and concrete teaching, learning, demonstration and testing opportunities during events of one day. One of the centres of excellence *mit uns digital* is stationed in the Leibniz Universität Hannover. The Institute of Product Development offers a workshop to the theme "Learning to Handle Product Data! – Product Data Management in the context of Industry 4.0", in which participants from SMEs with different competences, industrial experiences, expectations and knowledge about the topic can take part.
From the unknown professional backgrounds and demands for the workshop the challenge arises to set up a workshop concept to the subject Product Data Management in the context of Industry 4.0, which includes the most important points of the topic and gives enough time to respond to individual questions and demands. The aim is it to identify the focus of the participants with each workshop and to adapt and improve the workshop. Therefore the information level about the topic and the demands for the workshops between the participants and the instructor needs to be adjusted, so the information asymmetry can be identified and equalised. This happens during each workshop, but also after all four workshops held over one year. Next to the unknown professional backgrounds the challenge arises, that Industry 4.0 does not have an out-of-the box solution, but has to be adapted to every enterprise.

The workshop also serves as a forum to create own and clear ideas about Industry 4.0 and how to implement these in the participant's enterprise. In the following paper it is shown how participants learn what is Industry 4.0 and which impact it has on their product development.
Therefore, section 2 provides a review of problem-, project- and case-based learning in the engineering design. Section 3 presents the current approach of the workshop, giving details about education objectives, learning sequences and an example. The following section contains an evaluation about the workshop. Closing the paper, section 5 contains a brief summary and an outlook.

2 REVIEW OF PROBLEM-, PROJECT- AND CASE-BASED LEARNING

From the authors' point of view, a classical deductive lecture is not suitable for teaching PDM systems and Industry 4.0 sustainably. Especially to acquire the relevant knowledge about Industry 4.0 and the knowledge transfer to their enterprises has to be an educational objective that can only be dealt with by doing. Deductive teaching methods transfer responsibility for learning and content to the participants [4]. The instructor provides necessary information and assures that the learning objectives of the course is achieved, while the students identify needs and discover relevant knowledge by themselves. Problem-, project-, and cased-based learning approaches are used in engineering education [5].
The problem-based learning concept was implemented during the 1960's and contains three phases a student has to pass. In the first phase the problem is presented to the student with the help of an instructor and the professional reasoning skills are developed. The second phase aims to acquire the relevant knowledge for the solution by a self-directed study of the student. In the last phase the acquired knowledge is exercised to the given problem in presence of the instructor again and the learning process is reflected afterwards [4].
In the problem-based learning concept, a problem statement should be open-ended, ill-structured and of authentic kind [6]. The learning concept has also the characteristics that group work is possible and the time during class can be used for a group report, a class discussion or short, informative lectures. With the problem-based learning concept it is possible to guide students through the discovery of problem solutions and reflecting the learning process, which can be seen as a major benefit. The focus of the learning concept is the knowledge acquisition [7].
Between the problem-based and project-based learning concept exists many similar aspects. Both include student teams, which have to identify solution strategies to a given problem statement [6]. In contrast to the problem-based learning a project has a wider scope with multiple problems and leads to an end product. The knowledge the students need to complete the project is either previously acquired or taught in accompanying courses [8].
Case-based learning (and teaching) dates back to the end of the nineteenth century and regarding engineering education, case-based learning relies on engineering activities, problem statements or situations that reflect real-world problems as well as the background and complexity encountered by engineers today. Compared to problems in problem-based learning concept, a case is usually well-structured, involves a rich contextual background and is used to drive students to apply already existing knowledge. The typical setup of a case analysis is depicted in Figure 1 [6].

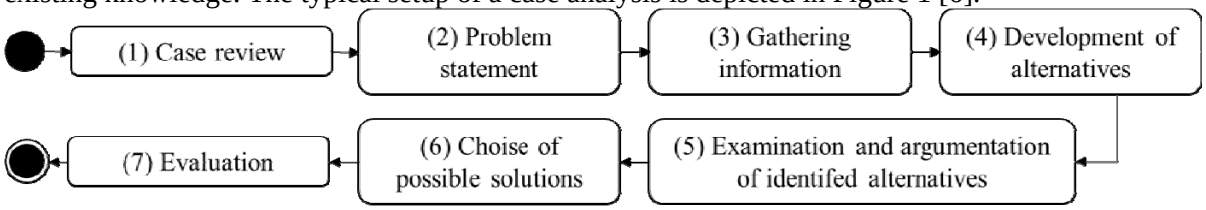

Figure 1. Typical Setup for a Case Analysis

3 MIT UNS DIGITAL – WORKSHOP

The aim of the training is to provide participants with the new information to develop approaches or ideas on how to implement a PDM system in their own enterprise. They are prepared when difficulties during the implementation arise and what it means to develop Industry 4.0 products without a functioning product data management system. Consequently, for this form of workshop, the concept of case-based learning is most appropriate, as first the background knowledge is conveyed and illustrated with a lecture example and then a similar problem can be dealt with in the exercises, demonstrated

with a torch. Within a day, the participants learn the basics of the topic of Industry 4.0 and PDM systems apply the theory with different exercises to the continuous example of a torch and then use a PDM system independently. The exercises focus on the problem of developing and supporting an Industry 4.0 product from different angles. During the workshop the time is always used to answer questions of the participants about similar problems from their own enterprise or to discuss the problem with other participants.

3.1 Educational Objectives and Course of Action

The workshop is an advanced course, which presumes a technical background and experience and has following module description for the Federal Ministry for Economic Affairs and Energy:
The workshop "Learning to Handle Product Data! – Product Data Management in the context of Industry 4.0" provides the basic information about Industry 4.0 and the skills to use the PDM system Autodesk Vault Professional. With the continuous example of a torch the development from a Non-Industry 4.0 product to an Industry 4.0 product is demonstrated.
It is organised in 14 sections. The lecture sections are a short introduction into the topic of 15 minutes. The exercise sections are 30 minutes long, with the exception of the computer exercise, which takes 60 minutes. The Learning Objectives and the corresponding Course of Action are depicted in Figure 2.

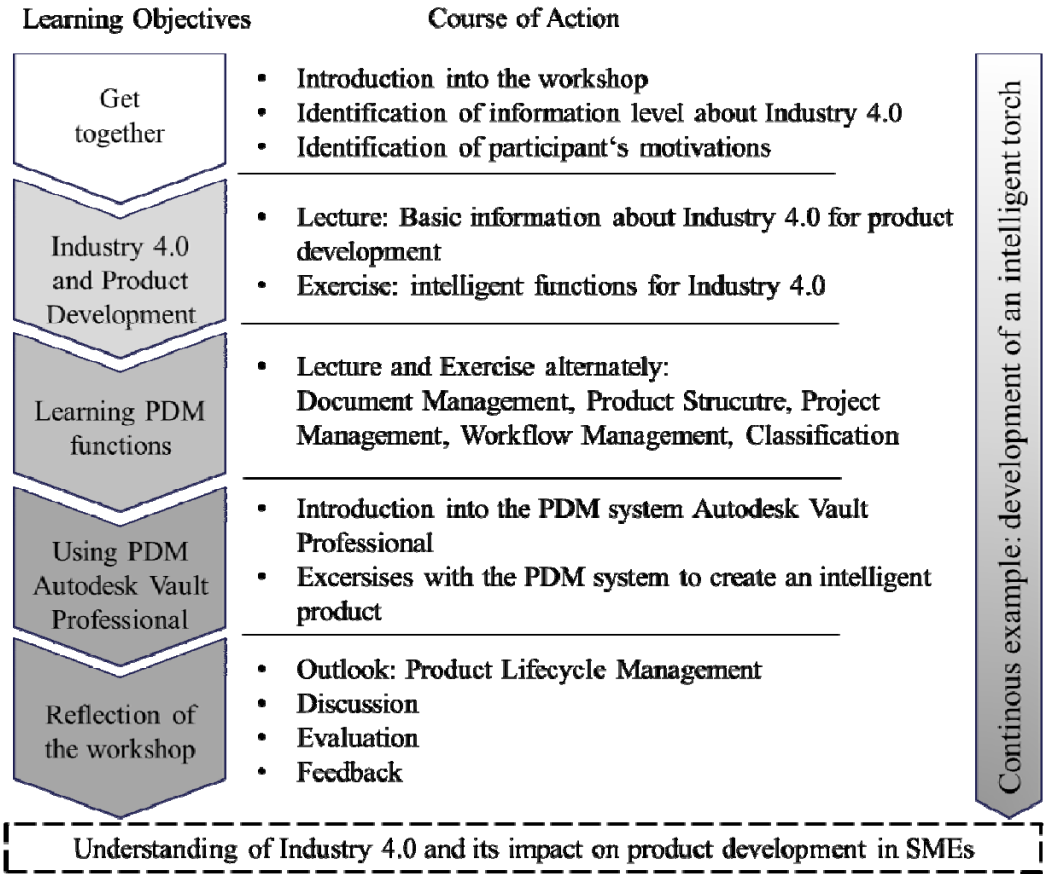

Figure 2. Education Objectives and Course of Action

3.2 Basic Information about Industry 4.0 for product development

The following subsection contains a detailed overview about the content of the first exercise that is dedicated to create new intelligent functions for an Industry 4.0 torch.

Background

Products are not always developed entirely new, but are based on existing products with further functions. Therefore it is possible to develop a product in the context of Industry 4.0 by using an existing design and implement new Industry 4.0 functions in it. These functions make the product "intelligent", which means the product provides additional benefits for the costumer through a digitalisation. The intelligent functions can be divided into four areas: (1) intelligent human-machine-communication, e.g. tooth brushes that communicate with the user via smartphone; (2) intelligent

Service functions, e.g. domestic appliance that order independently items, when needed; (3) intelligent System networks, e.g. in the context of autonomous driving and (4) intelligent production and disposition, e.g. machine to machine communication in a production, in which machine tools can communicate their status or demand maintenance [9, 10]. These functions have in common that the actual product needs sensors and communication technology to transfer data that can be used. For the development that means, the existing product in the PDM system needs to be expanded with a communication module and implemented in the PDM system [11].

Execution

One of the workshop parts is the exercise about intelligent function for Industry 4.0. In the first 15 minutes the instructor gives an impulsive lecture about the basics of Industry 4.0 and its consequences for the product development. In the following 5 minutes the instructor presents the task to develop intelligent functions for a conventional torch. For a better understanding different torches are handed to the participants, so they can inspect one during the work. According to the case-based learning, the participants first review and analyse the torch.

As results they discover that:

- The torch is a mass product and not individualised;
- The torch can just be turned on and off;
- The light focus can be changed just by hand;
- The torch does not record and collect information about itself.

In the following 25 minutes the participants work in groups of two or three at the task to identify intelligent functions and apply the previously acquired knowledge from the lecture to the torch. Therefore they write every idea they have on a card and according to the rules of creativity methods every idea is allowed, written down and not commented. They also have to put their ideas into one of categories for intelligent functions, human-machine-communication, service functions, system networks or production and disposition.

In the third part and the remaining 15 minutes, one of each group presents their ideas to the rest of the workshop. Therefore they pin their cards with their ideas onto a prepared wall into one of the four categories. Some functions are placed between two categories, when it is not directly clear where it belongs to or it has aspects of both categories. In Figure 3 the task's formularized results are depicted.

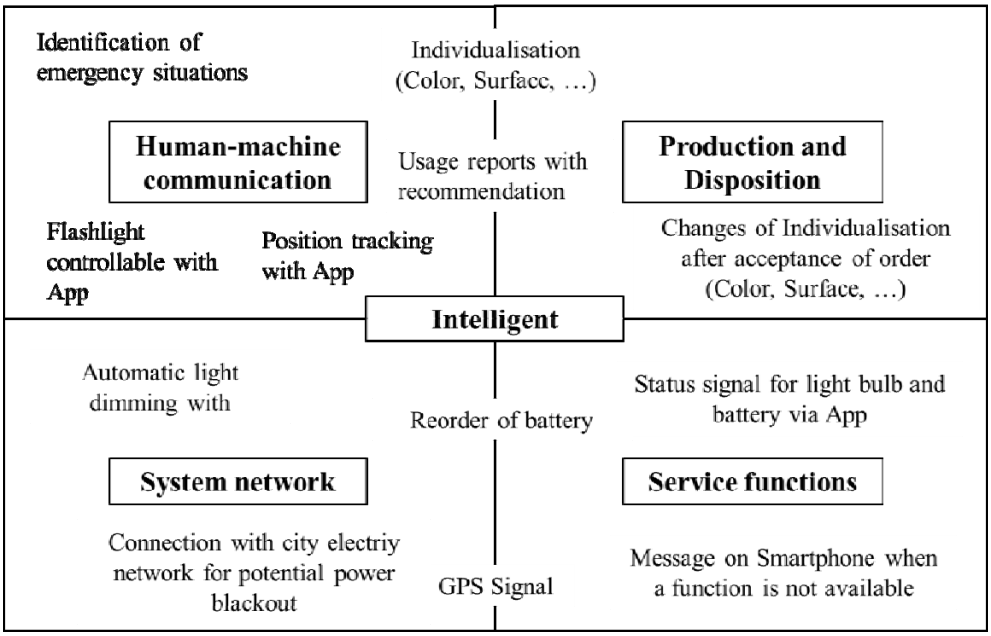

Figure 3. Results placed in the intelligent function categories

The participants have to take a closer look at the technical functions when all ideas are collected on the wall, to determine the effects for the product development. Although the participants generated individual ideas and worked in different groups, their ideas have in common the need of sensors and communication technology. For the product development this means that developing an intelligent torch need to be managed by a PDM system to create an additional benefit and new product data, e.g. requirement lists, drawings, production orders, and others.

3.3 Core Thesis

26 participants and 2 instructors worked together on the subject PDM systems in the context of Industry 4.0 in 2017. The workshop clarifies that:

- Industry 4.0 enables different intelligent functions for technical products;
- Intelligent functions need communication modules, which needs new knowledge domains to handle;
- The development of intelligent products does not start from zero, but can be based on existing products;
- However, the development brings new files and data, which needs to be managed;
- PDM systems help to manage files, but it does not matter if an enterprise develops, produces and sells intelligent products – it helps in both scenarios.

The participants worked on a conventional torch and what the development of an intelligent torch has an impact. The key aspects are displayed in Table 1.

Table 1. Key aspects of Exercise

1	A torch can be expanded with different intelligent functions to generate an additional benefit for the costumer, e.g. GPS signal for relocating, app for tracking battery status
2	Documents that already exists about a product are expanded with documents from the whole lifecycle, e.g. source codes, field information
3	Product structures are expanded with new parts for the ability to communicate
4	Workflows are new organized for the development of an intelligent torch

4 EVALUATION

The task was to inform SMEs about the basics and the impact of Industry 4.0 for the product development and how PDM system can be supportive. At the beginning the participants were asked about their experience with PDM systems and their expectations about the workshop and at the end they were asked about their abilities and the benefit of the workshop. They had to rank their answers always on a scale from 1 to 5.

For the initial question the participants estimated their PDM-abilities in average on 2.1. So the major part of the participants did not work with PDM systems at all or just a little before. For the second question the participants estimated their knowledge about Industry 4.0 in average on 2.8. In the final assessment, the participants rated that their expectation were met in average on 4.0. It was also asked, if the workshop motivated the participants to continue with the topic, which answered the participants in average with 4.6. In Table 2 the evaluation questions and the results are summed up.

Table 2. Evaluation Results

Evaluation question	**do not agree - 1**	**2**	**3**	**4**	**do agree - 5**	**Average**
The workshop's goals became clear	0	1	4	8	13	4,3
I was able to get involved	0	0	0	4	22	4,8
The content was understandble	0	0	4	5	17	4,5
I was able to communicate with other participants	0	0	1	0	17	4,8
My expectations were met	0	0	7	6	12	4,0
The workshop promoted the interest in the content	0	0	4	9	10	3,8
Content was consistent with the cours description	0	0	1	7	17	4,5
The benefit of the theme became clear	0	0	1	8	17	4,6
The workshop motivates me to continue with the topic	0	0	1	9	16	4,6

In the beginning the challenges was, that the professional background and the demands for the workshop are unknown before and to set up a workshop concept for PDM systems in the context of Industry 4.0, which includes the most important points and gives enough time to respond to individual questions and demands. The evaluations shows, that on average the expectations were met with a 4.0 and the participants are able to get involved into the workshop in average 4.8 on a 1 to 5 scale.

The last question in the evaluation was, if the participants have a (1) clear idea, (2) vague idea or (3) no idea how to realise the topic in the enterprise after the workshop. 20 participants, so 75%, had a clear idea and 6, so 25%, a vague idea how they realize Industry 4.0 and PDM in their enterprise. One of the initially mentioned challenged was, that Industry 4.0 does not have an out-of-the-box solution

and the workshop has to serve as a forum to create own and clear ideas how to implement Industry 4.0 and PDM system in their enterprises, what worked for 75% of the participants.

5 SUMMARY AND OUTLOOK

The workshop "Learning to Handle Product Data! – Product Data Management in the context of Industry 4.0" was founded in order to help SMEs to understand and implement Industry 4.0 in the context of product development and Product Data Management. The participants learn that Industry 4.0 has an impact on the product development and its corresponding processes and generates new product data, which need to be managed and structured. Therefore PDM systems are used and the participants learn the basic functions, a concrete PDM software system and how they can use it in their own enterprise. The results from the past four workshops are motivating to continue with the topic and to work with enterprises on it. On the one hand the participants understand the need and benefits of a working Product Data Management system, independent from Industry 4.0. On the other hand, the impact of Industry 4.0 for a small or medium enterprise is shown. At this point the 75% of participants have a clear idea if or how they work on the topic at their enterprise. SMEs also have the opportunity to continue with the topic with the support of the Institute of Product Development. The programme *Mittelstand Digital* supports this co-operation.

In 2018 the workshop will take place four times, so the concept will be tested on a higher number of participants and can be better validated. The next steps will be to overview the course description, so participants know better what the content will be. Furthermore, the instructor has to pay more attention, how participants can transfer the content of the workshop to their enterprise and implement them there.

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