Digital Twin Academy: From Zero to Hero through individual learning experiences

Jessica Ulmer[1], Youssef Mostafa[2], Jörg Wollert[3]

Abstract

Digital twins are seen as one of the key technologies of Industry 4.0. Although many research groups focus on digital twins and create meaningful outputs, the technology has not yet reached a broad application in the industry. The main reasons for this imbalance are the complexity of the topic, the lack of specialists, and the unawareness of the twin opportunities. The project "Digital Twin Academy" aims to overcome these barriers by focusing on three actions: Building a digital twin community for discussion and exchange, offering multi-stage training for various knowledge levels, and implementing real-world use cases for deeper insights and guidance. In this work, we focus on creating a flexible learning platform that allows the user to select a training path adjusted to personal knowledge and needs. Therefore, a mix of basic and advanced modules is created and expanded by individual feedback options. The usage of personas supports the selection of the appropriate modules.

Keywords

Digital Twins, Knowledge Transfer, Training

1 Introduction

Real and virtual components are increasingly merging in the context of Industry 4.0. For example, machines are not only planned digitally and evaluated using Virtual Reality, but processes are also tested in advance using simulations and virtual commissioning. To realize these applications with a benefit for the companies, digital twins play a significant role. Digital twins generally refer to a set of adaptive models that emulate the behavior of a physical system in a virtual environment [1].
While the term digital twin is widely used and active research is being conducted on applications of digital twins, the transfer of knowledge between research institutions, companies, vocational schools, and courses is still limited. In order to strengthen this knowledge transfer, the Digital Twin Academy (DTA) project was launched. The DTA aims to build up a community in the digital twin field, conduct application-oriented research, and transfer knowledge to all interested people through a hybrid training program. The challenge is that the DTA target groups have a wide variety of prior knowledge and experience. The training program must therefore be adaptable to individual requirements.
In order to achieve this individualization, a multi-pronged approach was adopted in the DTA (Picture 1). First, general knowledge on digital twins is introduced by basic online modules. The modules include, inter alia, information about the general idea of digital twins, implementation concepts, and technical backgrounds. Afterward, the learners can proceed to the advanced online modules. These are based upon actual use cases and highlight challenges and solution strategies for the implementation of digital twins. Finally, the participants have the chance to test their knowledge in projects at

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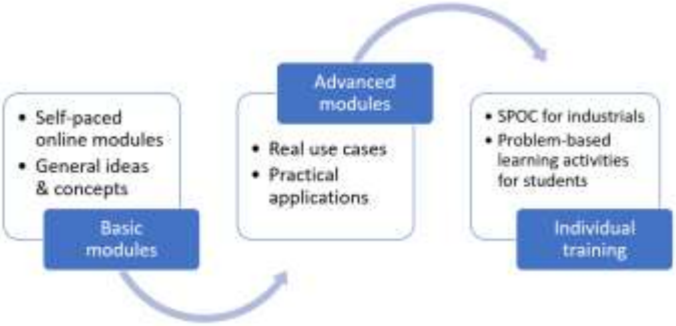
universities or in companies. During the project implementation, they are supported by the experts of the consortium. To meet the different requirements of the user groups, user profiles have been defined. This allows particularly suitable courses to be highlighted and facilitates the user's selection.



Picture 1: General learning procedure.

2 Background

2.1 Digital Twins

The idea of representing objects virtually and referring to the virtual representation of the physical objects as "digital twins" was first introduced by M. Grieves [2]. Grieves suggested a digital twin architecture composed of 3 layers: a physical layer, a virtual layer, and the connection layer between them. While the idea's core content stayed the same (i.e., representing important assets virtually), details of its description have evolved and varied in focus and scope. Five-layer models [3], as well as six-layer architectures [4], have evolved over the years to describe how a digital twin is built, expanding on the classical three-layer architecture to include services, data, and a focus on the flow of data from physical asset to the cloud [1]. In our projects, we use a digital twin architecture compatible with RAMI4.0 [5] to describe the virtualization of assets through digital twins using commonly used Industry4.0 terms. The model distinguishes between the type and the instance of an asset to further zoom into the data source. The data flow from the asset to the virtual domain and beyond is described by the Layers Axis included originally in RAMI4.0. The model introduces a data pool in which data is transformed into information and made ready for consumption through the application or other digital twins.

2.2 Knowledge Transfer

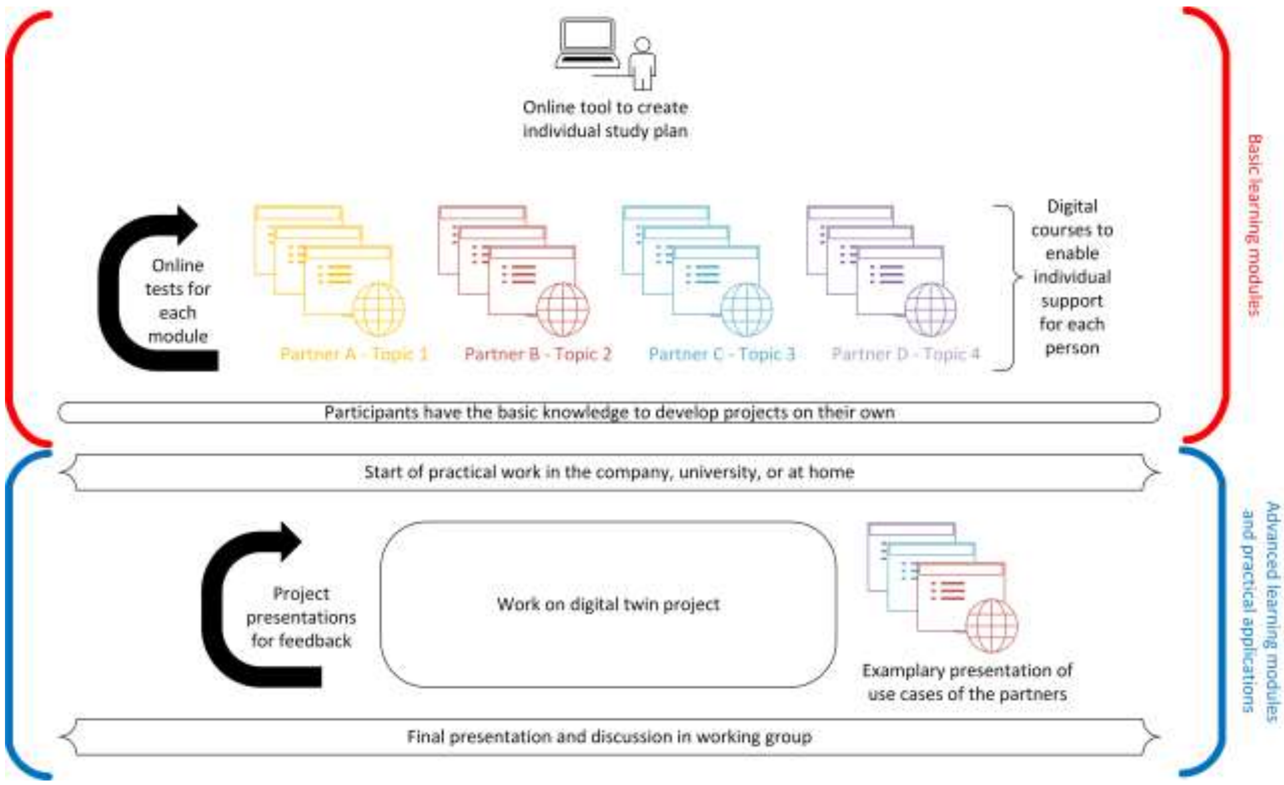
Acquiring new skills usually follows the 70:20:10 rule: 70% of the learning is done with hands-on practice and experience, 20% is done through working with colleagues and feedback, and 10% is done through reading. [6, 7] For this reason, the courses developed aim to be as interactive as possible, offering practical sessions whenever considered feasible. Because the program seeks to support companies in keeping a high level of competitiveness directly, a transparent knowledge transfer between academia and industry is established. This knowledge sharing should reduce the duplication of search efforts [8] and avoid the commonly identified restrictions arising from the commercialization of scientific research [8].

3 Concept

The training program should support companies in implementing their own digital twins. Therefore, it must fulfill several requirements:

- Accessibility to people from different backgrounds: Digital twins must be included in all processes in the company, from the shop floor to the management. Thus, employees with different experiences and educational backgrounds must be considered.
- Condensed information according to interest and needs: The learners have limited time to undergo the digital twin training. Therefore, the information should be provided efficiently by offering selection choices and by limiting the training time per topic.
- Practical relevance: After participating in the program, the participants should be able to understand and conduct digital twin projects. Therefore, the required basic knowledge, as well as exemplary implementation pathways, must be included.

In order to fulfill these requirements, a general learning path was defined. First, the participants gain fundamental knowledge using online learning modules. Second, they can proceed to the advanced learning modules, which explain real projects on digital twins. Third, they apply their knowledge to a project at a university, a company, or at home.



Picture 2: Concept for the usage of the learning material.

3.1 Creation of Learning Material

A consortium of experts from the field of digital twins should produce the learning material. In the beginning, different aspects of digital twins should be collected based on literature and own experiences. Next, the proposed fields should be discussed and adjusted in cooperation with industry representatives to extract relevant topics. Afterward, basic modules of approximately two hours of learning content should be developed, covering the general idea of digital twins, suitable technologies for the implementation of digital twins, and concepts to create and apply digital twins in different environments. Moreover, small exercises should allow the users to test their knowledge.
At the same time, use cases on digital twins should be conducted in industrial environments. From the idea and concept to the implementation and test, the whole process should be documented. Based on this, the advanced learning modules should be created showing exemplary ways to integrate digital twins in industrial environments. Moreover, the modules should highlight potential challenges and solutions which occurred during the project. This way, relevant strategies, and ideas should be transferred from the scientific partners to the industrial users of the advanced learning modules.
Practical tasks around digital twins should complement the learning modules. For students, different practical tasks should be offered at the universities. For employees, small private online courses (SPOC) tackling projects in the companies should be led by the consortium's experts. In both cases, the participants should regularly present their ideas and progress and discuss them with their peers. This feedback loop should enhance the results and allow an exchange between the participants.

3.2 Usage of Learning Material

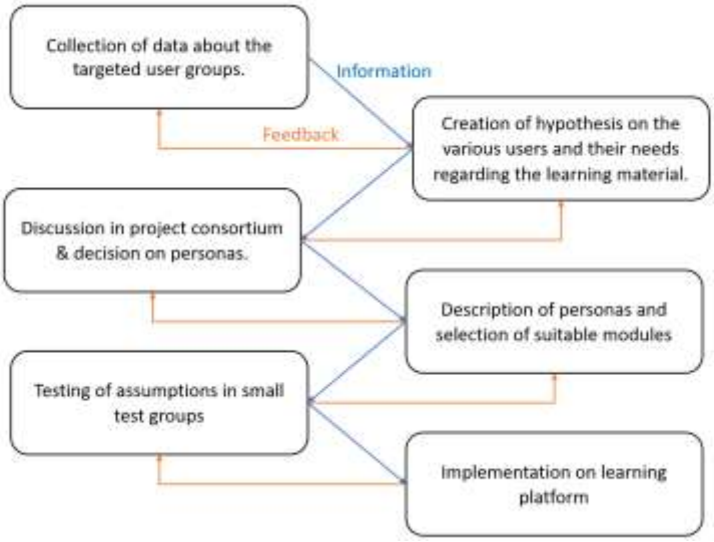
The online modules should allow an individual learning speed according to the user's preferences. However, current research indicates that the distributed studying technique allows students to memorize content better over a longer period. [9, 10] Therefore, the suggested learning path should not promote the mass reading of the material but recommend using the learning material over a more extended period with short breaks, e.g., by executing one learning module per four days [11] and by rereading main aspects of previous modules.

3.2.1 Online Modules

The learning modules will deal with different aspects of the digital twin on several abstraction levels. Thus, the learners must be able to access the modules according to their interests and knowledge. In order to ease the access to the learning modules, three different options are planned

1. Selection of modules according to topics,
2. Choice of modules according to user profiles,
3. Individual selection from a list of all modules.

Keywords should be specified for each module to allow a categorization. The persona method [12] shoud evaluate relevant aspects of the different user groups and identify suitable learning modules. Therefore, a process to create, test, and use personas are defined (Picture 3). This approach allows particularly appropriate courses to be highlighted and facilitates the user's selection. Bachelor students or trainees, for example, are offered practical modules that do not require any prior knowledge. Master's students or technical managers, on the other hand, gain direct insight into the current state of research, for example, by being introduced to concepts of digital twins.



Picture 3: Process for personas based on [12].

3.2.2 Practical Tasks

Practical tasks should allow the participants to use the obtained knowledge of the online modules in their own context. Different learning activities should be planned for students, which enable them to create, implement, and evaluate small-scale digital twin applications. Compared to the online modules, these activities should include a hands-on experience and a face-to-face meeting with the student groups. This approach also allows the usage of software and hardware at the universities.
For employees, SPOCs are planned by the experts in the consortium. The topic areas of the SPOCs should be defined in advance that the companies can register for relevant courses. Afterward, the registered participants are divided into small groups of five people [13] to allow an intense exchange during the project runtime. In these groups, participants with a similar background, such as technicians, developers, and managers, should be matched to adjust the SPOC to the participant's needs. In the beginning, the participants should receive a short introduction to the topic and the possible tools for implementation. Afterward, the group meets regularly to discuss the progress and collect information and feedback.

4 Implementation

The learning concept is currently implemented in the "Digital Twin Academy" project by a consortium of nine partners from Germany, Belgium, and the Netherlands. Therefore, not all elements of the learning concept (Picture 2) are already developed.

4.1 Content Selection

Initially, the consortium identified their expert areas as the basis for the developments and the thematic responsibilities. The areas included manufacturing, factory management, smart energy, and traffic. The consortium decided to provide basic learning modules focusing on

- introductions into the topic of digital twins from different perspectives;
- exemplary demonstrations of digital twin possibilities;
- concepts required to design digital twin applications;
- technologies to implement digital twin applications.

Afterward, possible topics for the basic modules were proposed, discussed, and selected. The focus of the SPOC was chosen by each expert individually as the expert must supervise the participants intensively. In contrast to the basic modules, the advanced modules as well as the problem-based learning activities could not be chosen freely but built upon the industrial use cases.

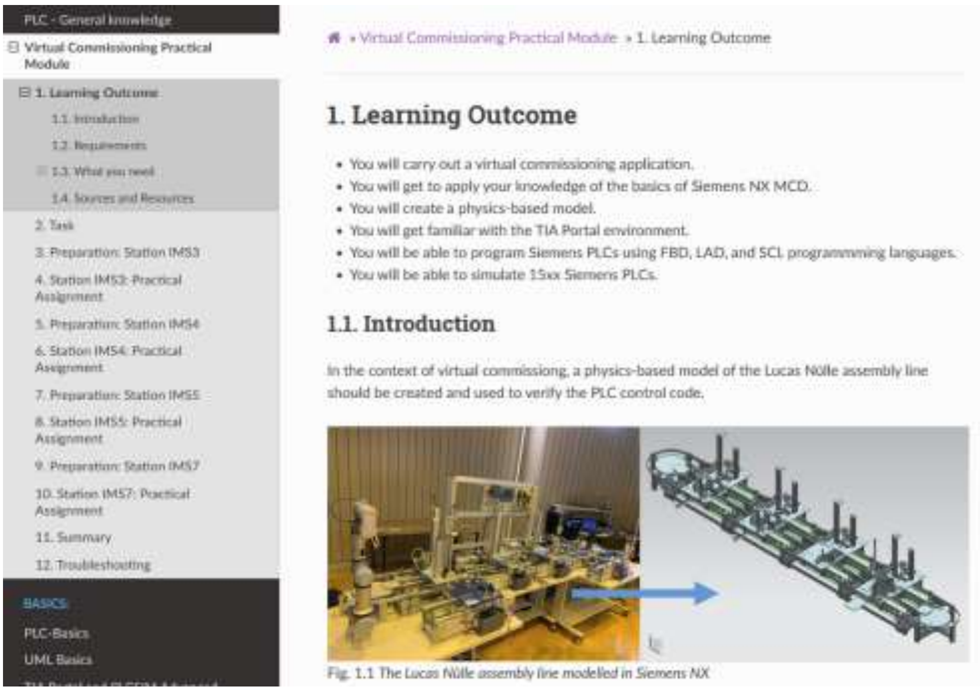
4.2 Creation Process

4.2.1 Basic Modules

The basic modules are implemented as two-hour online modules, whereby the learning modules can be selected independently of one another. The modules consist of texts, pictures, videos, and self-assessment activities. Moreover, a conclusion chapter and a download of the most critical aspects of each module are included to allow the users to remember and reread. The included videos were limited to a maximum duration of seven minutes to reduce students' cognitive load[14]. All basic modules will be provided on an edX learning platform [15].

4.2.2 Practical Tasks for Students

The practical tasks are developed using the hardware and software resources at the different universities. Therefore, the practical tasks are tested initially with students of existing courses to execute a first feedback and improvement cycle. Afterward, the course material is offered to all interested parties who possess the required materials. At FH Aachen, a tutorial and exercise for virtual commissioning applications using digital twins were developed. The course module consists of theoretical parts, which can be executed without software access, and practical parts, which require the usage of particular software. The content is provided on a website, which allows easy adjustments and interactive designs.



Picture 4: Example of a problem-based learning activity for students at FH Aachen.

4.3 Usage of Learning Material

For the selection of the modules according to the individual interest, a multi-answer questionnaire of the following format was chosen:

I am interested in learning about digital twins, specifically

- *the main concept*
- *The design part such as…*
- *The technical part such as…*

Moreover, different user profiles (personas) were defined based on the current affiliation and the background:

Current affiliation

- *Student*
  - *High School*
  - *Bachelor*
  - *Final year of Bachelor or Master*
  - *PhD*
- *Employee*
  - *Technician*
  - *Developer*
  - *Manager*
  - *Work seeker*

Background

- *Technical area (manufacturing, engineering, science, etc.)*
- *Economic area (accounting, business administration, etc.)*
- *Other*

Afterward, the personas were described according to their background, learning process, reasons for the usage of the training program, and relevant modules. Two examples of persona descriptions are shown in Table 1 and Table 2. Moreover, similar requirements regarding the modules were matched to reduce the number of module categories in the background. This process resulted in four categories to which the modules were assigned (Table 3). However, it must be noted that the current status of persona descriptions and the aggregation of the different personas to define categories was not yet tested. Therefore, updates and changes might occur in the future.

Table 1: Exemplary persona description for students.

Student – Master (technical area) / Bachelor in final year (technical area) / PhD	
Background	Previous technical knowledge Used to self-learning activities
Learning process	Can work on problems independently Can find necessary/ missing knowledge on his own Likes to find own solutions Practical tasks for better understanding and higher interest
Reasons/ motivation for usage	Mandatory activity for their study program Increase knowledge for application process/ future job opportunities
Type of modules	In-depth modules which require previous technical knowledge such as cad or programming Modules explaining conceptual backgrounds

Table 2: Exemplary persona description for employees.

Employee - Technician	
Background	Practical technical knowledge
Learning process	Focus on practical applications Hands-on experiences
Reasons/ motivation for usage	Proposal from employer Increase knowledge for application process/ future job opportunities
Type of modules	Introductory modules with relation to real productions Hands-on modules with a focus on practical applications

Table 3: Aggregation of personas into categories to reduce the number of required user profiles.

Categories	**Persona**
Category 1	Student – High School Student – Bachelor (technical or non-technical area) Work Seeker – No Technical Background (Retraining)
Category 2	Student – Master (technical area) / Bachelor in final year (technical area) / PhD Employee – Technical Development or Technical Management
Category 3	Student – Master (non-technical area) Employee - Management
Category 4	Employee – Technician Work Seeker – Technical Background

5 Conclusion and Outlook

Digital Twins are seen as one of the main technologies to pursue the goals of Industry 4.0. However, there is a gap between the technological possibilities identified in research projects and the companies' knowledge about practical benefits and implementation strategies. Moreover, specialists are missing who can understand, plan, and implement digital twin applications in the industry. To close this gap between academia and industry, the project "Digital Twin Academy" was introduced. It aims to connect experts and the industry by forming a close network, training students and employees according to their individual needs, and developing exemplary use cases to understand digital twins better. For the learning program, the different backgrounds and experiences of the participants must be considered. Therefore, the approach is divided into basic modules, advanced modules, and practical tasks. A selection tool identifies relevant learning modules according to the personal background and the interest of the user. Basic modules present the current state of the art and introduce the required knowledge to understand practical applications. Subsequently, advanced modules can be selected depending on the area of interest. These contain field reports on real-life applications and provide an insight into procedures and challenges. Parallel to the advanced learning modules, practical activities take place within the framework of internships at the universities, work on company-specific issues, or small-scale implementations at home.

Since the application-oriented, advanced modules are created in cooperation between companies and research institutions, knowledge about challenges, implementation strategies, and solutions can be conveyed directly to the students and employees. The use of practical activities in small groups also challenges creativity and solution-orientation. The first test phase of the developed concept is currently running at universities in Germany, Belgium, and the Netherlands.

6 Literature

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