## Network of Excellence Professional Learning

# PROLEARN

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***Flexible Architectures for TEL***

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## Legal Notices

# Contents

## Figures

## Management Summary

This deliverable is part of a business process-driven TEL approach that consists of the *consecutive deliverables* from month 36, 42 and 48 carried out in WP6 on “Business Models, Processes & Markets” of the EU-IST “Network of Excellence for Professional Learning (PROLEARN)” (see: Amendment History).

Starting with the deliverable on “*business process-oriented learning*” (D.6.7. Part 1, month 36) the thesis of a reciprocal relationship between business and learning processes that leverages future workplace learning concepts and environments was introduced. In the draft version of the deliverable on “*flexible architectures for learning management*” (Part 2, month 42), the usage of web 2.0 components – that are researched in PROLEARNs WP 15 on “Social Software” – were added to support (informal) learning processes at the workplace which were triggered by business process changes in terms of change management. Here, the SECI-model was defined as the conceptual layer to orchestrate different TEL tools for different learning purposes (LMS for formal & Web 2.0 for informal learning) in different phases of the knowledge creating SECI-spiral. Beside the reciprocal effects and transformation processes of explicit and implicit knowledge imparted into the SECI-model as integrative parts (suitability), the selection of the model for WP 6 activities was caused by the reason that it is already used in several workpackages of PROLEARN (e.g., WP 1, 7, 12), pre-defines a common (methodological) understanding that fosters the interconnection, -change and the transfer of the WP 6 research results to related activities within the PROLEARN workpackage structure.[1] In return, WP 6 has respective still receives useful input and implications from other WPs and its representatives (esp. RWTH; OUNL, KTH, KUL, imc and the associated participant SAP, see also: list of contributors).

*The final version* for month 48 concentrates on flexible IT-architectures and their model-driven design for TEL. For this reason, innovative approaches – like service-oriented architectures (SOA) – that are currently discussed in the context of *enterprise resource planning* (ERP) as traditional *business information systems* – in scientific research as well as in industrial practice – and are new to TEL will be focused here. The aim is, to provide a future-oriented view on what *can TEL learn* from these related developments that deal with the (same) topic of flexible IT-environments, which results can or should be adopted to TEL, how can the adoption being realized and which learning processes would benefit from these approaches.

The deliverable starts with the importance of business process management for service orientation and illustrates how (business) process models can be used for the design and realization of service-oriented architectures. To do so, a generic multi-level concept is introduced, consisting of a design, a configuration and an execution level. The approach presented here, bridges the existing research gap between conceptual modeling and service-oriented IT-support. The requirements analysis from an industrial scenario serves as a use case. The results show that up to now, too little importance has been devoted to organizational aspects in the SOA-discussion.

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[1] A SECI-based learning process framework for PROLEARN was developed by NAEVE et al. (2005), and it has formed the basis of the PROLEARN Roadmaping Process. A modified version of the SECI theory, with a focus on the difference between formal and informal learning processes is presented by NAEVE et al (2007). Detailed information can be found in:

Detailed information on the SECI-based framework for PROLEARN, see: NAEVE, A. et al.: A Conceptual Modelling Approach to Studying the Learning Process with a Special Focus on Knowledge Creation. Deliverable 5.3 of the PROLEARN EU/FP6 Network of Excellence, IST 507310, June 2005.

SECI-model based Roadmapping Process, see: KAMTSIOU, V. et al.: The PROLEARN Roadmapping Process, Deliverable 12.1.2 of the PROLEARN EU/FP6 Network of Excellence, IST 507310, June 2005.

Difference between formal and informal learning processes, see: NAEVE, A. et al.: A SECI-based Framework for Learning Processes @ Work. Deliverable 1.10 of the PROLEARN EU/FP6 Network of Excellence, IST 507310, June 2007

# 1 Introduction

Today – as stated by the business analyst company GARTNER INC. – the increasing importance of flexible value-adding business networks and operational business process (infra-)structure are subject to constant changes [cp. Figure 1].[2, 3] On the *organizational level* these changes initiate (1) information, (2) communication and (3) training actions in terms of *change management*, that represents one of the main challenges remaining:[4] Thus, the success of change management activities and the realization of intended effects is geared to the companies ability of integrating their employees – as later user groups – into process of change at an early state, to identify related changes within the skill references needed to carry out the (re-)engineered business process (*competency requirements*) on short notice and to provide intelligent designed trainings in order to develop those skills systematically – even in dynamic environments.[5, 6]

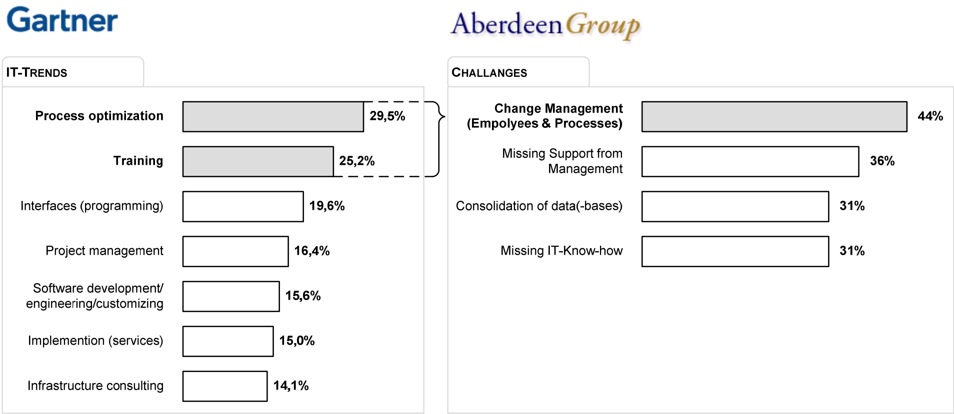


***Figure 1:*** *IT-trends and challenges*[7, 8]

On the *IT-level*, these process changes also define new *(technical) requirements* for the supporting software systems and have a fundamental effect on the design of the underlying IT-, and recently TEL-architectures.[9] The concept of *service-oriented architecture* (SOA)[10, 11] takes on this challenge. SOA strive at an IT-infrastructure, which automates enterprise business and learning processes by orchestrating service invocations. Thus, a SOA can react flexibly to ever changing requirements in professional environments. Service-oriented architectures follow a process-oriented view and on account of this, often to be considered as process-oriented software architectures.

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2 GARTNER INC. (Eds.): Prozesswissen ist gefragt: Welche IT-Dienstleistungen deutsche Unternehmen im kommenden Jahr einkaufen werden. In: Computer Zeitung (2005) 17, P 1

3 A generic view on reasons for process changes can be found in: SCHEER, A.-W. et al.: Business Process Change Management. Berlin [et al.]: Springer, 2003

4 ABERDEEN GROUP (Eds.): Die größten Herausforderungen in Projekten für das Geschäftsprozessmanagement. In: Computer Zeitung 37 (2006) 38, P. 1

5 KIRCHMER, M.; SCHEER, A.-W.: Change Management – der Schlüssel zu Business Process Excellence. In: SCHEER, A.-W. et al. (Hrsg.): Change Management im Unternehmen: Prozessveränderungen erfolgreich managen. Berlin [u.a.] : Springer, 2003, pp. 1-14

6 Focussed on changes or improvements on the IT-level, see: Stahlknecht, Peter; Hasenkamp, Ulrich: Einführung in die Wirtschaftsinformatik. 11., vollst. überarb. Aufl. Berlin [u.a.] : Springer, 2005

7 GARTNER INC. (Eds.): Prozesswissen ist gefragt: Welche IT-Dienstleistungen deutsche Unternehmen im kommenden Jahr einkaufen werden. In: Computer Zeitung (2005) 17, P 1

8 ABERDEEN GROUP (Eds.): Die größten Herausforderungen in Projekten für das Geschäftsprozessmanagement. In: Computer Zeitung 37 (2006) 38, P. 1

9 WESTERKAMP, P.: Flexible E-Learning Platforms: A Service-oriented Approach. Berlin : Logos, 2006

10 DOSTAL, W. et al.: Service-orientierte Architekturen mit Web Services: Konzepte – Standards – Praxis. Heidelberg: Elsevier, 2005

11 KRAFZIG, D.; BANKE, K.; SLAMA, D.: Enterprise SOA: service-oriented architecture best practices. Upper Saddle River: Prentice Hall, 2006

The *knowledge* about business process (logic of the control flow) as well as the knowledge embedded in the process (e.g. IT-systems, org. units, skills) and their operational and organizational structure is a critical success factor for the design and realization of an SOA [cp. Figure 2]. The process design must follow a comprehensive approach, which comprises planning and controlling.[12] *Modeling* has given proof of being useful for the support of such a systematic approach in process design.[13, 14] Modeling methods, such as the ´Unified Modeling Language (UML)´,[15] the ´Architecture of integrated Information Systems (ARIS)´[16] or PROMET[17] and pedagogical driven methods like ´IMS-Learning Design (IMS-LD)´[18] serve as operationalized approaches for the construction of business and learning process models. Beside IMS-LD, these methods are implemented in software tools for process modeling, such as Microsoft VISIO, IBM Rational or ARIS-Toolset which are supporting the design, analysis and simulation of business process models.[19]

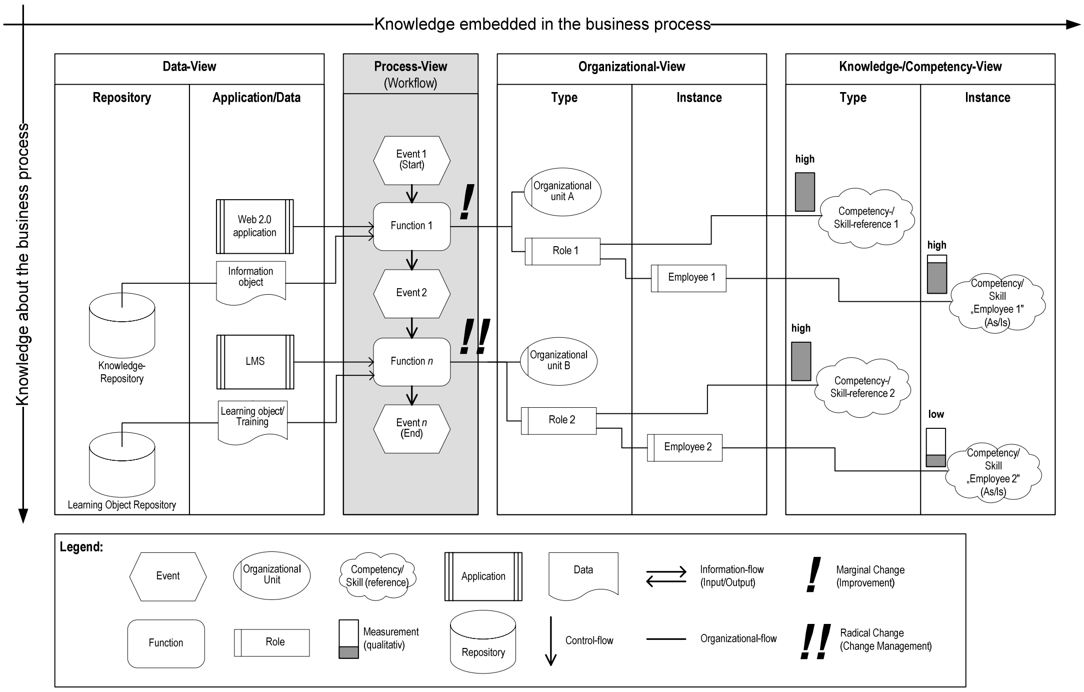


***Figure 2:*** *Business process knowledge, changes and learning needs*[20]

For a successful design and realization of service-oriented architectures companies must stand the central challenge of considering both conceptual, as well as technological aspects. Whereas process modeling has established both in research and industry especially for documentation and business re-engineering purposes, modeling process sequences from a information-technical point of view is a comparatively young field and highly dynamic. Difficulties arise in this context from the

12 BECKER, J.; KUGELER, M.; ROSEMANN, M. (eds.): Process Management: A Guide for the Design of Business Processes. Berlin: Springer, 2003

13 FRANKEL, D. S.: Model driven architecture: applying MDA to enterprise computing. Indianapolis: Wiley, 2003

14 HÜNDLING, J.; WESKE, M.: Web Services: Foundation and Composition. Electronic Markets 13 (2003) 2, pp. 108–119

15 OMG (ed.): Unified Modeling Language: Superstructure, version 2.0, formal/05–07–04. Needham: OMG, 2005

16 SCHEER, A.-W.: ARIS – Business Process Modeling. 2nd ed. Berlin [et al.]: Springer, 1999

17 ÖSTERLE, H.; BLESSING, D.: Ansätze des Business Engineering. HMD – Praxis der Wirtschaftsinformatik 41 (2005) 241, pp. 7–17 (in German)

18 KOPER, R.; OLIVIER, B.; ANDERSON, T.: IMS learning Design information model : Final Release. 2003. URL http://www.imsproject.org/learningdesing/index.cfm

19 BLECHAR, M. J.; SINUR, J.: Magic Quadrant for Business Process Analysis Tools, 2006. Stamford: Gartner, 2006

20 MARTIN, G.: Management von Lernprozessen : Konzept und Anwendung. Universität des Saarlandes 2007 (Working Paper).

fact that both the conceptual as well as the technical modeling of processes are usually not coupled with each other.

The problem in *information systems design* relies in very early and very late phases of modeling. Early modeling comprises the specification of a system from a high-level requirement and user or learners perspective. Late modeling defines the components and their interaction from a technical view and is often closely connected with the development environment used for the implementation. Due to the existing gap between the conceptual and the technical model a consistent transfer of conceptual requirements into supportive IT-systems cannot be guaranteed. Hence the problem is mainly caused by a lack of continuity between the conceptual and the technical level of modeling ("top-down-problem"). This difficulty is worsened by the fact that most changes are carried out ad hoc on the technical systems without affecting the documentation of the conceptual processes leading to a line-up in which the actual processes supported by IT-systems in the company and the documented, conceptual processes drift apart. The problem here is once again a lack of continuity in modeling, but in this context from the technical to the conceptual level ("bottom-up-problem"). The lack of such a mutual continuity of modeling is addressed by the approach proposed. In the context of the service-oriented structuring of information systems currently being discussed, this deliverable will focus on the model-based orchestration of already existing services based on a conceptual model.

The deliverable is organized as follows. In chapter 1 we motivate a model-based SOA design to achieve continuity between business and IT specifications in general. Chapter 2 presents related approaches that tackle parts of the problem areas described but do not provide a coherent solution. In chapter 3 we propose a framework that provides such a continuous methodology to design a SOA based on a 3-level modeling concept. This generic approach is instantiated in chapter 4 by a scenario. Each step of the methodology is illustrated along the case of a fictitious vocational training group, deriving a SOA design from the business and connected learning process models involved. Concluding on this case study, chapter 5 summarizes the critical success factors for the model-based design of a SOA for TEL and gives implication for its transformation into the ontology, developed within PROLEARNs WP 1.

# 2 Related Work

As it is characteristic for topics of information systems sciences, the approach presented here interfaces interdisciplinary fields between service-oriented software architectures, model-based software engineering, business process management (BPM) and learning management (LM). Whereas relevant research has been pursued in each of these areas, a comprehensive approach is still missing.

*Web Services in general*: While the concept of a service is not new to software engineering, it has gained a new momentum by the commoditization of internet technology bringing along web services. W3C[21] and FERRIS/FARRELL[22] define *Web Services* as software applications that can interact among each other over XML-based interfaces bound to URIs using XML-based messaging and internet protocols. Thus, web services are considered as a mean to expose functionalities of information systems and deliver them through web technology standards.[23] Applying the benefits of service-oriented computing to enterprises yields the notion of enterprise services, i.e. web services that execute business transactions within and across enterprise systems.[24] To make this cross-

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21 BOOTH, D. et al. (eds.): Web Services Architecture: W3C Working Group Note 11 February 2004. W3C, 2004

22 FERRIS, C.; FARRELL, J.: What are Web services? CACM 46 (2003) 6, p. 31

23 ALONSO, G. et al.: Web services: concepts, architectures and applications. Berlin: Springer, 2004

24 FREMANTLE, P.; WEERAWARANA, S.; KHALAF, R.: Enterprise services. CACM 45 (2002) 10, pp. 77–82

organizational vision happen, a multitude of (industry) initiatives have been founded to develop XML-based standards on how to describe, discover, and compose web services.[25, 26, 27] The notion of web services is further advanced by CHESBROUGH[28] as to be merged with other related, yet isolated fields to a service discipline. One challenge envisioned by the authors is to explore how information of the capabilities of artifacts is to be managed and (re-)composed to create value. However, this aspect of (business) value creation is still missing in practical methods of SOA engineering.

*Web Services and SOA*: Despite a long history of service-orientation for distributed computing,[29] the term SOA is mostly used in the ongoing scientific discussion synonymously for *service-oriented software architectures based on web service technology*. Nevertheless and despite a lenient usage by some authors, a SOA is more than simply a pool of web services capable of interacting with each other.[30] Rather, web service technology is seen as a vehicle to facilitate the basic principles of SOA – the interoperability of functions offered by different organizational units in (electronic) business scenarios.[31] Beyond the questions about the design, description and execution of services, there is quiet some work being done about the middleware infrastructure of a SOA, called *Enterprise Service Bus*.[32] This core component of a SOA is responsible for the execution and interaction of web services along specific processes. Although there is some related work on web service integration as a means of enterprise application integration (EAI), the existing concepts remain reserved to IT specialists instead of domain experts that should know best about their processes.

*Web Services and BPM*: Given the decisive characteristic of composition the design of a SOA must cover not only the specification of web services but also their flexible composition to business and learning processes.[33, 34] This chance, that is new to LM has been recognized by the field of BPM striving for process-driven application integration. ZHAO/CHENG [35] and MOITRA/GANESH [36] envision the advancement of web services as a universal computing platform that provides enterprise services to be flexible composed to value-creating business processes. Thus, earlier ideas expressed by VERNER[37] of a closed-loop from process design, process development to process deployment feeding information back to (re-)design are becoming reality. However, existing work like is often limited to a purely technical perspective on processes neglecting the decisive aspects of business or learning relevancy. Also, the instrument of process simulation – enabled by codified service processes – remains on the level of IT. [38]

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25 CLEMENT, L. et al. (eds.): UDDI Version 3.0.2: UDDI Spec Technical Committee Draft, Dated 20041019. Billerica: OASIS, 2006

26 ALVES, A. et al. (eds.): Web Services Business Process Execution Language Version 2.0: Committee Draft, 17th May, 2006. Billerica: OASIS, 2006

27 CHRISTENSEN, E. et al.: Web Services Description Language 1.1: W3C Note 15 March 2001. W3C, 2001

28 CHESBROUGH, H.; SPOHRER, J.: A research manifesto for services science. CACM 49 (2006) 7, pp. 35– 40

29 ALONSO, G. et al.: Web services: concepts, architectures and applications. Berlin: Springer, 2004

30 KRAFZIG, D.; BANKE, K.; SLAMA, D.: Enterprise SOA: service-oriented architecture best practices. Upper Saddle River: Prentice Hall, 2006

31 HÜNDLING, J.; WESKE, M.: Web Services: Foundation and Composition. Electronic Markets 13 (2003) 2, pp. 108–119

32 CHAPPELL, D. A.: Enterprise Service Bus. Beijing: O'Reilly, 2004

33 LEYMANN, F.; ROLLER, D.; SCHMIDT, M. T.: Web services and business process management. IBM Systems Journal 41 (2002) 2, pp. 198–211

34 ZENG, L. et al.: Flexible Composition of Enterprise Web Services. Electronic Markets 13 (2003) 2, pp. 141–152

35 ZHAO, J. L.; CHENG, H. K.: Editorial: web services and process management: a union of convenience or a new area of research? Decision Support Systems 40 (2005) 1, pp. 1–8

36 MOITRA, D.; GANESH, J.: Web services and flexible business processes: towards the adaptive enterprise. Information and Management 42 (2005) 7, pp. 921–933

37 VERNER, L.: BPM: The Promise and the Challenge. Queue 2 (2004) 1, pp. 82–91

38 TEWOLDEBERHAN, T. W.; VERBRAECK, A.; MSANJILA, S.: Simulating process orchestrations in business networks: a case using BPEL4WS. In: Proc. of the 7th intern. conference on Electronic commerce. Xi'an: ACM, 2005, pp. 471– 477

*Model-Driven Design of SOA*: The idea of *model-driven SOA* design is not completely unheard-of. BARESI et al.[39] use static and dynamic UML models to decide about the aptitude of certain middleware platforms for business information platforms. Their approach exhibits some convergence between modeling and SOA but concentrates solely on the validation of SOA and not on the specific needs to design a SOA. Another approach[40] examines how the concept of "Programming in the Large" is to be applied practically to SOA development based on process models. They use Business Process Modelling Notation (BPMN) as a process programming language which can be mapped to the Business Process Execution Language (BPEL). As both process languages are led by IT-relevant aspects they are hardly relevant for business analyst designing a SOA in terms of business needs. On the level of technical integration, the synergy effects between process modeling and SOA has been recognized by approaches related to the concept of Model-Driven Architecture, too. PFADENHAUER et al.[41, 42] have already proposed a model-driven service architecture but missed to integrate pure business requirements formulated by domain experts or other, non-technical employees. Contrasting to this prevailing technical understanding, WENHUI[43] confirms that the true potential of a process-driven SOA lies in innovative (business) models which are facilitated by web service infrastructure.

To sum up, among all existing approaches there is a missing link between moderate innovations a SOA brings to IT integration and unprecedented potentials to be leveraged for business integration. None of the related contributions examined acknowledges the fact that business process modeling has established throughout companies by means of semi-formal diagrams that are easy to understand and handle by non-technicians. The approach is to leverage this treasure of existing models created during longsome Business Process (Re-)Engineering (BPE/BPR) projects, representing both as-is and to-be business processes that can be interlinked with related learning processes, carried out in the same (technical) way.

# 3 Research Methodology

*Conceptual models* contain the potential business- and learning relevant context for each of the tasks, functions or activities etc. defined.[44] Technical descriptions however, contain the detail information needed for the IT-support of these processes including, for example the services involved, required input and output data or the interface information. The basic idea of the *integration of conceptual and technical process descriptions* is to incorporate the process logic shared by both levels of (business *and* learning process) modeling into a third level of process description utilizing it for the integration and synchronization of the conceptual and technical description level. This triple-layer design can be seen from the perspective of the underlying processes, the constructed models and the languages used [cp. Figure 3].

[39] BARESI, L. et al.: Modeling and validation of service-oriented architectures: application vs. style. In: Proc. of the 9th European software engineering conference held jointly with 11th ACM SIGSOFT intern. symposium on Foundations of software engineering. Helsinki: ACM, 2003, pp. 68–77

[40] EMIG, C.; WEISSER, J.; ABECK, S.: Development of SOA-Based Software Systems – an Evolutionary Programming Approach. In: Proc. of the Advanced Int'l Conference on Telecommunications and Int'l Conference on Internet and Web Applications and Services. IEEE, 2006, pp. 182–188

[41] PFADENHAUER, K.; DUSTDAR, S.; KITTL, B.: Comparison of Two Distinctive Model Driven Web Service Orchestration Proposals. In: Proc. of the 7th IEEE Intern. Conference on E-Commerce Technology Workshops. IEEE, 2005, pp. 29–36

[42] PFADENHAUER, K.; DUSTDAR, S.; KITTL, B.: Challenges and Solutions for Model Driven Web Service Composition. In: Proc. of the 14th IEEE Intern. Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprise. IEEE, 2005, pp. 126–134

[43] WENHUI, S. et al.: Develop a telecommunication service system using service-oriented architecture. In: Proc. of the IEEE Intern. Conference on e-Business Engineering. IEEE, 2006, pp. 674 –677

[44] For the usage of the CONZILLA for the definition of conceptual design of TEL-processes in PROLEARN, see: NAEVE, A. et al.: A Conceptual Modelling Approach to Studying the Learning Process with a Special Focus on Knowledge Creation. Deliverable 5.3 of the PROLEARN EU/FP6 Network of Excellence, IST 507310, June 2005.

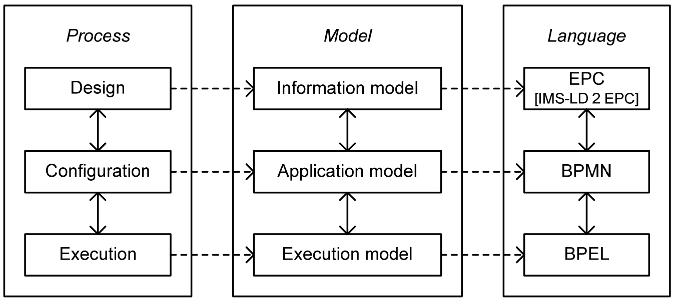


***Figure 3****: Framework for the model-based design of service-oriented architectures*

Based on the underlying processes one can differentiate between a design level, a configuration level and an execution level. On the design level, information models can be used to deal with the complexity connected with the conceptual description and requirement analysis. They can be constructed with a semi-formal graphical language such as the Event-Driven Process Chain (EPC)[45], that has recently been adopted to the modeling of learning processes or learning workflows.[46, 47] In this case, we refer to semantically matching of ARIS and IMS-LD [cp. Table 1]. A differentiation between the underlying modeling languages is not necessary and will be seen as comparable [cp. Figure 4].

*Table 1: IMS-LD to ARIS[48]*

| IMS-LD component | EPC-component | ARIS-View |
|---|---|---|
| Person | Person | |
| Role | Organizational Unit/Role | |
| Staff | Role instance | Organization View |
| Learner | Role instance | |
| Environment | Organizational structure [Module, incl. Hardware] | |
| Learning Object | Data Object | |
| Service | Data Object | |
| Notifications | Message | Data View |
| Conditions | Event | |
| Property | Event | |
| Activity | Function | |
| Activity Structure | Functional structure [Module, incl. application systems] | |
| Learning Activity | (Sub-)Function | Function View |
| Support Activity | (Sub-)Function | |
| Methods, Plays, Acts | (Sub-)Function | |
| Learning Objective | Goal | |
| Prerequisite | Input | Output View |
| Outcome | Output | |

45 Keller, G.; Nüttgens, M.; Scheer, A.-W.: Semantische Prozeßmodellierung auf der Grundlage Ereignisgesteuerter Prozeßketten (EPK). In: Scheer, A.-W. (ed.): Veröffentlichungen des Instituts für Wirtschaftsinformatik, No. 89, Saarland University, 1992

46 Martin, G.: Management von Lernprozessen : Konzept und Anwendung. Saarbrücken. Saarland University, 2007

47 Based on the unpublished work of Martin: Kraemer, W.; Grohmann, G.; Milius, F.; Zimmermann, V.: Modellbasiertes Learning Design : Integration von ARIS in Learning Management Architekturen. In: Loos, P.; Krcmar, H. (Eds.): Architekturen und Prozesse : Strukturen und Dynamik in Forschung und Unternehmen. Berlin [u.a.] : Springer, 2006, pp. 257-280

48 Martin, G.: Management von Lernprozessen : Konzept und Anwendung. Saarbrücken. Saarland University, 2007

On the *configuration level*, the complexity connected with the adaptation of information systems can be reduced with application models, in order to configure information systems model-based. The Business Process Modeling Notation (BPMN)[49] is a language suited to this. Thus, models containing the process logic of the information model level as well as technical details of the execution model level by using attributes can be constructed. On the process execution level, models contain the information needed for their technical execution, which can be expressed by languages such as the Business Process Execution Language (BPEL).[50]

The vertical connections between the levels in Figure 3 emphasize the importance of the bi-directional coupling of information models with execution models via application models. The horizontal links symbolize loose associations between elements of the same proximity to information technology in different fields of the framework. While the area on the left contains the major phases of information system engineering, the middle area shows model types used by each of these phases. By providing suitable languages to explicate these abstractions on the right hand side, the framework is completed. In the following, the integration of conceptual and technical process models will be illustrated on the basis of a case study. The languages used here are EPC, as well as the standards BPMN, BPEL and Web-Service Definition Language (WSDL).

# 4 Process Models for the Design and Implementation of SOA

## 4.1 Case scenario

The edut@inment GmbH is a *learning (profit) center* that belongs to an automotive manufacturer and is responsible for the development, administration and provision of all kinds of trainings – such as formal (vocational) trainings and informal workplace learning – for the manufacturer and its extended supplier-network. These trainings are either booked over the internet or by telephone. The software used for the support of the company's business and learning processes consists of a LMS as core-system, which is connected to the manufacturers' ERP system in order to exchange user (master) data as well as additional skill- and financial-information.

New products, engineering methods and production technology have caused many changes in the parent company and its suppliers (both: *customer*) that affected their skill-/competency requirements and planning goals and need to be enhanced by the provision of "*effective trainings*". At the beginning of 2006, the learning center management initiated the modeling project "Implementation of a Business and Learning Process Documentation". In co-operation with its customers, the objectives of the project were to collect, model and evaluate renewed business processes and requirements in selected areas, in order to provide a basis for learning process (re-)design, modification and optimization as well as a continuous learning process management. The activities were supposed to lead to an increase in effectiveness and efficiency. In accordance with the concept in Section 3, the project's intention was not to primarily aim at supplementary implementation goals, but rather strategic and design goals [cp. Figure 4].

On the *strategic level*, transparency in the learning processes, their adjustment to business processes (*context definition*) and roles (incl. corresponding *skill references*) on the aggregated level was to be achieved through the systematic and concise representation of core process models. Based on this, an optimization of the processes within the framework of coordinated projects was encouraged on the design level.

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[49] OMG (ed.): Business Process Modeling Notation Specification: Final Adopted Specification dtc/06–02–01. Needham: OMG, 2006

[50] ALVES, A. et al. (eds.): Web Services Business Process Execution Language Version 2.0: Committee Draft, 17th May, 2006. Billerica: OASIS, 2006

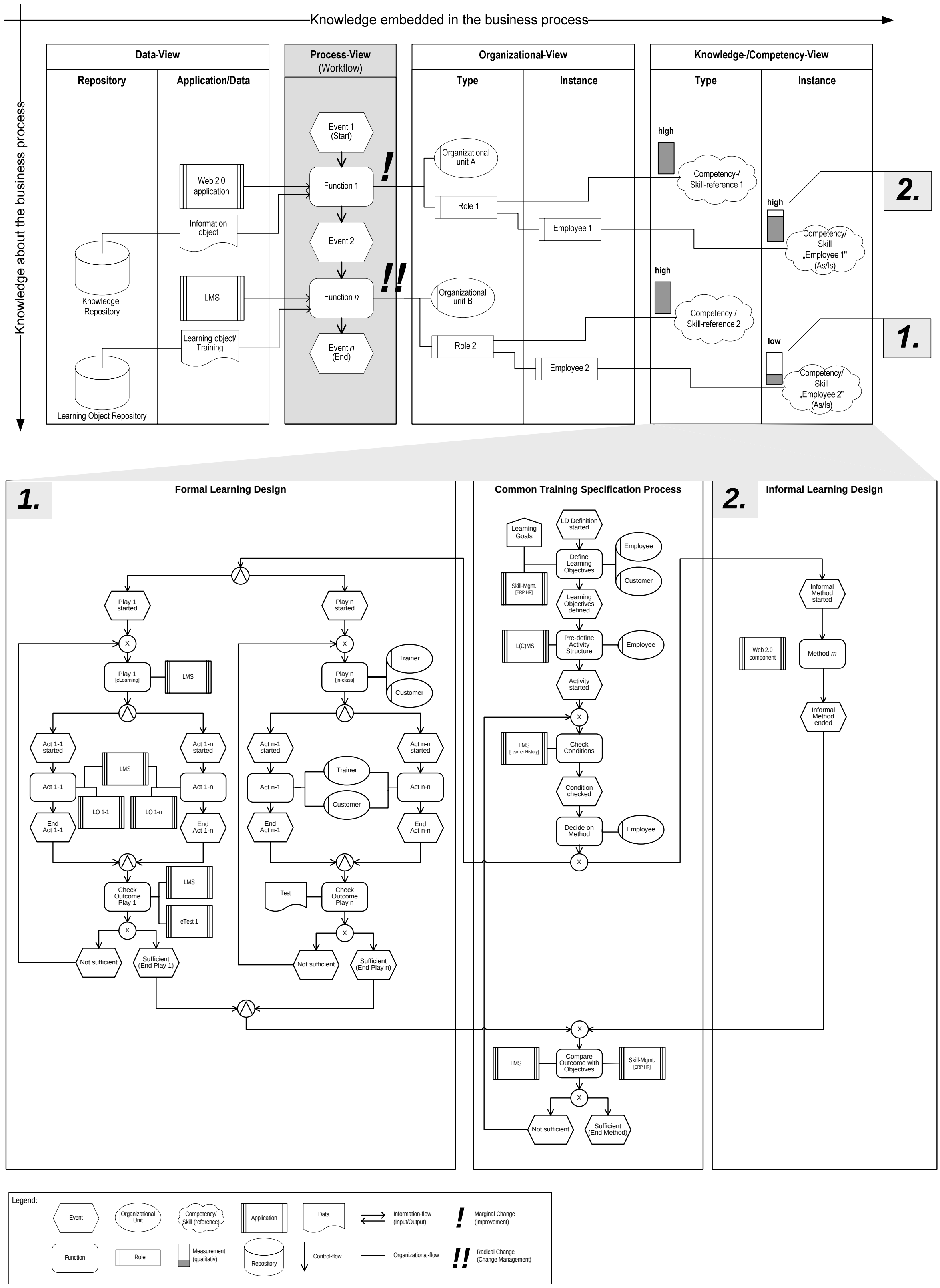


***Figure 4:*** *From process knowledge to learning design*[51]

A requirement analysis carried out within the framework of the documentation project showed the following improvement potentials:

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[51] MARTIN, G.: Management von Lernprozessen : Konzept und Anwendung. Saarbrücken. Saarland University, 2007

1. The company has to struggle with a large number of non-fitting or non-adjusted trainings. These, so-called "*ineffective trainings*" contain misstatements in terms of transparencies of (changing) business contexts, including pre-defined knowledge and skill goals, and trainings (*requirements*). Because the regulation of these ineffective trainings takes a huge effort, an automated comparison of competencies (*type-level*) with achieved individual skills (*instance-level or individual prerequisite*) should take place.
2. Up to now, only existing (formal) training offers from the LMS catalog were searched by meta-data queries on the LOR and selected according to the customers´ requirements. Information stored in web 2.0 components or non-LOR environments could not be retrieved automatically and neither imparted into new learning designs (*configuration*) nor offered separately to support informal workplace learning processes in terms of information needs caused by minor process changes.
3. Last but not least, beside the implemented learning logic in the LMS there was no "manage-able" documentation about the learning processes, goals and contents used (*knowledge about learning processes*) as shown in Figure 4.

Due to the potential of improvement recognized, the management added a new objective to the previous strategic and creative intentions followed up to this point: the flexible automation of processes for the reduction of processing times and increase in process quality through the continual design of a SOA. The SOA-concept is ideally suited to the realization of the described process changes for the following reasons:

1. The additional functionalities can be realized by a number of independent, loosely coupled learning services. These have, in part, already been realized and can be used via a standardized interface (e.g. SCDI-interface or XML-Gateway).
2. The new planned IT-infrastructure should be geared consequently to business processes, which will be assured by the orchestration of services.
3. Services can be realized in different programming languages and on different system platforms. Furthermore they facilitate the seamless integration of already existing functionalities from older systems.

## 4.2 Process Design

The EPC-model shown in Figure 5 illustrates the situation after the completion of the modeling project at the edut@inment GmbH. The model illustrates the potentials listed beforehand for the definition and execution of checking functions for the feasibility of the customers´ training order. The checking refers to the (1) ´`training order data`´, the (2) ´`trainings suitability to the pre-defined requirements`´ and (3) ´`training availability`´. Negative results such as: "`Training order data is incorrect`" or "`Training is not suitable`" lead to the rejection of the training order through the function "`Reject training order`". The functions should be automated by services within the framework of the SOA-initiative of the edut@inment GmbH. To identify the respective services for the support of the individual process steps, the conceptual activities were also described by input and output data. This extension was implemented in Figure 5, on the left, with organizational units, information objects and input and output performance.[52] Correspondingly, one also differentiates between organization flows, data flows and performance flows respectively. In modeling tools, these objects can be enriched by attributes whose value (based on a certain order) is then processed in the verify functions. One example is the tar-

[52] SCHEER, A.-W.: ARIS – business process modeling. 2nd ed. Berlin: Springer, 1999

get group data (for example: role, skill-reference, process involvement), which enters the function "`Specify training requirements`" over the information object "`Target group`".

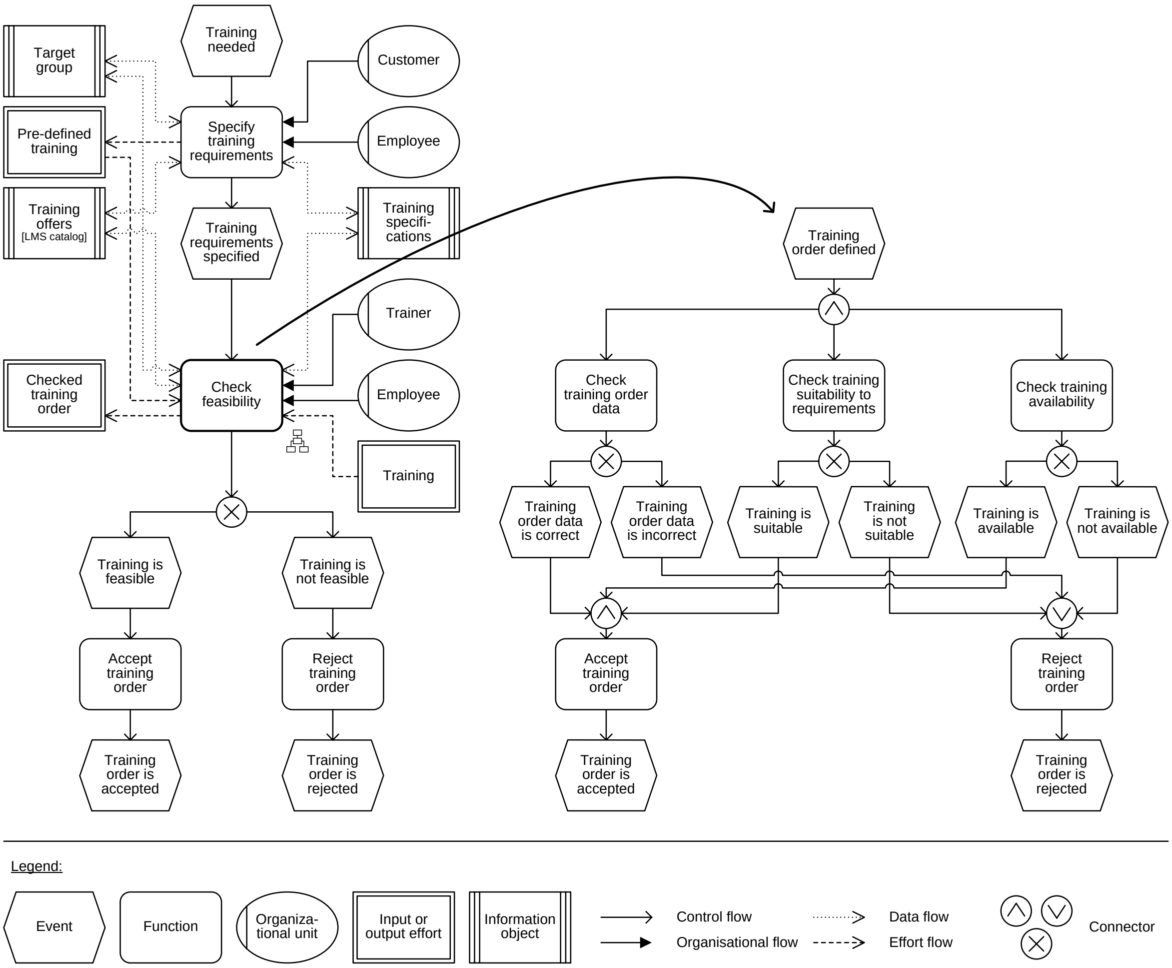


***Figure 5:*** *EPC-model for sales order check*

## 4.3 Process Configuration

In this section the transformation of the conceptual process model into a conceptual-technical application model will be described. The *Business Process Modeling Notation* (BPMN) was used here as a modeling language. It was developed by STEPHEN A. WHITE from IBM and accepted as a specification by the OMG in February of 2006.[53] The aim of its designers was to achieve high acceptance by business experts through an easily understandable graphical notation.

The starting point of the transformation is the existing process logic in an EPC-model. This is carried over to the BPMN-model using suitable language constructs from the BPMN. With it, the basic structure for the sequence of a process is defined. While this basic structure is complemented in the EPC through the annotation of organizationally relevant aspects in the form of further model elements, a supplementation of its basic process logical framework in the BPMN-model takes place with technical details for the process execution. Conceptual information about a process thus remains in the information model, while its basic process-logical framework is the starting point for an enrichment with execution-relevant technical information in the application model. In the follow-

[53] OMG (ed.): Business Process Modeling Notation Specification: Final Adopted Specification dtc/06–02–01. Needham: OMG, 2006

ing we will describe how the EPC-model in Figure 5 can be transformed into a BPMN-model. Figure 6 shows the resulting BPMN-model.

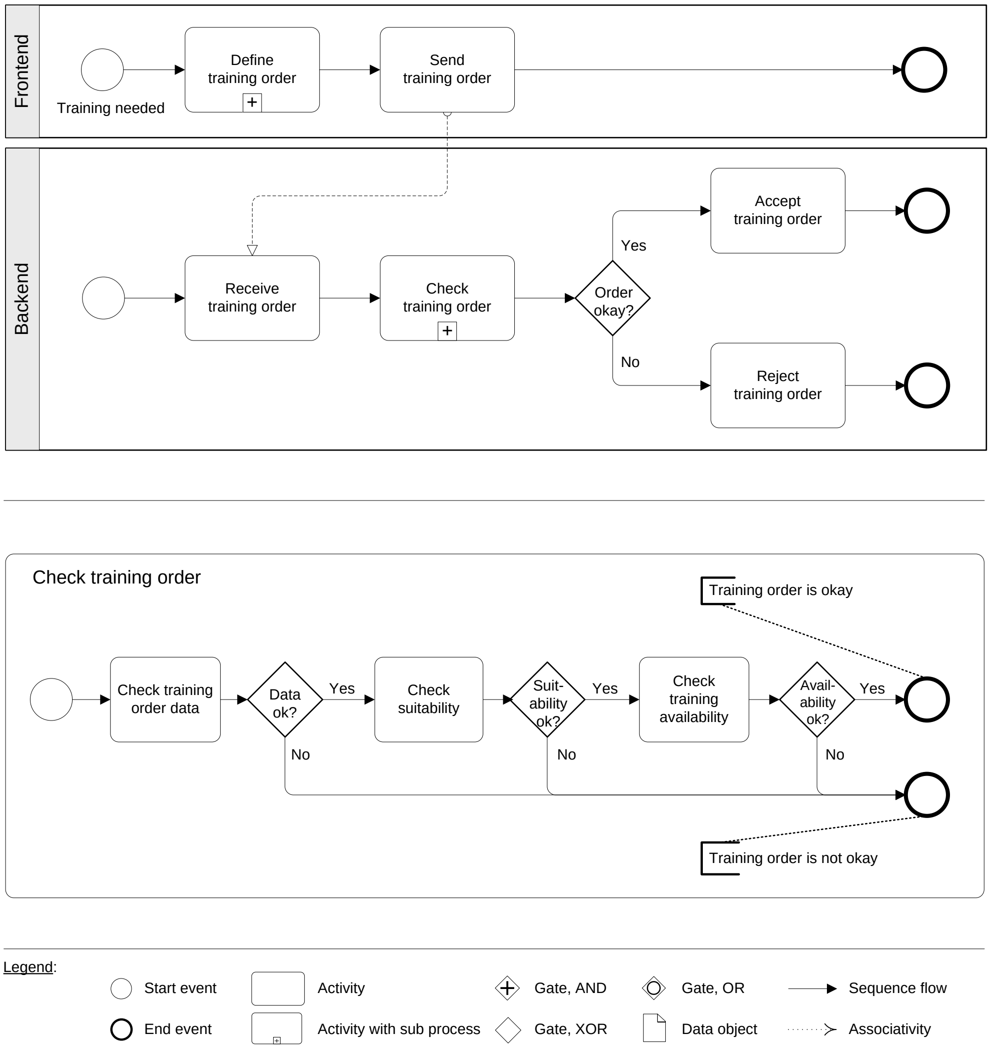


***Figure 6****: BPMN-model for sales order checks*

The process described in the EPC-model contains steps that can be allocated to two different organizational units and, different business partners involved: the companies´ face to the customer (frontend: employees) and the trainers´ (backend). In the BPMN, these partner processes can each be allocated to their own *pool* for the clarification of this fact. This pool can then be subdivided up into lanes in accordance with the companies´ internal organization structure. The representation of an interaction between different pools is, in comparison to lanes, only possible via a message flow.

The process described in the EPC starts with a customer‘s learning need. Here, the training order will be specified or defined. This is represented in the BPMN-model by a corresponding start event and an activity within the frontend-pool. Then the customers´ training order is checked in the EPC-model. This process is represented in BPMN by a message flow from the frontend-pool to the pool of the companies´ backend. One should note that the control flow in the EPC-model describes the logical course of a process from a conceptual view, while the sequence flow in the BPMN-model defines the order of the activities to be executed. To allow the mail order company to process the customers´ training order defined at the frontend desk, another message flow must be established between the backend partner in the BPMN-model, in conjunction with the respective activities "`Send training order`" and "`Receive training order`".

Further customer order processing now takes place in the pool referred to as "backend". After a training order is received using the activity "`Receive training order`", it is checked by the next activity in the sequence flow. Because the activity "Check training order" consists of several steps, it can be detailed as a sub-process, similar to the EPC-model. In contrast to the EPC, the BPMN differentiates between three types of sub-processes: "embedded", "independent" and "reference". Because the intended check only makes sense in the context of training order processing, an embedded sub-process is taken for a fine granular description. The embedded process is emblematized by a "+" in the activity symbol. A decision concerning the further course of the process is now dependent on the result from the customer order check. This circumstance is illustrated by a data-gate of the type XOR, which decides on the progression of the process according to the data made available by the previous activity. While the condition is noted in the gate itself, possible alternatives are noted on the outgoing sequence flow edges. Analogue to the EPC, the process is either continued with the activity "`Accept training order`" or "`Reject training order`" and then ends.

The sub-process contained in the activity "Check training order" is shown in the lower part of Figure 6; an embedding takes place directly through the enlargement of the relevant activity symbol of the superior process, not represented in the figure due to shortage of space. In comparison to the EPC, the sub-process generates the same results – a customer order is accepted when all three conditions are fulfilled. Because the order check described here is a fully automatic process, which in addition, is not time-critical due to the fact that the employees at the frontend was given the training order after having contact with the customer, the internal flow logic has been modified so that the verifications occur sequentially and not – as in the EPC-model – in parallel. This allows a more simple design and generation of the executable BPEL-process respectively. Through the internal configuration of the gates in the sequence flow of the sub-process, tokens reach the end of the sub-process, which leads to order acceptance or rejection. "Tokens" are imaginary markers, which wander through the model following the flow logic.

After the EPC is transformed into a BPMN-model, the model must be improved further in the sense of its technical executability. If there are no services available on the granularity level of the activities defined in the model already, then they can be improved further with sub-processes until a sufficient decomposition for the execution with web services is achieved. For the execution with web services, the activities in the BPMN-diagram can be enhanced with required attributes, such as the types of incoming and outgoing messages. These are not visible in the graphic model and at the same time, form a bridge between the configuration on the application model level and the execution level.

All things considered, the transformation of an information model into an application model, illustrated here with the languages EPC and BPMN, is a creative process, since the concepts on the conceptual level, such as strategies, resources, organizational units, trainings, skills, etc. must be represented on the technical level, affecting elements such as services, data, interfaces, transactions etc.. The reuse of the *knowledge* necessary for this and the securing of the systematic application of established solutions and best practices can occur over reference models and patterns during the model construction, as well as on the information and application model level.

## 4.4 Process Execution

As discussed above, the BPMN serves both as a graphic representation of the control flow and a textual attribution of the process elements. To transform this semi-formal intermediate result into a code-based, executable BPEL-model, the BPMN-specification provides design rules, which generate a formal BPEL-model on the execution level. The *Business Process Execution Language* (BPEL) is already considered by many as the de-facto-standard for business process implementation on the basis of web services. It is an XML-based language whose specification was initiated by IBM, BEA and Microsoft and is currently being developed further by the OASIS-standardization initiative in the Version 2.0. BPEL builds on the WSDL by combining the web services described in WSDL to a process.[54]

Based on XML, the Web Service Description Language has been published in the Version 1.1 in 2001 by the World Wide Web Consortium (W3C) in participation with SAP, Microsoft and IBM. It is used to describe the available data, data types, functions and communication protocols of a web service. Through the platform, protocol and programming language-independent description of web services, WSDL abstracts from the underlying IT-infrastructure.

A BPEL-process is generally seen as a number of service calls subject to a logical and chronological order. Single services are orchestrated or composed to become a process.[55] Thus a BPEL-process model is the IT-counterpart to the conceptual business process model. The goal is to invoke the previously selected services, according to the business process on the basis of the BPEL-process and thus, execute the process in business reality. In doing so the transformation of the BPMN-application system model into an executable BPEL-process represents the most technical task. While both of the previous modeling steps still took place on a graphical level and were carried out by technically oriented business analysts as well as system architects, the coding of the graphic application model into a textual execution model is an engineering task.

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54 ALVES, A. et al. (eds.): Web Services Business Process Execution Language Version 2.0: Committee Draft, 17th May, 2006. Billerica: OASIS, 2006

55 ALONSO, G. et al.: Web services: concepts, architectures and applications. Berlin: Springer, 2004

```
<process>
[...]
<sequence>
   <receive partnerLink="TrainingOrderRequest"> port
   operation=SendTrainingOrderRequest inputVariable=
   </receive>
   <invoke partnerLink="TrainingOrderDataChecking">
   inputVariable=TrainingOrderRequest outputVariable
   </invoke>
   <switch>
   <case condition=OrderData>
   <sequence>
      <invoke partnerLink="CustomerRating"> portType
      operation=CustomerRating inputVariable=Trainin
      outputVariable=CustomerRating
      </invoke>
      <switch>
         <case condition=CustomerRating>
         <sequence>
         <invoke partnerLink="AvailabilityCheck"> po
         operation=AvailabilityChecking inputVariabl
         outputVariable=Availability
         </invoke>
         <switch>
            <case condition=Availability>
            <invoke partnerLink="TrainingOrderProces
            portType="TrainingOrderCreateRequestConf
            operation="TrainingOrderCreateRequestCon
            inputvariable="TrainingOrderCreateReques
            outputvariable="TrainingOrderCreateConfi
            </invoke>
            </case>
            <otherwise>
            <invoke partnerLink="TrainingOrderReject
            portType="TrainingOrderRejction"
            operation="RejectTrainingOrder"
            outputvariable="TrainingOrderCheck"
            </invoke>
            </otherwise>
         </switch>
         </sequence>
         </case>
         <otherwise>
         <invoke partnerLink="TrainingOrderRejection
         operation="CreateTrainingOrder" outputvaria
         </invoke>
         </otherwise>
      </switch>
      </sequence>
      </case>
      <otherwise>
      <invoke partnerLink="TrainingOrderRejection"> portType="TrainingOrderRejection"
      operation="RejectTrainingOrder" outputvariable="TrainingOrderCheck"
      </invoke>
      </otherwise>
   </switch>
</sequence>
</process>
```

```
</wsdl:definitions>
[…]
<wsdl:message name="TrainingOrderCreateRequest_sync">
        <wsdl:part element="p2:TrainingOrderCreateRequest_sync"
        name="TrainingOrderCreateRequest_sync">
        </wsdl:part>
</wsdl:message>

<wsdl:message name="TrainingOrderCreateConfirmation_sync">
        <wsdl:part
        element="p2:TrainingOrderCreateConfirmation_sync"
        name="TrainingOrderCreateConfirmation_sync">
                          </wsdl:part>
</wsdl:message>

<wsdl:message name="StandardMessageFault">
        <wsdl:part element="p2:StandardMessageFault"
        name="StandardMessageFault">
                          </wsdl:part>
        </wsdl:message>

        <wsdl:portType
        name="TrainingOrderCreateRequestConfirmation_In">
        <wsdl:operation
        name="TrainingOrderCreateRequestConfirmation_In">
        <wsdl:input message="p1:TrainingOrderCreateRequest_sync">
        </wsdl:input>
        <wsdl:output
        message="p1:TrainingOrderCreateConfirmation_sync">
        </wsdl:output>
        <wsdl:fault message="p1:StandardMessageFault"
        name="StandardMessageFault">
        </wsdl:fault>
        </wsdl:operation>
        </wsdl:portType>
        […]
</wsdl:definitions>
```

***Figure 7:*** *BPEL-process and WSDL-description*

The transformation rules defined in the BPMN-specification are the starting point for this. They assign each BPMN-element and attribute to a corresponding BPEL-representation. The invisible attributes in conjunction with the graphically represented process sequence are part and parcel of the required data basis. In certain situations it may be necessary to adjust the BPMN process design according to execution constraints required by BPEL in compliance with the conceptual determining factors. As described above, within the case study of the edut@inment GmbH it was advisable to change from the parallel procession of check activities to a consecutive course. In addition, a BPEL-process created in this manner will exhibit non-conceptual information gaps, which are caused by the semi-formal definition of the BPMN and get in the way of the process executability. The task of the IT-developer is to fill these gaps and to detail vaguely formulated information respectively (for example: specify training requirements).

The deterministic rule base allows the IT-supported automation of the BPMN-BPEL-transformation. Accordingly, IT-supported BPEL-tools can decisively increase the efficiency of the procedure in implementation projects, in which executable process description languages such as BPEL are used. Almost all of the large software manufacturers offer such products or are currently working on BPEL-support. On the one hand, graphic modeling tools, such as SemTalk for Microsoft Visio or

Intalio, enable the transformation of a BPMN-model into BPEL-process code; On the other hand, integration platforms such as the BizTalk Server (Microsoft), embedded in the development environment Visual Studio, allow the import, creation, processing and export of service orchestrations. These tools provide process environments and support the management of process instances. An example for such a "BPEL-engine" in the open-source-environment is the ActiveBPEL (Active Endpoints, Inc.).

Figure 7 represents the process "`Create Training order`" specified in the BPMN-model on the company side in BPEL-code and the service description `CreateTrainingOrder` described in WSDL. The schematically represented BPEL-process expresses the control flow of the selected example and consists mainly of a sequence of service calls, which are split by the switch-construct. This switch is equivalent to the exclusive BPMN gateway. It divides the control flow up into two alternatives, which are dependent on the result of the previous order verification. This is returned from the preceding service call in the variables `TrainingOrderData`, `TrainingSuitability` and `Availability`. If one of these checking results is negative, the customer order is rejected by the service operation `RejectTrainingOrder`. If the check is positive three times then the training order is accepted by `CreateTrainingOrder`.

To show the transformation process with a practical service example and illustrate the potentials of ERP-systems, the service "Create Training Order" was selected. This is part of the process component "Training Order Process", which is published as an ERP-element within the framework of the Enterprise Service Workplaces on the SAP Developer Network Homepage (cp. URL http://www.sdn.sap.com/). The WSDL-description of this CreateTrainingOrder-service is shown on the right-hand side in Figure 7 and comprises the definition of the necessary XML-based messages (messages) and the combination of the service from Porttype and Operation. The latter is defined over the Input and Outputmessages, as well as a default message.

It becomes apparent in the discussed context that the sub-process of the BPMN-model was integrated into the BPEL-process. The alternative of implementing the activity "`Check training order`" by a so-called composite service, i. e. an independently callable BPEL-process conflicts with the flexible adaptability of the check activities to be executed in this sub-process. Instead, any possible check service can be inserted, exchanged or deleted in the process logic implemented in the BPEL-process.

# 5 Conclusion and Outlook

## 5.1 Conclusion

Many IT-solution providers consider a service-oriented approach as the architecture paradigm of the future. For instance, the analysts GARTNER have forecasted that until 2010 approximately 65% of the large companies will base over 35% of their application portfolio on a SOA-architecture.[56] Euphoria aside, it must be emphasized that service orientation does not represent an isolated software product, but rather a long-term, strategic adjustment of the company-wide IT-architecture. The respective change processes are characterized by creativity and are highly complex due to their diversity and dependency on the human judgment. The generalized procedure for the model-based design of SOA introduced here can be used to deal with this complexity. The following success factors are critical for its implementation and thus for a model-based SOA-implementation project:

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[56] MALINVERNO, P.: Service-Oriented Architecture Craves Governance. Stamford: Gartner, 2006

1. *Process knowledge*: The discussion about process-oriented organization has considerably influenced the development and structure of information systems. In order to realize efficient, IT-supported inter-organizational process integration, the software architecture must be extended to "orchestrate" the relevant corporate activities. With the goal of customer-oriented business and learning process design, the focus must be put on bringing together the various core competences distributed in the network according to the current requirements. The interdisciplinary knowledge about company processes thus forms the foundation for the identification and development of supportive services, as well as for the orchestration of these.
2. *Process documentation*: In addition to the knowledge about the processes, their documentation matters as well, especially in regards to the approach taken in this deliverable. Besides a textual description of the company's reality, graphical process models should be also available. This applies not only with regard to the planning and realization of an SOA. A new study from GARTNER RESEARCH has shown that the documentation of conceptual processes with their processing times and responsibilities leads to an increase in productivity of more than 12 %.[57]
3. *Process quality*: An IT-developer will however use a process model created by a business department for the implementation of an SOA only if the quality of the resulting technical models – and with it the software to be developed – is noticeably improved from his point of view. The quality of the conceptual process models has therefore a lasting and significant effect on the model-based design of a SOA.
4. *Process communication*: Process models are used to mediate between the business and domain experts with conceptual knowledge and those with methodological or technical knowledge, such as IT consultants or engineers. This applies for SOA-projects in two ways. On the one hand, process-oriented execution languages such as BPEL come to the fore due to standardization initiatives. And on the other hand, the importance of conceptual process description languages such as EPC increases due to the targeted orchestration of services.

In order to fully support the integration of process models, technical service models and actual software code, future SOA development environments will need to provide one integrated repository shared by all levels of modeling. The mapping of objects between information, application and execution models is stored here, so that actually work that is done at one of the three levels can be propagated and synchronized with the others in real-time. This vision is likely to require a common process ontology specifying generic modeling artifacts and in the long-run a standardized vocabulary bridging business and learning requirements and IT constraints.

## 5.2 Outlook: Implications for an TEL-ontology using EPC-process models

Even though a fundamental idea for the model-driven development of information systems, the linkage between natural language and graphic representation forms is a main problem of semi-formal modelling languages (here: EPC). The identifiers of the individual elements of a business process model are added in a natural language by the modeller, irrespective of his decision for a certain modelling language. An essential part of the semantics of a process model is thus always bound to the natural language, which, with its ambiguities, allows much room for interpretation. This is not a problem as long as a model is created and read by only one person. Clearly defined semantics for each model element are however necessary, if process models from various modellers are combined, searched and translated or if it is planned that the semantics in the models should be automatically validated and used for the configuration of an information system.

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[57] MELENOVSKY, M. J.: Business Process Management's Success Hinges on Business-Led Initiatives. Stanford: Gartner, 2005

The problem mentioned above can be met through the linkage of the elements of a business process model with concepts from an ontology. In the following, such a semantic extension for a process modelling language, which represents the semantics of the labels of process model elements with concepts of a formal ontology is briefly outlined. This semantic extension will be carried out exemplified by the EPC, which has been selected due to its popularity in modelling practice. However, such an approach is principally transferable to other semi-formal modelling languages.[58]

The semantics of individual model elements will be specified using concepts from a formal ontology. The linkage of model elements with the ontology required for this will be realized using a sepa-rate metadata level. Concepts from the ontology are used in the metadata to specify the meaning of model elements. Therefore, the ontologies used must contain the required concepts or they must be added to the ontologies in the course of the creation of the metadata.

A standardization of terms for and concepts on ontologies has been the topic of research for years in the field of artificial intelligence and the semantic web. According to GRUBER, an ontology is "a for-mal, explicit specification of a shared conceptualization"[59]. The basic idea of the se-mantic web, which is to give information a well-defined meaning in order to make it processable both for humans and machines,[60] can be transferred to the field of business process management.

In the area of TEL, reusability and interoperability issues essentially influence the productivity and efficiency of learning and authoring solutions. There are two basic approaches how to overcome these problems – one attempts to do it via standards and the other by means of the Semantic Web. Since the CONZILLA tool is based on semantic web technology and provides a totally flexible human-semantic frontend,[61] which is connected to a machine-processable (machine)-semantic backend, it is quite suitable for such applications.[62] They can be used in isolation, but that is not desirable. In practice, the existing solutions are based on ontologies that take into account the available specifications and try to integrate them. Moreover, these ontologies can help us to achieve a certain kind of consensus and to contribute to the harmonization of the existing standards. KRAVCIK/GASEVIC aim at addressing the issues of leveraging the Semantic Web to improve mechanisms for knowledge representation in the area of adaptive education.[63] They attempt to view adaptive education from different perspectives and consider relationship of various aspects that often appear not to be connected.

In the following, a simple example of an ontology is shown and illustrated by means of a graphic representation [cp. Figure 8]. The ontology framework exemplarily contains classes for organizational units, tasks, events, services and rules as relevant elements of an enterprise description. These classes can be specialized arbitrarily. In this example, the classes Event and Service were further specialized. In addition to classes, the example ontology contains instances, which symbolize a member of a class. The properties `partOf` and uses are defined to be transitive, so that additional facts can be inferred by querying the ontology with query languages. In the following, this

[58] NAEVE, A. et al.: A Conceptual Modelling Approach to Studying the Learning Process with a Special Focus on Knowledge Creation. Deliverable 5.3 of the PROLEARN EU/FP6 Network of Excellence, IST 507310, June 2005.

[59] GRUBER, T. R.: Toward principles for the design of ontologies used for knowledge sharing? In: International Journal of Human-Computer Studies 43 (1995) 5–6, pp. 907–928

[60] BERNERS-LEE, T.; HENDLER, J.; LASSILA, O.: The Semantic Web. The Scientific American, May 2001

[61] PALMÉR, M.; NAEVE, A.: Conzilla – a Conceptual Interface to the Semantic Web. Invited paper at the 13:th International Conference on Conceptual Structures, Kassel, July 18-22, 2005, published in the proceedings: DAU, F., MUGNIER, M-L., STUMME, G. (Eds.), Conceptual Structures: Common Semantics for Sharing Knowledge, Springer Lecture Notes in Computer Science, ISBN 3-540-27783-8, 2005

[62] In the PROLEARN Deliverable 1.2, we concluded that the existing standards do not support interoperability in a satisfactory way, as a common abstract model is missing. For a published version of D 1.2. see: AROYO, L.; DOLOG, P.; HOUBEN, G.-J.; KRAVCIK, M.; NAEVE, A.; NILSSON, M.; WILD, F.: Interoperability in Personalized Adaptive Learning. In: Educational Technology & Society, 9 (2006) 2, pp. 4-18

[63] KRAVCIK, M.; GASEVIC, D.: Leveraging the Semantic Web for Adaptive Education. In: Journal of Interactive Media in Education, 2007.

example ontology will be used to specify the model element-specific semantics of the elements of an EPC-model.

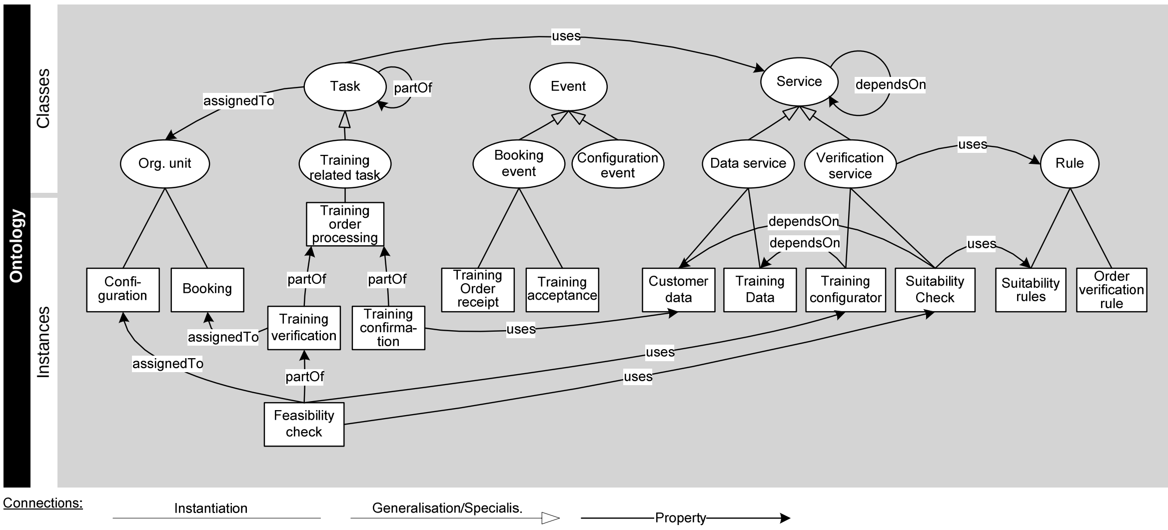


***Figure 8**: Framework for an enterprise ontology*

To specify the semantics of EPC-model elements through relations to ontology concepts, the EPC first must be represented within the ontology. In regard to the representation of the EPC in the ontology, one can differentiate between a representation of EPC-language constructs and a representation of EPC-model elements. EPC-language constructs such as "`function`" or "`event`", as well as the control flow are created in the ontology as classes and properties. Subsequently, the EPC-model elements can be represented through the instantiation of these classes and properties in the ontology. Figure 9 shows this by means of a simple process fragment.

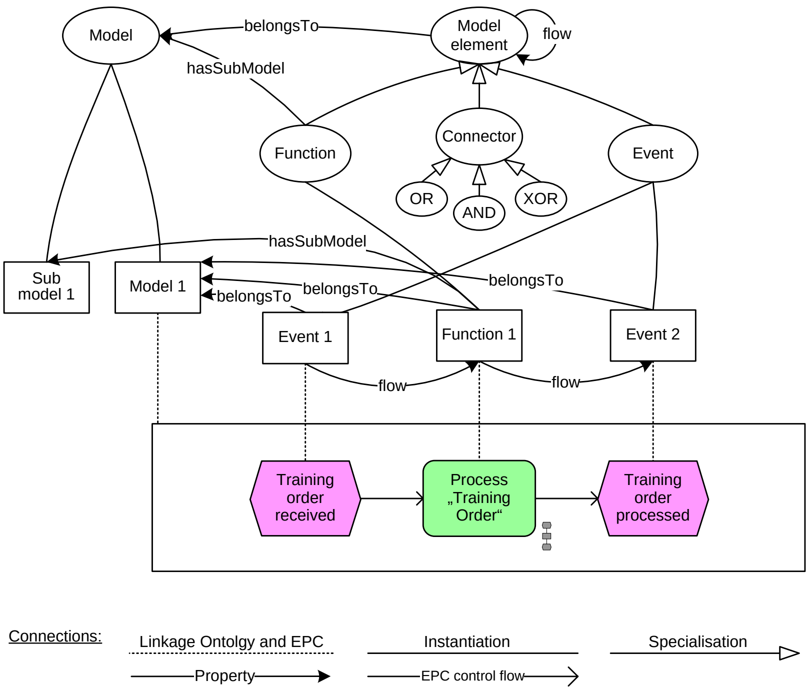


***Figure 9:** Representation of the EPC in the ontology*

The linkage of EPC-model elements with ontology instances can also be referred to as a process of semantic annotation. The EPC-model elements already represented in the ontology are thereby put in relation to further instances of the ontology. In order to illustrate the overall approach, **Figure 10** provides an example which on the one hand is small enough to avoid unnecessary visual complexity but on the other hand is comprehensive enough to capture the main ideas of our approach. The linkage of the ontology and EPC-model element instances is accomplished by the usage of properties; these are represented as `semType`-properties. Just as the name indicates, these properties specify the semantics of an EPC-model element through a relation to an ontology instance with formal semantics defined by the ontology.

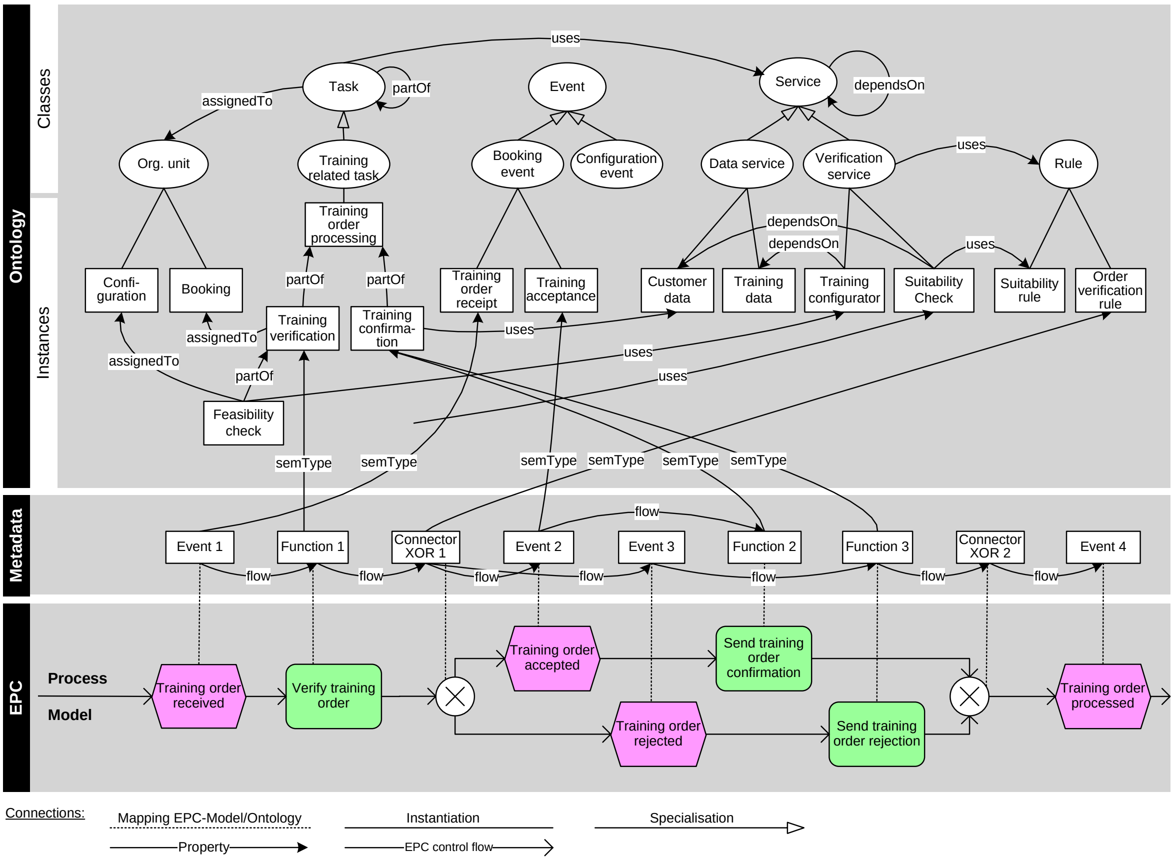


***Figure 10:*** *Semantically annotated process model*

In addition to the decoupling of the semantics of an individual model element from its natural language label, the context of a model element is specified more accurately through the linkage of an ontology instance to the model element. This happens via relations, which exist between the ontology instance representing the EPC-model element and further instances of the ontology. In contrast to plain syntactic approaches, the shown concept allows the semantic annotation of business process models, thus it can serve as a basis for cooperative business process modelling and can further improve the establishing of a common understanding within the scope of business process reengineering or change management efforts.

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