Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 45 (2020) 522–527

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

10th Conference on Learning Factories, CLF2020

Process model driven learning scenario implementation

Christof Thim[a,*], André Ullrich[a], Norbert Gronau[a]

[a]*University of Potsdam, August-Bebel-Str. 89, 14482 Potsdam, Germany*

Abstract

The implementation of learning scenarios is a diversely challenging, frequently purely manual and effortful undertaking. In this contribution a process based view is used in scenario generation to overcome communication, coordination and technical gaps. A framework is provided to identify, define and integrate technological artefacts and learning content as modular, reusable building blocks along a modeled production process. The specific contribution is twofold: 1) the theoretical framework represents a unique basis for modularization of content and technology in order to enhance reusability, 2) the model based scenario definition is a starting point for automated implementation of learning scenarios in industrial learning environments that has not been created before.

Peer-review under responsibility of the scientific committee of the 10th Conference on Learning Factories 2020.

Keywords: Learning factories; Learning scenario implementation; Process modelling

1. Introduction

Learning new tasks and technologies in an industrial environment occurs along production processes. Learning factories mimic this environment. However, the configuration and implementation of learning scenarios is challenging due to different stakeholder positions: Education specialists focus on learning objectives, methods and content. Technicians, on the other hand, concentrate on providing new technologies such as Augmented Reality devices, autonomous mobile robots, or wearables for the learning scenario. They abstract from the learning content, not considering skill conveyance and didactic principles adequately [1]. This leads to translation and coordination efforts

* Corresponding author. Tel.: +49-331-977-3423.
E-mail address: cthim@lswi.de

2351-9789 © 2020 The Authors. Published by Elsevier Ltd.

Peer-review under responsibility of the scientific committee of the 10th Conference on Learning Factories 2020.
10.1016/j.promfg.2020.04.071

between both parties, resulting in a scenario that lacks adaptability, configurability and reusability. In this contribution a process based view on developing learning scenarios is presented to overcome communication, coordination and technical gaps. By defining technological artifacts and learning content as modular, reusable building blocks, educators and technicians have separated domains in the scenario development. Integrating both domains requires a common ground: The graph based specification of Business Process Model and Notation (BPMN) provides means for both stakeholder groups to combine their artifacts along he flow of production tasks. By using the standardized symbol vocabulary of BPMN, the discussion is structured around tasks and their association with different technological artifacts and learning content to ensure the learning objective. Furthermore, the underlying meta-model of BPMN eases scenario deployment and execution. A workflow management platform can interface between the production environment and the learning content, evoking machine actions, information augmentation and content delivery. The specific contribution thus is twofold: 1) the theoretical framework represents a unique basis for modularization of content and technology in order to enhance reusability 2) the model based scenario definition is a starting point for automated implementation of learning scenarios in industrial learning environments that has not been created before. Section 2 elaborates on stakeholders in learning factories and describes the different artifacts. Section 3 outlines their integration through the framework, while its usage is demonstrated in section 4.

2. Stakeholders and Artifacts in Learning Factories

The education specialists are the first stakeholder group. Their primary objective is to construct a scenario that meets the learner's needs in order to convey desired competences. Needs are identified from three sources 1) socio-demographic information about the learner, 2) the requirements on the learner's current and future work environment, and 3) the desired contributions to the education of the individual learner [2]. Tasks and materials need to be chosen with regard to prior knowledge and experience in order to build up the learner's competences. Conceptually learning objectives account for the expected outcome of the scenario, such as learning a new process, building up organizational capabilities or experiencing the impact of a new technology [3]. Objectives and outcomes are usually identified by the educator in workshops, surveys or interviews prior to the scenario development [4]. Means of organizing the scenario outcomes can be a competence matrix and role definitions for each learner. In the technical dimension this is translated into learner's profiles in order to measure learning success and record the individual progress with regard to the outcome metrics.

Educators use taxonomies in the construction of learning scenarios according to underlying learning theories and competence levels. Providing adequate information, mental, and psycho-motoric procedures for the learner is essential in defining the objectives of the learning scenario [5]. Educators design tasks and content to guide the learner through achieving this objective. One approach to address these objectives is to modularize learning content like information material, instructions or tests into processable chunks according, which increases the likelihood of sustainable internalization. Content is usually organized in catalogues, where artifacts are described by their attributes (such as topic, subtopic, medium, skill-level, type). Digital content can be packaged and described according to e-learning concepts like Learning Object Metadata (LOM) [6] and organized through the SCORM-standard (Sharable Content Object Reference Model) [7, 8]. The Learning Design Specification (LDS) [9] on the other hand can be used to describe didactical processes or sequence used in the learning scenario. By organizing the content on an e-learning platform in a modules and catalogues, it is kept accessible and abstract for other stakeholders [10, p. 4]. One application example is the didactic concept of the Research and Application Center Industry 4.0 (RACI 4.0) learning factory that comprises a variety of learning modules for industrial competences [3]. Each module can be associated to different competence facets: manual task-based modules (such as robot operation) focus on the psycho-motoric facet, interpretation modules (such as understanding the machine utilization prediction) address the mental facet, while content-based modules (such as instruction on lot prioritization) capture the information facet [3]. While task-based modules are bound to the factory environment, content- and interpretation-related modules are either conveyed in classroom settings or integrated into demonstration scenarios. Thereby, corresponding learning modules can be selected in dependence from learning needs and arranged into a flow of different task. This flow forms the learning scenario. The educator's view on technology is concerned with the correct balance between task- and technological complexity to best fit the learning objectives, competences and capabilities of the learners.

On the contrary, technicians have to provide a stable learning environment by implementing, extending and maintaining the learning factory's infrastructure. The infrastructure can comprise physical machinery (intra-logistics equipment, robots, conveyors), hard- and software components (user interfaces, information systems), as well as inputs and outputs. The technicians' approach on architecture is guided by questions of software and hardware organization like the distribution of elements, the communication protocols and conduits as well as code compatibility and extensibility captured e.g. by UML-diagrams (Unified Modeling Language) [11]. They tend to focus on technical descriptions by means of interfaces, frameworks and protocols. Educational aspects are often specific cases of their architectural implementation. However, these implementations should also be modularized to ensure adaptability [12]. Service based architectures are one way to organize the technical components in a reusable and flexible way. Each artifact thereby provides a service in the learning factory's infrastructure. Technically these services can be described formally e.g. through SoaML (Service oriented architecture Modeling Language) [13]. A service repository and the service descriptions ensure the reusability and interoperability of the services [14].

3. Process modelling as an integrative perspective

There are three fundamental views which need to be integrated into the scenario: Learning objectives, learning content and technical artefacts. While the definition of scenarios is conventionally done verbally (scenario description, learning objectives definition) or graphically (storyboard) from the educational perspective [15], the technical implementation is often based on an UML representation to define the technical entities and their cooperation. Each stakeholder specific perspective leads to more specialization but also raises the need for a common integration view, since do not possess an overlapping vocabulary or notation to implement learning scenarios. The integration of different artefacts therefore needs a common definition approach. Business process modelling provides a common ground for educators and technicians through an abstract representation. Different notations can be used to describe business processes. In the proposed integrative view BPMN is used as a modeling approach for scenarios. BPMN was originally designed to bridge the defined gaps. It is applicable to the conceptual level as a means of communication as well as to the technical level as a means of task control and orchestration.

3.1. Combining artefacts in BPMN

Educational content and technical artifacts are usually centered around different tasks in a learning factory. Tasks embed the technology into the work context. Task sequences mirror the educator's view on competence gain in the learning process on a technical level. Tasks are also central in business process modeling. BPMN provides a standardized and predefined set of notation elements and syntactical rules to model task flows (for a definition of rules and elements see [16]). This common vocabulary and graphical representation enhances a scenario's transparency and bridges communication barriers between technical and educational personnel in the development process.

A starting point is the conceptual definition of learner roles such as foreman or machinery operator. Each role has a specific task flow which can be interlinked to task flows of other roles enabling interaction between participants. BPMN distinguishes the roles through swim lanes. Tasks flows are modeled within these lanes. For each flow the educator can select from different task types each with specific symbols. Computer-based tasks capture data-entry and control by the user e.g. by operating a terminal, while service tasks trigger machine actions, e.g. starting the conveyor or a robot. The scenario's task flow is modeled by connecting tasks through directed edges (arrows). Gateways are used to fork and parallelize processes as well as to react to external triggers such as messages from other participants or systems. Thus different paths are possible within a scenario depending on the choices of the learner. Tasks can be further specified by associating learning content and objects (document symbol) through undirected edges, e.g. the task "Operate Powder Coding Station (PCS)" can have instructional material associated to it. Another option to specify a task is by connecting a technical implementation, such as the user-interface or an automated service (task with gear symbol). Standard technical implementations can be drawn from the service repository. Figure 1 shows how the different artifacts are combined into a flow.

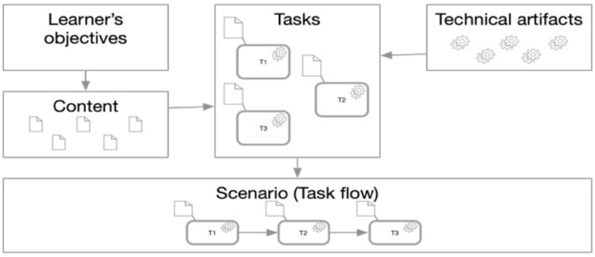

Fig. 1. Relation between artefacts in scenario creation.

The integration of existing artifacts from common repositories leads to reuse and subsequent extension of the technical services. Technological development does not need to embed of their technology into the complete scenario, but can implement separate artefacts which are included into the process through standardized interfaces. By using the underlying meta-model of BPMN, the conceptual process model is the base for seamless workflow automation. Once a process is deployed to the workflow platform, the resulting instance is managed according to the predefined rules, guiding the learner through a succession of tasks with varying machinery. The task flow does not need to be observed by technical personnel. The graphical representation of tasks, materials and technical artifacts further clarifies the requirements to the scenario for educators and technicians. It thereby defines a common ground for both stakeholder groups and establishes a separation of concerns. The following section will provide an overview of how to develop an integrated scenario.

3.2. The process of scenario modelling using the framework

In the starting point of scenario development, the educator identifies the competences and objectives, by analyzing the learning needs. On that basis, non- and digital content addressing competence development is generated, classified and stored in a content repository. The educator furthermore selects an appropriate task flow for the learner, which is also stored in the repository as a didactic design. The educator then defines specific tasks with content from the repository. The technician on the other hand, implements and maintains technological artefacts (e.g., AR-glasses, exoskeleton, etc.) as well as registers newly implemented technology in a service repository, which can be accessed from both technicians and educators for configuring the scenarios. Using a modeling tool, the educator then defines a preliminary scenario by adding technological services to the tasks and generating a task flow. Both, educator and technician jointly refine tasks and critically discuss assigned technologies. On that basis, the process flow is, afterwards, discussed and finally defined. Then, the model is evaluated by the technicians concerning the technical feasibility and refined if it does not meet the requirements or has missing properties. The finalized model is deployed into the learning factory's infrastructure and tested. In case of any required modifications based on test runs, either content, tasks or technologies can be altered, by looping back to the respective step in the process. Educators can then run the scenario in their training sessions with the participating learners. The scenario definition ends with the evaluation by the learners which provides feedback for further refinement. In reoccurring training sessions, the output of a prior session can be used to modify the objectives and competences for the next session. With clear learning objectives, educators can select tasks, technologies and materials already available in the repositories. The service repository is one interface between educators and technicians. If there is the need for a new technical artefact, requirements can be collected from the objectives and scenario definition.

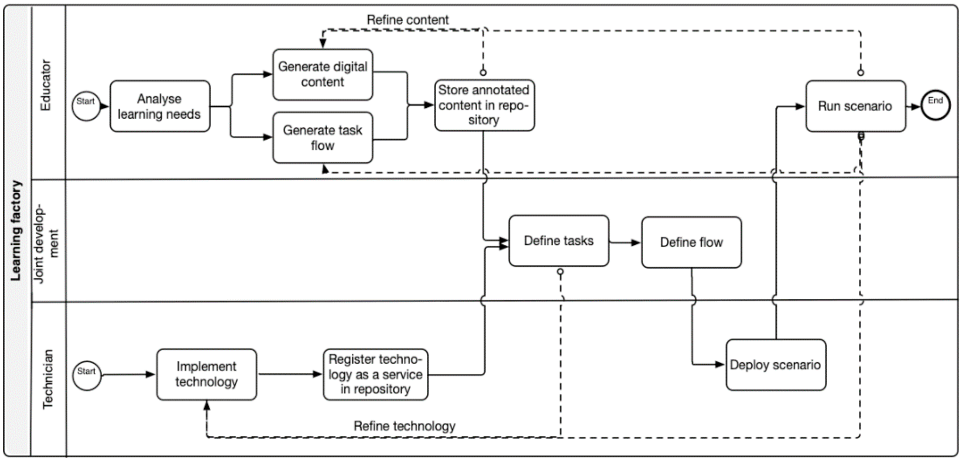

Fig. 2. Scenario development process model.

4. Demonstration

In order to demonstrate the feasibility of our modeling approach, a specific scenario from the RACI 4.0 learning factory [17] was selected. The training session is aimed at senior factory workers to attain knowledge on the changes associated with altering a production schedule in order to add a priority lot as well as the integration of modern information and planning tools. The objective of the training session is therefore to train the interaction and troubleshooting in a production environment using novel technologies. In this example only an outtake of the scenario is used, where one learner (Learner A) is operating a Powder Coding Station (PCS) and a Quality Control Station (QCS) for lot scheduling. Instead of a daily production plan, ad hoc information is provided through augmented reality (AR-glasses) and mobile technology (tablet).

In the educational view information and instructional material was developed. This included instructions on how to operate the machinery as well as decision rules about how to prioritize. Information for this decision such as Overall Equipment Efficiency (OEE), priority lot specification, and the resulting delivery date variations was prepared by the educators. In this outtake the analytical tasks to perceive the relevant information and decision making for a lot prioritization were selected. Manual tasks for operating the machinery were defined in order to provide a sufficient level of immersion and active engagement. An assistance system provides information about the process changes when the production process starts. In a first step, the tasks were selected and a task flow was modeled. Learner A receives information on the priority lot, decides on its integration and operates the quality control (QCS) as well as the powder coating station (PCS). This flow was extended with the instruction and information material from the e-learning system and the technical services from the service repository. An non-interrupting signal event was used to trigger the services (see [16] for specification). By defining the necessary services the focus in scenario development shifted from the educational to the technical view. Some elements such as the PCS and QCS were already present in the service repository. The augmentation and tablet interface needed to be implemented separately, thereby extending the service repository. Service development was carried out by the technical personnel. The resulting process in Figure 2 was then deployed to the Camunda Workflow Engine and run in different training sessions.

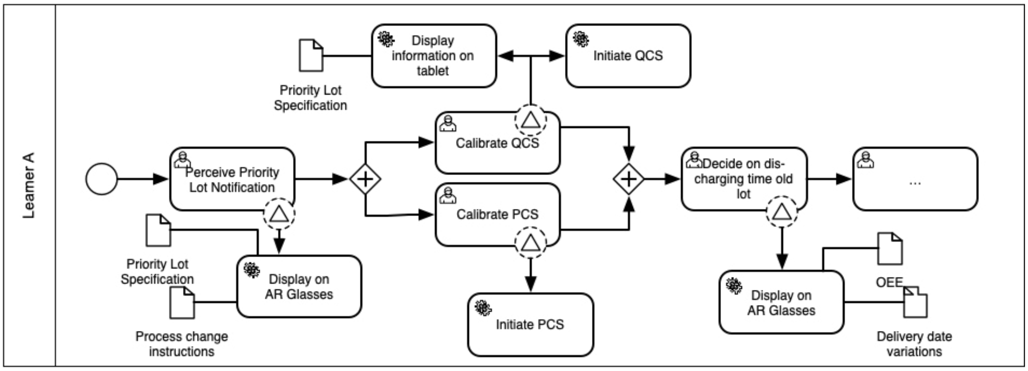

Fig. 3. Outtake from scenario description in BPMN.

5. Conclusion

This contribution introduces a framework that enables process modelling and implementation of learning scenarios. Thereby, identification, definition and integration of technological artefacts and learning content as modular and reusable building blocks into learning factories is enabled. In this way, communication, coordination and technical gaps between educators and technicians can be overcome, since the modeling language represents the middle ground between those parties. Future work focusses the completive implementation of the framework into the RACI 4.0 as well as the continuous evaluation, reflection, and improvement of the implementation mechanisms and the extension of the artefact library, available for application.

References

[1] M. Teichmann, A. Ullrich, N. Gronau, Subject-oriented learning-A new perspective for vocational training in learning factories, Procedia Manufacturing, 31 (2019), 72-78.

[2] B.S. Bloom, M.D. Engelhart, E.J. Furst, W.H. Hill, D.R. Krathwohl (Eds.), Taxonomy of educational objectives. The classification of educational goals, handbook I: Cognitive domain. New York: David McKay Company, (1956).

[3] N. Gronau, A. Ullrich, M. Teichmann, Development of the Industrial IoT Competences in the Areas of Organization, Process, and Interaction based on the Learning Factory Concept, Procedia Manufacturing 9C (2017), 294-301.

[4] J. Pershing, H. K. Lee, "Concern Matrix: Analyzing Learners' Needs.", Instructional Design in the Real World: A View from the Trenches, ed. Anne-Marie Armstrong, 1-9 (2004).

[6] R.J. Marzano, J.S. Kendall (Eds.), The new taxonomy of educational objectives. Corwin Press, (2006).

[6] W. Hodgins, E. Duval, E. et al.: Final Draft Standard for Learning Object Metadata. Learning Technology Standards Committee, (2002).

[7] U-D. Ehlers, J.M. Pawlowski (Eds.): European Handbook of Quality and Standardisation in E-Learning. Berlin, Heidelberg: Springer, 2006.

[8] O. Bohl, J. Scheuhase, R. Sengler and U. Winand, "The sharable content object reference model (SCORM) - a critical review", International Conference on Computers in Education, 2002. Proceedings., Auckland, New Zealand, (2002), 950-951.

[9] B. Olivier, C. Tattersall, The Learning Design Specification, R. Koper, C. Tattersall (eds), Learning Design, (2005).

[10] F. Paulsson, Modularization of the learning architecture: supporting learning theories by learning technologies (2008).

[11] H-E. Eriksson, M. Penker. "Business modeling with UML." New York (2000): 1-12.

[12] I. Gräßler, A. Pöhler, J. Pottebaum, Creation of a Learning Factory for Cyber Physical Production Systems., Procedia CIRP (2016), 107-112.

[13] B. Elvesæter, et al. "Aligning business and IT models in service-oriented architectures using BPMN and SoaML.", Proceedings of the First International Workshop on Model-Driven Interoperability (2010).

[14] J. Minguez, F. Ruthardt, P. Riffelmacher, T. Scheibler, B. Mitschang, Service-Based Integration in Event-Driven Manufacturing Environments. In: Chiu D.K.W. et al. (eds) Web Information Systems Engineering – WISE 2010 Workshops. WISE 2010. Lecture Notes in Computer Science, vol 6724. Springer, Berlin, Heidelberg (2011).

[15] L. Hall, et al., "Using storyboards to guide virtual world design.", Proceedings of the 2004 Conference on Interaction design and children: building a community (2004).

[16] OMG Architecture Board ORMSC, Object Management Group Model Driven Architecture (MDA), MDA Guide rev. 2.0, OMG Document, (2014), https://www.omg.org/cgi-bin/doc?ormsc/14-06-01.

[17] B. Bender, M. Grum, N. Gronau, A. Alfa and B. T. Maharaj, "Design of a Worldwide Simulation System for Distributed Cyber-Physical Production Networks," 2019 IEEE ICE/ITMC, Valbonne Sophia-Antipolis, France, (2019), 1-7.