Digital Transformation through Conceptual Modeling: The NEMO Summer School Use Case

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Abstract: In the digital age, achieving a balance between human creative thinking and technology capabilities is crucial. Recognizing the potential of such collaborations, OMiLAB (Open Model Initiative Laboratory) developed a conceptual framework for establishing experimental innovation spaces in which skills to advance human-machine interaction can be taught and applied. The resulting Digital Innovation Environment incorporates both business and engineering perspectives, emphasizing the importance of interdisciplinary settings. Conceptual models and Digital Twins play a pivotal role within the environment, seamlessly bridging business strategies with cyber-physical systems. This paper offers a comprehensive understanding of the OMiLAB network, highlighting its alignment with the principles of a Community of Practice and emphasizing the knowledge exchange, exemplified by the NEMO Summer School Series. We present insights, best practices, and educational paradigms vital for navigating the digital transformation landscape.

Keywords: Digital Innovation Environment; Community of Practice; OMiLAB; Conceptual Modeling; Knowledge Transfer; NEMO Summer School Series

1 Introduction

The ongoing digital transformation represents a fundamental shift in the way organizations navigate the increasingly complex and interdisciplinary landscape of the digital era. This shift requires rethinking the infrastructures, underlying processes, and educational frameworks to realize innovative solutions [va22]. Moreover, the effective collaboration between humans and various forms of technology has become a crucial factor for the conceptualization and realization of business ideas [Vo23b]. While humans provide domain expertise and innovative thinking, technologies, including IoT devices, robots, and autonomous vehicles, emerge as independent entities, often working alongside humans within interconnected cyber-physical environments. Consequently, the necessity emerges to bridge the gap between humans and technology, with the goal of fostering interaction among them. Addressing this dynamic, OMiLAB (Open Model Initiative Laboratory) introduced the Digital Innovation Environment, a conceptual framework used to establish experimentation spaces as physical laboratories [Ka20; Va22]. The main objectives the environment targets are of an experimental and educational nature [OM20]. From an experimental perspective,

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it addresses the complexity of digital transformation projects by facilitating prototype development to test innovative solutions in a physical space. From an educational perspective, it advocates a comprehensive skill profile that is required to bridge the human-technology interaction gap. Moreover, the utilization of conceptual models as bridging component within the Digital Innovation Environment is emphasized, which has the potential to address design issues related to conceptual modeling education [Bu19; GOB20].

In this work, we highlight the fundamental dynamics of knowledge transfer within the OMiLAB network by building upon the Digital Innovation Environment and the Community of Practice concept. For this purpose, we start by affirming the OMiLAB network's alignment with the Community of Practice criteria to then focus on the knowledge transfer corresponding to the experimental and educational facets. A practical showcase is provided through the lens of the NEMO Summer School Series 2023, exemplifying the implementation of this knowledge transfer. The resulting dynamics are guided by the notion of an ongoing learning loop, which is central to the Community of Practice concept.

The corresponding structure of this contribution is as follows: Section 2 outlines the relevant theoretical background, encompassing the Community of Practice concept and the OMiLAB Digital Innovation Environment. Section 3 forms the core contribution of this work, detailing the OMiLAB network's characterization as a Community of Practice, highlighting the experimental and educational goals, and illustrating their combined implementation in a key community event. The summarized insights are captured in Section 4.

2 Theoretical Background

2.1 Community of Practice

The complexity accompanying digital transformation projects is characterized by rapidly advancing technologies and significant shifts in industry demands. In such complex environments, the sharing of experiences and expertise persists as a crucial element, leading to the continuous emergence of communities of practice. In short, "*Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly*." [WW15, p.2] Consequently, such communities provide a platform for academics and practitioners to exchange valuable insights and aggregated knowledge based on their unique focus. These aspects are illustrated in Fig. 1, emphasizing the collaborative nature of a Community of Practice and the goal of learning both from and with each other. Its members should thus benefit from the resources and ideas provided by the community so that they can utilize them for their respective purposes. Subsequently, members can share their experiences, reflecting on what aspects did or did not work effectively. In this way, communities of practice facilitate educational resources in an ongoing learning loop engagement, known as experience storytelling [We23]. Finally, it is relevant to mention the three criteria that must be met to instantiate the concept of

Community of Practice [WW15], as they form the basis for the OMiLAB Community of Practice instance described subsequently (cf. Section 3.1):

1. The **domain** defines the shared concern or passion of the community.
2. The **community** provides domain expertise and supports the sustainable exchange of valuable results and insights.
3. The **practice** encompasses experiences gained within the community through the utilization of shared knowledge and resources.

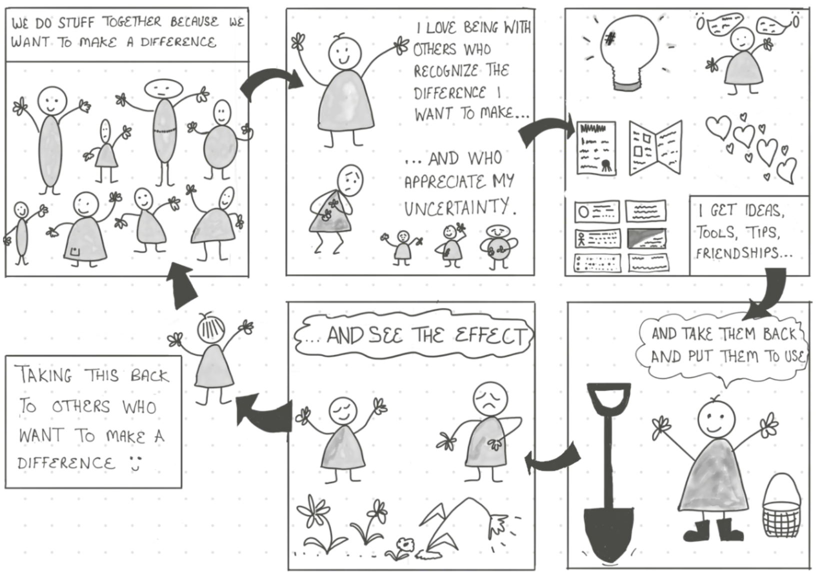

Fig. 1: Community of Practice: Ongoing learning loop [We23]

2.2 OMiLAB Digital Innovation Environment

The Digital Innovation Environment supported by OMiLAB encompasses both a physical and virtual space, equipped with software and hardware to foster collaboration among stakeholders with diverse expertise. It facilitates iterative experimentation, testing, and evaluation of the interaction and collaboration between humans and machines [Bo19]. These elements are organized into three foundational pillars, as shown in Fig. 2, that guide the physical and digital manifestation of corresponding laboratories. The essence of each pillar is introduced in the following, as well as selected approaches and technologies.

Pillars. Conceptual modeling underpins all activities related to the Digital Innovation Environment, as conceptual models form the fundamental component upon which all work is based. The corresponding pillar, driven by the open metamodeling platform ADOxx [BO20] and the Agile Modeling Method Engineering (AMME) life cycle [Ka15], facilitates the *design of smart models* (Pillar II) to represent and operationalize domain-specific knowledge with the goal of aligning business ideas and technological capabilities [KBU22]. The initial *creation of innovative business ecosystems* (Pillar I) is supported by Design Thinking, fostering collaboration and co-creation among diverse stakeholders in corresponding workshops that can be tailored to context-specific needs [MP22]. Technological capabilities are assessed through the *engineering of Digital Twins* (Pillar III), following the underlying objective of setting up experimental proofs of concept using various technologies, tool deployments, and cyber-physical experiments available in the environment [Bo19; Wa19]. This can be achieved by establishing and configuring cyber-physical systems that interact with conceptual models [Wa18], thus serving as feasibility assessments [Ka20; Va22].

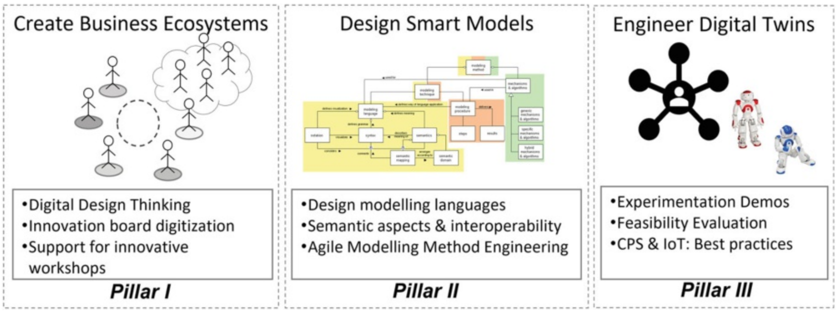

Fig. 2: Core pillars of the OMiLAB Digital Innovation Environment [OM20]

Approaches & Technologies. The approaches and technologies utilized in the context of the Digital Innovation Environment are freely distributed by the OMiLAB community following the openness principle. Selected aspects are further discussed in the following based on their relevance to this contribution:

- The **Digital Twin** concept has been defined in various ways within the scientific literature, with notable variations resulting from the respective application context. The proposed definitions are often based on the differentiation between digital and physical twins, and the information transfer established between them [Gr19; Kr18]. The origin of the concept is grounded in the manufacturing domain, where Digital Twins describe potential or existing products with respect to their stage of the product lifecycle, leading to the separation between Digital Twin prototypes without a matching physical part, and Digital Twin instances as real-time models mirroring physical entities [GV17; Si21]. Beyond this production-centric interpretation of Digital Twins, both tangible and non-tangible enterprise assets have been used in a conceptualization of the Digital Twin paradigm as subjects to be digitally represented. The core components of the resulting Digital Twin concept are divided into (i) diverse data used to create a virtual representation of the asset, (ii) semantic technologies that give meaning to the data, (iii) analytical and intelligent services for asset optimization, and (iv) interfaces that facilitate bidirectional interactions between the Digital Twin and its real-world counterpart [DP20]. In a similar manner, a Digital Twin of a system was defined as "*a set of models of the system, a set of contextual data traces and/or their aggregation and abstraction collected from a system, and a set of services that allow using the data and models purposefully with respects to the original system.*" [Ki20, p.91] Considering the underlying notion of this definition, we adopt a semantic-driven Digital Twin understanding discussed in [Ka20; KBU22], where varying data sources are integrated into interconnected, human- and machine-readable diagrammatic models to form Digital Twin representations of the modeled system.

- **Conceptual Modeling** has the goal of representing "*certain aspects of complex realities through a small number of modeling constructs, with the intent that they can support some kinds of analysis.*" [Yu09, p.101] In other words, the goal of conceptual modeling is to simplify a system under study by focusing on the representative concepts and the relationships between them while also acknowledging the need for further processing capabilities. To serve this purpose, abstraction is performed, which describes the process of reducing objects to their key properties to achieve the desired simplification [MT21]. The corresponding models are created using modeling languages, which specify a consistent syntax, semantics, and notation of created models [Fr11; KK02]. Consequently, human-readable diagrammatic representations are used to improve understanding and communication among stakeholders from diverse disciplines [My92]. Machine interpretation is facilitated by metamodels, detailing the concept structure of a modeling language in a machine-processable manner [Fr11; KK02]. Moreover, intelligence of models is enabled through mechanisms and algorithms, which extend the capabilities of modeling languages to offer further functionalities, thereby distinguishing them from diagrams used only for visualization purposes. Such functionalities can encompass model analysis (e. g., consistency checking, path analysis [Ka16]), model transformation (e. g., SQL generation [Ka16]; Linked Open Models translation [KB16]), and model integration with other systems (e. g., operating cyber-physical components [Wa18]). Considering these elaborations on different facets of conceptual modeling, the aforementioned design of smart models can be characterized by their ability to decompose a modeled system across multiple perspectives using diagrammatic representations that are both human- and machine-understandable while providing further capabilities to process model content and interact with other systems [Ka20].

- **Design Thinking**, and more specifically haptic Design Thinking workshops, have gained popularity in recent years as an approach that enables domain experts to express innovative ideas and develop solutions for problems that require the knowledge and perspective of different actors within an organization and beyond [Sc16]. The term *haptic* refers to using tangible materials like sticky notes and paper figures within Design Thinking approaches, as they enhance the participant engagement in corresponding workshops, fostering the exploration and design of innovative ideas.

- **Scene2Model** is an ADOxx-based tool developed to bridge haptic Design Thinking workshops and digital conceptual models. It enables the transformation of tangible artifacts created during such workshops into conceptual models by translating each paper figure into a modeling object [Mi18; MMK19]. Within the tool environment, translated objects can be further enhanced with additional semantics, and relevant concepts from related modeling languages can be added to foster integration across different perspectives [MP22]. Considering the business-oriented view of the first pillar, references to business process models can be established to create a comprehensive view of business model ecosystems [We19]. Following the previously emphasized notion of semantic-driven Digital Twins, we consider the conceptual modeling-based, digital representation of scenarios created within haptic Design Thinking environments as Digital Twins for Design Thinking (cf. [Ka; Mu24]). In this context, a set of interconnected, digital models is used to represent business ecosystems by abstracting data traces encoded in the form of paper figures during workshops. Moreover, services such as the automated publication of models on suitable platforms are offered, enabling the collection and processing of feedback to derive meaningful insights and implications for the development of the initially modeled system [Vo23b].

To conclude this section, the desired impact of the Digital Innovation Environment, divided into experimental and educational objectives, is discussed:

- **Experimental objectives** follow the notion that complex and interdisciplinary projects related to digital transformation often require the setup of experimental prototypes to test and validate the feasibility of proposed solutions [Ka20]. The third pillar is thus crucial in determining best practices for the evaluation of innovative ideas. It emphasizes encoding knowledge into conceptual models, which can be verified in the context of experimental cyber-physical setups [Wa18; Wa19].
- **Educational objectives** promote the importance of advancing a skill profile required to successfully navigate the complex digital transformation landscape [KBU22]. While the concept of a *Digital Engineer*, as a distinct educational profile, was proposed long ago [WDW00], the accelerating pace in the digital age requires the consideration of skills not yet widely adopted in higher education curricula [Ka20]. Consequently, several professional roles need to be covered, namely, the one of a *Digital Innovator* coming up with novel business ecosystems, and of a *Digital Engineer* capable of setting up experimental prototypes [Ka20; Va22]. Other contributions further emphasize the relevance of a *Knowledge Engineer* responsible for bridging the other two perspectives through the design of Digital Twins in the form of semantic-rich conceptual models [KBU22]. The aggregation of these roles into one skill profile was coined *Digital Leader* in our most recent work [Vo23a]. Nevertheless, this skill profile does not imply that a single individual must embody all these roles but rather that higher education institutions should cultivate a composite set of skills across learners to prepare them for interdisciplinary digital transformation projects.

3 An Ongoing Learning Loop within the OMiLAB Community of Practice: The NEMO Summer School Series

The contribution of this work consists of several interrelated aspects that highlight the knowledge transfer within the OMiLAB network. Each of these aspects is displayed as one of five frames in Fig. 3, which, as a whole, forms an OMiLAB instance of the learning loop underlying the Community of Practice concept (cf. Section 2.1). In the first step, it is therefore argued that the OMiLAB network meets the previously introduced criteria of a Community of Practice (Frame 1). Subsequently, the remaining frames (Frame 2-5) are used to discuss the transfer of knowledge within this community as an ongoing learning loop using the example of the NEMO Summer School Series[3].

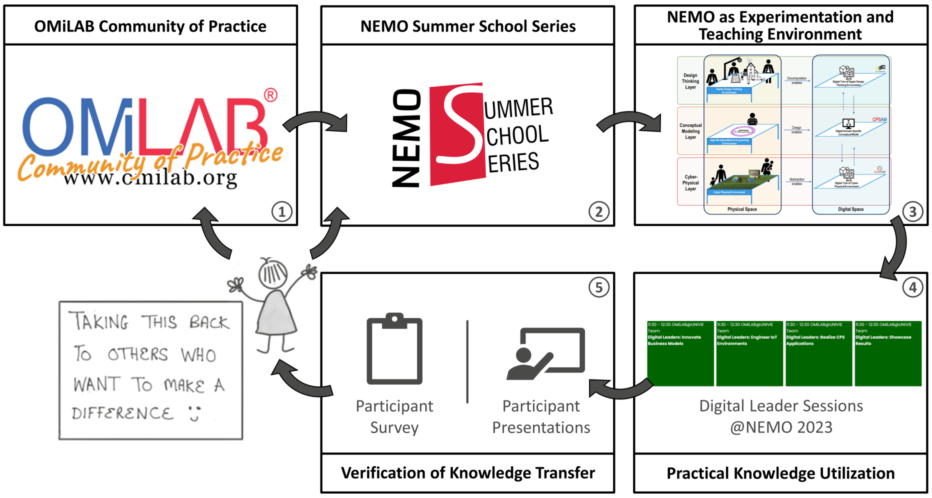

Fig. 3: OMiLAB Community of Practice: Ongoing learning loop (based on [Vo23a; We23])

3.1 The OMiLAB Community of Practice (Frame 1)

OMiLAB promotes the benefits of establishing innovation laboratories, which offer a physical and virtual experimentation space for the purpose of advancing the design, implementation, and evaluation of solutions for challenges resulting from complex digital transformation landscapes. In this effort, relevant resources such as hardware, software, learning materials, and documentation of best practices are provided in an open-source manner (e. g., [Ka16]). By joining the OMiLAB network of nodes, entities from academia to industry can seamlessly integrate the conceptual framework of the Digital Innovation Environment into their premises, enabling them to build on a shared infrastructure fostering co-creation among network

[3] https://nemo.omilab.org/

members. Each node follows the same principles of the fundamental pillars, while specific implementations diverge based on their unique focus, thereby forming an instance of the Digital Innovation Environment [Va22]. An invariant across all instances is the use of conceptual models, which are vital in bridging business-oriented and technology-oriented perspectives [KBU22]. These models are created using conceptual modeling with dedicated modeling methods that are designed by community members, resulting in a diverse selection of openly available modeling tools[4].

Based on the insights provided in this section, we argue in the following that the OMiLAB network meets the criteria to be considered a Community of Practice:

1. The shared **domain** within the OMiLAB network encompasses conceptual modeling, and more specifically, the creation of value through conceptual models in both virtual and physical settings [Va22]. This shared domain is captured by the Digital Innovation Environment's commitment to bridging the business and technical facets of digital transformation by utilizing smart models. Through its network of nodes, OMiLAB ensures that this domain is globally represented, thereby advancing its core notion and fostering an environment dedicated to collaborative learning and innovation.
2. The OMiLAB **community** offers aggregated knowledge from research and industry that is used for the development of valuable insights, methodologies, and best practices related to the shared domain. To distribute and exchange this aggregated expertise, OMiLAB engages in a variety of community activities [Va22]. Events like conferences and workshops offer platforms for direct interaction and discussion of ideas while training events and tutorials ensure support regarding the approaches and technologies utilized within the Digital Innovation Environment [GMS16]. The subsequently discussed NEMO Summer School Series, in particular, manifests as OMiLAB's commitment to community and educational engagement, ensuring a continuous knowledge exchange between existing members and like-minded people interested in joining the community [Bo19; GMS16; Va22].
3. For OMiLAB, the most important **practice** is the Digital Innovation Environment employed as conceptual framework by the network of nodes. Domain-specific modeling tools based on the ADOxx metamodeling platform [BO20] play a crucial role in this, allowing nodes to tailor solutions to the needs of their unique focus. Collaborative research projects further enhance this practice by bringing together diverse groups to work on shared goals over a longer period of time. The iterative evaluation of shared concepts, methods, and tools by the community ensures continuous adaption to the changing requirements during the ongoing learning loop. Furthermore, the publication of contributions from diverse research groups of the community in book series [Ka22; KMM16] showcases OMiLAB's commitment to disseminating knowledge and promoting best practices across the broader domain.

[4] https://www.omilab.org/activities/projects/

3.2 NEMO Summer School Series: An Example of the Learning Loop within the OMiLAB Community of Practice

After having established OMiLAB as a Community of Practice, the NEMO Summer School Series is showcased through the remaining frames of the learning loop displayed in Fig. 3.

Frame 2: NEMO Summer School Series The second frame emphasizes the possibility for anyone interested in the OMiLAB activities to meet like-minded people, namely in the form of the annual NEMO Summer School Series, reaching its 10th edition in 2024. NEMO was initiated to serve as an interactive space where researchers, industry professionals, and students from various backgrounds[5] discuss the evolving facets of conceptual modeling in the digital era [Bo19]. Recognizing the rapid shifts in industry demands and technological advancements, this annual gathering is valuable for combining academic insights with practical challenges to offer a holistic perspective on digital transformation with conceptual modeling at its core [GMS16]. The respective program of NEMO thus includes both theoretical and practical sessions, covering the latest research findings of domain experts that are associated with the streams listed below. Moreover, the program is adapting over time, emphasizing the continuously evolving facets of a required skill profile (cf. Section 2.2). The corresponding curriculum of NEMO encompasses six streams [Va22]:

- Foundations of Conceptual Modeling: This stream dives into the scientific principles of conceptual modeling and the foundations of conceptual models, that incorporate, beyond syntax and notation, the semantics of the domain they address.
- Smart Models for Humans and Machines: This covers domain-specific modeling methods applicable across various sectors, that enable the design of human- and machine-interpretable models. Through the utilization of the AMME life cycle, these methods are iteratively reworked and adjusted to changing requirements [Ka15].
- Semantics and technologies for Digital Ecosystems: It addresses the domain-specific use of semantic technologies. To enable the design of smart models, mechanisms and algorithms that enhance model value through extended functionalities are introduced.
- Digital Design Thinking: In this stream, disruptive business model transformations and the benefit of co-creation tools in fostering global collaboration are emphasized.
- Enterprise Digital Twins: It explores the virtual counterpart to enterprise assets and their static and dynamic features. For this purpose, conceptual models are utilized, corresponding to the semantic-driven notion of Digital Twins (cf. Section 2.2).
- Cross-Cutting Issues: This stream addresses the intricate processes involved in model creation, verification, and knowledge interpretation.

[5] The diverse academic and professional backgrounds of NEMO 2023 participants is detailed through a survey from our previous work [Vo23a], which is further utilized within Frame 5.

Frame 3: NEMO as Experimentation and Teaching Environment The third frame represents the learning materials, tools, and conceptual ideas that participants receive from the community in the context of NEMO 2023. For the purpose of meeting the experimental and educational objectives of the OMiLAB Digital Innovation Environment (cf. Section 2.2), a specialized instance is required in this context. In our most recent work, we propose such an instance that addresses challenges related to establishing an updated Digital Leader skill profile [Vo23a]. The *Smart Innovation Environment for Digital Leaders* resulting from these efforts makes up the third frame, which is also displayed separately in Fig. 4 for better legibility. The respective layers of the environment are summarized in the following, as they form a vital component within the learning loop example:

- Design Thinking Layer: On the first layer, business innovation is supported by the creation pillar of the Digital Innovation Environment, leveraging haptic Design Thinking workshops based on SAP Scenes[6] for effective co-creation. Moreover, Scene2Model automates the conversion of workshop artifacts into Digital Twins of haptic Design Thinking, capturing implicit knowledge and offering deeper analysis.
- Conceptual Modeling Layer: This layer forms the crucial bridge between Design Thinking and cyber-physical perspectives, enabling the integration of two Digital Twin environments through conceptual models. In this context, the Cyber-Physical System Abstraction Model (CPSAM), a prototype method under development, plays a key role. CPSAM employs an interoperability algorithm to identify IoT devices and necessary capabilities from scenarios digitized using Scene2Model. Furthermore, utilizing the REST [FT00] API from the open-source IoT platform OpenHAB, registered IoT devices (referred to as items) are imported and matched with those represented within the *Digital Twin of the Haptic Design Thinking Environment*. Items aligning with scene-extracted devices are colored in green, while unmatched ones are indicated in orange. Modelers then have the capability to link these items to custom-defined rules, involving triggers, actions, and conditions, as illustrated in Fig. 5. Ultimately, these modeled rules are deployed back into the IoT environment to evaluate their physical execution, leveraging tool functionalities through the REST API.
- Cyber-Physical Layer: The foundation of this layer is guided by the experimental objective of the Digital Innovation Environment, aiming at the setup of physical prototypes to evaluate the feasibility of scenarios from the Design Thinking layer. The IoT platform OpenHAB is employed to design Digital Twins of these setups through the abstraction of functionalities of the corresponding physical devices on one hand and to facilitate data exchange between the cyber-physical and conceptual modeling layers on the other. This integration allows for the implementation of scenarios in a proof-of-concept setting, utilizing rules and events specified as conceptual models.

[6] `https://apphaus.sap.com/resource/scenes`

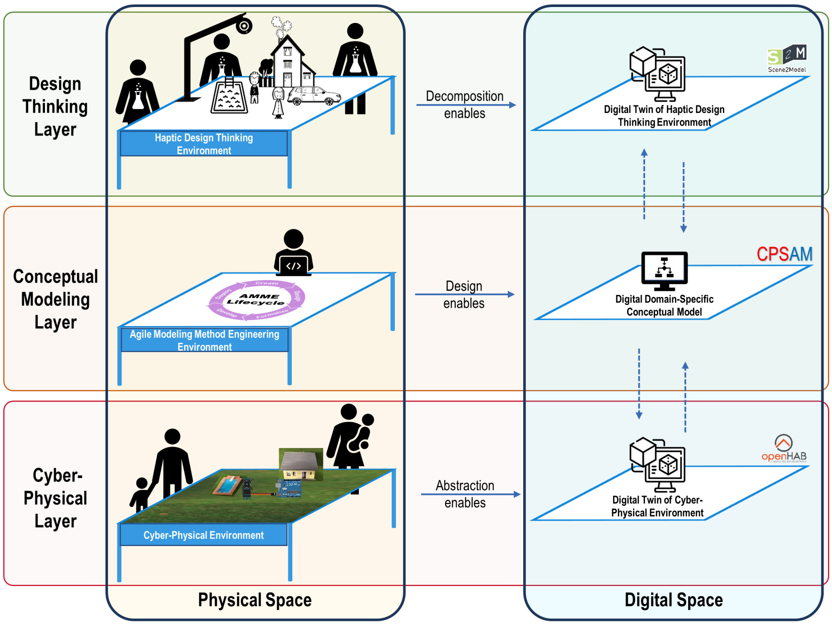

Fig. 4: Smart Innovation Environment for Digital Leaders (updated version from [Vo23a])

By building upon the OMiLAB ecosystem, the three layers not only foster hands-on experience but also lay the foundation for an approach to teaching the facets of the Digital Leader skill profile (cf. Section 2.2). This approach follows the same notion of setting up physical training laboratories in higher education designed as environments for applying the skills required in interdisciplinary digital transformation projects [Mo18; Va22].

The application of the approach derived from the Digital Innovation Environment instance during NEMO 2023 consisted of a theoretical introduction and a separate lecture that demonstrated how to realize a business idea through the utilization of each layer. Subsequently, students were given the task of applying the demonstrated knowledge in groups during dedicated sessions, which are elaborated as part of the fifth frame. In the first part of the demonstration lecture, a scenario regarding pool safety was designed using the Scene2Model tool in combination with domain-specific paper figures covering relevant IoT devices. The digitalized scene was then enriched by connecting the necessary capabilities of the scenario to the respective modeling objects of the IoT devices. Next, a cyber-physical environment corresponding to the scenario was set up using an Arduino, sensors, actuators, and a Raspberry Pi that was linked to an already configured instance of the IoT platform OpenHAB. Due to the time limitations of the lecture, the registration of IoT devices necessary to create a *Digital Twin of the Cyber-Physical Environment* was prepared in advance. In the final step, the registered devices were automatically imported into the CPSAM modeling environment, enabling their mapping to visual representations of custom rules. An example of such a rule is depicted in Fig. 5. The items colored green, imported from OpenHAB, correspond to devices represented in the *Digital Twin of the Haptic Design Thinking Environment*. The trigger *KidNearPool* is connected to an *RFIDreader* item, indicating that when the sensor identifies a specific tag, the rule *Save Child* is activated. In return, this activation triggers two actions: *NotifyParent*, which turns on the item *GreenLED*, and *ClosePool*, which engages the item *Servo*. Specialized tool functionalities were then used to deploy the modeled rules to the configured OpenHAB instance so that the intended functionality could be confirmed. On this basis, both experimental and educational objectives set out in Section 2.2 can be effectively realized by first introducing participants to the underlying mechanisms of the environment and then further developing their skills through hands-on exercises.

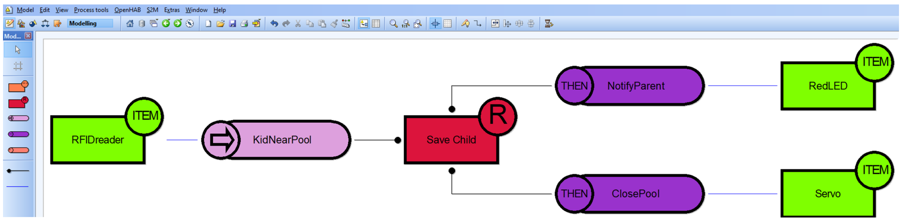

Fig. 5: An example rule created within CPSAM related to the pool safety scenario

Frame 4: Practical Knowledge Utilization Students were given the task to apply the *Smart Innovation Environment for Digital Leaders* in a practical manner during three distinct sessions, which are displayed in the fourth frame of Fig. 3 as their assigned time slots within the NEMO 2023 program[7]. Each session corresponded to working on one of the environment layers and involved three groups of twelve students guided by an advisor. In addition, each group was allocated a separate domain (Garden, Greenhouse, Coffeeshop), within which they had to define their own scenario following the approach of the demonstration lecture using extensive documentation of utilized tools and devices.

Frame 5: Verification of Knowledge Transfer The fifth frame of Fig. 3 addresses both experimental and educational objectives within the verification of knowledge transfer. Moreover, this part of the learning loop is about seeing the effects resulting from the previous frames and assessing which aspects worked successfully. For this evaluation, we revisit a survey presented descriptively in our previous work [Vo23a], aiming to repurpose its results to draw insights for the ongoing learning loop in the context of this contribution. The survey captured participants' personal information, understanding of the innovation environment for Digital Leaders, their practical experiences within the environment's three layers, the utility of the provided tools, and the value of using conceptual models. In total, 34 out of the 36 students participating in the Digital Leader sessions filled out the survey. The respective results are displayed in Tab. 1, forming the basis for evaluating the knowledge transfer within the OMiLAB Community of Practice learning loop against our set objectives.

[7] The last of the green time slot corresponds to the participant presentations of Frame 5.

Tab. 1: Selected question from the second part of the survey and corresponding mean values of answers rated on a scale from 1 (Not at all) to 5 (Very much)

Question	Mean Answer
The haptic design thinking environment was beneficial in generating innovative scenarios.	4.00
The tangible paper figures foster creativity and cooperation in the workshops.	4.06
Setting up a cyber-physical environment was beneficial for understanding and abstracting the relevant technical capabilities needed in the context of the created scenario.	3.88
The conceptual modeling layer helped me to understand the relationships between the haptic design thinking environment and the cyber-physical environment.	3.76
The Scene2Model tool effectively supported the digitalization of the created scenarios in the haptic design thinking environment.	3.79
The CPSAM modeling method eased the definition and deployment of the capabilities needed for the defined scenario.	3.38
The conceptual modeling layer helped me to understand the value of using conceptual models in a domain for a specific purpose.	3.91

Regarding experimental objectives, it needs to be assessed whether the provided tools, hardware, documentation, and learning materials were sufficient to set up cyber-physical testing environments within the context of the interdisciplinary tasks. The perception of the tool support was overall good, while Scene2Model was seen to support the participants on the Design Thinking layer to a greater extent in comparison to the CPSAM tool. This can be explained by the latter being still in a prototype phase with iterative refinements needed. Additionally, many students were not familiar with the practices of conceptual modeling prior to NEMO, making it more complicated to understand the syntax, notation, and functionalities of the CPSAM tool. Scene2Model, on the other hand, does not require such deeper knowledge of conceptual modeling, as concepts are automatically imported into the modeling environment, where they can be intuitively adapted and enriched. Nevertheless, students successfully implemented cyber-physical functionalities through conceptual models, thereby achieving the desired impact of the experimental objectives.

Educationally, our focus was integrating the Digital Leader skill profile into higher education by promoting the *Smart Innovation Environment for Digital Leaders* to teach upcoming generations about the interdisciplinary that goes along with digital transformation. As mentioned before, this skill profile combines the facets of a business-oriented and an engineering-oriented view while enabling their bridging through the use of conceptual models. Survey results affirmed the efficacy of Design Thinking workshops and tangible paper figures in fostering innovation collaboratively. In accordance with the experimental objective, the setting up of a cyber-physical experimentation environment was also perceived as a useful component for understanding the technical capabilities necessary to realize innovative scenarios. Moreover, participants could see their ideas being executed in the real world, which sparked particular excitement among the presenting groups after working as intended. Finally, the shared domain that unites the OMiLAB Community of Practice, conceptual modeling, and model value, forms the crucial element within the innovation environment. Participants acknowledged its role in highlighting the value of conceptual models and their bridging role between business and engineering perspectives. In summary, the *Smart Innovation Environment for Digital Leaders* effectively addressed the experimental and educational objectives within the NEMO Summer School Series 2023, which is further supported by the lessons learned that were reported as part of our previous work [Vo23a].

Ongoing Learning Loop. The learning loop instance displayed in Fig. 3 has two potential paths to be completed, which are represented as two separate arrows leading back to the first and second frames. The first path suggests that summer school participants decide to join the OMiLAB community by establishing a laboratory or developing their own modeling method, which can form the basis for actively contributing to upcoming events, as indicated by the second arrow. Apart from these two represented paths, the insights generated from the survey results can be utilized to improve future applications of the proposed experimentation and teaching environment, also independent of the NEMO context.

4 Conclusion

This paper presents a comprehensive exploration of the OMiLAB Digital Innovation Environment, emphasizing its pivotal role in fostering knowledge transfer. We highlighted how these dimensions collectively meet experimental and educational objectives by delving into a specialized instance of the three-layer structure, consisting of Design Thinking, conceptual modeling, and cyber-physical facets. The experimental objectives emphasize the need for prototypes in digital transformation projects to test solution feasibility, while educational objectives underscore the need for a multifaceted skill profile in the digital transformation age. The illustrative example of the NEMO Summer School Series 2023 underpinned the efficacy of the utilized framework in creating experimental setups that use physical devices, specifically emphasizing the strengths of conceptual modeling, which often falls outside the scope of regular education curricula [Bu19]. To provide a foundation on how to address these objectives in the future, we positioned NEMO as an ongoing learning loop within the Community of Practice concept that fosters knowledge transfer through theoretical foundations, industry insights, applied use cases, and hands-on experience. Moreover, emphasis is put on fostering collaboration and co-creation among stakeholders from diverse backgrounds in the context of an interdisciplinary setting. In conclusion, this contribution promotes and advances the notion of empowering future generations to tackle real-world challenges effectively in the context of digital ecosystems that require the bridging of business and engineering perspectives, focusing on the utilization of conceptual models for this purpose. As we move forward, it is our aim that the approach and insights presented herein serve as the foundation for further applications within and outside of education.

References

[Bo19] Bork, D.; Buchmann, R.; Karagiannis, D.; Lee, M.; Miron, E.-T.: An open platform for modeling method conceptualization: the OMiLAB digital ecosystem. Communications of Association for Information Systems 44/, pp. 555–579, 2019.

[BO20] BOC Asset Management GmbH: The ADOxx Metamodeling Platform, 2020, URL: https://www.adoxx.org.

[Bu19] Buchmann, R. A.; Ghiran, A.-M.; Döller, V.; Karagiannis, D.: Conceptual modeling education as a "design problem". Complex Systems Informatics and Modeling Quarterly 21/, pp. 21–33, 2019.

[DP20] Dietz, M.; Pernul, G.: Digital Twin: Empowering Enterprises Towards a System-of-Systems Approach. Business & Information Systems Engineering 62/2, pp. 179–184, 2020.

[Fr11] Frank, U.: Multi-perspective enterprise modelling: Background and terminological foundation, eng, ICB-Research Report 46, Essen, 2011.

[FT00] Fielding, R. T.; Taylor, R. N.: Architectural Styles and the Design of Network-Based Software Architectures, PhD thesis, 2000.

[GMS16] Götzinger, D.; Miron, E.-T.; Staffel, F.: OMiLAB: An Open Collaborative Environment for Modeling Method Engineering. In (Karagiannis, D.; Mayr, H. C.; Mylopoulos, J., eds.): Domain-Specific Conceptual Modeling: Concepts, Methods and Tools. Springer International Publishing, Cham, pp. 55–76, 2016.

[GOB20] Ghiran, A.-M.; Osman, C.-C.; Buchmann, R. A.: Advancing Conceptual Modeling Education Towards a Generalized Model Value Proposition. In (Siarheyeva, A.; Barry, C.; Lang, M.; Linger, H.; Schneider, C., eds.): Advances in Information Systems Development. Springer International Publishing, Cham, pp. 1–18, 2020.

[Gr19] Grieves, M.: Virtually Intelligent Product Systems: Digital and Physical Twins. In (Flumerfelt, S.; Schwartz, K. G.; Mavris, D.; Briceno, S., eds.): Complex Systems Engineering: Theory and Practice. American Institute of Aeronautics and Astronautics, pp. 175–200, 2019.

[GV17] Grieves, M.; Vickers, J.: Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems. In (Kahlen, F.-J.; Flumerfelt, S.; Alves, A., eds.): Transdisciplinary Perspectives on Complex Systems: New Findings and Approaches. Springer International Publishing, Cham, pp. 85–113, 2017.

[Ka] Karagiannis, D.: How Digital Twins for Design Thinking Support Innovative Business Models. The Kyoto Economic Review Retirement Commemorative Issue/2024, To be published.

[Ka15] Karagiannis, D.: Agile Modeling Method Engineering. In (Karanikolas, N.; Akoumianakis, D.; Nikolaidou, M.; Vergados, D.; Xeno, M., eds.): Proceedings of the 19th Panhellenic Conference on Informatics. Association for Computing Machinery, New York, NY, USA, pp. 5–10, 2015.

[Ka16] Karagiannis, D.; Buchmann, R. A.; Burzynski, P.; Reimer, U.; Walch, M.: Fundamental Conceptual Modeling Languages in OMiLAB. In (Karagiannis, D.; Mayr, H. C.; Mylopoulos, J., eds.): Domain-Specific Conceptual Modeling: Concepts, Methods and Tools. Springer International Publishing, Cham, pp. 3–30, 2016.

[Ka20] Karagiannis, D.; Buchmann, R. A.; Boucher, X.; Cavalieri, S.; Florea, A.; Kiritsis, D.; Lee, M.: OMiLAB: A Smart Innovation Environment for Digital Engineers. In (Camarinha-Matos, L. M.; Afsarmanesh, H.; Ortiz, A., eds.): Boosting Collaborative Networks 4.0. Springer International Publishing, Cham, pp. 273–282, 2020.

[Ka22] Karagiannis, D.; Lee, M.; Hinkelmann, K.; Utz, W., eds.: Domain-Specific Conceptual Modeling: Concepts, Methods and ADOxx Tools. Springer International Publishing, Cham, 2022.

[KB16] Karagiannis, D.; Buchmann, R. A.: Linked Open Models: Extending Linked Open Data with conceptual model information. Information Systems 56/, pp. 174–197, 2016.

[KBU22] Karagiannis, D.; Buchmann, R. A.; Utz, W.: The OMiLAB Digital Innovation environment: Agile conceptual models to bridge business value with Digital and Physical Twins for Product-Service Systems development. Computers in Industry 138/, p. 103631, 2022.

[Ki20] Kirchhof, J. C.; Michael, J.; Rumpe, B.; Varga, S.; Wortmann, A.: Model-Driven Digital Twin Construction: Synthesizing the Integration of Cyber-Physical Systems with Their Information Systems. In: Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems. Association for Computing Machinery, New York, NY, USA, pp. 90–101, 2020.

[KK02] Karagiannis, D.; Kühn, H.: Metamodelling Platforms. In (Bauknecht, K.; Tjoa, A. M.; Quirchmayr, G., eds.): E-Commerce and Web Technologies. Springer, Berlin Heidelberg, p. 182, 2002.

[KMM16] Karagiannis, D.; Mayr, H. C.; Mylopoulos, J., eds.: Domain-Specific Conceptual Modeling: Concepts, Methods and Tools. Springer International Publishing, Cham, 2016.

[Kr18] Kritzinger, W.; Karner, M.; Traar, G.; Henjes, J.; Sihn, W.: Digital Twin in manufacturing: A categorical literature review and classification. IFAC-PapersOnLine 51/11, pp. 1016–1022, 2018.

[Mi18] Miron, E.-T.; Muck, C.; Karagiannis, D.; Götzinger, D.: Transforming Storyboards into Diagrammatic Models. In (Chapman, P.; Stapleton, G.; Moktefi, A.; Perez-Kriz, S.; Bellucci, F., eds.): Diagrammatic Representation and Inference. Springer International Publishing, Cham, pp. 770–773, 2018.

[MMK19] Miron, E.-T.; Muck, C.; Karagiannis, D.: Transforming Haptic Storyboards into Diagrammatic Models: The Scene2Model Tool. In: Proceedings of the 52nd Hawaii International Conference on System Sciences. ScholarSpace, Honolulu, pp. 541–550, 2019.

[Mo18] Molina Gutiérrez, A.; Miranda, J.; Chavarría, D.; Noguez, J.; Ramírez, M.; Macías, M. E.; López, E. O.; Bustamante, M. R.; Molina, M.; Ponce, P.; Cortés Serrano, D.; Ramírez, J.: Open Innovation Laboratory for Rapid Realisation of Sensing, Smart and Sustainable Products: Motives, Concepts and Uses in Higher Education. In (Camarinha-Matos, L. M.; Afsarmanesh, H.; Rezgui, Y., eds.): Collaborative Networks of Cognitive Systems. Springer International Publishing, Cham, pp. 156–163, 2018.

[MP22] Muck, C.; Palkovits-Rauter, S.: Conceptualizing Design Thinking Artefacts: The Scene2Model Storyboard Approach. In (Karagiannis, D.; Lee, M.; Hinkelmann, K.; Utz, W., eds.): Domain-Specific Conceptual Modeling: Concepts, Methods and ADOxx Tools. Springer International Publishing, Cham, pp. 567–587, 2022.

[MT21] Mayr, H. C.; Thalheim, B.: The triptych of conceptual modeling. Software and Systems Modeling 20/, pp. 7–24, 2021.

[Mu24] Muck, C.: Metamodels at Runtime: Adjusting Modelling Environments to Meet Dynamically Changing Requirements, PhD thesis, (PhD thesis Status: Submitted), University of Vienna, 2024.

[My92] Mylopoulos, J.: Conceptual modelling and Telos. In (Loucopoulos, P.; Zicari, R., eds.): Conceptual modelling, databases, and CASE: An integrated view of information system development. John Wiley & Sons, New York, pp. 49–68, 1992.

[OM20] OMiLAB Team: A Digital Innovation Environment powered by Open Models Laboratory, 2020, URL: https://doi.org/10.5281/zenodo.3899990.

[Sc16] Schleicher, J. M.; Vögler, M.; Inzinger, C.; Fritz, S.; Ziegler, M.; Kaufmann, T.; Bothe, D.; Forster, J.; Dustdar, S.: A Holistic, Interdisciplinary Decision Support System for Sustainable Smart City Design. In (Alba, E.; Chicano, F.; Luque, G., eds.): Smart Cities. Springer International Publishing, Cham, pp. 1–10, 2016.

[Si21] Singh, M.; Fuenmayor, E.; Hinchy, E. P.; Qiao, Y.; Murray, N.; Devine, D.: Digital Twin: Origin to Future. Applied System Innovation 4/2, p. 36, 2021.

[Va22] Vaidian, I.; Jurczuk, A.; Misiak, Z.; Neidow, M.; Petry, M.; Nemetz, M.: Challenging Digital Innovation Through the OMiLAB Community of Practice. In (Karagiannis, D.; Lee, M.; Hinkelmann, K.; Utz, W., eds.): Domain-Specific Conceptual Modeling: Concepts, Methods and ADOxx Tools. Springer International Publishing, Cham, pp. 41–64, 2022.

[va22] van Meeteren, M.; Trincado-Munoz, F.; Rubin, T. H.; Vorley, T.: Rethinking the digital transformation in knowledge-intensive services: A technology space analysis. Technological Forecasting and Social Change 179/, p. 121631, 2022.

[Vo23a] Voelz, A.; Muck, C.; Amlashi, D. M.; Karagiannis, D.: Bridging haptic Design Thinking and cyber-physical environments through Digital Twins using conceptual modeling. In: Joint Proceedings of the BIR 2023 Workshops and Doctoral Consortium co-located with 22nd International Conference on Perspectives in Business Informatics Research. Pp. 195–208, 2023.

[Vo23b] Voelz, A.; Muck, C.; Amlashi, D. M.; Karagiannis, D.: Citizen-Centric Design of Consumable Services for Smart Cities. Digit. Gov.: Res. Pract. 4/3, p. 17, 2023.

[Wa18] Walch, M.: Operating cyber-physical systems with microservices: the s* IoT conceptual modelling approach. In: 2018 7th International Congress on Advanced Applied Informatics (IIAI-AAI). IEEE, New York, NY, pp. 787–792, 2018.

[Wa19] Walch, M.; Morita, T.; Karagiannis, D.; Yamaguchi, T.: A Knowledge-Based Conceptual Modelling Approach to Bridge Design Thinking and Intelligent Environments. In (Douligeris, C.; Karagiannis, D.; Apostolou, D., eds.): Knowledge Science, Engineering and Management. Springer International Publishing, Cham, pp. 524–536, 2019.

[WDW00] Walczowski, L. T.; Dimond, K. R.; Waller, W. A. J.: A Digital Engineering Curriculum for the New Millennium. International Journal of Electrical Engineering & Education 37/1, pp. 108–117, 2000.

[We19] Weske, M.: Business Process Management: Concepts, Languages, Architectures. Springer, Berlin Heidelberg, 2019.

[We23] Wenger-Trayner, E.; Wenger-Trayner, B.; Reid, P.; Bruderlein, C.: Communities of Practice within and across organizations. A guidebook. Social Learning Lab, 2023.

[WW15] Wenger-Trayner, E.; Wenger-Trayner, B.: Introduction to communities of practice - a brief overview of the concept and its uses, 2015, URL: https://www.wenger-trayner.com/introduction-to-communities-of-practice.

[Yu09] Yu, E. S.: Social Modeling and i*. In (Borgida, A. T.; Chaudhri, V. K.; Giorgini, P.; Yu, E. S., eds.): Conceptual Modeling: Foundations and Applications: Essays in Honor of John Mylopoulos. Springer, Berlin Heidelberg, pp. 99–121, 2009.