Gran Sasso Science Institute

**COMPUTER SCIENCE DOCTORAL PROGRAMME**

Cycle XXIX - AY 2013/2016

# Modelling, Design and Evaluation of a Process-Driven Framework for Workplace e-Learning

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# Declaration of Authorship

I, VENKATAPATHY SUBRAMANIAN, declare that this thesis titled, "Modelling, Design and Evaluation of a Process-Driven Framework for Workplace e-Learning" and the work presented in it are my own. I confirm that:

- This thesis has been composed by myself and the presented work is my own under the guidance of my supervisor(s) Antonia Bertolino and Guglielmo De Angelis for a research degree at this University.
- Chapter 4 is re-elaboration of my work [1] co-authored with my supervisor Antonia Bertolino. Part of the work from Chapters 5, 6 are re-elaboration of my works [2–5] co-authored with my supervisor Antonia Bertolino.
- At the time of this writing a Journal paper and a Patent Application are pending for submission, partially based on Chapters 5,6 and 7. My supervisors Antonia Bertolino and Guglielmo De Angelis will be co-authors for these works.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

GRAN SASSO SCIENCE INSTITUTE

# *Abstract*

Computer Science at GSSI

Doctor of Philosophy

**Modelling, Design and Evaluation of a Process-Driven Framework for Workplace e-Learning**

by Venkatapathy Subramanian

Workplace learners are particularly exigent and selective; they learn just what they need and perceive as useful only what can be applied to their tasks. Current e-learning techniques may not be effective for workplace learning. They focus mostly on managing the learning content for cohorts of learners with similar entry levels, and do not give proper emphasis to the process applied during learning.

Approaches to workplace learning must be founded on the alignment of the educational content with the processes and tasks to be carried out. Hence, the need emerges for a paradigm shift in the design of workplace e-learning systems, towards a process-driven learning approach. Interestingly, alongside the demand for innovative approaches to workplace learning, a steady progress can be noticed in another thread of the organization called Business Process Management Systems (BPMS) where process-driven approaches are used in the design of information systems and to manage the collaboration activities of various stakeholders.

In this thesis, we propose that BPMS can also be exploited for the design of e-learning systems for workplace learning. The addressed research question is: How can we provide tools and methodologies for process-driven learning in the design of workplace e-learning systems? Or, how can we effectively use BPMS while providing solutions for the process-driven learning approach? To this end we first conduct a systematic survey of the state-of-the-art on using the business process for e-learning. Then, we argue how identified gaps can be filled and a Business Process Management-based Learning System (BPMLS) can be implemented.

We introduce a model called the Learning Path specification that can be used for the learning process. In BPMS, the Business Process Model and Notation (BPMN) is widely used for modeling, implementation, execution and monitoring of business applications. Likewise, our Learning Path specification provides a method to seamlessly add a learning pedagogy in the workplace to the already existing BPMN model. We provide the theoretical definition of the Learning Path and the specification of an architecture of a BPMLS. We also implemented a prototype of BPMLS based on its architectural specification, and evaluated it on a pilot study. This pilot study followed the Technology Acceptance Model (TAM) to have an evidence-based understanding on how users receive BPMLS as a new technology for learning. The users' feedback on each of the TAM constructs that directly affect the acceptance of the BPMLS technology was positive. Hence, we can conclude that the proposed new approach to workplace e-learning can be expected to contribute to new useful directions in the development and integration of learning in the workplace.

# *Acknowledgements*

Today is the day: writing this note of thanks is the finishing touch on my dissertation. It has been a period of intense learning for me, not only at the scientific level but also on a personal level. I would like to thank and acknowledge some persons who have supported and helped me so much throughout this period.

I owe my deepest gratitude to my supervisor Antonia Bertolino. Without her continuous optimism concerning this work, enthusiasm, encouragement and patience I would hardly have been completed my PhD. The professionalism, hard work, and sincerity that she displayed during these three years are important life-lessons for me, and I will always strive to imbibe those qualities in me. I also express my warmest gratitude to my other supervisor Guglielmo De Angelis. Without his timely help, I wouldn't have completed my work. His guidance in technical details of the work and supervision have been essential during my PhD. I am also glad that I got to learn from some of his technical expertise.

I am deeply grateful to Professor Rocco Di Nicola, coordinator of the computer science department and other professors and researchers for making it possible to carry out my studies in the department. Special thanks to Gran Sasso Science Institute and its director Professor Eugenio Coccia for giving me this opportunity to pursue doctoral studies. My heartfelt gratitude to the administration staff of GSSI, who helped me whenever I faced difficulties especially during my initial period of stay in this new place. I want to express my gratitude to the revisors of the manuscript Professor Dimitris Karagiannis and Professor Barbara Thonssen. I am also grateful to the members of my committee for their patience and support in overcoming numerous obstacles I have been facing through my research.

On a personal note, I am grateful for all the people I met during the PhD. During this period, I got an opportunity to meet people from many different countries and cultures that gave me exposure to alternative perspectives and experiences of life. I am particularly grateful to meet friends like Mutti, Darko, Gabriela, Breno, Tan, Abhi, Yuri among others. We were not only able to support each other during the difficult phases but also were happy talking about things other than just our papers. To other friends, I wish to convey my thanks and my apologies for not being able to mention them personally here.

Finally, I would like to thank my family who is always there for me. I must express my very profound gratitude to them for providing me with unfailing support and continuous encouragement throughout my years of study. My deepest gratitude to my Guru Adinarayanan and Smrithi Rekha. This accomplishment would not have been possible without them. I dedicate this thesis to my Family and my Guru.

# Contents

**Declaration of Authorship** 1

**Abstract** 2

**Acknowledgements** 4

**List of Figures** 9

**List of Tables** 11

**Glossary** 13

**Acronyms** 15

**1 Introduction** 1
- 1.1 Structure of the Thesis . . . 4
- 1.2 Published Material . . . 5

**2 Research Methodology** 7
- 2.1 Identify the Problem Statement . . . 7
- 2.2 Identify State-of-the-Art . . . 9
- 2.3 Identify the Solutions for the Problem Statement . . . 10
- 2.4 Define Architecture of the System . . . 10
- 2.5 Implement Prototype and Validate . . . 10
- 2.6 Discuss Conclusion and Future Work . . . 11

**3 Background** 13
- 3.1 Business Process and Business Process Models . . . 13
- 3.2 Business Process Management (BPM) . . . 14
- 3.3 Business Process Management Systems (BPMS) . . . 15
- 3.4 Business Process Model and Notation (BPMN) . . . 16
- 3.5 Process-driven Learning Systems . . . 18
- 3.6 Learning Path Specification . . . 19
- 3.7 Learning Process Management . . . 20

**4 Identifying State-of-the-art 21**
4.1 Need for a Systematic Mapping Study . . . 22
4.2 Research Methodology . . . 23
4.2.1 Planning . . . 23
4.2.1.1 Research Question(s) . . . 23
4.2.1.2 Search Strategy . . . 24
4.2.1.3 Selection of Primary Studies . . . 26
4.2.2 Data Extraction Strategy . . . 26
4.2.2.1 Qualitative Analysis . . . 27
4.2.2.2 Emerged Sub-questions (Category Groupings) . . . 30
4.3 Research Results . . . 32
4.3.1 Primary Studies . . . 32
4.3.2 General Findings . . . 37
4.3.3 Q1. What is the Maturity of the Work? . . . 37
4.3.4 Q2. What is the Contribution of the Articles? . . . 39
4.3.5 Q3. What Business Process Techniques are Used? . . . 40
4.3.6 Q4. What e-Learning Standard Models are Used? . . . 40
4.3.7 Mapping Study . . . 41
4.4 Discussion . . . 44
4.4.1 Principal Findings . . . 44
4.4.2 Threats to Validity . . . 47
4.4.3 Implications for the Thesis . . . 47
4.4.4 Implications for Research and Practice . . . 49

**5 Learning Path Specification: Conceptual Model and Formal Definitions 51**
5.1 Motivational Example . . . 52
5.2 Learning Path Specification for Business Process Models . . . 55
5.3 Formal Relation between Business Process Models and Learning Path Specifications . . . 57
5.3.1 BPMN Graph Definitions . . . 57
5.3.2 Learning Path Definitions . . . 59

**6 Business Process Management-based Learning System (BPMLS) 63**
6.1 BPMLS: Integrating BPM and LPM . . . 63
6.2 Phase of BPMLS . . . 64
6.2.1 Build Time Phase . . . 65
6.2.2 Run Time Phase . . . 67
6.2.3 Control Time Phase . . . 67
6.2.3.1 Tracking the Learning . . . 68
6.3 Architecture of BPMLS . . . 70
6.3.1 Components of Build Time Phase . . . 70
6.3.2 Components of Run time Phase . . . 71
6.3.2.1 Learning Process Engine . . . 71
6.3.2.2 Business Process Engine . . . 73
6.3.3 Components of Control Time Phase . . . 74

**7 Prototype Implementation and Validation of BPMLS** **75**
7.1 Technology Acceptance of BPMLS . . . 77
7.2 Methodology to Test TAM Variables for BPMLS . . . 78
7.2.1 Case Studies . . . 78
7.2.2 Hypotheses . . . 79
7.2.3 Questionnaire . . . 81
7.2.4 Sampling Technique . . . 84
7.2.5 Data Collection . . . 84
7.3 Data Analysis and Results . . . 86
7.3.1 Descriptive Analysis . . . 87
7.3.2 Inferential Analysis . . . 88
7.4 Threats to Validity . . . 93
7.4.1 Threats to Construct Validity . . . 93
Choice of Case Studies: . . . 94
Low statistical power: . . . 94
Evaluation Metrics: . . . 94
7.4.2 Threats to internal validity . . . 95
Experiment Effect: . . . 95
Testing Effects: . . . 95
Subject effects: . . . 95
7.4.3 Threats to external validity . . . 95
Selection Bias: . . . 96
Generalisation and constructs: . . . 96
Experimentation Environment: . . . 96
Complexity of the Case Study: . . . 96

**8 Conclusions and Future Work** **97**

**A XSD Schemas** **101**
A.1 XSD Schema for the Learning Path Specification . . . 101
A.2 XSD Schema for Learning Scenarios . . . 103

**Bibliography** **107**

# List of Figures


2.1 Research Methodology . . . . . 7

3.1 Life Cycle of BPM . . . . . 14
3.2 BPMN Elements . . . . . 18
3.3 Life Cycle of LPM . . . . . 20

4.1 Study Selection Process and Results . . . . . 33
4.2 Distribution of Articles by Year . . . . . 37
4.3 Global Heatmap of Selected Articles . . . . . 38
4.4 Contribution of the Selected Articles . . . . . 38
4.5 Categorization of Business Process Techniques Used . . . . . 40
4.6 e-Learning Standards Used . . . . . 41
4.7 Cross-mapping between Q2 and Q5 . . . . . 42
4.8 Cross-mapping between Q2 and Q3 . . . . . 43
4.9 Cross-mapping among the Multiple Options of Q2 . . . . . 44
4.10 Cross-mapping between Q3 and Q4 . . . . . 45
4.11 Mapping of Results for Questions in Table 4.2 . . . . . 46

5.1 An Abstract Business Process Model . . . . . 52
5.2 Learning Scenario for Employee X . . . . . 53
5.3 A complex Learning Scenario with two Learning Activities for the Employee Y . . . . . 55
5.4 Learning Path Specification . . . . . 56

6.1 Intertwining Business Process and Learning Process . . . . . 64
6.2 Business Tasks to Learning Tasks . . . . . 69
6.3 Architecture of BPMLS . . . . . 70
6.4 Various Components of a Learning Process Engine . . . . . 73
6.5 Various Components of a Learning Activity Monitor . . . . . 74

7.1 Technology Acceptance Model as Proposed by Davis [6] . . . . . 76
7.2 Loan Assessment Process . . . . . 79
7.3 IT-Help Desk Process . . . . . 80
7.4 Demo video within BPMLS . . . . . 85
7.5 UI of the Learning Simulator in which the User will do the learning. . . . . 85
7.6 Online survey form embedded within BPMLS . . . . . 86
7.7 Occupation of the Participants . . . . . 87
7.8 Work experience of the Participants . . . . . 87

7.9 Answers for the question: *Do you encounter the need to learn and understand processes?* . . . . . 88
7.10 Answers count for the question: *Please state the frequency with which you use the modalities to learn processes* . . . . . 89
7.11 Code Snippet from R-Studio . . . . . 91
7.12 R Command and output for Upper-tail One sample T-Test . . . . . 92

# List of Tables


4.1 Electronic databases considered in this research . . . . . 24
4.2 Sub-questions, motivation for choosing them and their corresponding answers . . . . . 30
4.3 List of Selected Papers . . . . . 36
4.4 List of Excluded Studies . . . . . 36

7.1 List of Questions for Part 1 of the Questionnaire . . . . . 81
7.2 List of Questions in Part 2 of the Questionnaire . . . . . 83
7.3 List of Questions in Part 3 of the Questionnaire . . . . . 84
7.4 Calculated Mean Values for each Part of Section 2 of the Questionnaire, per User . . . . . 90
7.5 One Sample t-test: Null-hypothesis, P-value and Conclusion . . . . . 91
7.6 Upper-tail Alternative Hypothesis One Sample T-test . . . . . 92
7.7 TAM Variables: Descriptive Statistics . . . . . 93

# Glossary

**Build Time Phase** Build time phase focus on design and implementation of the business and the learning process models. 64, 74, 77

**Business Process Management (BPM)** a discipline *supporting business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information*. 13

**Business Process Management System(s)(BPMS)** Enterprise software developed for leveraging the business process management concepts to organize and automate processes.. 2, 14

**Business Process Model** a visual and/or formal representation that is used to specify the flow of business activities of the business process.. 15, 75

**Business Scenario** business scenarios for a given Business Process Model, can be identified by a Path and a set of input/output data objects generated during its execution.. 58

**Control Time Phase** Control time focus on the measurement, collection, analysis, and reporting of data about learners and their contexts that are required for the Learning Analytic aspects of the BPMLS.. 66, 75

**Coverage** A Criteria which identifies how much of learnign scenario is needed to cover a given set of learnign activities.. 60

**Experience API (xAPI)** The Experience API (xAPI) is a defined by Advanced Distributed Learning with an aim for providing better interoperability between different types of learning systems and devices. It does so by collecting and analyzing learning experiences happened in different contexts. . 67

**Learning Process Model** a visual and/or formal representation that is used to specify the learning activities of a learning process.. 75

**Learning Record Store (LRS)** A Learning Record Store (LRS)[1] is a data store system that serves as a repository for learning records collected from connected systems where learning activities are conducted. It is an essential component in the process flow for using the Experience API (xAPI). 73, 75

**Learning Scenario** Learning Scenario for a given Business Process Model can be identified by a Path and a set of input/output data objects generated during its execution one or more business activities from the model marked for learning.. 59

**Path** For a given Business Process Model, a path consists of a sequence of activities from the start event to the end event. 10, 11, 57

**Process-Driven Learning** alignment of the learning content with the business processes and tasks to be carried out. 2, 95

**Process-Driven Learning Design** It consists of inter-related learning tasks or activities that promote active learning through "collaboration, critical thinking, problem-solving and authentic interactions with real-world problems.. 17

**Run Time Phase** Run Time phase focus on actual execution of the various learning path models, its learning scenarios, and corresponding business process models.. 66, 75

**Workplace learning** learning or training undertaken in the workplace. 1

# Acronyms

**AOP** Aspect Oriented Paradigm. 75

**ATD** Association for Talent Development. 1

**BAM** Business Activity Monitoring. 66

**BPM** Business Process Management. 3, 19, 50, 62, 75, 95, 96

**BPMLS** Business Process Management-driven Learning System. 4, 59, 61, 62, 72, 74, 75, 93, 96

**BPMN** Business Process Model and Notation. 56, 72, 96

**BPMS** Business Process Management System. 2, 8, 10, 16, 47, 50, 64, 74, 95, 96

**ICT** Information and Communication Technology. 2, 13, 95

**LAM** Learning Activity Monitoring. 66, 73, 75

**LMS** Learning Management System. 18, 67, 77

**LPM** Learning Process Management. 19, 50, 62, 75, 96

**LRS** Learning Record Store. 73

**TAM** Technology Acceptance Model. 76, 77

**xAPI** Experience API. 73

*Dedicated to Matha, Pitha, Guru and Daivam...*

# Chapter 1

# Introduction

In the current evolving and high-tech business world, organizations are required to find new ways to improve their competitive advantages in the market. The performance of the employees plays an important factor in organizational success. Fast integration of information and communication technology and the need for dynamic changes in the work of the organization require that the employees stay up-to-date with the changes in their work [7]. Due to this, organizations are investing more money in the training of the employees than ever before [8]. According to the Association for Talent Development (ATD), organizations continue to invest in learning and development spending approximately $156.2 billion on employee learning alone [9]. Then, improving systems that are used for workplace learning becomes crucial for enhancing employees' performance and reducing related costs.

Workplace learning is considered as an informal learning, which is implicit, opportunistic and unstructured learning that takes place in the absence of a teacher [10]. Workplace learning environments are dynamic, learner-centered and have 'moving' curricula. [11]. Traditional instructor-led classroom training may not be efficient for workplace learning due to its complexity, non-linearity and ever-changing nature. E-learning can be a viable alternative as it provides easy access to learning contents, just-in-time delivery, and cost-effectiveness of setting up the environment. Hence it is favored by organizations, especially by small- and medium-sized enterprises, for supporting education and training in the workplace [12, 13].

A recent survey [14] asked to employees and managers what are the greatest challenges when starting a new job. 44% of employees and 60% of managers interviewed answered that mastering new processes and procedures tops their list of concerns when joining a company. Moreover, 17% of employees and 12% of managers said that learning how to use new technology and tools is another difficult part of a new job. Conventional e-learning tools may not be adequate to support solutions that can help the employees to learn about the new processes and procedures they are involved in. One reason for this inadequacy may be that traditional e-learning focuses on a set of curriculum syllabuses whereas workplace e-learning depends on the business tasks and goals of the organization. Workplace learners are particularly exigent and selective; they learn just what they need and perceive as useful only what can be applied to their tasks. The training in an e-learning system must be such that it gives the employees the opportunity to acquire knowledge and skills that are related to their tasks. However, aligning learning tasks to the business tasks is difficult with currently available e-learning tools. A second reason is that traditional e-learning tools focus mainly on managing the learning content and do not give proper emphasis on managing the learning process that in workplace learning corresponds to the business process. Indeed, approaches to workplace learning must support the *alignment of the educational content with the business processes and tasks to be carried out.* This new approach is referred to as Process-Driven Learning [15]. In a process-driven learning approach, the design of learning contents and systems is organizational, individual, and business application-specific. However traditional e-learning tools do not provide methods for this new approach to learning design.

Interestingly, along with this demand for innovative approaches to the design of workplace e-learning systems, a steady progress can be noticed in another thread of the organizational efforts to optimize their businesses: we refer to the Business Process Management System(s)(BPMS). With the pervasive penetration of Information and Communication Technology (ICT) in business organizations, BPMS provides efficient tools to make the integration of ICT and work procedures easier and more effective [16]. BPMS provides a process-driven approach to the design of ICT systems that can be used to seamlessly represent as well as implement the collaboration activities of various stakeholders including both humans and automated business service systems.

In this thesis, we propose that BPMS can also be exploited for the design of e-learning

systems for workplace learning. Since BPMS is already used for building business applications, using it as a basis for developing workplace e-learning applications as well is an added advantage. An e-learning platform supported by BPMS can provide an environment for the employees where they can learn about the business processes while actually doing them, e.g., by simulating the business activities. We can also align the learning and the business activities by using the same set of tools to define the business as well as the learning activities.

We conducted a systematic survey of the literature on the exploitation of BPMS and its techniques for e-learning purposes and concluded that there does not yet exist much research in this direction. Our proposal is inspired by the recently concluded European Union FP7 Project Learn PAd [17, 18]. One of the objectives of Learn PAd was to provide a procedural learning approach based on simulation and monitoring that supported learning by doing. In line with Learn PAd, we address this objective by using BPMS for the design of the learning environment. However our solution introduces some important extensions to the solution given in Learn PAd (which are discussed in detail in Section 2.1).

BPMS does not provide means to include any specifications or models related to learning into the business applications. Business Process Management (BPM) techniques are originally developed for optimizing business activities and hence lack methods to include learning concepts along with the business activities. To bridge this gap, we introduce what is called the Learning Path Specification for Business Process Models. The proposed specification is based on the existing specification on learning models from Janssen and co-authors [19–21], who proposed a generic specification to the design of learning models for adult learning. We extend their generic definition to use it in the BPMS: we provide model specification and formal definitions to the Learning Path Specification extended for the business process models.

We also extended the BPMS to include ways to design process-driven learning systems. We call this the Business Process Management-based Learning System(s) (BPMLS). BPMLS exploits the already available methods of BPMS to define the business processes, and in addition provides methods to define the learning models for the business process models using the Learning Path Specification that we introduce. We provide a reference architecture for the BPMLS and a prototype implementation based on this

architectural specification, which we use for validation purposes. Precisely, we evaluated the BPMLS prototype by conducting a pilot study with real users. The pilot study followed the Technology Acceptance Model (TAM) [22] to obtain a quantitative analysis on the acceptance of e-learning systems designed using the process-driven learning approach of BPMLS.

In summary, the contributions of this thesis include:

1. A systematic literature survey to identify the state-of-the-art of the research on using the business process approaches for e-learning purposes.
2. A metamodel called the Learning Path Specification for Business Process Models, based on the Learning Path specification by Janssen et al. [19–21]. Precisely, they proposed a framework for defining a Learning Path that can be used for adult, informal learning scenarios. We extended it for the Process-driven learning context.
3. A Reference Architecture of a system that can be used for designing of process-driven e-learning systems, called the BPMLS.
4. A proof-of-concept of the proposed BPMLS architecture that is made publicly available[1].
5. A pilot study with real learners to validate the acceptance of the proposed BPMLS.

## 1.1 Structure of the Thesis

In this section we outline the structure of the subsequent chapters of the thesis:

In Chapter 2 we describe the six-step research methodology that we followed to conduct the research work in this thesis.

In Chapter 3 we discuss some concepts and terms that we use later in the thesis. Some or all of it can be skipped based on what the readers are already familiar with.

In Chapter 4 we describe a systematic survey of the literature that we conducted to identify works related to our research and to find out the missing gaps in those related

[1] https://github.com/venkatapathy/bpmls-framework

works. This chapter will bring out the state-of-the-art in the field of using business process techniques in e-learning domains.

In Chapter 5, we define the Learning Path Specification for Business Process Models. In particular, we provide a formal definition of the Learning Path Specification that maps the learning path to the business process model.

In Chapter 6 we describe the generic architecture of our proposed BPMLS. We also describe the different phases of the BPMLS and the components that cover each of these phases.

In Chapter 7 we explain in detail the development of a prototype BPMLS. In the same chapter we report about how we conducted some validation tests to understand the perceived usefulness and ease of use of the BPMLS among real users.

Finally, we provide the conclusions and future work for this thesis in Chapter 8.

Appendix A contains technical references, more specifically the XML Schema of Learning Path Specification.

## 1.2 Published Material

Some contents of Chapter 4 is pending review in:

[1] Subramanian V. and Bertolino A., A Systematic Mapping Study on Business Process-oriented e-Learning, *Submitted*

The contents of Chapters 5, 6 are partially published in:

[2] Subramanian V., and Bertolino A. (2016). Learning Path Specification forWorkplace Learning based on Business Process Management.In Proceedings of the 8th International Conference on Computer Supported Education - Volume 1: CSEDU, ISBN 978-989-758-179-3, pages 172-180. DOI: 10.5220/0005815301720180

[3] Subramanian V., and Bertolino A. (2016). Monitoring of Learning Path for Business Process Models.In Proceedings of the International Workshop on domAin specific Model-based AppRoaches to vErificaTion and validaTiOn - Volume 1:

AMARETTO, (MODELSWARD 2016) ISBN 978-989-758-166-3, pages 62-72. DOI: 10.5220/0005845300620072

[4] V. Subramanian (2016), Towards Business Process Management Based Workplace e-Learning, IEEE 16th International Conference on Advanced Learning Technologies (ICALT), Austin, TX, 2016, pages 555-557. DOI: 10.1109/ICALT.2016.135

[5] Subramanian V., and Bertolino A. (2016), A Model-Driven Approach to Business Process-Based Learning, Computers Supported Education, 2016, DOI: 10.1007/978-3-319-63184-4

For papers [1–5], I was responsible for the idea, the study design and analysis, the implementation [2–5] or data collection [1], and writing. My supervisor Bertolino contributed with guidance in all phases of the work and reviewed the papers.

Besides, at the time of this writing a Journal paper and a Patent Application are pending for publication partially based on Chapters 5, 6 and 7.

# Chapter 2

# Research Methodology

A research methodology provides the steps to be followed to systematically solve a research problem [23]. The research methodology we followed includes six steps as illustrated in Figure 2.1. Each of the steps is summarized in the remainder of the chapter.

## 2.1 Identify the Problem Statement

The first step in our work is to define the context and the research problem tackled by this thesis. Chapter 1 already started to address this aspect by reporting an overall introduction on the thesis goal, specifically to provide methods for the design of a process-driven learning system. There are some important criteria that a process-driven learning

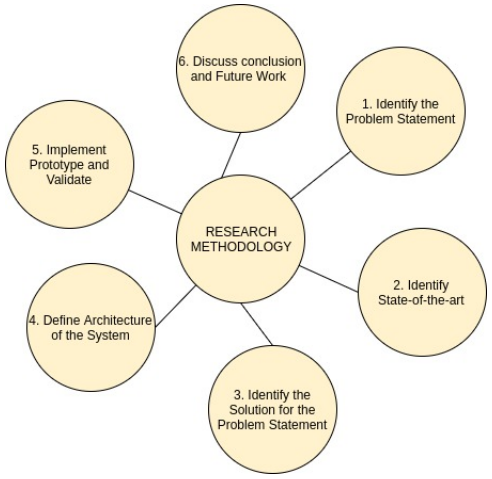


FIGURE 2.1: Research Methodology

system should cover. A successful process-driven, workplace e-learning system should include:

- efficient ways to align learning activities to business activities
- the capability to simulate the actual working environment for the employees
- efficient and cost-effective ways to set up the training environment
- the capability to track and customize the learning tasks to the profile of the employees

We suggest that BPMS can be exploited to build a learning system that might satisfy the above requirements.

This thesis is inspired by the European Union Project Learn PAd [17, 24]. The main aim of the Project Learn PAd is to develop a social, collaborative and learning platform for civil servants. By using the Learn PAd platform, workers in the Public Administrations (PAs) can engage in a holistic and collaborative learning experience, centred around an enriched model of the to-be-learned Business Process (BP). The platform supports multiple learning paradigms, among the others: *i.* informative learning, by allowing learners to explore business related knowledge by browsing wiki pages; *ii.* collaborative learning, by supporting the interaction of civil servants to comment, discuss and enhance content associated to models and model elements; *iii.* performative learning, by providing possibility to simulate the business processes so that the civil servants can assess if they operatively understood the procedure; and *iv.* assisted learning, by introducing tutoring mechanisms [25]. Concerning the performative learning approach based on simulation, Learn PAd aims at providing a simulation environment in which the learners can engage in training activities by operating on real cases. Simulation can be done individually or cooperatively with colleagues.

We observed that the Learn PAd solution for simulation-based learning has some restrictions. They are listed in the following:

- In the current version of the Learn PAd simulation environment, there is no way to define customized learning requirements for an individual learner. The use cases defined for simulation will be common to all the employees.

- The flow of activities is defined in a process model. This flow cannot be changed in the Learn PAd during the definitions of simulation parameters for learning.
- Grouping use cases based on the learning requirements is not possible in the Learn PAd. For example the set of use-cases for a beginner may be different from that for an expert.

These are the some of the limitations of the process-driven learning environment envisioned in Learn PAd. In our thesis, we address the above limitations.

To summarize, the goal of this thesis is to provide a solution for process-driven e-learning systems for workplace learning. We propose the means to achieve this is by enhancing BPMS also for designing workplace e-learning applications. The solution should provide methods to develop an e-learning system to mimic real-life workplace scenarios that will help the employee to learn from. And given the advantages of BPM Methodology, the solution should reuse the BPM approaches and its already available robust technologies for the development of the e-learning system. To concisely define the problem statement we ask the following research questions: **How can we provide tools and methodologies for process-driven learning approach in designing of workplace e-learning systems? How can we effectively use BPMS while providing solutions for the process-driven learning approach?**

## 2.2 Identify State-of-the-Art

After we identify the research questions, we move to the next step in our research methodology. In this step, we consider more research work to understand the current state-of-art related to our research problem. We do so by conducting a systematic survey of the literature. Apart from contributing to our thesis, the outcome of the systematic survey will be of interest to researchers who wish to investigate the use of the business process techniques in e-learning domains. At the end of this step, we identify the missing gaps, if any, in the current state-of-the-art and the implications it will have for the thesis. We also summarize the implications for general research in this area. This step is explained in more detail in Chapter 4.

## 2.3 Identify the Solutions for the Problem Statement

In this step, we will provide the solutions to overcome the limitations we observed in Learn PAd and in the state-of-the-art. The solutions should provide ways to enhance the BPMS with methods and models so that it can be used for also designing e-learning applications. We mentioned earlier that we propose a Learning Path Specification for the Business Process Model. This step is about providing the metamodel and formal notations of the Learning Path Specification. The formal definition gives a technologically agnostic specification that subsumes several representations and implementations of the Learning Path Specification for the Business Process Models. More details of this step are given in Chapter 5.

## 2.4 Define Architecture of the System

After introducing the conceptual and the formal definition of the Learning Path Specification, we can specify the process-driven learning system called the BPMLS. In this step, we integrate BPMS with the Learning Path Specification to enhance it as BPMLS, and derive a set of tools that can be used as a system for process-driven learning for the workplace. BPMLS can then be seen as a suite of software that assists in design, execution, and control of both the business process and learning activities and that can be used for process-driven learning. This step is explained in more detail in Chapter 6.

## 2.5 Implement Prototype and Validate

In this step, we develop an implementation of the BPMLS architecture. For the sake of efficiency, we intend to reuse as much as possible the existing tools and methodologies of BPM and adapt them to e-learning purposes. We implement the prototype and a set of case studies targeting the users for learning. Then we test some of our hypotheses on the effectiveness of BPMLS for learning, by conducting a survey where the users will use the BPMLS and provide a feedback on their experience. More details and the results of the study are given in Chapter 7.

## 2.6 Discuss Conclusion and Future Work

In the final step of the Methodology, we conclude our thesis with a discussion about our approach and the solutions we derived. We will also identify the future work we wish to do after the completion of this thesis. The Conclusion and Future Work are given in Chapter 8.

# Chapter 3

# Background

This chapter covers some of the concepts that we will use in this thesis. Some or all of it can be skipped, based on the familiarity of the readers with the concepts.

## 3.1 Business Process and Business Process Models

A classic definition of the business process is given by Davenport in which he states that "A process is a specific ordering of work activities across time and place, with a beginning, an end, and identified inputs and outputs: a structure for action." [26]

Models that are based on standard definitions and that capture the flow of work activities and their various decision points of the business processes are called as business process models. A business process model can often be visualized as a flowchart. Formal models also exist to define the business process. Simpler graphic-based models can be used to represent the conceptual point of view of the business processes in order to capture its behavioural, structural or semantic characteristics while abstracting away complex details [27]. Yet, the formalization allows for seamless integration and interoperability between the different types of models [28]. Business process models play a central role in a BPMS.

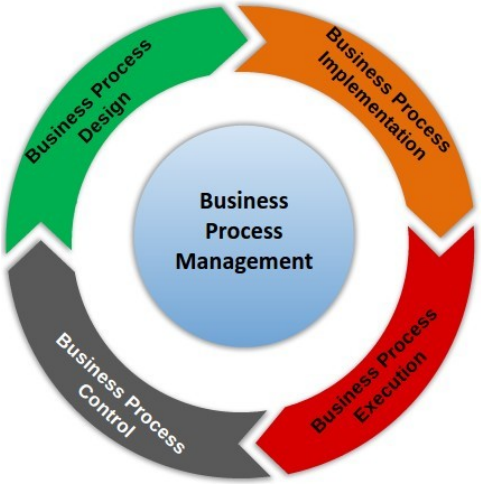


FIGURE 3.1: Life Cycle of BPM

## 3.2 Business Process Management (BPM)

Within the scope of this thesis we will refer to Business Process Management (BPM) by adopting the operational definition proposed by van der Aalst and co-authors [29]. Specifically, BPM is a discipline *supporting business processes using methods, techniques, and software to design, enact, control, and analyse business processes involving humans, organizations, applications, documents and other sources of information.* BPM is a management science that is multi-disciplinary subject involving knowledge from management theory, computer science, mathematics, linguistics, semiotics, and philosophy [30]. Over three decades, BPM has become well-known for providing robust approaches to operational management. Implementing processes with BPM supported by ICT helps improving efficiency and effectiveness of business operations [16]. A BPM covers a broad range of activities often categorized within different phases [31]: design, implementation, execution, and control. A diagrammatic representation of the BPM lifecycle is given in Figure 3.1.

Design phase involves identification of the relevant processes in the business activities. The implementation phase is about moving from the conceptual model to reality. It involves the development of various system services and software that will be used to execute the business processes. During the implementation phase, abstract design is transformed into system-specific model elements usually through techniques such as Model Transformation [32, 33]. Execution involves orchestration of the various activities implemented in the BPM so that regulating the foreseen interactions among the actors of

the business process. Control involves two steps of monitoring and optimization. Monitoring consists of tracking the execution of processes during the runtime. This way the behaviour and relevant metrics of one or more processes can be analysed and used to identify and rectify problems that may occur during execution of the business processes. During the optimization, process performance information is retrieved from modelling or monitoring phase and used for identifying the potential or actual bottlenecks. Also opportunities for cost savings or other improvements are investigated; possible enhancements could be eventually reflected during a following iteration on the design phase of the business process.

## 3.3 Business Process Management Systems (BPMS)

Information systems dealing with the definition, administration, customization and evaluation of tasks evolving from business processes are called Business Process Management System(s)(BPMS) [34]. BPMS is an information system with a set of software tools that can be used during the lifecycle of BPM. There are three critical components of a BPMS:

- **Integrated Development Environment** a set of design tools to model, design and implement the business processes
- **Process engine** a robust platform for executing process-based applications
- **Business Analytics** a set of control tools that can be used for measurement and evaluation of business processes.

Optionally the BPMS may also contain a content management system for storing and securing electronic documents, images, and other files, and collaboration tools to remove intra- and interdepartmental communication barriers through discussion forums, dynamic workspaces, and message boards. One of the primary goals of BPM and BPMS is to provide approaches and a set of tools that can be used to develop the end-to-end IT solutions for the organizations.

BPM as a methodology can be applied successfully in the organizations without any need for IT-integration, or usage of the BPMS tools. Yet, in this thesis, we focus on using the BPMS, the technology that has evolved over the period in time along with BPM.

BPMS has been used within organizations for creating business applications in a more efficient way. Since we want to develop workplace learning applications we believe BPMS technology can lend its support. Hence in this thesis, we will focus on BPMS technologies that conform to the BPM discipline and how we improvise them for workplace learning.

## 3.4 Business Process Model and Notation (BPMN)

A Business Process Model is an artefact that describes a process as a flow of work activities and their various decision points. Many standards exist that promise to provide a common language that can be used throughout the several BPM phases such as Workflow-Nets [35], XPDL [36], and BPMN [37]. Usually these standards admit both a visual or textual representation in order to specify the flow of business activities. Visual notations are more common during the design phase (e.g. during the interactions among business users that may not be familiar with technical syntaxes); textual notations are usually preferred when automation aspects emerge (e.g. mostly during execution or control phases). For practical reasons, our research refers to BPMN 2.0 [38] though the principal findings of this work also apply to other modelling notation as long as they conform to the graph-based definition of the business process given later in Section 5.3.

BPMN is a standard proposed and maintained by the Object Management Group (OMG) [38]. The primary goal of BPMN is to provide a standard notation that can be readily understood by all the stakeholders of the organization: from the business analysts who create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes [38]. This way, BPMN can be used as a standardized bridge all along the business process design, implementation and control.

BPMN was introduced in 2002 and standardized by the OMG in version 1.0 in 2006 [39]. BPMN 2.0 [38] is the current version released by the OMG. Version 2.0 adds many improvements over its previous version. *BPMN 2.0 is the first notation and interchange format that combines business user-friendly modelling with the detailed technical specification of an executable model within the same process model. This fosters collaboration between business analysts and technical developers of the IT system that supports the*

*business [40].* BPMN 2.0 also provides a standardized execution semantics for BPMN, which allows tool vendors to implement interoperable BPMS [40].

In this thesis, we consider BPMN 2.0 to represent the business process models, hence in the following the term BPMN always refers to BPMN 2.0. Precisely we consider only a subclass of the elements from BPMN.2.0. In order to keep the learning model simple, we excluded some important elements such as parallel and inclusive gateways. According to some studies [41–44], it is in fact convenient to minimize the level of concurrency in the business process models represented by elements such as parallel gateways and ad-hoc subprocesses, especially if the activities in parallel are 'manual tasks' and only one person is responsible for those. Concurrency, which is represented by parallel gateways, may in fact generate ambiguity. Also, the behaviour of the BPMN 2.0 inclusive gateways is not well-defined by specification [38] (i.e. open semantic-variation points). This way the notation could be customized in order to comply with possible domain-specific needs. Among the others such semantic-variation points also affect concurrency aspects. Nevertheless in our context we target individual learners who will simulate business scenarios to learn about the processes and how to execute them. Thus, we restrict the business model notations to the bare minimum required to enable such users to understand their work. We hope to include more elements in our future work. Figure 3.2 introduces the BPMN objects that we use in this thesis. In the following, we briefly describe these graphical objects as given by the OMG specification.

An Event is something that "happens" during a process execution. The Start Event indicates where and how a process will start. Likewise, the End Event indicates where a process will end. An Activity represents an action, i.e., a unit of work performed; it can be atomic or compound. In this work, we consider the atomic activity. There are different types of activity: i. *User Activity:* Activity is performed by a user of BPMS. ii. *Service Activity:* A *Service Activity* invoked automatically. A gateway controls the process flow splitting it into one or more alternative paths. The number of pathways in a business process depends on the gateways. Exclusive gateway is used when only one of the paths must be taken. A Sequence Flow is used to show the order in which the activities will be performed. A Data Object represents a local variable at a process level. Its value is visible to other elements of the process. It can be passed as input/output to a process activity or can be tested by a gateway condition. An Association is used to link information with the elements. Data Objects connect to other model elements

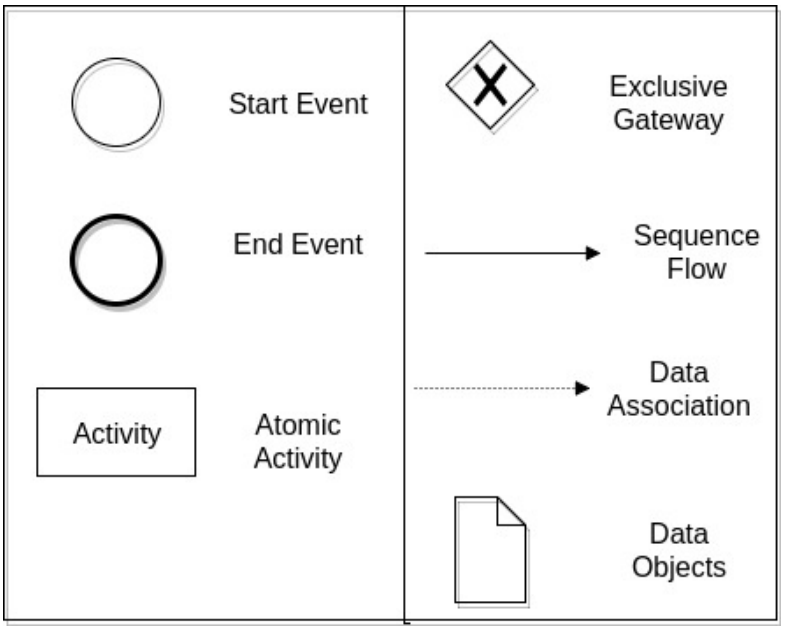


FIGURE 3.2: BPMN Elements

through Data Associations. One end of the data association is connected to activity to Data Objects and the other end to an activity or event. This way Data Association represents a mapping between that variable and a data input or output of the activity or event [45]. Data objects can be used to represent the data flow between the activities of the process.

## 3.5 Process-driven Learning Systems

In this section, we will see theories and concepts related to process-driven systems especially from workplace e-learning point of view. Personal knowledge is built through the experience of interaction with the real-world problem [46]. The design of a learning environment should "conceive of a problem, question, or project as the focus of the environment, with various interpretative and intellectual support systems surrounding it. The goal of the learner is to interpret and solve the problem or complete the project" [47]. Process-Driven Learning Design falls under the categories of constructivist theory of learning [48] of Active Learning and Authentic Learning that focus on goal-driven, problem-solving tasks in which the content is designed to facilitate, simulate and recreate real-life complexities and occurrences [48, 49]. Process-driven learning systems consist of inter-related learning tasks or activities that promote active learning through

"collaboration, critical thinking, problem-solving and authentic interactions with real-world problems" [50]. Any system that is designed for process-driven learning should be based on the design philosophy as explained above.

## 3.6 Learning Path Specification

Learning paths contains a sets of one or more learning activities that leads to a particular learning goal[20]. A **learning path** is described as the chosen route, taken by a learner through a range of learning activities, which allows them to build knowledge progressively [51]. It can be used to formally describe learning scenarios [19]. A learning path includes the flow of learning, which contains orchestration details for learning activities, roles, and other learning resources [52]. Learning path specification should also define learning objectives or outcomes. There have been attempts to standardize the definition of learning paths across Learning Management System (LMS) such as Sharable Content Object Reference Models (SCORM) [53] and Learning Object Metadata (LOM) [54]. However, until recently only simple approaches of learning standards were defined by the learning community [53, 55]. To overcome the limitations of the hard-structured learning standards on informal learning, 'workflow-based' learning systems have been proposed. Workflow technology enables the coordination of different tasks as well as the integration of tools and technologies used to support individual tasks, and hence it offers a flexible way for designing learning paths [56]. One such specification that is based on workflow design is the IMS- Learning Design (IMS-LD) [57]. IMS-LD allows the definition of activities along with the roles that should perform those activities. The activities can also be sequences, supporting materials and services that can also be specified and mapped to certain objectives. Jassen et al. also provided a Learning Path Specification [20, 21]. Their specification supported:

- Description of Lifelong Learning Paths
- Selection of Suitable Learning Paths
- Personalization of Learning paths
- Navigation of Learning Paths

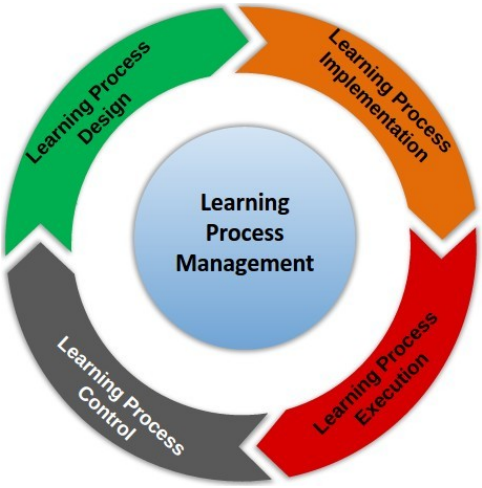


FIGURE 3.3: Life Cycle of LPM

The Learning Path Specification proposed by Jassen and the co-authors is just a method to describe and connect learning actions. Though the specification has been qualitatively assessed [20], their adaptation to a process-driven framework such as presented in this thesis is yet to be studied. In this thesis we will work in this directions by taking some elements from the specification provided by Jassen and use them to extend the business process models with learning.

## 3.7 Learning Process Management

The pedagogical assets defined by the Process-Driven Learning were the background for the establishment of more technical approaches focusing on the design of e-learning platforms; among the others the Learning Process Management (LPM) [58].Given this similarities, the lifecycle of BPM can be extended to the learning process as well [31]. Learning Process Management (LPM) can then be seen as a methodology to design, develop, manage and control the learning processes models. In Figure 3.3 we represent the lifecycle of LPM. Learning process models are referred as those artifacts that are used to specify the learning activities and their flow. They include models such as IMS-LD, Learning Path Specification that we explained in the previous section.

In the next chapters, we will see more details on our proposed Learning Path Specification and the BPMLS.

# Chapter 4

# Identifying State-of-the-art

In this chapter we will see an overview of the state-of-the-art in the field of using business process techniques in e-learning domains. Their combination is gaining interest, due to the demand from the learning community for an alternative effective way of designing the learning activities for adult learners. Actually works on exploiting business process techniques for process-oriented learning have been around for almost a decade now. However, their frequency has been sporadic and often the proposed solution are uncoordinated. Thus it becomes difficult for a new researcher in this field to figure out the state-of-the-art and the research challenges. The need emerges for a systematic study that identifies and correlates the existing work in this area. This chapter is towards filling this need. Apart from contributing to our thesis, this work will be of interest to the researchers in this field.

Technological advancements in BPM allow in fact a seamless transition between the modeling of processes and their execution, so using a BPMS facilitates the design and simulation of a work environment and its scenarios for training purposes. In [59], this kind of learning platform is called a Virtual Learning Process Environment. The recent European project PROLIX [60] coupled business processes in corporate environments with learning processes. Similarly, the European project Learn PAd [24] pursued a model-based process-oriented learning approach tailored for the complex procedures and workflows in Public Administrations. A few standards have emerged over the years that can be used for the design of process-oriented learning systems. IMS-Learning Design [57] is among the most common modeling approaches, providing a formal pedagogical

standard and an educational modeling language to describe technology supported scenarios based on rich instructional design models. However due to its complexity so far only a few working systems have been developed based on these standards.

A *systematic mapping study*: i. Provides a definite procedure for identifying the nature and extent of the research available in any specified research area; ii. Identifies gaps in current research and suggests directions for future work; iii. Establishes a framework and the background on top of which future research activities can be based.

To the best of our knowledge, no systematic survey yet exists in the research area linking Business Process with e-learning technologies. In this chapter, we thus present the first systematic mapping study on this topic. Our goal is to answer the research question: *How are Business Process techniques exploited into e-learning techniques, and how has their intersection benefited either domain?*.

From a systematic search of the literature, we have found a set of several hundred potential papers dealing with business processes and e-learning, out of which 41 papers have finally been elected to be part of the mapping study. We analyze this set of papers providing several quantitative and qualitative classifications.

## 4.1 Need for a Systematic Mapping Study

Given the maturity of BPM in the area of process-oriented designs, as we said in the Introduction some researchers investigate the effectiveness of using BPMN for learning purposes. Technological advancement around business management suite such as BPMN allows a seamless transition between process modeling and execution, and so it is attractive to design and simulate a learning environment for workplace learners using BPMN.

There are ample systematic research works available individually on both business process management and e-learning. However, as far as we know no systematic work has been done yet in the research area linking business process to process-oriented e-learning methodologies. One related work is the survey performed by Schmid and Kern [61], which evaluates state of the art in the integration field between BPM and Knowledge Management (KM). However, that survey does not entirely cover the concepts being discussed in this thesis. KM has a broader scope than e-Learning, and the concept itself

deals with the process of capturing, developing, sharing, and effectively using organizational knowledge [62]. In contrast, we aim at evaluating state of the art in the integration field between BP and e-learning.

## 4.2 Research Methodology

We have performed a systematic mapping study following the now well-established guidelines in literature for this type of studies, including the works of Kitchenham [63], Budgen et al. [64], and Petersen et al. [65]. We also used as a reference a recent nicely structured mapping study by Fernandez et al [66]. that covered a different topic (web usability evaluation).

Our mapping study includes three stages: Planning, Data Extraction, and Reporting. We describe planning and data extraction stages in the following subsections and discuss reporting stage (i.e., the obtained research results) in the next section.

### 4.2.1 Planning

During the planning stage, we performed the following activities: 1. Formation of the research question(s); 2. Definition of search strategy; 3. Specification of guidelines for primary studies selection. Each activity is further explained below.

#### 4.2.1.1 Research Question(s)

The goal of this study is to identify the intentional correlation between business process techniques and learning process techniques, and how such relationship has been applied in the e-learning and business process fields. Coherently our central research question is:

*How are Business Process techniques exploited into e-learning techniques, and how has their intersection benefited either domain?*

Addressing this question will allow us to categorize and summarize the past and current research work on mutual cross-relation between business process and learning process, identify the research gap and hence provide a guide for researchers entering this field.

| **Electronic Database** | **URL** |
|---|---|
| IEEE Xplore Digital Library | http://ieeexplore.ieee.org |
| SpringerLink | http://link.springer.com |
| ScienceDirect | http://www.sciencedirect.com |
| ACM Digital Library | http://www.dl.acm.org |

TABLE 4.1: Electronic databases considered in this research

A usual approach to answering a broad research question as the one above is to decompose it into more focused and specific sub-questions so that from the analysis of literature it is easier to select the primary studies and categorize them. However, due to the novelty of topic, we were unsure on what would be interesting subquestions/categories. Therefore we proceeded iteratively:

i we first selected the set of relevant papers using a broad search strategy (see below).

ii Then, Instead of deciding a priori the categories under which classify the studies, we let the categories emerge from reading the papers. More precisely, we applied *coding, memoing and constant comparison* techniques to identify in an exhaustive and meaningful way the key topics discussed in the selected papers.

iii Based on the identified categories, we formed a-posteriori the sub-questions.

iv Finally, we mapped the selected articles to the sub-questions and their corresponding categories and discussed the results of this mapping study.

This process is explained in detail in Section 4.2.2.1.

#### 4.2.1.2 Search Strategy

For the purpose of identifying the relevant primary studies, we followed a 2-step search strategy as explained in the following.

This 2-step strategy ensures that the main research articles related to the research question(s) are retrieved (Step 1), and that as many of the existing relevant articles as possible are covered (Step 2). Precisely:

1. **Electronic Databases Search using Key Terms**
   As a first step, we perform an automatic search exploring the electronic databases

that are listed in Table 4.1. These electronic databases are selected because of: (i) their high accessibility; (ii) the capability to export search results from them into well-defined, computation-amenable formats; and (iii) their wide usage in conducting systematic literature reviews in software engineering [67].

The search query is formed to naturally reflect the objective of this survey. Since the research question involves the two domains of Business Process and e-Learning, we combined the most common keywords from the two domains. Listing 1 below shows the search command that has been used. The search was performed on the metadata associated to papers in each database, such as title, abstract, and keywords.

Once selected, each of the articles will be read based on selection criteria and will be included for the mapping studies if it fulfills the criteria. The selection of studies will be explained later in this section. For the search, we did not put any timeline restriction in each of the digital library, i.e. we put no time limit on the starting year for retrieving the published articles. The last date at which we updated the automated search is **22th September 2016**, so all the relevant articles that are indexed until then are retrieved for the mapping study.

```
((" business  process" OR "process−oriented" OR "process oriented" OR "process−integrated")
  AND
(elearning  OR learning OR teaching OR "e−learning"))
```

LISTING 4.1: Search string-2 used for studies selection from electronic databases.

2. **Backward and Forward Snowballing**

In order to cover more articles beyond the limits of the searched electronic databases, we also conducted Backward and Forward Snowballing [68]. Wohlin defines *backward snowballing* as "using the references list from the selected articles to identify new papers to include", and *forward snowballing* as "identifying new papers based on those papers citing the paper being examined." Once a new set of papers is identified, backward and forward snowballing are applied again to the new set. The snowballing technique is applied iteratively as long as no new studies are found.

#### 4.2.1.3 Selection of Primary Studies

Once the potentially relevant primary studies have been obtained, they need to be assessed for their actual relevance. For this, it is necessary to define inclusion/exclusion criteria to identify those primary studies that are directly relevant to us.

The inclusion criteria are as follows:

- Study that primarily focuses on e-learning approach and uses some of the business process management techniques and methodologies at any step and for any objective.
- Study that primarily focuses on business process management techniques and methodologies and uses some e-learning techniques and methodologies

The exclusion criteria are:

- Study that is written in language different from English
- Study that is not peer-reviewed by the scientific community such as Master Thesis, etc.,

### 4.2.2 Data Extraction Strategy

After the selection of primary studies, data extraction was applied on all of them. A prerequisite for data extraction is to identify the most meaningful research sub-questions that map and categorize the relevant information.

As we already explained in Section 4.2.1.1, due to the lack of previous mapping studies and categorizations, we decided not to provide a-priori the research sub-questions before selecting the papers, but after based on their contents. This way, we can avoid a bias towards mapping the results to our pre-defined questions, and ensure that the relevant categories are identified. As anticipated, our approach to defining sub-questions followed a qualitative analysis of applying coding, memoing and constant comparison techniques. It is a bottom-up approach used to extract from available data first the categories and then, through clustering them, the sub-questions. Here the data are the contents of the selected primary studies.

#### 4.2.2.1 Qualitative Analysis

The techniques we adopted for qualitative data analyses included: coding, memoing and constant comparison. Holton defines coding as the process of organizing a large amount of data into smaller segments that can be easily retrieved when needed [69]. Memoing refers to deriving insights from the coding process and reflecting on the data. It is during the memoing stage that we defined and refined the conceptual categories. Finally, moving back and forth between coding and memoing to make appropriate adjustments is referred to as the constant comparison.

Though the above process is a subjective qualitative process, it offers following advantages:

1. By not providing the sub-questions beforehand and keeping an open mind for the emerging questions, we can avoid pre-conceived expectation and bias that we have had before starting the mapping study.
2. By consolidating the topics discussed in the articles and then forming the sub-questions based on the categories discussed will cover much broader scope in the mapping study
3. Since the process is transparent and all the materials are made available, other researchers can replicate the process, discuss and include any changes than might be needed in the future.

Coding, memoing and constant comparison are today routine part of the qualitative data analyst toolbox [70], and are extensively used in Grounded Theory [69].

In light of the above features, in our mapping study we also adopted these qualitative analysis techniques to ensure that we introduce no subjective bias in choosing the sub-questions, and that a broader information is covered during data extraction. During the process, we selected the key phrases from reading each of the 41 selected articles. Then, the highlighted key-phrases are consolidated, grouped together based on relevance, and the groups are labeled based on wordings that might reflect the group scope. Finally, sub-questions are formed such that the categories consolidated during coding and memoing can answer them. To further improve the transparency and verifiability of our study we

provide a link[1] where all relevant documents related to the coding and memoing can be found. In this way the transparency and verifiability of our study is ensured.

Though the application of the above qualitative analysis techniques is relatively time consuming, the process helped us in gaining deeper and structured insights from the papers included in the mapping study. We present the results of this analysis in the following section.

| **Research sub-questions, their categories, and motivation** | | |
|---|---|---|
| Sub-question | Options | Motivation |
| **Q1.** What is the maturity of the work? | Single Choice<br>✓ i. Opinion Paper<br>✓ ii. Theoretical Description<br>✓ iii. General Framework without Implementation<br>✓ iv. Implemented Software Tool<br>✓ v. Experience Report | To understand what is the current trend in this subject and how the community conduct and present result in this field |
| **Q2.** What is the technical contribution of the work? | Multiple Choices<br>× a. BP Graphical Modeling<br>× b. BP Workflow for Execution<br>× c. BP to EML Translation<br>× d. EML to BP Translation<br>× e. Learning Objects in Business Process<br>× f. Definition of new learning approach | To understand how the business process techniques and e-learning methods are combined |

[1] https://github.com/venkatapathy/bpelearnsurveyresults

| | | |
|---|---|---|
| **Q3.**<br>What Business Process techniques are used? | Multiple Choices<br>× a. BPMN<br>× b. BPEL<br>× c. XPDL<br>× d. Non-standard BP model<br>× e. State Transition Model<br>× f. Workflownet<br>× g. YAWL<br>× h. JPDL<br>× i. BPMO<br>× j. Not Defined | To understand the common BP techniques and methodologies used for the integration |
| **Q4.**<br>What e-learning standard models used? | Single Choice<br>✓ i. IMS-LD<br>✓ ii. CELTS<br>✓ iii. OWL- Guidance Ontology<br>✓ iv. Learnflownets<br>✓ v. PoEML<br>✓ vi. SCROM<br>✓ vii. None | To understand what kind of e-learning methodologies are used |

| | | |
|---|---|---|
| **Q5.** Where is it used? | Single Choice<br>✓ i. Academic Learning<br>✓ ii. Industrial Learning<br>✓ iii. Not Defined | To understand the usage of the proposed research work |

TABLE 4.2: Sub-questions, motivation for choosing them and their corresponding answers

#### 4.2.2.2 Emerged Sub-questions (Category Groupings)

After applying the coding, memoing and constant comparison techniques, we identified five sub-questions. A consolidation of the five sub-questions, their corresponding categories, and a brief motivation for choosing them are provided in Table 4.2. In the table, the categories are itemized with a tick sign when only one of the categories can be chosen, and with a cross sign when multiple choices can apply.

Q1. First sub-question is about the *maturity of the research articles*. For sub-question Q1, a paper can be classified in one of the following categories:

1. *Opinion Paper:* If the paper argues on business process and e-learning integration but does not provide any implementation or example
2. *Theoretical Description:* If the paper proposes a new approach for the integration that includes proposing new algorithm, approach or model
3. *General Framework without Implementation:* If the paper describes a framework, but only provides a preliminary prototype or working example
4. *Implemented Software Tool:* If the paper claims that it is used/using the tool in real world practice
5. *Experience Report:* If the paper contains case study of scientific approach defined elsewhere

Q2. Next sub-question addresses *the technical contribution of the work.* The categorization for this is based on how the business process and e-learning techniques are each used and combined, and the categories are as follows:

1. *BP Graphical Modeling:* If the paper includes methods to model learning scenarios based on business process modeling approach
2. *BP Workflow for Execution:* If the paper proposes BP workflow approach for execution of learning scenarios
3. *BP to EML Translation:* When the learning objects[2] designed using business process approach are converted into EML for execution.
4. *EML to BP Translation:* When learning objects defined using an EML is translated to a business process model for execution
5. *Learning Objects in Business Process:* If the paper proposes ways to introduce learning approaches to an existing BPMS or BPM approach
6. *Definition of new learning approach:* When the authors define a new approach for e-learning that is centered on combined usage of business process and e-learning techniques.

The answer for Q2 is multiple choices, meaning more than one option can be used for one paper.

Q3. This sub-question consolidates various business process standards used within the research articles and again consists of multiple choice options. The options for them are standards based on business processes as provided in Table 4.2.

Q4. This is complementary to Q3 and explores the various e-learning standard models that are used. It is also multiple choice question for which the options are provided in the Table 4.2. Like, in Q3 for details on the subject we refer the reader to the dedicated literature in the field.

[2]A learning object is "a collection of content items, practice items, and assessment items that are combined based on a single learning objective"

Q5. The sub-question Q5 provides us with the answer to the question *To which context of usage is the work destined?*. The answer is a single choice among the options consisting of:

1. *Academic:* Where the proposed research work is used in the context of academic e-learning
2. *Industry:* Where the proposed research work is used for Industrial learning also called as workplace e-learning.
3. *Not Defined:* If the research article is a theoretical study or when no explicit usage was defined.

Data were extracted from the papers based on the above sub-questions, and the results are described in the next section.

## 4.3 Research Results

Results from the application of previously described methodology are reported here. We first provide quantitative ethnographic data and then summarize qualitative conclusions.

### 4.3.1 Primary Studies

The selection process is represented in Figure 4.1, and detailed in the following.

The search query in Listing 1 was used to search within the four digital libraries reported in Table 4.1. For each of the retrieved potential studies (641), title and abstract were used to select those studies that use both the concepts of Business Process and e-Learning for a Process-Oriented e-learning system. A total of 20 articles were selected. Then forward and backward snowballing was applied as mentioned in the previous section, finding 33 more relevant studies, so that a total of 53 articles was selected for the next stage of analysis.

Further filtering was applied while reading the papers, and twelve more articles were excluded because considered out of scope. As a result, for the final mapping study and

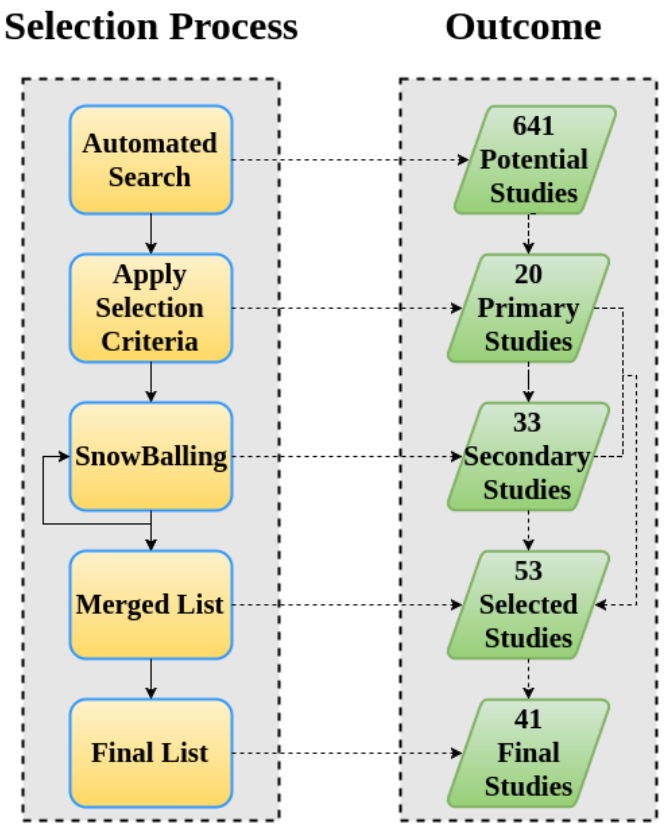


FIGURE 4.1: Study Selection Process and Results

research analysis, a total number of 41 papers was selected. Table 4.3 lists all the 41 included papers, while the removed articles are listed in Table 4.4 and the motivations for exclusions are detailed below.

Article R1 was removed because it is a Master thesis and hence not peer-reviewed. Same goes to the article R12 since it is a delivery report, may not be from the peer-reviewed community. R3 is removed for the same reason since it was a Thesis proposal. R4 deals with learning through a business game, and falls under the category of gamification and not e-learning, hence it does not fit into the context of this mapping study. Article R11 was removed because it discusses the project detailed already in S24, but do not provide any significant advancement related to the business process and e-learning that is not already discussed in S24. Articles R4 through R10 discuss the integration of Business Process and e-Learning. However, none of them contain any details on how such integration is done. Since very less detail was given about the integration and none of the research questions that are mapped can be answered, we excluded them from our study.

| Paper ID | Title |
|---|---|
| S1 | A full lifecycle oriented examination transaction management system [71] |
| S2 | A general architecture for the authoring and the operationalization of e-learning applications with educational modelling languages [72] |
| S3 | A Moodle Extension for Supporting Workflowdriven Collaborative Learning [73] |
| S4 | A workflow based eLearning architecture in service environment [74] |
| S5 | Adaptive E-learning System Based on Accumulative Digital Activities [75] |
| S6 | Adding Process-driven collaboration support in Moodle [76] |
| S7 | Bridging the Gap between e-learning Modeling and Delivery through the Transformation of Learnflows into Workflows [52] |
| S8 | Carrying on the e-Learning Process with a Workflow Management Engine [77] |
| S9 | COLearn and open discovery space portal alignment: A case of enriching open learning infrastructures with collaborative learning capabilities [78] |
| S10 | CoLearn: Real Time Collaborative Learning Environment [79] |
| S11 | Collaborative learning using service-oriented architecture: A framework design [80] |
| S12 | Cow, a flexible platform for the enactment of learning scenarios [81] |
| S13 | Data flow between tools: Towards a composition-based solution for learning design [82] |
| S14 | Delivering Specification-Based Learning Processes with Service-Oriented Architecture: A Process Translation Approach [83] |
| S15 | e-learning Activities in Educating e-business: a Pilot with a Process-Oriented e-learning Environment [84] |
| S16 | Eduoutreach: A suite of business processes for online teaching [85] |
| S17 | Instructional design in the vocational training on âĂIJcomputer networkingâĂİ [86] |
| S18 | Integrating Learning Objects to Business Processes [87] |

| | |
|---|---|
| S19 | LeadFlow4LD: A Method for the Computational Representation of the Learning Flow and Data Flow in Collaborative Learning [88] |
| S20 | Leadflow4ld: Learning and data flow composition-based solution for learning design in cscl [89] |
| S21 | Managing Collaborative Learning Processes in e-Learning Applications [90] |
| S22 | Modeling and Mining of Learnflows [91] |
| S23 | Multi-tenant enabled eLearning platform: Blended with workflow technologies [92] |
| S24 | On Using Workflow Technology to Model eLearning Process [93] |
| S25 | Personal Learning Assistant Agents in the Business Process Domain [94] |
| S26 | Platform Support for Pedagogical Scenarios [95] |
| S27 | Process Control Model in Web-Based e-Learning [96] |
| S28 | Roughing up processes the wiki way–knowledge communities in the context of work and learning processes [97] |
| S29 | Simplified workflow representation of IMS learning design [98] |
| S30 | Simulation as Efficient Support to Learning Business Dynamics [99] |
| S31 | Study of the dataflow problem in complex adaptive collaboration learning scripts [100] |
| S32 | Supporting adaptive e-Learning: an approach based on open-source learning management systems [101] |
| S33 | Supporting PoEML Educational Processes in Moodle: a Middleware Approach [102] |
| S34 | Supporting the Authoring and Operationalization of Educational Modelling Languages [103] |
| S35 | Technology-supported management of collaborative learning Processes [104] |
| S36 | Time2Competence: The PROLIX Project [105] |
| S37 | Toward an Open and Interoperable e-Learning Portal: OEPortal [106] |
| S38 | Towards a Common Graphical Language for Learning Flows: Transforming BPEL to IMS Learning Design Level A Representations [107] |
| S39 | Towards a novel graphical editor for modeling Learning scenarios [108] |

| | |
|---|---|
| S40 | Using workflow technology to manage flexible e-learning services [109] |
| S41 | WOntoVLab: A Virtual Laboratory Authorship Process Based on Workflow and Ontologies [110] |

TABLE 4.3: List of Selected Papers

| Paper ID | Title |
|---|---|
| R1 | Application of Business Process Management: In Web-Based Education [111] |
| R2 | Business Rules Approach to E-learning Systems Development [112] |
| R3 | E-learning in Process-oriented Knowledge Management [113] |
| R4 | Enhancing participant business process perception through business gaming [114] |
| R5 | A framework for integrating learning into business processes [115] |
| R6 | Agent-oriented e-Learning Process Modeling [116] |
| R7 | An innovation model in curriculum design for teaching engineering at universidad EAFIT [117] |
| R8 | An Overall Lifecycle Modeling Method for E-Learning Services and the Cooperative Mechanism Based on PCDA [118] |
| R9 | Flexible Processes in Project-Centred Learning [119] |
| R10 | Making flexible learning more flexible [120] |
| R11 | On workflow enabled e-learning services [121] |
| R12 | PROLEARN framework for process-oriented learning and knowledge work [122] |

TABLE 4.4: List of Excluded Studies

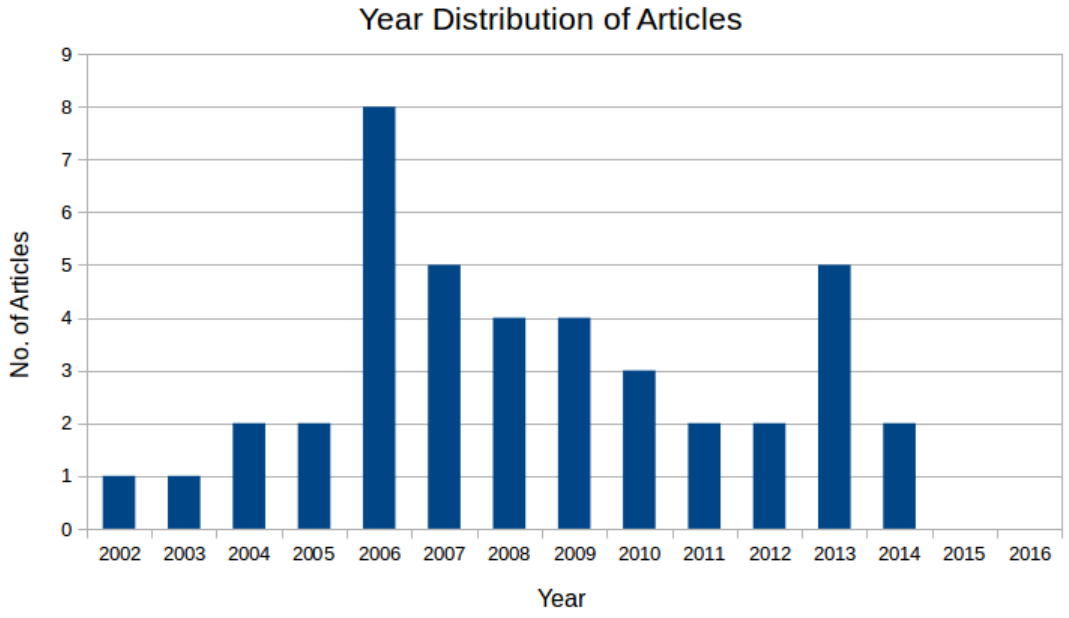


FIGURE 4.2: Distribution of Articles by Year

### 4.3.2 General Findings

We first performed some ethnographic analyses on the selected 41 articles. First, we derived the chronological order of the articles. Figure 4.2 provides the distribution of the articles over the years. The observed chronological distribution suggests that there is a limited yet constant interest in using the business process for e-learning purposes. A peak during the years 2006 and 2007 (of 8 and five papers) might be correlated with the scientific production of two European projects, PROLIX [105] and PROLEARN [122]. This observation seems also supported by the heatmap in Figure 4.3 that shows that most of the conferences submitted by the primary studies are within the Europe. This hints at a widespread interest in that part of the world.

Regarding the diversity of the articles regarding publications, there were 6 Book Chapters, 7 Journal Papers, 3 Lecture Notes in Computer Science. The remaining 25 articles were published as part of proceedings of conferences.

### 4.3.3 Q1. What is the Maturity of the Work?

We now comment the data categorization according to the five sub-questions in Table 4.2, starting from Q1.

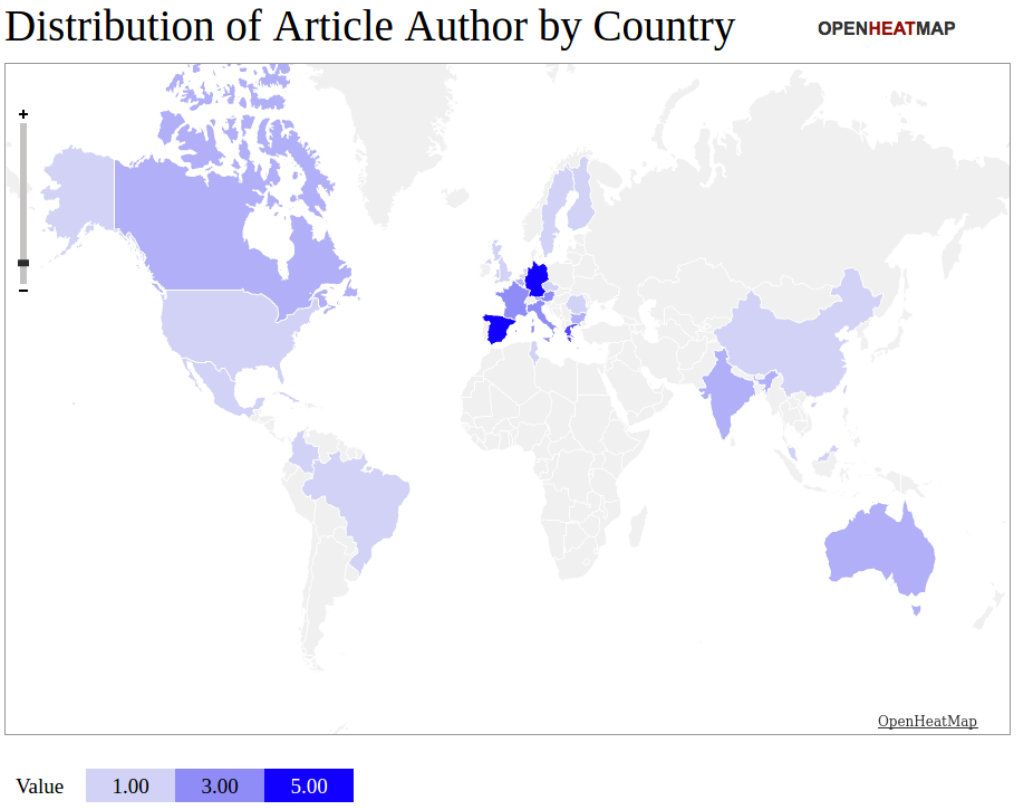


FIGURE 4.3: Global Heatmap of Selected Articles

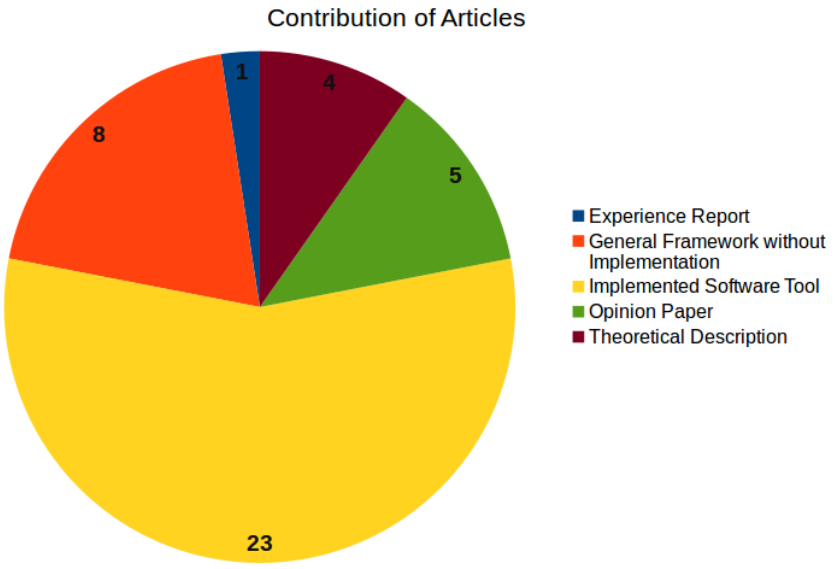


FIGURE 4.4: Contribution of the Selected Articles

25 articles, which is slightly more than half of the total, propose a demonstration of implemented software tools, 88% of which are independent tools including 14 standalone software and eight web-based tools. Only three papers (12% of the total) propose approaches to be integrated with Moodle[3]. The tools are not related to one another and do not follow any standard. Each of them was developed as an ad-hoc approach. This indicates the lack of established standards on the development of tools utilizing business process and e-learning. Six papers provide a general framework or algorithm for the integration of business process into the e-learning or vice versa.

There is five opinion paper where the authors discuss the possibility of merging Business Process and e-Learning, and at least three papers go a step further giving a theoretical description for such merging but without providing an implementation. The results also include two experience report.

### 4.3.4 Q2. What is the Contribution of the Articles?

Q2 explains how the business process and e-learning techniques are used.

Only four articles, which is less than 1% of the total in the analysis, propose to enhance business process models with learning objects.

All other 36 articles covering 88% of the primary studies focus on using Business Process techniques or their off-the-shelf software for e-learning purposes.

Out of them, 66% (22 articles) propose Business Process Modeling language as a graphical tool for designing of learning scenarios. Five studies that use the business process for course modeling convert them into the Education Modeling Language of IMS-LD to be executed within an IMS-LD compliant engine. Whereas 11 studies use a business process defined execution engine also for execution.

In total 31 papers (76%) use the business process as an execution engine to execute the learning scenarios. Six articles that use the business process for execution use IMS-LD for designing learning scenarios and transform to a business process format for execution. A total of 30 articles uses business process concepts either for modeling or execution of learning scenarios with 17 of them using both.

[3]Moodle[123] is an open-source software learning management system used for blended learning, distance education, flipped classroom and other e-learning projects in schools, universities, workplaces and other sectors.

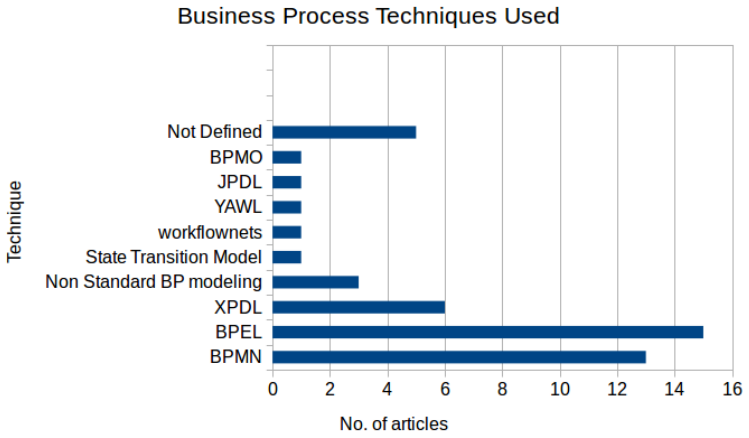


FIGURE 4.5: Categorization of Business Process Techniques Used

Paper S22 provides a new definition of *learnflow net* on top of workflow net that is a type of business process representation based on Petri nets. S1 is also different in that it uses Business Process Management techniques for the designing of e-learning systems and does not mention any usage of business process management systems.

### 4.3.5 Q3. What Business Process Techniques are Used?

To answer question Q3 about what Business Process techniques are used in the article, we listed and sorted the techniques proposed in each article. Five articles constituting of 11% of the total did not explicitly define the business process methodology used. Another five ones use more than one business process technique in their approach. Figure 4.5 lists the BP techniques used in the primary studies along with their count. Except for BPEL, BPMN, and XPDL, all other techniques were used only once. BPMN and BPEL are the broadest used BPM techniques in process-oriented e-learning.

### 4.3.6 Q4. What e-Learning Standard Models are Used?

In the case of Q4, e-learning standard models used for the integration, IMS-LD seems to be the most used EML standard with 18 articles (42% of the total articles) using it. It can be noted that IMS-LD standardly is similar to their business process counterparts such as BPMN and BPEL, and usage of both for the integration can be justified. However, more recently IMS-LD standards are less popular regarding usage. More than 50% do

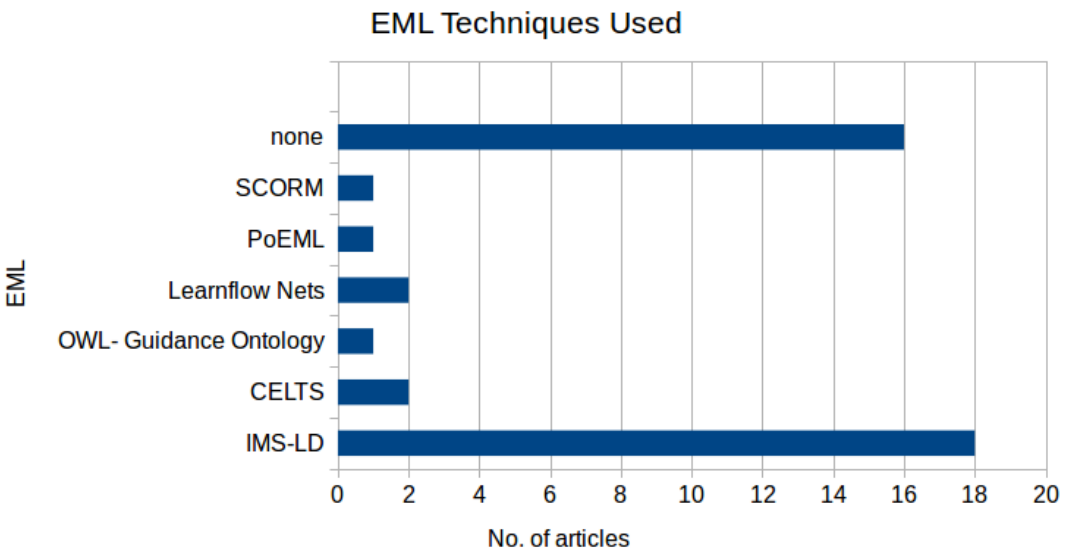


FIGURE 4.6: e-Learning Standards Used

not use any e-learning standard relying entirely upon their business process techniques counterpart. Figure 4.6 provides the complete list with counts of EML used.

The above gives the general observation of the data extracted from the primary studies.

### 4.3.7 Mapping Study

We also considered the five sub-questions in combination to map the different results and obtain the relation of a question to the other. Such combined mapping study can give us more insights on this study. The complete mapping results can be found in Figure 4.11.

In the following, we describe the different combinations we considered and some insights from the obtained results.

The first mapping study compares Q2(contribution) and Q5(Usage). Figure 4.7 shows the mapping results when they are combined. These results may indicate that:

- The majority of studies on the integration between business process and e-learning is aimed at academic usage
- Most of the contributions involve using off-the-shelf BPMS for either modeling or executing learning scenarios

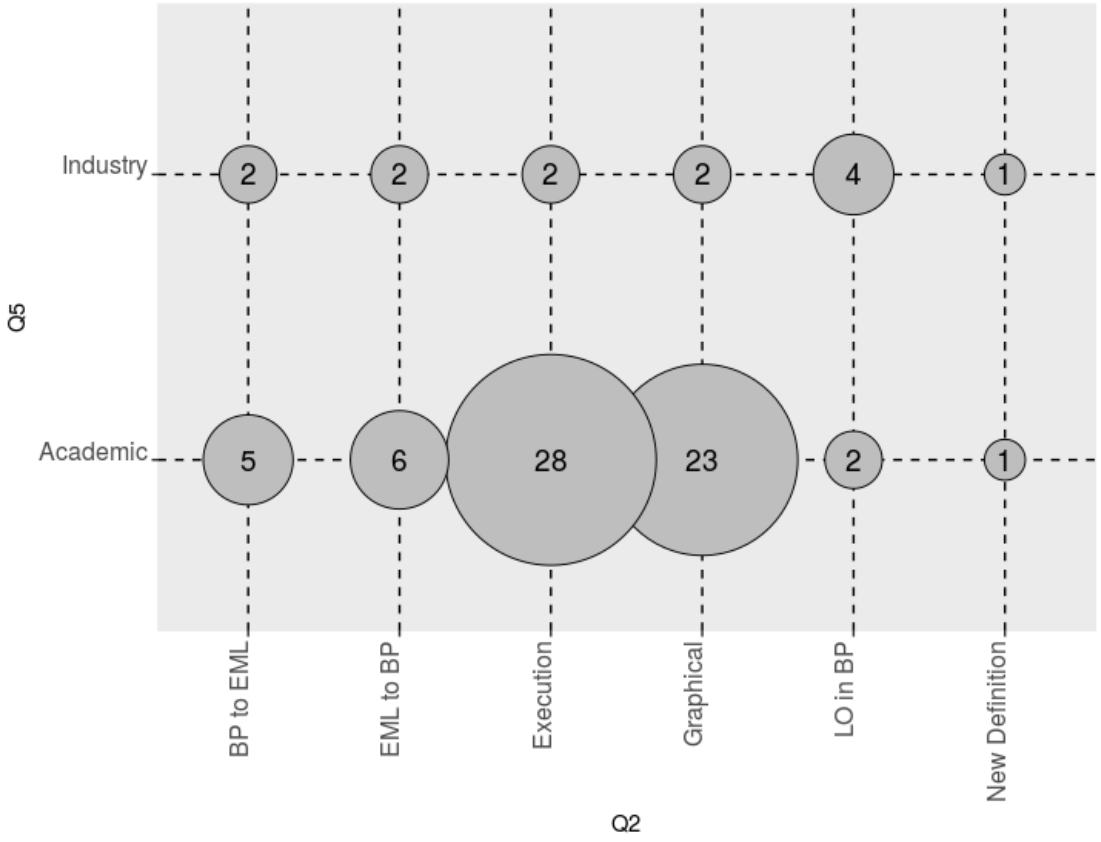


FIGURE 4.7: Cross-mapping between Q2 and Q5

Figure 4.8 shows a mapping study combining Q2(contribution) and Q3(BP standards used). As noted in Section 4.3.5, except for BPMN, BPEL, and XPDL, all other were used only once. For clarity of illustration, then, in the figure, we only considered the above three notations. Considering this mapping study with the previous mapping results may indicate that:

- BPMN is the most used standard for modeling of learning scenarios.
- the majority of study uses BPEL for execution of learning scenarios. Since BPMN uses BPEL for inbuilt execution, BPEL stands out the most used standard for executing in an e-learning system

We now focus on the integration of BPM and e-learning techniques. Figure 4.9 shows the results of mapping the different options of Q2. These results may indicate that:

- most contributions only involve the stable BPM technique either for execution or modeling for learning purposes

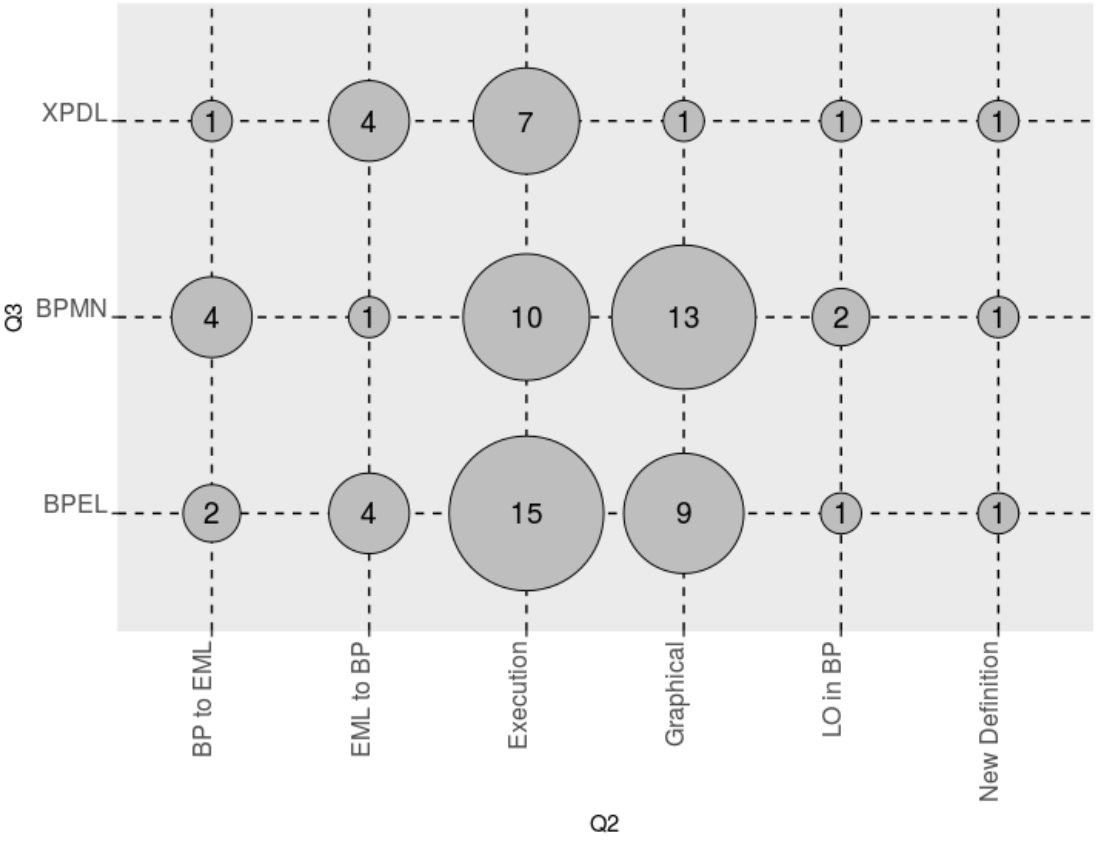


FIGURE 4.8: Cross-mapping between Q2 and Q3

- involves Transformation between a business process model and a learning model involve mostly IMS-LD

Another mapping study is shown in Figure 4.10 is between the questions Q3 and Q4, which shows the correlation between EML and BP standards. The results may indicate that:

- Most work exists only between BPMN and IMS-LD or BPEL and IMS-LD
- Widely used standards such as SCROM and OWL-Ontologies are yet to be used along with the business process models.
- involves Transformation between a business process model and a learning model involve mostly IMS-LD

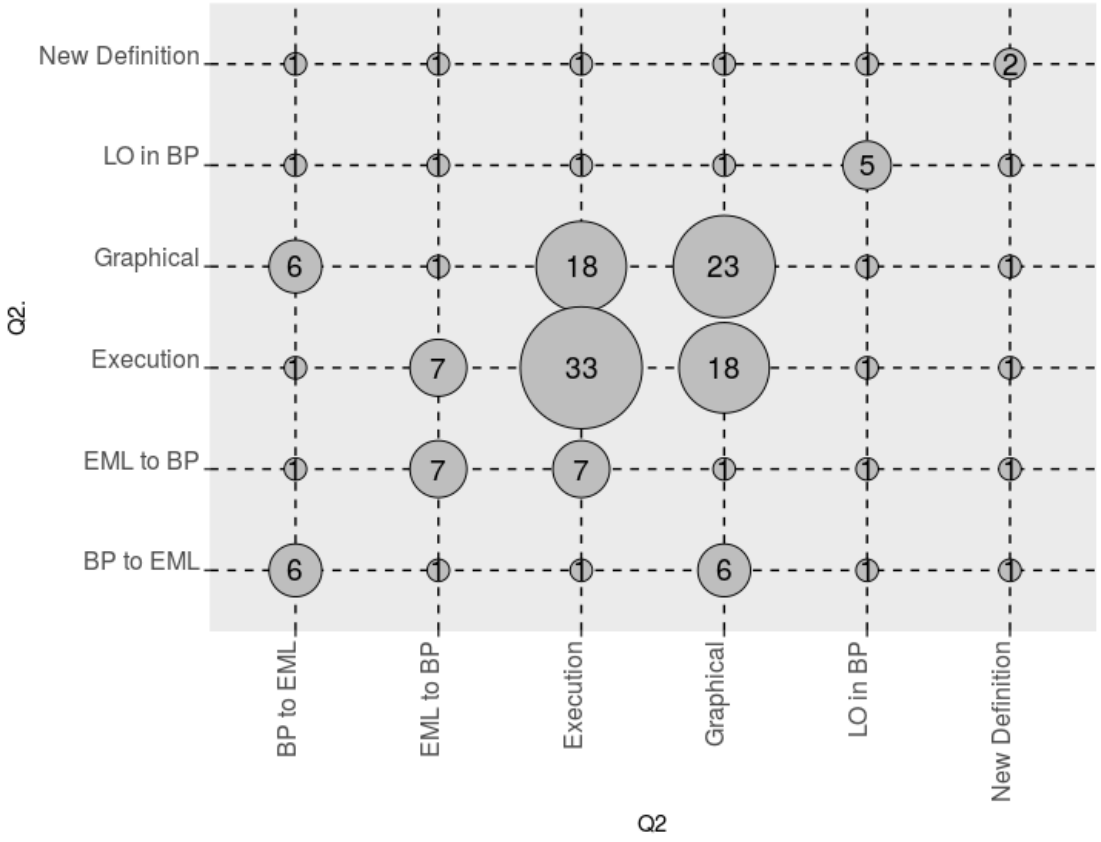


FIGURE 4.9: Cross-mapping among the Multiple Options of Q2

## 4.4 Discussion

In this section, we discuss the principal findings of this mapping study. We also highlight the implications of this study as well the threats to validity.

### 4.4.1 Principal Findings

By conducting the systematic study, we wanted to know how the business process and e-learning, two seemingly different topics, are used to benefit each other. The initial motivation to conduct this mapping study is related to the carrying out of the European project LearnPAd [24], having the goal to define and implement a framework for Model-Based Social Learning for Public Administrations. As we started to look at related work, we realized that the research in this area is in its initial stage and much effort still needs to be done. As a contribution to the community, we executed this mapping study, and in the following, we make a summary of the principal findings:

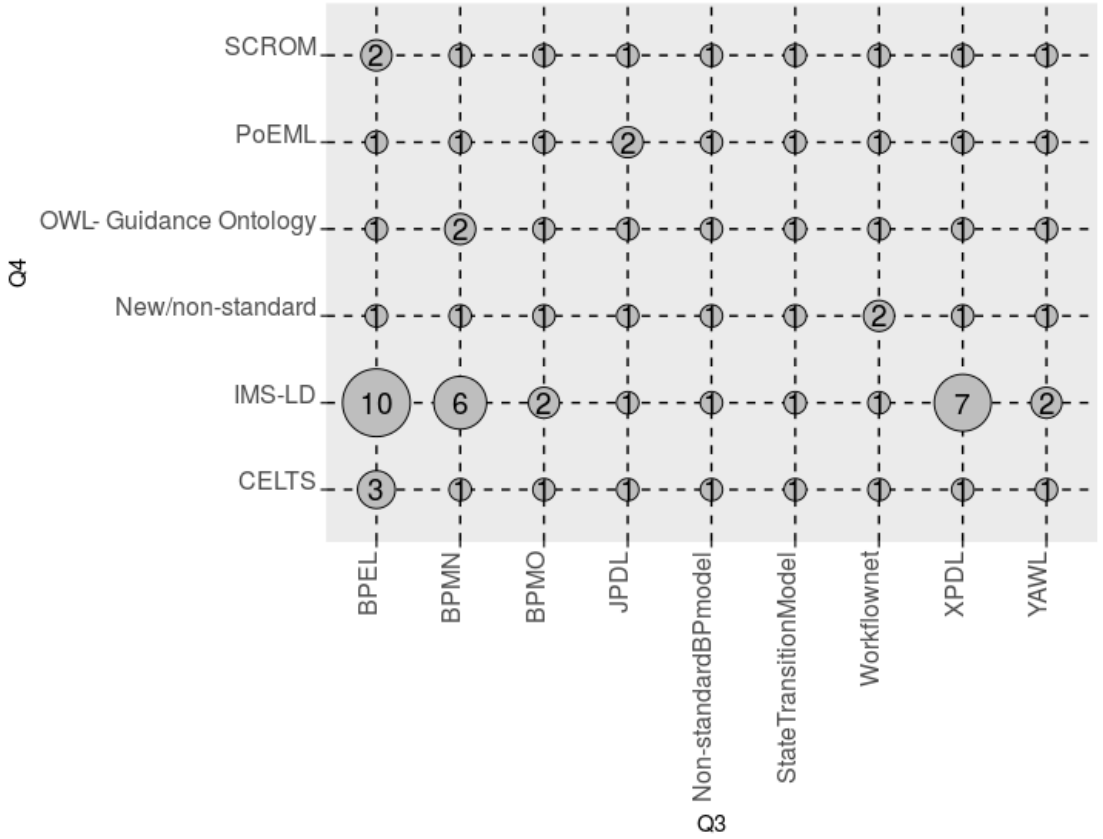


FIGURE 4.10: Cross-mapping between Q3 and Q4

- As we hoped, there exists a continuous research interest in the mutual intersection of business process and e-learning. However, as evidenced by the sparsity of bubble plots in Figures 4.7-4.10, the approaches, and techniques vary considerably, depending on the context. Most of the articles use off-the-shelf components for their needs without applying any change or proposing original solutions. Only a few articles [91, 108] focus on the theoretical aspects of combining the process and e-learning techniques.

- The majority of work focuses on e-learning for educational purposes. Very few research efforts, which include some European projects, attempt to leverage this topic for workplace learning. This finding was surprising to us, especially when there is a need for new techniques to improve workplace learning, given that merging business process and e-learning techniques can very well cater to these requirements.

- Current enhancement to BPMN (e.g., BPMN.2.0) is rarely used in this research context. BPMN.2.0 is slowly becoming the de facto standard of the industry, and

| ID | Q1 | | | | | Q2 | | | | | | Q3 | | | | | | | | | Q4 | | | | | | | Q5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | i | ii | iii | iv | v | a | b | c | d | e | f | a | b | c | d | e | f | g | h | i | j | i | ii | iii | iv | v | vi | vii | i | ii | iii |
| S1 | | | | ✓ | | × | × | | | | | × | | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S2 | | | ✓ | | | | × | | | | | | × | | | | | | | | | ✓ | | | | | | | ✓ | | |
| S3 | | | | ✓ | | × | × | | | | | × | | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S4 | | | ✓ | | | × | × | | | | | | × | | | | | | | | | ✓ | | | | | | | ✓ | | |
| S5 | | | | ✓ | | × | × | | | | | × | | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S6 | | | | ✓ | | × | × | | | | | × | | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S7 | | | | ✓ | | | × | | × | | | | | × | | | | | | | | ✓ | | | | | | | ✓ | | |
| S8 | | | | ✓ | | × | × | | | | | × | | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S9 | | | | ✓ | | × | | × | | | | × | | | | | | | | | | ✓ | | | | | | | ✓ | | |
| S10 | | | | ✓ | | × | | × | | | | × | | | | | | | | | | ✓ | | | | | | | ✓ | | |
| S11 | ✓ | | | | | × | × | | | | | × | × | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S12 | | | | ✓ | | | × | | × | | | | | × | | | | | | | | ✓ | | | | | | | ✓ | | |
| S13 | | ✓ | | | | | × | | | | | | | × | | | | | | | | ✓ | | | | | | | ✓ | | |
| S14 | | | ✓ | | | | × | | × | | | | × | | | | | | | | | ✓ | | | | | | | ✓ | | |
| S15 | | | | ✓ | | × | × | | | | | | | | × | | | | | | | | | | | | | ✓ | ✓ | | |
| S16 | | | | ✓ | | × | × | | | | | | | | | × | | | | | | | | | | | | ✓ | ✓ | | |
| S17 | | | | ✓ | | × | × | | | | | × | × | | | | | | | | | ✓ | | | | | | | | | ✓ |
| S18 | | | | ✓ | | | | | | × | | × | | | | | | | | | | | | ✓ | | | | | | ✓ | |
| S19 | | ✓ | | | | | × | | | | | | | × | | | | | | | | ✓ | | | | | | | | | ✓ |
| S20 | | | | ✓ | | | × | | | | | | × | | | | | | | | | ✓ | | | | | | | | | ✓ |
| S21 | | | | ✓ | | | × | | | | | | × | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S22 | | ✓ | | | | | | | | | × | | | | | | × | | | | | | | | ✓ | | | | | | ✓ |
| S23 | | | | ✓ | | × | × | | | | | | × | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S24 | ✓ | | | | | × | × | | | | | | | | | | | | | | × | | | | | | | ✓ | ✓ | | |
| S25 | ✓ | | | | | | | | | × | | | | | | | | | | | × | | | | ✓ | | | | | ✓ | |
| S26 | | | | ✓ | | | × | | × | | | | | × | | | | | | | | ✓ | | | | | | | ✓ | | |
| S27 | | | ✓ | | | × | × | | | | | | × | | | | | | | | | | ✓ | | | | | | ✓ | | |
| S28 | | | | ✓ | | | | | | × | | | | | | | | | | | × | ✓ | | | | | | | ✓ | | |
| S29 | | | | ✓ | | × | | × | | | | | | | | | | × | | | | ✓ | | | | | | | ✓ | | |
| S30 | ✓ | | | | | | | | | × | | | | | | | | | | | × | | | | | | | ✓ | | ✓ | |
| S31 | | | | | ✓ | | × | | | | | | × | × | | | | | | | | ✓ | | | | | | | ✓ | | |
| S32 | | | | ✓ | | × | × | | | | | × | | | | | | | | | | | | | | | | ✓ | ✓ | | |
| S33 | | | | ✓ | | × | × | | | | | | | | | | | | × | | | | | | | ✓ | | | ✓ | | |
| S34 | | | ✓ | | | | × | | | | | | × | | | | | | | | | ✓ | | | | | | | ✓ | | |
| S35 | ✓ | | | | | × | × | | | | | × | × | | | | | | | | | ✓ | | | | | | | ✓ | | |
| S36 | | | | | ✓ | × | | × | | | | | | | | | | | | | × | | | | | | | ✓ | | ✓ | |
| S37 | | | | ✓ | | × | × | | × | | | | × | | | | | | | | | | | | | | ✓ | | ✓ | | |
| S38 | | | ✓ | | | × | | × | | | | × | × | | | | | | | | | ✓ | | | | | | | ✓ | | |
| S39 | | | | ✓ | | | × | | × | | | | × | | | | | | | × | | ✓ | | | | | | | | ✓ | |
| S40 | | | | ✓ | | × | × | | | | | | | | × | | | | | | | | | | | | | ✓ | ✓ | | |
| S41 | | | | ✓ | | × | × | | | | | | | | × | | | | | | | | | | | | | ✓ | ✓ | | |
| Σ | 5 | 3 | 6 | 25 | 2 | 24 | 31 | 5 | 6 | 4 | 1 | 13 | 15 | 6 | 3 | 1 | 1 | 1 | 1 | 1 | 5 | 18 | 2 | 1 | 2 | 1 | 1 | 16 | 32 | 5 | 4 |

FIGURE 4.11: Mapping of Results for Questions in Table 4.2

it offers a seamless transition between modeling and execution. It offers lots of capabilities for use in this research context.

- Majority of implementations presented are independent tools, which limits their scope for broader usage. Few works tried to integrate the available framework from the two different perspectives of business process and e-learning. [76] This provides us with encouraging perspectives for our research on the topic.

- None of the articles goes beyond using the business process systems modeling and execution of learning scenarios. However, BPMS is more than a system for just modeling or executing. Many robust tools and techniques have been developed within BPM such as Business Process Monitoring, which can provide us with ways

to align employee training to the organizational goals. There is a need for the researchers to go beyond the current state-of-the-art work to exploit more efficiently the different aspect of the business process for e-learning.

### 4.4.2 Threats to Validity

There are some limitations to this systematic mapping study. Precisely, as in [66], the threats to validity may include publication bias, selection bias, inaccuracy in data extraction and misclassification.

Publication bias is shared by all literature surveys and refers to the problem that positive results are more likely to be published than negative ones, since negative results take longer to be published or are cited in other publications to a lesser extent (Kitchenham [23]).

Selection bias refers to the problem of not including as many relevant articles as possible. To handle such risk, we combined two different type of search: electronic and snowballing. However, we did not consider non-peer-reviewed articles such as Ph.D. thesis, proposal, etc., and this may have affected the validity of our results to some extent. To alleviate selection bias, our first stage of search included broader criteria to include the largest possible amount of papers that fit into our business process and e-learning domain.

Another bias is related to potential inaccurate data extraction and misclassification. In particular, due to the non-availability of previous studies, we did not have any other work to compare our results to for validation. However, to eliminate the bias, we did not define the classification criteria a priori based on subjective thinking. As we explain in detail in Section 4.2.2, we defined the categories after selecting the primary studies using the standard coding and memoing. We also provide the intermediary results for anyone who would like to replicate our process. This way our principal findings are open to criticism and change.

### 4.4.3 Implications for the Thesis

At the end of the systematic study we identified that the majority of the work, consisting of 88% just use the BPMS or its components for the designing or execution of learning

models. Only a few of the articles from the systematic study (e.g., [87]) have proposed ways to integrate learning into the business process design. They are not adequate enough to provide a solution for our research problem. For example, in [87] the idea is proposed to add metadata information to the business processes. They can support learning through information, but do not support learning by doing, which is the main motivation of this thesis. Again, out of the total number of 41 articles, 25 of them use some type of learning process models to either define or execute the learning scenarios. They also use the business process techniques as a complementary technique to some already available process-driven learning techniques: e.g., they use the graphical notations of the business process to model the learning scenarios or use the available process execution engine of BPMS to execute the already defined learning scenarios. Usually, they involve transformation techniques from the business process models to the learning models or vice versa. This idea of using the business process models to supplement some functions of the learning process models for the process-driven learning systems may be useful in the context where both the business process techniques and the learning process techniques may not be needed together. Such a scenario may exist in an academic setting where the need is to design curriculum based on regular subjects. Whereas in our case of workplace e-learning, both the business process and the learning process techniques are needed and not to supplement each other but for their own purposes.

Hence, the available solutions may provide some partial solutions to our requirement of process-driven workplace learning, but they may not be complete by themselves. One crucial requirement for such systems is a method to align the learning tasks of the employee to business tasks and goals of the organization. Currently available techniques do not propose an adequate solution for this requirement. As we saw in Chapter 3, BPM has its own lifecycle and while extending the BPM and BPMS for learning we need to clarify how the introduction of learning techniques into BPM affects the different phases of its lifecycle.

We already defined some important criteria that a process-driven learning system should cover in Section 2.1. Many of the selected studies from this survey may offer partial solutions, but they do not provide an integrated approach for extending BPMS with process-driven learning. From this systematic study, we understood the methods to associate a learning model to the business process model, for instance: using IMS-LD

along with the business process models (almost 88% of the total articles propose methods for the association).

Based on the observations we made during this survey, we provide our solution in which we extend BPMS with learning solutions to fill the gap that is present in the current state-of-the-art.

### 4.4.4 Implications for Research and Practice

From a wider perspective, our mapping study will have implications both for the researchers who are planning to conduct new studies in the area of business process and e-learning as well as the practitioners who are looking for process-oriented e-learning solutions for the workplace.

For researchers, we believe that this work can be the starting point to help them understand the current state-of-the-art in this field, the possibilities, and limitations it offers. Since no effort has been made until now to organize the research in this area, many of the works often are disconnected to each other, and in some cases, the approach has been same and redundant. We encourage the new researchers in this field to understand our work before considering developing a new approach for their implementation.

For the industrial practitioners, this work provides the basis for an alternative possibility for workplace learning. They can benefit from the different opportunities the integration of business process and e-learning can offer for their training purposes.

# Chapter 5

# Learning Path Specification: Conceptual Model and Formal Definitions

Until now, we have described the need for a process-driven learning system and the current missing gaps in Learn PAd and the state-of-the-art, in using them to build such learning systems. We proposed to extend the BPMS as process-driven learning systems. We call this the Business Process Management-based Learning System(s) (BPMLS). Before describing the details of the actual system, we wish to elaborate further on the learning path specification that facilitates this extension of BPMS to BPMLS. Among the others, two kind of models are at the core of the proposed BPMLS: the business process model which can be used to capture the sequence of activities that an organization or (a department that is part of it) do towards fulfilling a goal or the desired customer service, and the learning process model that represents the part of the business process that an employee should learn. Before proposing a learning system based on BPMS that may combine BPM and LPM, it is important to understand the relationship between the business process models and the learning process models: their similarities, the differences, and their connections. The presentation is introduced by a motivational example aiming to describe the relationship we propose between these model kinds within the context of workplace learning. The motivational example represents an abstract and

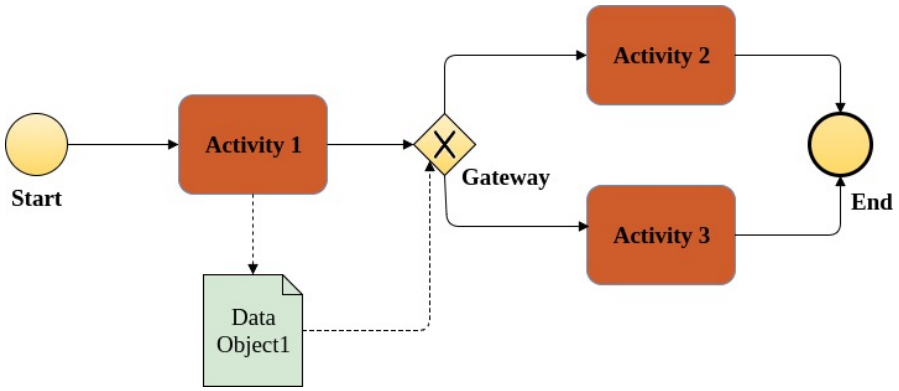


FIGURE 5.1: An Abstract Business Process Model

simple model of business process as well as the learning process. The models can be made more complex as long as the models follow the guidelines.

## 5.1 Motivational Example

Figure 5.1 depicts a simple business process model specified according to the notation BPMN 2.0 [38]. It consists of a Start Event, an End Event and three activities: Activity 1, Activity 2, and Activity 3. In addition, the model contains a Data Object labelled in the diagram as Data Object 1, and a Gateway. The nodes in the model are connected by means of Sequence Flow elements. During execution, the completion of Activity 1 produces an output (i.e. Data Object 1) which is then passed as input to the Exclusive Gateway. The evaluation of the value instance received by the gateway enables either the enactment of Activity 2, or Activity 3.

The business process model in Figure 5.1 admits only one of the two following sequence of activities from the Start Event to the End Event:

- Start Event --→ Activity 1 --→ Exclusive Gateway --→ Activity 2 --→ End Event
- Start Event --→ Activity 1 --→ Exclusive Gateway --→ Activity 3 --→ End Event

We refer to each admissible sequence of activities as a **Path**. Each Path in a business process model subsumes several (possibly infinite) scenarios; each scenario is defined by the set instances of the data objects covered by the considered Path.

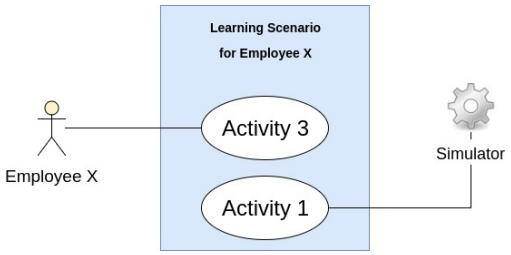


FIGURE 5.2: Learning Scenario for Employee X

Let us assume that a novice employee (i.e. Employee X) is assigned to perform only the business activity Activity 1 from Figure 5.1. Learning activities targeting to procedural knowledge [124] should relate to the business activities the novice is supposed to perform within the context of the given Business Process Model (i.e. Activity 1). In this sense, a workplace e-learning framework could promote learning materials mostly explaining/documenting/training on the specific task the employee is involved. In addition, e-learning framework providing support for learning-by-doing [125] should be able to setup simulation sessions that conform with the specification of the referred Business Process Model, and enabling the employee to perform the tasks he/she is assigned under realistic assumptions. In this latter scenario, those activities that are uncovered by the employee training must be automated by some dedicated engine within the e-learning framework, so that the Business Process Model can be executed as per its definition (see Figure 5.2)

In the following we refer to Learning Scenario as a concept that subsumes the set of valid values for input/output data objects foreseen during the correct execution of a path in a given business process model. In other words, the definition of a learning scenario determines the sets of admissible executions in a business process model specifically conceived or selected for some learning purpose.

Let us now consider another novice employee (i.e. Employee Y) who is assigned to perform both the activities Activity 1, and Activity 3 from Figure 5.1 . In this case, let us focus on the Path including both the activities. Here, it is possible to refer to three different classes of Learning Scenarios for the same Path: a first one where learning activity for the Employee Y is only Activity 1 and Activity 3 automated by some dedicated engine; a second one where learning activity for the Employee Y is only Activity 3 and Activity 1 automated; and a third one where learning activity for the Employee Y are both Activity 1, and Activity 3 in sequence. Notice here that though there are only two

admissible sequence of activities called as Path, we can define three different Learning Scenarios based on the combination of the activities we assigned for learning. Also, the guards on the Data Object governing the gateway can advocate for the definition of more fine grain classes of Learning Scenario. Thus, the complexity of any Learning Scenario depends on both the admissible simple combinations of considered activities (i.e. represented by the Path), and also on the values assigned to the Data Objects referred during the execution of the Path. This way, several Learning Scenarios with different complexities can be originated from a given Path.

Marking a set of activities in a business process model as subject of learning (e.g. by means of simulation session), it is possible to decide if a set of Learning Scenario is suitable for a given learning objective. In the following we will refer to Coverage as the formal criteria guiding such a decision.

In this perspective we envision a Learning Path Specification as a collection of competencies and learning goals that contains a set of working activities; competences are acquired by reaching a set of target learning goals; learning goals are defined in terms of sets of training sessions (i.e. simulations), and each training session is prescribed by a Learning Scenario. Each Learning Path can also declare a list of prerequisites and constraints required to be accomplished before its enactment: the arrangement of structured learning session leverages on chaining groups of Learning Paths.

Section 3.6 already introduced that our work is inspired to the concepts of Learning Path proposed by Jassen and co-authors' [20, 21] in order to relates artefacts of a Learning Process with a Business Process Model. However, Janssen's Learning Path specification embraces a context that is broader than workplace learning and do not specifically designed for supporting e-learning framework. As we mentioned in the Chapter 1, since we focus on process driven e-learning framework we formalized their broader framework specifically for e-learning systems. In the following sub-sections the paper aim to propose a refined conceptual model for the Learning Path specification (i.e. Section 5.2) that will cover some of the concepts we introduced in the motivational example; then Section 5.3 establishes a formal mapping between the Business Process Notation, Learning Scenarios and Learning Paths so that to automatically exploit the same artefacts describing flows of work activities (i.e. Business Process Models) also as source of use cases driving learning activities in a e-learning platform.

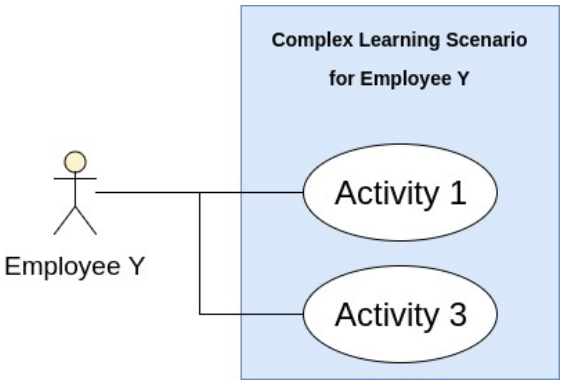


FIGURE 5.3: A complex Learning Scenario with two Learning Activities for the Employee Y

## 5.2 Learning Path Specification for Business Process Models

In [21] Janssen proposed a Learning Path Specification that contains a Start and Finish and a set of LearningActions that lead from start to finish. It also has a set of one or more competences and associated levels of proficiency. We refer the readers to their works for further reading on their proposal of Learning Path Specification [19–21]. However, Janssen's Learning Path Specification embraces a broader context than workplace learning. Also in our context, we focus on developing the learning scenario based on business process. As a consequence, the original definition lacks in detailing aspects that are useful in shaping learning contexts that can be automatically supported by a computer-aided learning framework. Hence, in the following, we modify Janssen's Learning Path Specification for our required of learning process models for business process models.

Figure 5.4 represents a conceptual model of our Learning Path Specification. A learning path consists of a set of learning activities. These learning activities point to activities from the BPMN model and represent what an employee should learn. Though it is derived from the BPMN model, the learning path may not reflect the same order in which it is represented in the BPMN model. For example from a given sequence of three business activities from a BPMN model, a learning path specification may point to first and last activities as learning activities skipping the second one. It gives us the flexibility to group learning activities based on the learners' need.

Given a learning path with a set of learning activities, the learning path is said to be completed if it satisfies a set of learning goals. Learning goals consists of a set of learning

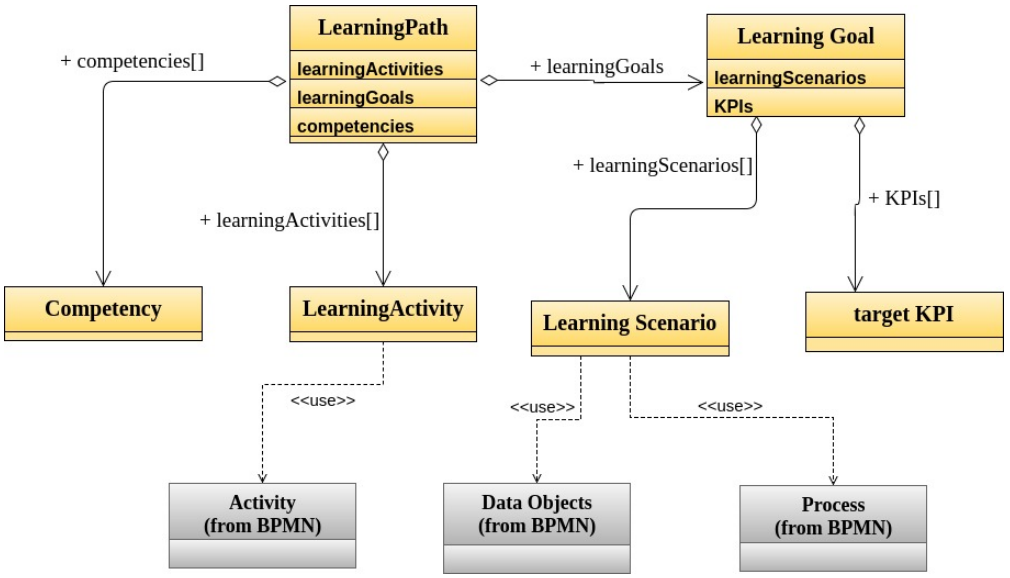


FIGURE 5.4: Learning Path Specification

scenarios and a set of target KPIs that need to be reached. A Learning Scenario is an instance of the BPMN model during execution with an appropriate instantiation of its data objects. A learning scenario may also contain some evaluation functions to check if the execution is following a certain execution path and if data instantiation fits the expected values. They are explained formally in Section 5.3. Learning scenario provides us with a method to describe a flow of activities to the actual business scenario. It may also contain more information such as how the user interactions are enabled during execution and how the UI is presented to the user, etc., which are beyond the scope of this work. KPIs consists of a quantifiable measure that can be used to evaluate the users learning process during the execution of the learning path. A user who is executing a learning path can be said to reach the learning goals if the valuation of the learning scenarios holds true and if the target KPIs are reached.

We can associate a set of competencies to the learning path or its learning activities. In the literature various competency models have been proposed, many of which are inspired by the well-known Bloom's taxonomy [75]. A competency model describes different levels at which knowledge or skill is acquired. A complete definition of a learning path should specify for each activity what is the required competency level. At this stage, our focus is mainly in showing how a learning path can be related to a business process. We consider only a generic notion of work-oriented competency [126], which can be defined as the ability to perform the activities within an occupation or function to the level of performance expected in employment [127]. This concretely means that for a given

competency, the employee should be able to demonstrate that he/she can perform the activities related to it, and to acquire a competence means to learn the tasks related to the competence. So the learning path and its learning activities and the similar learning scenarios should be mapped to the competency such that the completion of learning path may lead to the earning of one or more competencies.

Figure 5.4 is created using Unified Modeling Language [128] for graphical representation. It facilitates better visual communication about the model. In the next subsection, we provide formal definitions for our Learning Path Specification and how it is related to the BPMN.

## 5.3 Formal Relation between Business Process Models and Learning Path Specifications

In this section, we provide a formal definition for the BPMN and the Learning Path Specification. In Section 5.3.1 we introduce the structural properties of the BPMN as a directed graph. Representing BPMN graph as a directed graph makes it easy to relate them to our proposed Learning Path Specification. Then, in Section 5.3.2 we define the structure of a Learning Path Specification and its related definition.

### 5.3.1 BPMN Graph Definitions

As briefly discussed in Section 3.4 the BPMN graph is restricted to a subclass BPMN specification. Our definition of the Process graph definition is based on the work of Braghetto et al.[129]. We modified their definition also to include definitions of Data Objects.

**Definition 1. BPMN Graph:** We define the BPMN as a directed graph, $bg$ as the tuple: $bg \in BG = (V, E, D, C, \delta, \gamma)$ with $V = S \cup A \cup G \cup F$, where:

- $S$ is a set of vertexes representing the start events
- $A$ is a set of vertexes representing the atomic activities of BPMN
- $G$ is a set of vertexes representing the gateways

- $F$ is a set of vertexes representing the end events
- $E \subseteq (V \times V)$
- $D$ is a set of Data Objects used in $bg$
- $C$ is a set of boolean expressions over D
- $\delta : V \rightarrow 2^D$ is a function that associates vertexes in $BG$ with sets of Data Objects. In this sense, Data Objects are variables whose values can be used (i.e. read/updated/deleted) by any vertex in V during the execution of the Process Model. In the following the notations $\delta_r$, and $\delta_w$ will be used to denote the set of those Data Objects that are used during the execution of a vertex in V.
- $\gamma : E \rightarrow C$ is a mapping function that associates to each edge of the Process Model a guard regulating its activation.

In the following the set of activities belonging to a BPMN Graph bg will be denoted as:

$$activities(bg) = a_1, a_2, \ldots a_n | 0 < i \leq n, a_i \in A \tag{5.1}$$

**Definition 2. BPMN Path:** We informally defined Path in Section 5.1. Here we define them for the BPMN graph. Let $bg$ be a BPMN Process graph and $v_1, v_n \in V$. A Path from $v_1$ to $v_n$, represented by $v_1 \rightsquigarrow v_n$ is a sequence of vertexes $v_1, v_2, ..., v_n$ (with $v_i \in V$) such that, for $0 < i < n, (v_i, v_i + 1) \in E$.

**Definition 3. Valuation Function:** A Path in BPMN graph represents only the sequence of vertexes. However, we need to represent Path with a set of input/output values for its Data Objects(refer Section 5.1). Hence, we define an abstract valuation function to be used later. Let us assume

$$Val : V \times D \rightarrow \Delta \tag{5.2}$$

an abstract valuation function that binds a given Data Object with an element in a proper non-empty domain $\Delta$.

**Definition 4. Path Consistency:** We define Path Consistency that can be used to verify that a given path follows the defined sequence of activities and also that the data

object values are as expected. A given valuation function $Val$ is consistent with a given BPMN path $v_1 \rightsquigarrow v_n$ (i.e. $Val \subset v_1 \rightsquigarrow v_n$) when :

$$\underset{1 \leq i < n}{\forall} \underset{d \in D}{\forall} d \quad \notin \quad \delta_w(v_{i+1}) \quad \Longrightarrow \quad Val(v_{i+1}, d) \quad = \quad Val(v_i, d) \tag{5.3}$$

**Definition 5. Interpretation:** Given a valuation function $Val$, let define

$$\Phi_{Val} : C \rightarrow \{true|false\} \tag{5.4}$$

an interpretation for the Boolean expressions over D.

In this settings, we provide the definition for Business Scenario for the BPMN graph, what is called as BPMN trace. Intuitively for a BPMN diagram, it refers to an admissible path beginning with a start event and ending with an end event where all the data objects result properly instantiated so as to satisfy the guards of all the edges in the path. More formally:

**Definition 6. BPMN Trace:** Given a BPMN Process $bg$, a trace $t$ for $bg$ is:

$$\begin{aligned} t = v_1 \rightsquigarrow v_n | v_1 \in S_{bg} \wedge v_n \in F_{bg} \wedge \\ \{\exists Val \subset v_1 \rightsquigarrow v_n | \\ \underset{1 \leq i < n}{\forall} \{e = (v_i, v_{i+1}) \in E_{bg} \wedge \Phi_{Val}(\gamma_{bg}(e)) = true\}\} \end{aligned} \tag{5.5}$$

### 5.3.2 Learning Path Definitions

Definitions about Learning Paths provide a way to group together activities and sequence them in the order that is meaningful for acquiring knowledge. Defining them on top of BPMN Process graph make it possible to use BPMN and its related software systems for learning purposes. In this section, we finally introduce the formal specification for Learning Path and related concepts that are important for the development of Business Process Management-driven Learning System (BPMLS).

A Learning Scenario, as defined in Section 5.1 describes a case of execution for a given business process. In this formal definition, it relates to a process trace, a set of target activities in the process trace that has to be performed by learner, a configuration for the

input data objects of the business process, and a chain of expected values for the data objects so to bring the actual execution of the process trace successfully to completion. More formally:

**Definition 7. Learning Scenario:** Given a $bg$ be a BPMN process graph, a Learning Scenario is a tuple $(t, T, Val_0, OracleVal)$ where :

- $t = v_1 \rightsquigarrow v_n$ is a process trace on $bg$
- $T \subseteq \{v_i | v_i \in p_{ls} = v_1 \rightsquigarrow v_n\}$ the subset of *target* vertexes from $bg$
- $Val_0$ is a given valuation function so that $Val_0$ C $v_1 \rightsquigarrow v_n$ and it sets at least those data objects in $D$ that have to be provided as input for $bg$.
- $OracleVal = (Val_1, \ldots, Val_n)$ is a sequence of valuation functions so that:

$$\underset{1 \leq i \leq n}{\forall} \qquad Val_i(v_i, d) = \begin{cases} \alpha & \text{if } d \in \delta_w(v_i) \\ Val_{i-1}(v_i, d) & \text{otherwise} \end{cases} \tag{5.6}$$

  where $\alpha$ is the expected value for a data object $d$ when the execution of the process trace $t$ configured with the inputs given in $Val_0$ reaches the vertex $v_i$.

In this settings, a set of Learning Scenario represents a set of training cases for learners on a given business process. Specifically, as $t$ is an admissible BPNM trace then a suitable valuation function $Val_0$ exists (see Definition 6), and it is also possible to choose proper valuations for the data objects referred by the vertexes in the given path.

A simulation framework can exploit the values in the valuation functions in $OracleVal$ to assess learner behavior during the execution of the BPNM trace $t$, for example by comparing the input values provided by the learner during an activity with the expected values from the functions within $OracleVal$. A simulation framework revealing a mismatch in such a comparison could drive the learner to repeat the particular activity asking for proper input, or it could abort the simulation session reporting about the failure. Both the cases may impact on the learner's KPIs. Also, as a Learning Scenario only targets a subset of the vertexes listed in the process trace (i.e. $\tau_i \in T$), a simulation

framework can exploit the expected valuations in $OracleVal$ to configure the simulation context of a given activity before a learner executes it.

**Definition 8. Coverage:**

Similarly, coverage metrics for a set of Learning Scenarios on its related process graph would tend to estimate the significance of the training set. Let $bg$ be a BPMN process graph, $LS$ the Learning Scenarios related to $bg$, and $V$ a set of vertexes. The relation $Cov_V : 2^{LS} \rightarrow \{true, false\}$ checks if the given set of Learning Scenarios *covers* all the elements in $V$. More formally:

$$Cov_V(LS) = \begin{cases} true & \text{if } \{ \bigcup_{ls \in LS} T_{ls} \} \cap V = V \\ false & \text{otherwise} \end{cases} \quad (5.7)$$

Coverage can be used to verify if a set of Learning Scenarios is sufficient for a given set of learning activities. Also, Coverage metrics in software testing tend to estimate the significance of a test suite on a given program[130].

**Definition 9. Learning Goals:** Learning Goals relates a set of cases on which a learner is examined with the objectives that he/she has to achieve. Specifically, given a process graph $bg$, it is a pair $G = (LS, KPI)$ where:

- $LS$ a set of Learning Scenarios related to $bg$
- $KPI$ is a set of target KPIs for the learner whose values can be measured and computed during simulation sessions oven the cases in $LS$

**Definition 10. Learning Path Specification:**

Learning Path specification is used to group a set of work-related activities based on the learning requirement of an employee. It consists of the activities to be learning and learning goals which include a set of learning scenarios and the target KPIs to be reached. Let $bg$ be a BPMN Process graph as specified in Def. 1. A Learning Path specification $lp$ is a tuple $(L, Pre, C, \rho, G)$ where:

- $L$ is a set of vertices representing the atomic learning activities belonging to learning path. $L$ is related to the given BPMN graph $bg$ so that $L \subseteq activities(bg)$

- $Pre$ list the prerequisites required for this learning path and contains a set of other Learning Paths that need to be completed before the current one can be attempted. Given $LP$ the Learning Paths related to the given BPMN graph $bg$, $Pre \subset 2^{LP}$.

- $C$ is a set competencies associated with the Learning Path. Each competency $c \in C$ represents the knowledge, skills, and behaviors that will be acquired by a learner after the successful completion of the specific Learning Path $lp$. Currently we dont specify any competency model, but refer to the generic notion of work-oriented competency as described in Section 5.2. [126]

- $\rho$ is a mapping function, $\rho : C \rightarrow L$ which maps the competencies of the learning path to learning activities

- $G$ specifies the Learning Goals associated with the learning path so that: $Cov_L(LS_G) = true$

To avoid deadlock or cyclical references in this definition, it is necessary that for all the $lp \in LP$ there are no cyclical references among the $Pre$ lists. In the scope of this thesis, we assume that such requirements are satisfied. Currently, we also have kept the representation of competencies abstract in our Learning Path Specification definition. The above definition provides a way to relate Learning Path Specification, its set of Learning Scenarios and their Business Process Models. The components of our BPMLS architecture are developed based on the above definitions, which is explained in detail in the next Chapter.

# Chapter 6

# Business Process Management-based Learning System (BPMLS)

The technical definitions described in Chapter 5 provide a foundation for researchers and developers who wish to develop a workplace e-learning system using a process-driven approach. In this chapter, we discuss further details of our proposed BPMLS: the phases of BPMLS and its high-level architecture.

## 6.1 BPMLS: Integrating BPM and LPM

In Chapter 3, we saw BPM as "a disciplined approach to identify, design, execute, document, measure, monitor, and control both automated and non-automated business processes to achieve consistent, targeted results aligned with an organization's strategic goals" [131]. On the other side LPM is a similar approach designed for the learning processes. Our proposed BPMLS, as a suite of software systems, combines and intertwines both the approach of BPM and LPM to have a hybrid approach. Though, both BPM and LPM have a different point of focus; they can represent potential linkage when it comes to workplace e-learning. "A business process provides the context information necessary to identify learning needs and design matching learning processes that are meaningful for organizational business goals and individual learning goals" [31]. Whereas learning

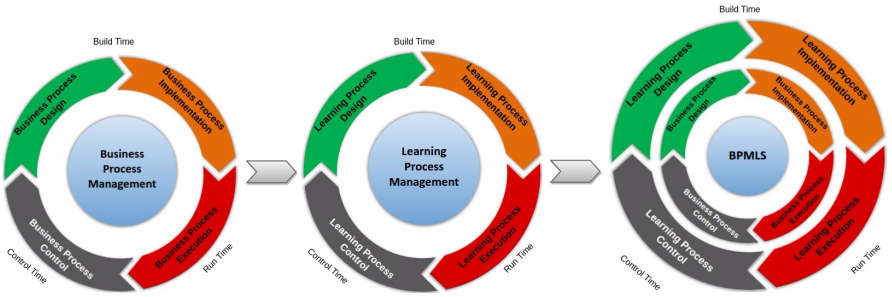


FIGURE 6.1: Intertwining Business Process and Learning Process

process can help the employees enhance their knowledge to perform business process better. The business process can provide the contextual information necessary to identify the learning scenarios that are meaningful for the organizational as well as individual goals [132]. By aligning learning activities to business processes, as well as by structuring the learning content based on the business context allows for a systematic end-to-end development of e-learning systems with the added advantage of remaining as closely aligned to the business needs as possible.

Figure 6.1 sketches the similarities of both BPM and LPM, and how their cycles can be integrated. Specifically, each cycle refers to a phase which, among the others, also bring to a separation of concerns for the definition of different usage scenarios, the different category of users, and possibly different software components. Within the scope of this work, we refer to the following main phases: Build Time, Run Time, and Control Time [133].

## 6.2 Phase of BPMLS

As defined before, we call this BPM based e-Learning system as Business Process Management-based Learning System (BPMLS). Before introducing the architecture of the BPMLS, we will describe the three different phases that the architecture of BPMLS will cover. The three phases separate the BPMLS software components based on their functionality. The phases also provide a separation of concern for different users of BPMLS in that each phase will be delegated to a certain category of users. The three phases are i. Build time, ii. Runtime and iii. Control time [133]. We will see each phase in detail in the following sections.

### 6.2.1 Build Time Phase

Build Time Phase is focused on analysis, design and implementation of the business and the learning process models. Build time involves designing, modelling, and development of business models, their related web services, learning scenarios, learning path, development of User Interface, etc., Build phase of BPMLS involves two steps. First is the modelling of the business processes. A variety of graphical modelling tools exists both online and offline [134–136], that can be used for modelling of business processes using BPMN specification. Along with the business process models, a set of learning scenarios needs to be developed based on the business process model and the learning requirements. In Section 5.3.2, we defined how a Learning Scenario is related to a path in the business process model. BPM lifecycle is iterative ie., the build time phase may use some artefacts from the phases of its previous iteration and we will see, in Section 3.2 about the process optimization during the last phase of BPM lifecycle, Control Time Phase. One of the methods of optimization involves process mining techniques[137] which aim at the automatic construction of models and their various properties based on the behaviour observed in the event log of BPMS. The aim of the process mining is to offer different perspectives on the process based on its execution log. One of the perspectives that can be traced by the execution log is case perspective[137]. Cases can represent the path of the process or by the originators working on a case. Cases can also be characterized by the values of the corresponding data elements. Cases discovered by process mining of actual traces of business process execution can be used during designing the learning scenarios by taking advantage of the relation between the Path and the Learning Scenario. This shows how, in BPMLS, available business data can be used to build integrated, consistent, data-based learning contexts that are based on real-life scenarios. The value derived for the data objects from the cases can be used to assess the input from the users during a simulation session. This way, BPMLS provide a preliminary approach similar to ECAAD (Evidence-centred Activity and Assessment Design) environments such as described in NEXT-TEL project [138] which focuses on how a design and execution approach can be realized using a model-driven interpretation framework. Currently, converting a real-life business case to a learning scenario is done manually in BPMLS by expert users and the potential methods of automatically deriving learning scenarios from the cases available are left for future work.

The next step is the designing of learning paths with the set of activities that are marked as learning and mapping them to the learning scenarios. Development of learning scenarios includes the building of appropriate User Interfaces, creating simulated services that will mimic the business process execution and implementation of data objects. Such tasks belong to engineering the BPMLS into a product, whereas in this thesis we develop a proof-of-concept prototype. So we leave such requirements for future work. Business Process Archives consisting of the business process models, mock business services, etc., and Learning Process Archives consisting of the learning path model, learning scenario configurations, user interface in the form of HTML files, etc., are the outcome of this phase.

The design and implementation of the business process models and the learning process models are done by the business analysts and top-level managers. They are the ones who decide on what are the business process that the organization needs and who are the employees that should learn about them. And based on their decision on models and services the IT developers will model the UI, mock services, etc., Hence the components of BPMLS in build time phase will be used by the following users: business analysts, IT developers, top-level managers such as COO, CEO, Department heads, etc., The models that are got from this phase should comply with the definitions of BPMN specification [38] for the business process models and learning path specification for the learning process models, that we defined in Section 5.2. The main advantage of our Learning Path Specification is that the learning models can be designed based on the roles and competence of a user. For a successful organizational performance Executives, Intrapreneurs of the organization should understand organizational learning and use this knowledge to develop new competencies or improve existing ones [139]. They usually are aware of the overall process that is happening within the company. In this phase, they also design what learning path should be assigned to the employees. This way their knowledge and experience can directly be transformed into learning goals for the employees. In the preliminary level, this is designed based on the experience of the top-level executives, we believe that in the long run this can be improved with advanced tools for assistance such as business intelligence and data analytics[140], using which the executives can understand the bottlenecks in the understanding of the process models by the employees.

### 6.2.2 Run Time Phase

Run Time Phase focuses on the actual execution of the various learning path models, the learning scenarios, and corresponding business process models. The business process models in the form of BPMN specification and the learning process models in the form of Learning Path Specification that are created during the build phase of BPMLS are deployed during the run time phase. Run time is the phase in which the users can use the BPMLS for the execution of learning path specification for learning. In other words, during this phase employees use the BPMLS framework simulating their involvement in actual business activities according to the e-learning artefacts (i.e. Learning Paths, and their related Learning Scenarios) they are assigned to. BPMLS actors in the run time phase include but are not limited to: employees as learners, IT personnel providing support for the deployment and the maintenance of the e-learning framework instance.

### 6.2.3 Control Time Phase

Control Time Phase focuses on the measurement, collection, analysis, and reporting of data about learners and their contexts that are required for the learning analytic aspects of the BPMLS. It is also concerned with methods to convert learning results to standard formats so that the learning outcome from BPMLS can be compared with other related standard learning activities that might be present in LMS such as Moodle. We call this as Learning Activity Monitoring (LAM). We derive this term from the Business Activity Monitoring (BAM), well-known within the BPM community. BAM involves gathering meaningful intelligence by aggregation, analysis, and presentation of real-time information about business activities inside organizations and involving customers and partners [141]. BAM software does that by analyzing business events for deeper business intelligence. Similarly, in LAM we convert the learning events data that are collected during the execution of the learning path models in BPMLS to deriving meaningful learning analytics. BPMLS actors in the control time phase include but are not limited to: learning analytics experts business analysts, top-level managers (e.g. COO, CEO, Department heads), employees.

#### 6.2.3.1 Tracking the Learning

For converting learning events and their related business task events into learning information, we use the emerging inter-operable learning specification standard called Experience API. The Experience API (xAPI) is a standard defined by Advanced Distributed Learning with an aim for providing better interoperability between different types of learning systems and devices. It does so by collecting and analyzing learning experiences happened in different contexts [142]. It is defined as a successor of SCORM to overcome its limitations. Until recently SCORM was considered the de facto standard for defining learning outcomes from the LMS [53]. Also, up until the introduction of Experience API, learning experiences are limited only to LMS. With xAPI, this changes because any system can now record and send 'learning statements' to a xAPI enabled system called Learning Record Store. The statements can then be used for statistical learning analytics. It is ideal for our case of BPMLS because we can record learning statements based on the business tasks that the user are executing as part of their learning process. Experience statements are at the core of the xAPI. These statements form "activity streams" that provide a trajectory of the learning activities. The activity streams form the foundation for the learning analytics of BPMLS.

Though the xAPI specification defines what capturing of the learning experience is, it does not define how to capture the experience statements. This is where our learning path specification defined on top of the business process model can be used to convert business activity event-streams into learning streams. Figure 6.2 provides an overview of how the business process events are related to learning path events and xAPI verbs.

Based on this mapping it is possible to record the various learning experiences happening in BPMLS. An example statement can look like in the Listing 6.2.3.1

```
{
  "id": "b8569011-c038-4693-b724-c43d808f2127",
   "actor": {
       "mbox": "mailto:user@mail.com"
    },
    "verb": {
        "id": "http://adlnet.gov/expapi/verbs/launched"
    },
    "object": {
```

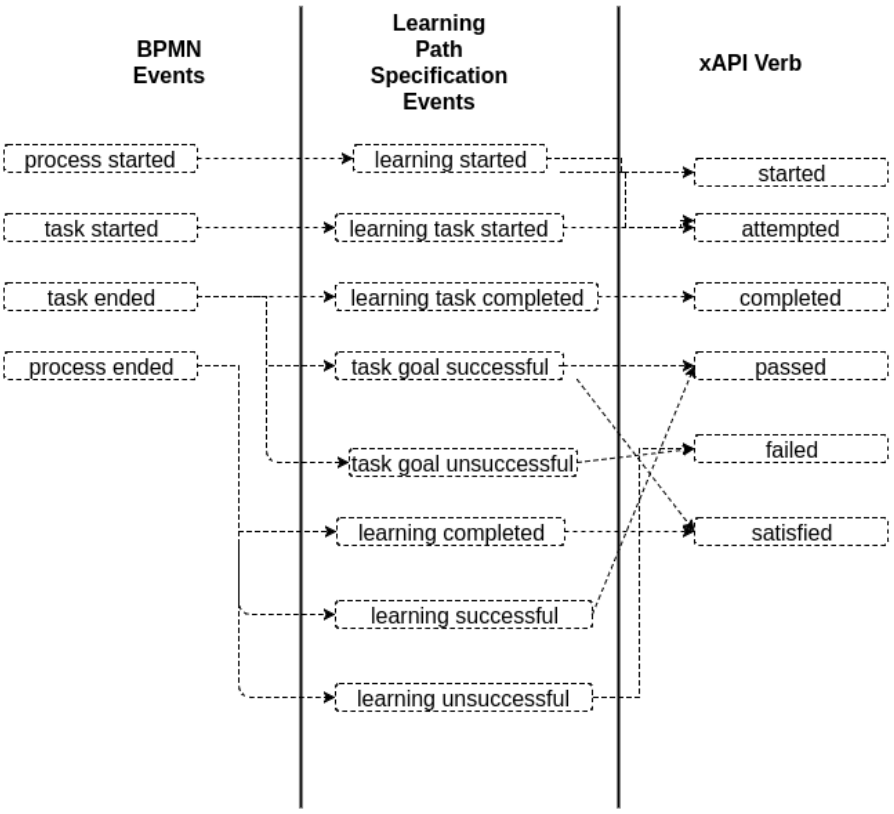


FIGURE 6.2: Business Tasks to Learning Tasks

```
        "id": "learning  activity ",
    },
    "timestamp": "2017-07-03T13:30:57.279+02:00"
}
```

LISTING 6.1: xAPI Statement Example

This way the BPMLS can be a useful tool in the control phase to do various types of standard learning analytics for our BPMLS. By making our BPMLS xAPI-enabled, it is also possible to compare the learning outcomes from BPMLS with other standard LMS such as Moodle. Hence it will be possible to combine different types of learning to the employees such as providing them with courses in LMS portal such as Moodle, Courseera and combine them with task-based learning using our BPMLS system. Users of the control time phase are the managers who will be given the responsibility for monitoring the learning progress of the employees.

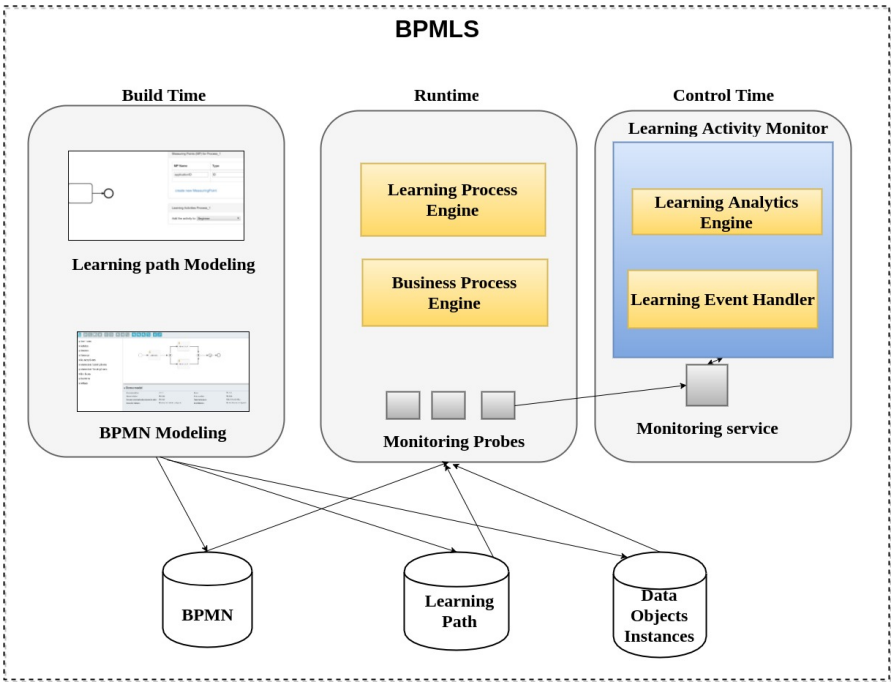


FIGURE 6.3: Architecture of BPMLS

## 6.3 Architecture of BPMLS

In this section, we describe the architecture of BPMLS. BPMLS will have software components that assist in all the three phases as described before. The high-level architecture is represented in Figure 6.3. In the following, we will see in detail of the different components that are used in each of the three phases.

### 6.3.1 Components of Build Time Phase

Since build time focus on design and implementation of the business process models and the learning process models, it consists of two components: one for BPMN modelling and one for Learning Path Modeling. BPMN specification has guidelines for some of its semantics [38], and the BPMN model should conform to it. Also, tools that can be used for the design and implementation of business process models have evolved and improved [143, 144]. Hence, BPMLS exploits existing methodologies and modelling tools supporting the BPMN 2.0 specification. Once the business process models and its related artefacts are defined, the e-learning artefacts can be designed on the basis of both business artefacts and the learning requirements. About e-learning artefacts, the BPMLS framework provides a set of XSD schema enabling the formalization of the

learning-depended concepts given in Section 5.2 and Section 5.3.2 as XML bundles(see Appendix A for the XSD schema). Furthermore, these schema represents the building blocks enabling the synthesis of a variety of IT modules according to the Model-Driven Engineering principles [145][146].

### 6.3.2 Components of Run time Phase

The high-level architecture of BPMLS distinguishes these software components as organized in two interacting sub-systems: the Business Process Engine and the Learning Process Engine.

#### 6.3.2.1 Learning Process Engine

The Learning Process Engine includes dedicated components enabling the simulation and the monitoring of the selected learning paths; Supporting of the data persistence across learning sessions are included as well. This component is responsible for overall execution of a learning path selected for execution. This includes selecting the set of learning scenarios in an appropriate order, delegating the execution of the business process to the Business Process Engine, and orchestrating between the other modules. During the execution, it is also responsible for collecting input from the learner wherever appropriate. While serving on learning-by-doing sessions, the Learning Process Engine is also responsible for collecting and dispatching observed events relevant for tracing the overall progress on the learning activities. Learning Process Engine include features for retrieving configurations and data instances distinguishing the Learning Scenarios defined during the Build Time Phase. The learning scenarios include some configuration files and include activities which need to be simulated or executed by a learner based on the learning path configuration. Learning Scenario Simulator sub-component is responsible for assembling appropriate simulated activities that are not executed by a learner. We divide the Learning Process Engine into further sub-components. We designed components of the Learning Process Engine based on the architecture of some of the popular open source Business Process Engine [147, 148]. The component diagram is represented in Figure 6.4. The Learning Process Engine consists of four service components. During the Run Time Phase, the Learning Process Engine delegates the work to the four service

components based on the work requested. Each of the components is explained in detail in the following:

- *Authorization Service:* This component provides a set of APIs that can be used to authorize the user who accesses the BPMLS. Authorization Service will be used by almost all the components to authorize any actions from the users.

- *Repository Service:* This component is used by the users from the Build Time Phase to deploy the learning process models and other resources required for the successful execution of the learning path. Repository service is responsible also to check the integrity of the models especially for checking the consistency of the valuation functions provided as defined in Definition 4 of Section 5.3 and that the learning scenario covers all the learning activities defined in the learning path as explained in Definition 8 of Section 5.3.2.

- *Runtime Service:* Runtime Service provides features for the evolution of the user-independent context of the simulation. In other words, this component orchestrates the progression of those activities in the corresponding business process models that are not subject to learning in the learning scenario. Among the others, the Runtime Service is responsible for inferring meaningful values for the active data objects subsumed by the trace (see Definition 7, and Definition 4) defined in the considered learning scenario. Indeed, the Runtime Service interacts with the Business Process Engine through the *businessProcessExecution* API.

- *Task Service:* Task Service support user in proceeding with learning task during the execution of business activities that are subject to learning. The sub-component validates the data provided by the user by interacting with the *Oracle Service*. Specifically, the Oracle Service assesses if the received inputs conform with the admissible values for that step in the Learning Scenario (see Definition 7). Also, it exposes APIs that can be used to assign values to the Oracle functions (see Section 3). Finally, the Task Service requires an interface to the Business Process Engine component to notify the user-input data and let the simulation step over forthcoming business activities.

- *Oracle Service:* Oracle Service is used to initialize and update the data objects and to verify the path consistency of the business process execution. (see Section

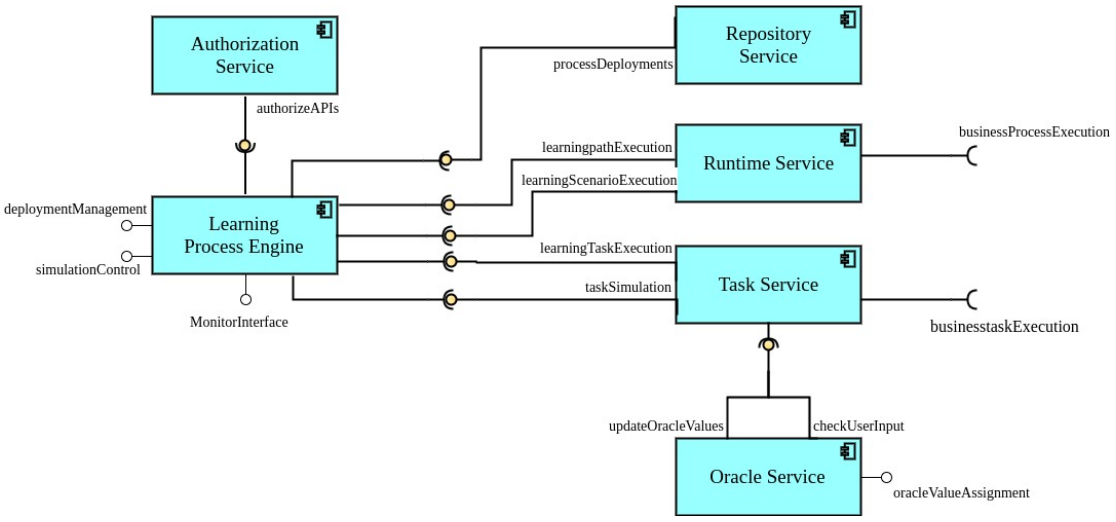


FIGURE 6.4: Various Components of a Learning Process Engine

4). It exposes APIs that can be used to assign values to the oracle functions. (see Section 3).

#### 6.3.2.2 Business Process Engine

We described how the execution of learning path involves execution of a set of learning scenarios and how learning scenarios are built based on the BPMN process model. This means that any execution in a BPMLS is the execution of a BPMN process model. Business Process Engine module is responsible for the execution of the BPMN process model, configured with a given set of simulated data. Many robust process engine exists that is based on BPMN specification, and our idea of BPMLS is to use the preexisting engine to make the development of process-based learning systems easier. Reference implementations for the BPMLS platform leveraging on on-the-shelf BPMN engines are supposed to be more robust and integrated with existing workflow engines possibly in place within an organization. In addition, these solutions could better focus on the development of components within the Learning Process Engine. Also, the enactment of the BPMN 2.0 artefacts in the Business Process Engine requires the instantiation of data/behaviours simulated according to specific learning needs. For all these reasons the Business Process Engine should foresee an API supporting the interactions between the two subsystems[1].

[1]Note that the current BPMLS prototype uses the open-source Camunda platform (`https://camunda.com/`) as BPMN engine. At the time of this writing, some modules in our implementation may specifically bound to this technology

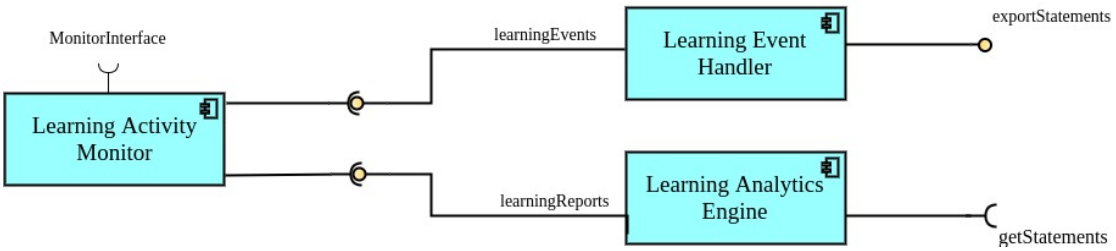


FIGURE 6.5: Various Components of a Learning Activity Monitor

### 6.3.3 Components of Control Time Phase

Components of control time phase component of the BPMLS consists of a set of monitoring probes which are responsible for collecting the various business and learning activity events happening during the execution phase. These events are then sent to the monitoring service which collects these events and passes it to the Learning Activity Monitoring (LAM). The LAM consists of two sub-components:

- **Learning Event Handler** is responsible for converting the incoming business and learning events from the learning system of BPMLS into xAPI statements. These converted xAPI statements are sent for storing to what is called as a Learning Record Store (LRS) for persistent storage. "A Learning Record Store (LRS) is a data storage system that serves as a repository for learning records collected from connected systems where learning activities are conducted. It is an essential component in the process flow for using the xAPI."
- **Learning Analytics Engine** components mediate the retrieval of the xAPI statements and it enables the aggregation and the presentation different aspects of learning with the BPMLS platform.

In this chapter, we explained the Architecture of the BPMLS and the various high-level components that are part of BPMLS. We implemented a prototype version of BPMLS based on this architecture and did some validation study to understand the perceived usefulness of the concept of process-driven learning that is brought out in our framework of BPMLS, which is discussed in the following chapter.

# Chapter 7

# Prototype Implementation and Validation of BPMLS

Based on the high-level architecture described in Chapter 6, we built a prototype of BPMLS. As mentioned before we reused already available BPMS tools in our BPMLS. For the BPMS we used an open source suite of software called as Camunda BPM [1]. Camunda BPM provides the complete suite for design, implementation, execution, and monitoring of business process as defined using BPMN. Along with that it also provides user management to define the users that can access the system. They also provide an easier way to design UI based on a concept called HTML forms. We reuse all available tools of Camunda for our BPMLS.

The prototype covers all the three phase of BPMLS as described in Section 6.2. BPMLS tools for the Build Time Phase includes BPMN modelling and Learning Path Specification Modeling tool. For BPMN Modeling, we used a graphical tool called Camunda Modeler [2]. Camunda Modeler is a desktop application for editing BPMN process diagrams. The tool has the provision for both the business analysts and the developers to work on the same model. For the Learning Path Specification modelling, we do not have any graphical editor yet. Currently, we use XML editors to define Learning Path Specification for the Business Process Models that validates the generated XML data with the Learning Path Schema that we defined (see Appendix A). It makes it easier to design learning scenarios for the Learning Path Specification.

[1] www.camunda.com
[2] https://camunda.org/download/modeler/

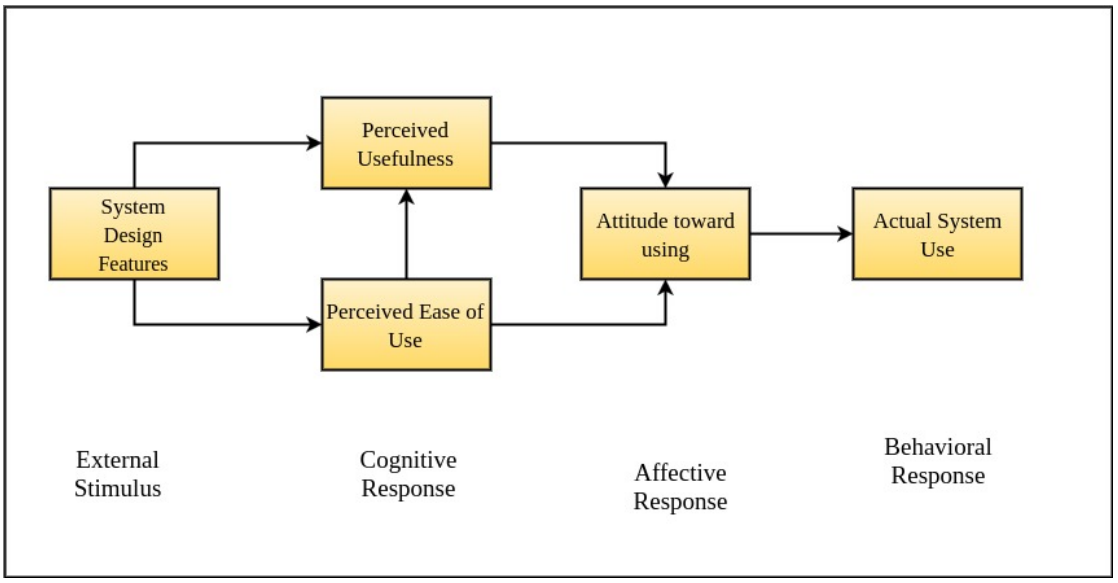


FIGURE 7.1: Technology Acceptance Model as Proposed by Davis [6]

The components used for the Run Time Phase and the Control Time Phase of the BPMLS are developed as described in their component architecture represented in Figures 6.4 and 6.5 respectively. For the implementation of these components, we used Spring Boot. Spring Boot is a Java framework that makes it easy to create stand-alone, production-grade based applications that we can just run, with minimal configuration [149]. We also use Aspect Oriented Paradigm (AOP) paradigm to build the components of the prototype. AOP "refers to a type of programming that aims to increase modularity by allowing the separation of cross-cutting concerns" [150]. Both of the above concepts are beyond the scope of this thesis, and we suggest the users read the literature to know more about them. For the Learning Record Store (LRS) sub-component that is within the LAM component, we used an Open Source LRS called OpenLRW. "OpenLRW is a standards-focused learning records warehouse with support for event capture with xAPI." [3] A web-based front end was also implemented to provide a User Interface to access the BPMLS during the Run Time and Control Time phases. The prototype of the BPMLS that we developed is available as Open Source for other researchers and developers to use to get a deeper understanding of the system. [4]

## 7.1 Technology Acceptance of BPMLS

We began this thesis with the reasoning that we need a paradigm shift in the design of workplace e-learning systems, towards a process-driven learning approach; And we proposed a BPM-driven learning design for the same. We also proposed the BPMLS as a suite of software that assists in the design of such learning systems. BPMLS tries to provide the solution for the research questions that we asked at the beginning of this thesis: **How can we provide tools and methodologies for process-driven learning approach in designing of workplace e-learning systems? How can we effectively use BPMS while providing solutions for the process-driven learning approach?** Now, to ascertain how successful has BPMLS been in providing the solution to this research question, we need to evaluate the usefulness of the BPMLS. BPMLS, like BPM, has both the methodology and the technology. Evaluation of BPMLS methodology needs a certain maturity in this field to understand its shortfalls and correct them. It might take a long time to realize. Hence validating the methodology now, when it is being proposed is not possible. However, we can evaluate how well BPMLS is accepted as a technology for process-driven learning. One of the main factors that decide the success of a new information system is the user acceptance of the technology [6]. Major influences on user acceptance are user attitudes, user perceptions and beliefs, and actual system use [22]. Many models and framework exist that predict the user acceptance [151–153]. The most widely-used framework is Technology Acceptance Model (TAM) [22].

The TAM model as proposed by Davis [6] is represented in Figure 7.1. It explains how various user experiences affect the actual system use and acceptance. According to the model, a prospective user's overall attitude towards the given system is a major determinant factor that decides whether or not he or she uses it. Attitude towards using, in turn, is affected by two beliefs: Perceived Usefulness and Perceived ease of use. System design features have a direct influence on perceived usefulness and perceived ease of use. Perceived ease of use also has an influence on perceived usefulness. By affecting perceived usefulness and perceived ease of use, system design features have an indirect influence on the attitude toward using the system. The same study [6] then provides empirical evidence that the TAM motivational variables: attitude toward using, perceived usefulness and perceived ease of usefully mediated the effect of system design

[3] https://github.com/Apereo-Learning-Analytics-Initiative/OpenLRW
[4] https://github.com/venkatapathy/bpmls-framework

features on usage. It means that the system characteristics influence the behaviour through these motivational variables and have no additional direct effect on use. The effect of perceived usefulness affects more in the attitude towards the behaviour than the perceived ease of use. It proved a key invisible finding that users are maybe willing to tolerate a difficult interface to access the functionality that helps them on their job. Also apart from the indirect influence of system design features on the attitude toward using through the perceived usefulness and perceived ease of use, it also exerts some direct influence. Thus, the TAM model views the usage behaviour to be extrinsically motivated, driven by concern over performance gains and associated rewards.

TAM provides a promising tool to test an early acceptance of the technology. The validity of TAM has been empirically proven in many other previous studies too [154–156]. TAM has also been adopted and tested in relation to e-learning and LMS [157, 158]. Hence we decided to use the TAM model to have an evidence-based understanding of how users accept BPMLS as a new technology for learning. We evaluated the TAM variables from a given set of users feedback to see how well the BPMLS is accepted among them for learning. The detailed methodology of our study on these variables is given in the next section.

## 7.2 Methodology to Test TAM Variables for BPMLS

The typical approach for user acceptance suggested in TAM is to build a prototype of the application, have the potential users interact with it, measure various performance criteria and subjective evaluations, and iteratively refine the design [6]. We already mentioned about the design of the prototype of the BPMLS at the beginning of this chapter. Using the tools of Build Time Phase of BPMLS we implemented two case studies targeting two different groups of potential users for our learning system.

### 7.2.1 Case Studies

The first case study is based on a Loan Assessment Process loosely adapted from the work of Fernandez [159]; its BPMN representation is depicted in Figure 7.2. We defined a Learning Path Specification for this Loan Assessment Process with three different learning scenarios. The Learning Path Specification was defined for the Loan Officer

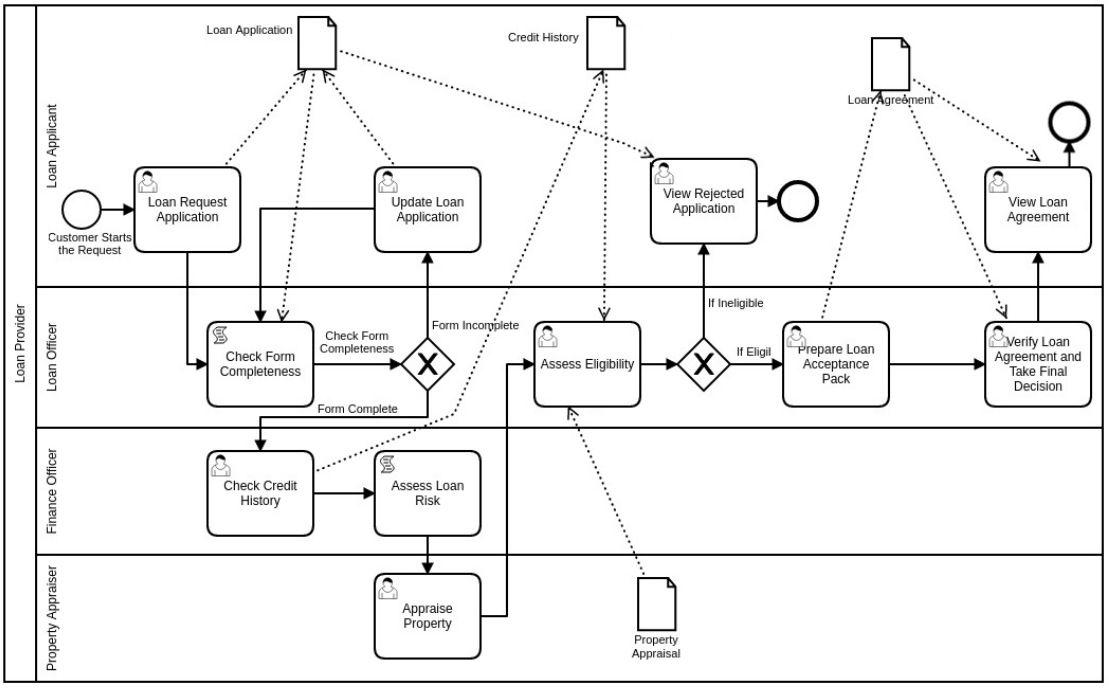


FIGURE 7.2: Loan Assessment Process

role in the process specification. The Learning path specification with its three scenarios can be found in the link: https://github.com/venkatapathy/bpmls-framework/blob/master/backend/src/main/resources/schema/bankloanlearningpath1.xml.

The second case study is based on a generic process that represents the activities to be carried out in any IT-company if an employee faces an IT-related problem. The Process is called as IT-Help Desk, and the BPMN diagram is represented in Figure 7.3. The Learning Path Specification was also defined for the Employee role with two learning scenarios. The Learning path specification for the IT Help Desk with its scenarios can be found in the link: https://github.com/venkatapathy/bpmls-framework/blob/master/backend/src/main/resources/schema/LearningPath.xml.

### 7.2.2 Hypotheses

Following are the hypotheses that we want to verify during this validation process. The hypotheses are based on the TAM variables that we saw earlier:

H1 Users feel confident and self-efficacious after learning from BPMLS

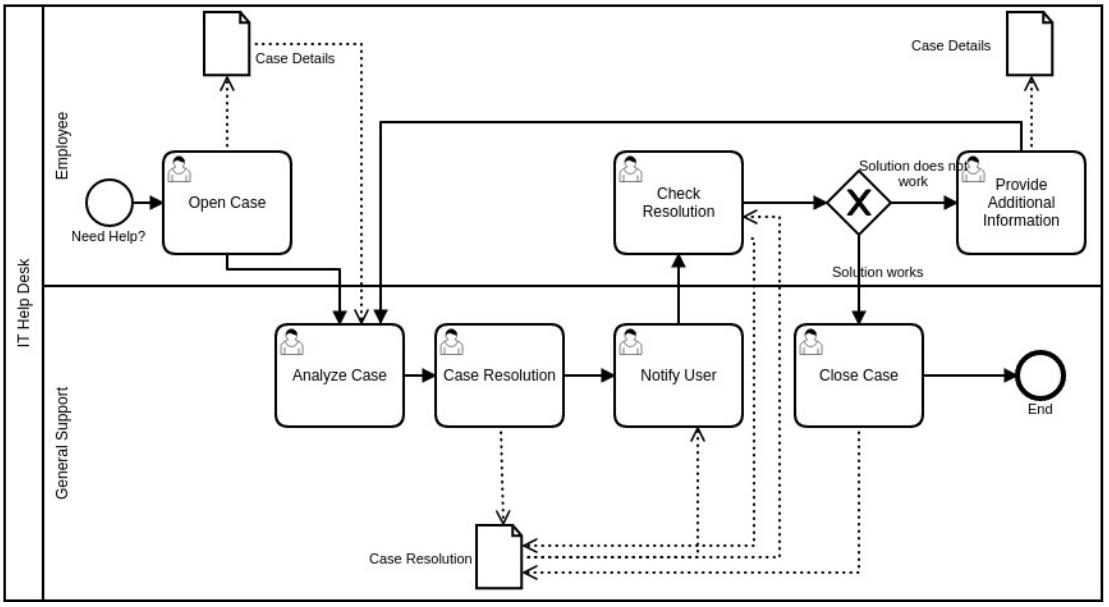


FIGURE 7.3: IT-Help Desk Process

H2 Users feel that they are in control of their learning progress, and are goal driven by themselves

H3 Users perceive that the BPMLS is useful for them

H4 Users find it easy to use the BPMLS

H5 Users are satisfied with the BPMLS

H6 Users are motivated to learn while using the BPMLS

H1 and H2 evaluate the System Design feature of the TAM model because one of the main aims of developing process-driven learning is making the employees self-efficacious and competent in their work. Another one is giving the control back to users, so that the learning is self-directed by the user, at his/her own choice of time and pace. H3 evaluates the perceived usefulness. H4 evaluates the perceived ease of use. Attitude towards using the system is evaluated by the hypotheses H5 and H6. Since the TAM model has already proved the relationship between the variables, our hypothesis tests if the user's perception of the TAM variables is positive.

### 7.2.3 Questionnaire

The study is quantitative in nature and uses an online survey for data collection. To ensure content validity, the questionnaire was adapted from the original scales used in TAM [6] and from other literature [160–162]. The online survey consists of a questionnaire that the users will be asked to complete. The questionnaire consists of three main parts. The first part includes questions to understand how the users encounter the need to learn and understand the process in their learning or work environment. This part uses a 5-point Likert response scale where

1: Never,

2: Rarely,

3: Sometimes,

4: Often,

5: Always.

The questions are represented in Table 7.1.

| Part 1: About learning a Process | |
|---|---|
| 1.1 | In your work or learning environment, do you encounter the need to learn and understand processes? |
| 1.2 | Among the following modalities of learning, please state the frequency with which you use the modalities to learn processes<br>• Text Documents<br>• Videos<br>• One-on-One Training<br>• Simulations |

TABLE 7.1: List of Questions for Part 1 of the Questionnaire

The second part of the survey measures the TAM constructs used in this study. All the questions in this section use a 5-point Likert response scale where:

-2: Strongly Disagree,

-1: Disagree,

0: Neutral,

1: Agree,

2: Strongly Agree.

As shown in Table 7.2, there are 28 items that are measured according to our TAM model. The measured items include Learner Self-efficacy (3 questions), Learner Control (4 questions), Perceived Usefulness (7 questions), Perceived Ease of Use (5 questions), Satisfaction (4 questions) and Learner Motivation (5 questions).

| Part 2.1: Learner Self-Efficacy (see H1 in Section 7.2.2) | |
|---|---|
| 2.1.1 | I feel confident in performing the process in real-world |
| 2.1.2 | I feel confident in my knowledge and skills of how to manage the process flow |
| 2.1.3 | I feel confident in using BPMLS to learn a new process flow |
| **Part 2.2: Learner Control (see H2 in Section 7.2.2)** | |
| 2.2.1 | I repeated the process flow by my learning needs |
| 2.2.2 | I can understand the inter-related learning tasks |
| 2.2.3 | While learning a task of a process, I can validate the forms I am requested to fill in, and I can immediately check and correct my errors |
| 2.2.4 | I can be goal-driven in learning the process |
| **Part 2.3: Perceived Usefulness (see H3 in Section 7.2.2)** | |
| 2.3.1 | It helps me to be effective |
| 2.3.2 | It helps me to be productive |
| 2.3.3 | It is useful |
| 2.3.4 | It gives me good understanding of the processes |
| 2.3.5 | It makes easy for me to accomplish my objectives |
| 2.3.6 | It will save me time later while doing actual tasks |
| 2.3.7 | It meets my learning needs |

| Part 2.4: Ease of Use (see H4 in Section 7.2.2) | |
|---|---|
| 2.4.1 | I learned to use a process quickly |
| 2.4.2 | I easily remember how to use a process |
| 2.4.3 | It is easy to use the BPMLS System to learn about a process |
| 2.4.4 | I quickly became skillful with the process |
| 2.4.5 | I quickly became skillful with the BPMLS |
| **Part 2.5: Satisfaction (see H5 in Section 7.2.2)** | |
| 2.5.1 | I am satisfied with the BPMLS System |
| 2.5.2 | I would recommend BPMLS to a friend |
| 2.5.3 | BPMLS works the way I would like it to work |
| 2.5.4 | BPMLS is pleasant to use |
| **Part 2.6: Learner Motivation (see H6 in Section 7.2.2)** | |
| 2.6.1 | I felt stimulated and challenged to learn better |
| 2.6.2 | I improve from my mistakes |
| 2.6.3 | It holds my interest while learning |
| 2.6.4 | I feel encouraged as I do the process right |
| 2.6.5 | I find this learning valuable to pursue |

TABLE 7.2: List of Questions in Part 2 of the Questionnaire

The final part of the questionnaire identifies respondents' basic demographic characteristic that is relevant to this study. The questions are listen in Table 7.3.

| Part 3: About the User | |
|---|---|
| 3.1 | Please give the emailId that you used with BPMLS |
| 3.2 | Please state your age |
| 3.3 | Please state the name of your organization/institution |
| 3.4 | Please state your period of work experience(eg: 32 months, or 3 years) |

| | |
|---|---|
| 3.5 | Which ONE of the following best describes your current occupation? (Please select one)<br>• Employed<br>• Retired<br>• Unemployed<br>• Full-time Student<br>• Part-time student |

TABLE 7.3: List of Questions in Part 3 of the Questionnaire

### 7.2.4 Sampling Technique

Sampling technique is used to make inferences about a population from a sample. We used non-probability technique [163], in which the samples are selected based on the subjective judgment, rather than random selection. It is because the system is targeted to a particular group of users with certain characteristics. In particular, we used Quota sampling and Snowball sampling technique [164, 165].

### 7.2.5 Data Collection

The prototype BPMLS with the implemented case study was deployed online for the users to use them and to learn from. The link to the site can be found at `atlantis.isti.cnr.it:24098`. Then a message was forwarded to the relevant users to use the system and give feedback on how they feel about the system by answering the questionnaire as described above. The message was forwarded to users that belong to one of the following groups:

- Banking Professionals
- IT Professionals who are familiar with IT helpdesk process
- Management students who specialize in Business Operations.

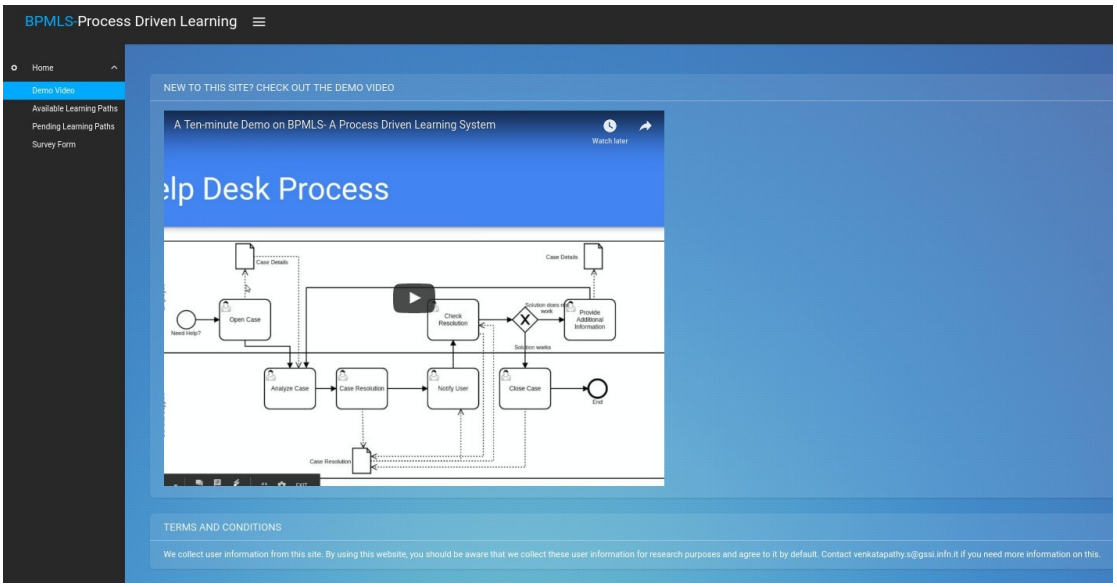


FIGURE 7.4: Demo video within BPMLS

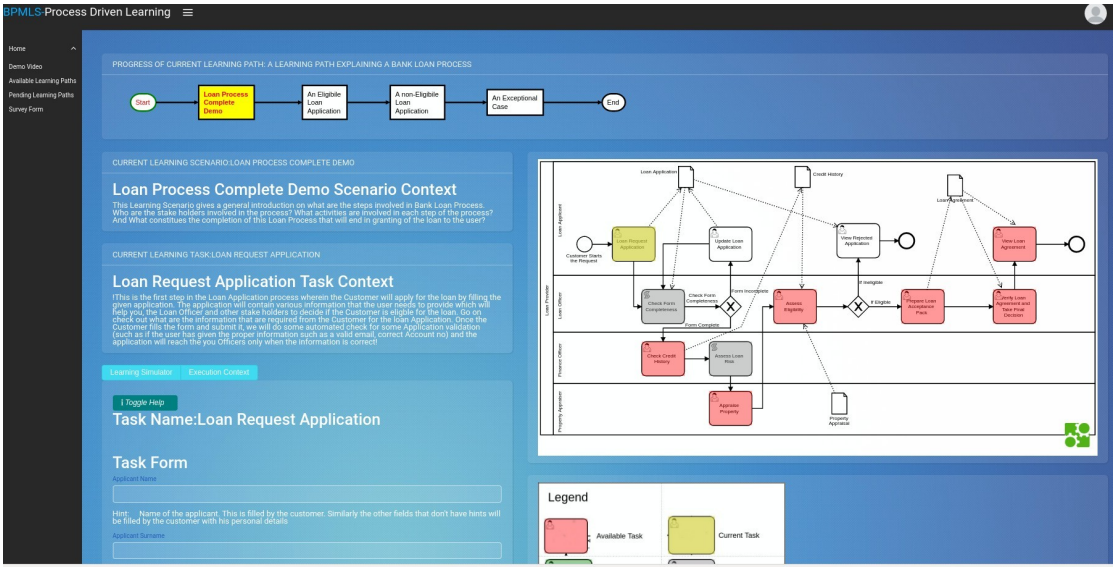


FIGURE 7.5: UI of the Learning Simulator in which the User will do the learning.

No information is provided in the request for participation, but the users are required to follow a three-step process:

1. They are requested to watch a 10-minute introductory video that is provided along with the system, see Figure 7.4. The video gives a brief introduction to BPMLS and guides the user on its usage.

2. They should do one of the two Learning Path available. They can choose one that is relevant to them. Choosing a learning path will take them to a page where they should do the learning, see Figure 7.5.

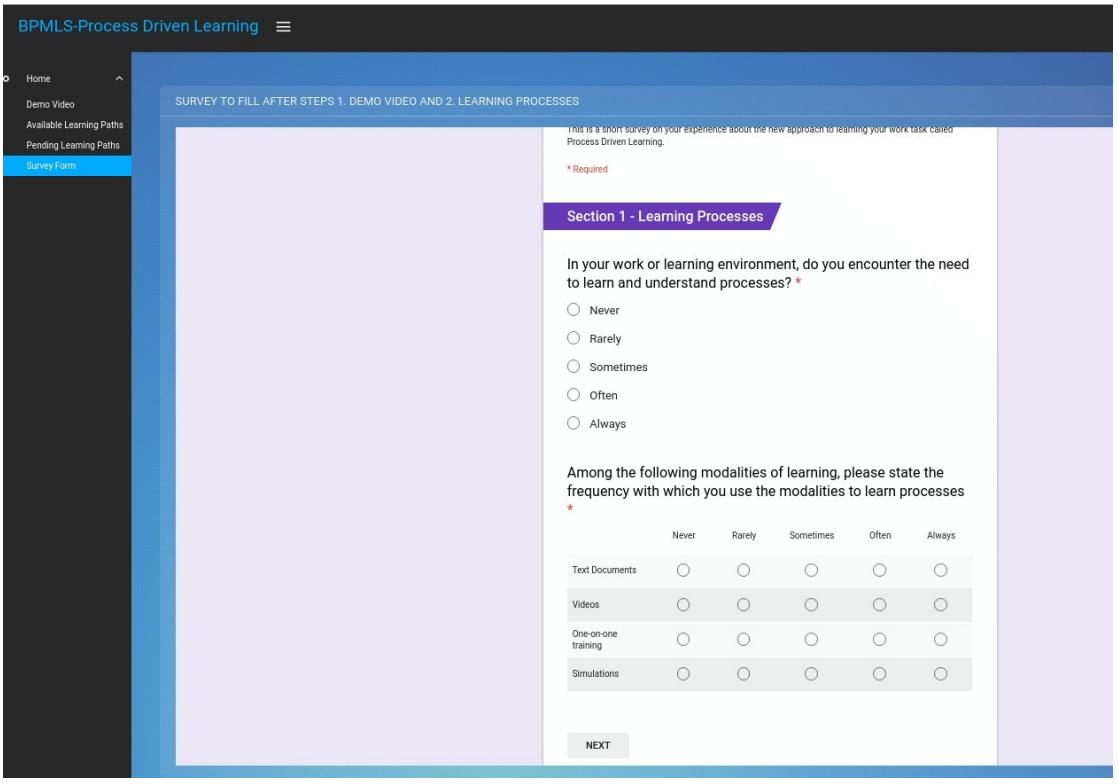


FIGURE 7.6: Online survey form embedded within BPMLS

3. Finally, they should fill the survey form that is available on the site, see Figure 7.6.

It is significant to note that this study is not only about taking the answers to the survey but also includes a learning phase before that. We estimated that it would take about 30-40 mins to finish the steps required by the user. Until this time, 33 responses were recorded. But we realized that out of the 33 users, six respondents answered the survey after watching only the video without doing any learning. We believe that this might not be the valid response, so we excluded them from the study. Hence the final 27 responses were used for analysis.

## 7.3 Data Analysis and Results

This section describe the different analysis we did from the responses we got for the experiment. We divide the analysis part into two, Descriptive Analysis and Inferential Analysis, which are listed in the following:

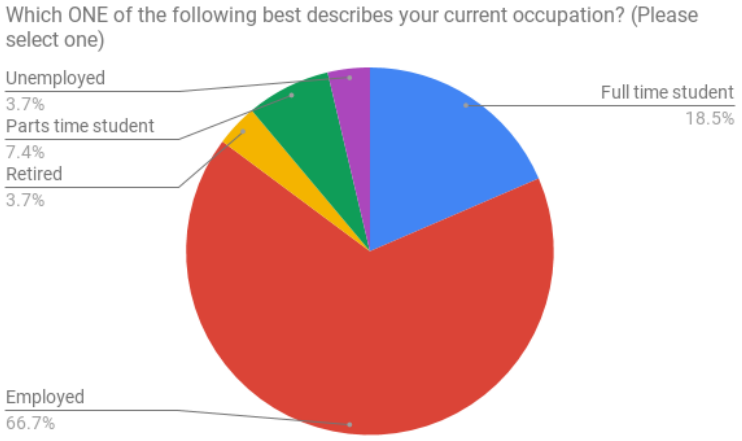


FIGURE 7.7: Occupation of the Participants

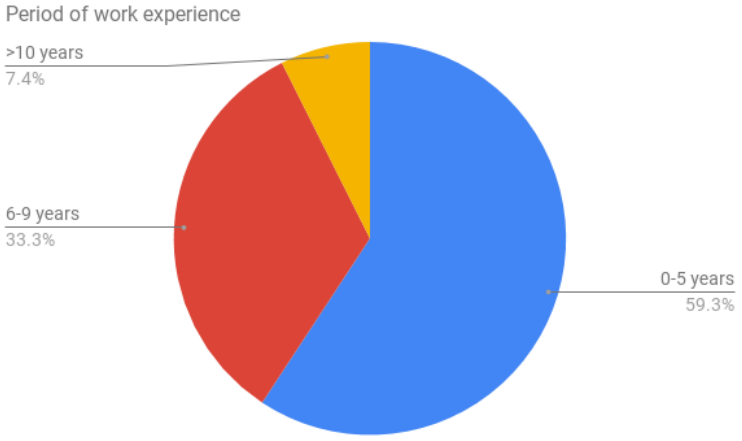


FIGURE 7.8: Work experience of the Participants

### 7.3.1 Descriptive Analysis

First, let us see the demographic details of the participants. Out of the total participants, the majority of them are employed professionals covering almost 67%. Next majority of participants are students. Rest of the participants include retired and unemployed users. Figure 7.7 represents the split of occupation among the participants, and Figure 7.8 shows the split of work experience among them. The majority of the participants have 5 or fewer years work experience.

Out of the whole set of 27 participants, almost the 93% of the users have encountered the need to understand and learn a process at least "*Sometimes*" (i.e. 37.0+40.7+14.8); the full split up is shown in a pie chart in Figure 7.9. Figure 7.10 reports the break-down of the interviewed participants on their favourite option for learning a process. The chart

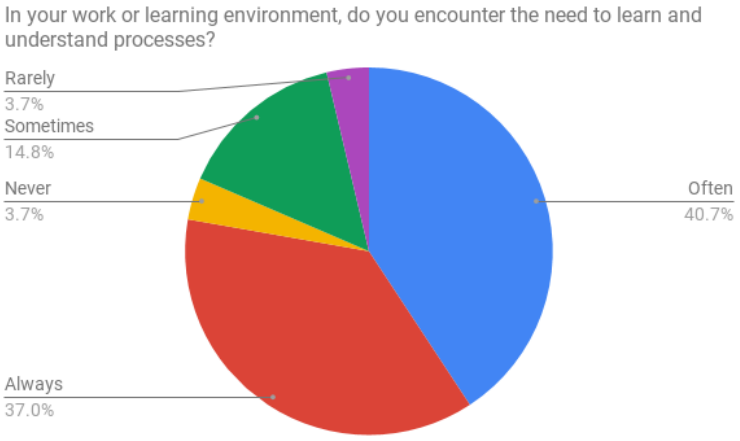


FIGURE 7.9: Answers for the question: *Do you encounter the need to learn and understand processes?*

only refers to participants that studied a process at least once. In our case, out of 27 participants, one response has been that the user has never encountered the need to learn about the process. Hence we consider the rest of the 26 responses for the following analysis, until the end of this section. Among the 26 participants, we found that only around 23% (i.e. six people out 26, as one person, have not encountered the need to learn process) "*Often*" or "*Always*" use simulations for learning the process. This result can be considered somehow expected because, as reported in previous sections, at the time of this writing e-learning systems supporting the *learn-by-doing* paradigm are not so common, yet. Furthermore, out of the 26, 16 participants (61%) "*Often*" or "*Always*" use Text documents for learning about process, and 14 participants (53%) "*Often*" or "*Always*" use Video documents for learning.

### 7.3.2 Inferential Analysis

Now, we will see some inferential analysis focusing on Part 2 of the questionnaire for the 27 responses we got during the study. As discussed in Section 7.2.3, Part 2 of the questionnaire measures the TAM constructs used in this study. When the participants were invited to this study, they would not have been aware of BPMLS. Then the assumption is that if they were to answer this questionnaire before this exercise of using the BPMLS, their choice for the answers would have been neutral. And based on the values we assigned to the questions (see Section 7.2.3) if we were to add the values for the answers- assuming the choice would have been neutral, the mean for each of the

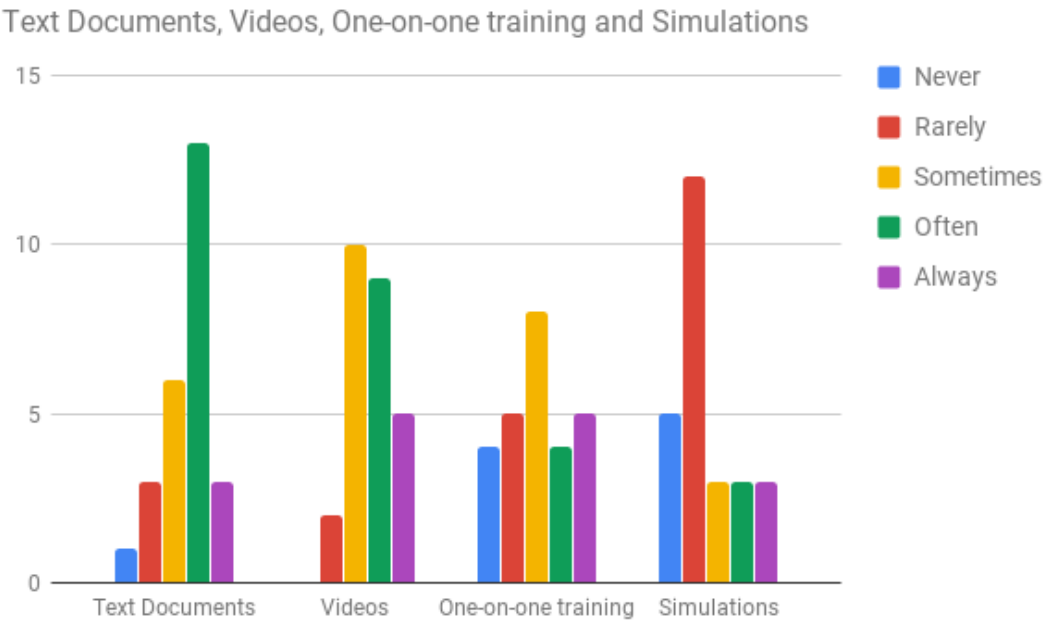


FIGURE 7.10: Answers count for the question: *Please state the frequency with which you use the modalities to learn processes*

TAM constructs would have been 0. We call this as *hypothesized mean*. Now, to know the impact of BPMLS on the user perception, we wanted to know if there is any change in user's perception about the process-driven learning, **after** they have used the BPMLS system. To confirm if there is any change in perception of user's view on BPMLS, we use the well-known statistical approach called One Sample t-test. The One-Sample t-test determines whether the derived sample mean is statistically different from the hypothesized mean. The hypothesis that says that there is no change in the derived sample mean and the hypothesized mean is called as the null hypothesis. The null hypothesis assumes that the difference between the true mean and the comparison value (hypothesized mean) is equal to zero. The purpose of the one sample t-test is to determine if the null hypothesis should be rejected, given the sample data.

To calculate this, first, we derived the mean value for the responses given by each user, categorizing the questions based on the parts (see Section 7.2.3). The calculated means for each of the parts of Section 2 (that corresponds to the TAM variables), per user, is provided in Table 7.4. For each of the TAM constructs, we derived a null hypothesis that corresponds to its hypothesized mean 0. The null hypothesis expects that the user's don't have any change of opinion (neither positive nor negative change), even after using the BPMLS system. The derived null-hypothesis is given in the following:

| Sl. No. | Learner Self Efficacy | Learner Control | Perceived Usefulness | Ease Of Use | Satisfaction | Learner Motivation |
|---|---|---|---|---|---|---|
| 1 | 1.000 | 2.000 | 1.571 | 2.000 | 1.000 | 1.000 |
| 2 | 2.000 | 1.750 | 1.429 | 2.000 | 2.000 | 1.600 |
| 3 | 1.667 | 1.000 | 1.571 | 1.200 | 1.500 | 1.400 |
| 4 | 1.000 | 1.500 | 1.429 | 1.000 | 1.000 | 1.200 |
| 5 | 1.667 | 1.500 | 1.714 | 1.600 | 1.000 | 1.200 |
| 6 | 1.000 | 1.250 | 1.286 | 1.400 | 1.250 | 1.200 |
| 7 | 1.667 | 1.250 | 1.857 | 1.600 | 1.750 | 1.800 |
| 8 | 1.000 | 1.250 | 1.857 | 1.600 | 1.250 | 1.200 |
| 9 | 1.333 | 1.000 | 1.857 | 1.400 | 1.500 | 1.200 |
| 10 | 1.667 | 1.250 | 1.286 | 1.000 | 1.500 | 1.200 |
| 11 | 1.333 | 1.000 | 1.714 | 1.600 | 1.500 | 1.200 |
| 12 | 1.333 | 1.750 | 1.286 | 1.200 | 1.250 | 1.400 |
| 13 | 1.333 | 1.000 | 1.143 | 1.600 | 1.750 | 1.200 |
| 14 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 15 | 1.000 | 1.000 | 1.286 | 1.200 | 1.000 | 1.000 |
| 16 | 1.000 | 1.500 | 2.000 | 2.000 | 1.250 | 1.000 |
| 17 | 1.000 | 1.000 | 1.571 | 1.000 | 1.000 | 1.000 |
| 18 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 19 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 20 | 2.000 | 2.000 | 2.000 | 1.400 | 1.250 | 1.600 |
| 21 | 1.000 | 1.000 | 1.000 | 1.000 | 2.000 | 1.000 |
| 22 | 1.333 | 1.000 | 1.286 | 1.400 | 1.250 | 1.400 |
| 23 | 1.000 | 1.000 | 1.286 | 1.200 | 1.500 | 1.200 |
| 24 | 1.333 | 1.250 | 1.571 | 1.200 | 1.750 | 1.600 |
| 25 | 1.667 | 1.750 | 1.571 | 1.600 | 1.500 | 1.200 |
| 26 | 1.000 | 1.000 | 1.143 | 1.200 | 1.500 | 1.200 |
| 27 | 1.667 | 1.000 | 1.286 | 1.000 | 1.000 | 1.000 |

TABLE 7.4: Calculated Mean Values for each Part of Section 2 of the Questionnaire, per User

NH1 Users don't have any opinion on Learner Self-efficacy of BPMLS

NH2 Users don't have any opinion on Learner Control of BPMLS

NH3 Users don't have any opinion on Perceived Usefulness of BPMLS

NH4 Users don't have any opinion on the Ease of Use of BPMLS

NH5 Users don't have any opinion the Satisfaction of using BPMLS

NH6 Users don't have any opinion on Learner's Motivation for using the BPMLS

We tested these null hypothesis against the derived mean given in Table 7.4, using the One Sample t-test. The test gives a p-value for the null hypothesis. **If the p-value is greater than 0.05 then we accept the null hypothesis; if the p-value is less**

```
> t.test(BPMLS$LearnerSelfEfficacy, mu=0)

        One Sample t-test

data:  BPMLS$LearnerSelfEfficacy
t = 19.953, df = 26, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 1.162754 1.429838
sample estimates:
mean of x
 1.296296
```

FIGURE 7.11: Code Snippet from R-Studio

| **Null Hypothesis** | **P-Value** | **Conclusion** |
|---|---|---|
| NH1 | $<$ 2.2e-16 | Reject |
| NH2 | $<$ 2.2e-16 | Reject |
| NH3 | $<$ 2.2e-16 | Reject |
| NH4 | $<$ 2.2e-16 | Reject |
| NH5 | $<$ 2.2e-16 | Reject |
| NH6 | $<$ 2.2e-16 | Reject |

TABLE 7.5: One Sample t-test: Null-hypothesis, P-value and Conclusion

**than 0.05 then we reject the null hypothesis (this is the assumption that the confidence interval is 95%).** We used a Software called R-Studio [166] to test the null-hypothesis and derive the p-value. A code snippet from R-Studio to run the One Sample t-test for one of the TAM variable (Learner Self-Efficacy), is shown in Figure 7.11. The results from the One Sample t-test for the null hypothesis is given in Table 7.5. From the result, we can conclude that after using BPMLS, the user did express some opinion about the BPMLS that is not neutral.

Now, the null hypothesis test only verifies whether the derived sample means is statistically different from the hypothesized mean. It does not explicitly verify if the difference is positive or negative. We can test the resultant mean against our hypothesis defined in Section 7.2.2, using a kind of One Sample t-test called the alternative hypothesis. The alternative hypothesis is of three types depending on the goal of the test. If the goal is to measure any difference, regardless of direction, a two-tailed hypothesis is used. If the direction of the difference between the sample means and the comparison value matters,

```
> t.test(BPMLS$LearnerSelfEfficacy, mu=0, alternative = "greater")

        One Sample t-test

data:  BPMLS$LearnerSelfEfficacy
t = 19.953, df = 26, p-value < 2.2e-16
alternative hypothesis: true mean is greater than 0
95 percent confidence interval:
 1.185487      Inf
sample estimates:
mean of x
 1.296296
```

FIGURE 7.12: R Command and output for Upper-tail One sample T-Test

| **Null Hypothesis** | **Alternative Hypothesis** | **P-Value** | **Conclusion** |
|---|---|---|---|
| NH1 | H1 | $<$ 2.2e-16 | Accept H1 |
| NH2 | H2 | $<$ 2.2e-16 | Accept H2 |
| NH3 | H3 | $<$ 2.2e-16 | Accept H3 |
| NH4 | H4 | $<$ 2.2e-16 | Accept H4 |
| NH5 | H5 | $<$ 2.2e-16 | Accept H5 |
| NH6 | H6 | $<$ 2.2e-16 | Accept H6 |

TABLE 7.6: Upper-tail Alternative Hypothesis One Sample T-test

either an upper-tailed or lower-tailed hypothesis is used. The upper-tail alternative hypothesis assumes that the derived mean of the sample is greater than the hypothesized mean. We will use the upper-tail alternative hypothesis because we would like to test the positive effect of BPMLS. In the One Sample t-test approach, even for the alternative hypothesis, we always test the null hypothesis. If the resulting p-value is greater than 0.05 then we accept the null hypothesis; if the p-value is less than 0.05, then we reject the null hypothesis in favour of the alternative hypothesis. The code snippet from R-Studio to run the Upper-tail Alternative Hypothesis One Sample t-test for one of the TAM variable (Learner Self-Efficacy), is shown in Figure 7.12. The Null hypothesis, Alternative Hypothesis, p-value calculated and the conclusion we derived using the upper-tail one sample t-test is given in Table 7.6. The resulting mean derived from the user response for each of the TAM constructs is proved to be positive. Based on this we can infer that the participants have a positive opinion when it comes to the proposed process-driven learning approach using BPMLS.

Table 7.7 presents the mean and variance of the values provided by the users for each of

| TAM Variable | Mean | Variance |
|---|---|---|
| Learner Self-efficacy | 1.296 | 0.114 |
| Learner Control | 1.259 | 0.113 |
| Perceived Usefulness | 1.444 | 0.096 |
| Ease Of Use | 1.348 | 0.106 |
| Satisfaction | 1.343 | 0.102 |
| Learner Motivation | 1.222 | 0.050 |

TABLE 7.7: TAM Variables: Descriptive Statistics

the questions in Part 2 of the Questionnaire. From Table 7.7, it can be noted that the mean of all the TAM constructs is greater than one, which means that the Users positively agree to the point of view in each of the categories addressed in the questionnaire. The low variance of the data set reveals that participants had similar opinions about their training experience with BPMLS.

The highest mean that we got among the TAM variables are for the Perceived Usefulness. This is encouraging because the Perceived Usefulness exerts the major influence on the actual use of the system [6]. It shows that the participants can see the usefulness of BPMLS for their learning purposes. In conclusion, this pilot study has been encouraging to us. Many users of the system have felt positive about BPMLS. This initial study has also given us good practical hints on the need of the users, and what to expect from them in a process-driven learning system such as our BPMLS.

## 7.4 Threats to Validity

The validity of a study indicates the trustworthiness of the results observed. It indicates to what extent the results are true and not biased by the researchers' subjective point of view [167]. It is important to consider the threats to the validity of the study and the results [168]. In the following, we discuss the different threats to the validity for our validation results.

### 7.4.1 Threats to Construct Validity

Threats to construct concern the assumptions or decisions that have been considered during the definition or the set-up of the experiment that may potentially impact on the final results. We identify the following threats to construct validity:

**Choice of Case Studies:** The validation involved just two generic case studies. Though the case studies were based on the real-world problems, they were simplified and were generalized to cater to a larger crowd. So the case studies might not directly reflect the problems that the users of the study face in their workplace. We tried to reduce this threat through the sampling-technique we employed to select the users. The sampling technique should make sure that the users of the system have some general ideas about the case study. Yet, they might affect the validation of the system.

**Low statistical power:** Low statistical power occurs when the sample size of the study is too small given other factors. The sample size of this study is 27. Though the number is not large, we did monitor the responses from the users to see if they really answered the survey questions only after learning from the system. Except for 6 people, all the other users watched the video and took up one of the two learning activities which are the requirements to consider their answers. This, we believe, has increased our confidence in their response especially when the users had no idea what they will do with BPMLS, before watching the video. In future, to overcome this, we plan to extend this study to more people.

**Evaluation Metrics:** Among the others, the evaluation is influenced by the kind of questions that we selected for ex-post questionnaire discussed in Section 7.2.3. We tried to adopt standard questions from the literature, yet customising them to map them to the TAM variables may be biased due to the non-availability of the ready-made standards to our specific study. Another threat is the restriction of range. We chose the Likert scale for the survey questions. This might reduce the power of the experiment as the respondents are forced to only choose between the options we gave them. However, we tried to minimize the error from this threat by using standard questions, and standard measurement techniques to draw the conclusions. One more threat is the instrumentality. In this test we focus on testing the BPMLS, there is a bias in showing only our system for the validation. To remove this threat we wish to conduct a comparison study in future of BPMLS with similar systems.

### 7.4.2 Threats to internal validity

This category refers to the extent to which the results obtained are a function of the systematic observation/manipulation of the variables in the study.

**Experiment Effect:** The study was designed to be self-contained so that videos and other visual hints and aids were provided during the learning session for the users. This was based on the difficulties that the experimenter foresaw during the study design. This might bias the users towards favouring the system.

**Testing Effects:** We only took the ex-post response from the users without any ex-ante questionnaires. This way we might not be able to exactly identify the impact of the usage of the system. We are aware that this may affect our validation, but it was the best we were able to afford with our time and effort constraints. Besides, ex-post questionnaires exploited answers based on self-assessment. These collected answers were inherently subjective and this may influence the validity of conclusions. We try to remove the bias to compare the results with the assessment to determine whether the user really used the system before answering the questions. Still, this will not totally eliminate the subjective bias of the user study.

**Subject effects:** Subject effects (or participant reactivity) occur when the way that participants behave in an experiment is different from the way that they would normally behave. Subject effects are likely to be greater in staged experiments where it is particularly obvious that subjects are part of an experiment (e.g., laboratory settings), compared with less staged environments where participants know that they are part of an experiment. In our case, the participants know apriori that they are part of an experiment though they do not know the nature of the experiment.

### 7.4.3 Threats to external validity

This category refers to the extent to which the results of our study can be generalized, and how the threats affect the generality of the results. We identify the following threats to external validity:

**Selection Bias:** Selection bias happens when the sample in the study does not represent the actual population. Samples may not be the perfect representation of the population, even when the samples are carefully chosen. As a result, when other researchers try to replicate a study, it is possible that the samples are not similar, and different results are attained. Selection bias may limit the generalizability of results to a wider population.

**Generalisation and constructs:** Generalisation also depends on how we defined the constructs and variables we wanted to measure. We designed the constructs of the experiment that we want to measure based on the concept we are interested in. In this validation we wanted to understand the effectiveness of process-driven learning system from the learner's point of view, using our BPMLS system. This was a single construct measurement, and the problem that we face when viewing this construct in such a simple way is that we do not know the potential effect that this construct has when introducing other variables to the construct.

**Experimentation Environment:** The study for this experiment involves people to log in to BPMLS which was provided as an online system, and the users are at their liberty to study based on their availability. This may not be valid in a real-time scenario where the users maybe constrained by their office environment or have time constraints.

**Complexity of the Case Study:** The case study that we took maybe relatively simple, and may not represent the actual complex processes that an employee face in his real-time work environment. Though we informed the users about the nature of this study, it is difficult to find out how the results may vary in actual scenarios without studying them.

# Chapter 8

# Conclusions and Future Work

As major obstacles of e-Learning technologies are solved by efficient hardware, robust software and fast internet connections, integration of learning as part of the organizational process is still facing lots of hindrances [169]. With the pervasive penetration of ICT in business organizations, the BPMS is today among the most effective technologies to make the integration of ICT and work procedures easier and more efficient [16]. Similar claim cannot be done for e-learning systems developed for the workplace. Still today, there is high demand for innovative approaches to workplace learning. In this thesis, we proposed that BPMS can be extended beyond its original purpose and used as process-driven workplace learning systems. Towards this goal, our research questions were: **How can we provide tools and methodologies for process-driven learning approach in designing of workplace e-learning systems? How can we effectively use BPMS while providing solutions for the process-driven learning approach?**. Since our research falls at the intersection between two areas of research, namely BPM and Process-Driven Learning, in Chapter 3 we included a brief background to both BPM and Process-driven Learning that is needed for understanding the context of our thesis.

To grasp the current state-of-the-art in this research area, in Chapter 4 we conducted a systematic survey. The study covered a total of 41 articles that are related to our thesis. The process of conducting the systematic survey brought out many aspects of the current state of art. Through the systematic search, we were able to include also some European Union Projects, which started with the similar research objective such as ours [105, 122]. Besides, during the systematic search, we were also able to understand the missing gap

of the current approach to pusiness process-driven learning. For instance, only 4 out of 41 articles, which was less than 1% of entire articles, propose to enhance business process models with learning models. Most of the studies use BPMS as a graphical tool for design of learning scenarios, or as an execution engine to execute the learning scenarios. None of the articles goes beyond using the business process systems modeling and/or execution of learning scenarios. Likewise, the current enhancement to BPMN (e.g., BPMN.2.0) is rarely used in this research context. Such results from our mapping study will have implications both for the researchers who are planning to conduct new research in the intersection area of business process and e-learning as well as the practitioners who are looking for process-oriented e-learning solutions for the workplace.

From the principal findings of Chapter 4, we realized that the best way to integrate the learning process and the business process would be to define a learning model that complements and enhances business process model for learning purposes. Based on this need we proposed a conceptual model of our Learning Path Specification for Business Process Models. We modified an already available generic Learning Path Specification to suite our requirement of Learning Process Models for Business Process Models. Along with a graphical representation of the conceptual Learning Path specification, we provided a formal definitions for our Learning Path Specification and discussed how it is related to the process model that we use in this thesis- BPMN. The formal methods help us in the definition and implementation of our proposed process-driven learning system called the BPMLS.

The technical definitions described in Chapter 5 provide a foundation for researchers and developers who wish to develop a workplace e-learning system using a process-driven approach. In Chapter 6, we discussed further details of our proposed BPMLS: the phases of BPMLS and its high-level architecture. BPMLS offers an integrated approach for BPM and LPM. Though, BPM and LPM have a different point of focus; they can represent potential linkage when it comes to workplace e-learning. The business process can provide the contextual information necessary to identify the learning scenarios that are meaningful for the organizational as well as individual goals [132]. By aligning learning activities to business processes, as well as by structuring the learning content based on the business context, our approach allows for a systematic end-to-end development of e-learning systems with the added advantage of remaining as closely aligned to the business needs as possible. The integration of BPM and LPM is made possible by our

proposed Learning Path Specification, and the BPMLS that uses it. We also provided the architecture of the BPMLS and the various high-level components that are part of BPMLS.

In Chapter 7, we explained in detail about the prototype we implemented based on the specification of BPMLS architecture. The BPMLS prototype that we developed is available as Open Source for other researchers and developers to use and to get a deeper understanding of the system. [1] In the same Chapter 7, we present a pilot study to evaluate the prototype of BPMLS. BPMLS is seen as both a methodology and technology with a suite of software. Detailed evaluation of BPMLS needs a certain maturity in this field to understand its shortfalls and correct them. A comprehensive evaluation needs some time to be completed, hence validating the methodology now, within the context of this thesis, is not possible. However, we can evaluate how well the users accept BPMLS as a technology for process-driven learning. We decided to use the TAM model to have an evidence-based understanding on how users receive BPMLS as a new technology for learning. We did a pilot study and evaluated the TAM variables derived from the user's feedback for seeing how well the BPMLS is accepted among them. The users positively agree to each of the TAM constructs that directly affects the technology acceptance of BPMLS. The highest value for acceptance that we got among the TAM variables is for the Perceived Usefulness. This result is encouraging because the Perceived Usefulness exerts the major influence on the actual use of the system [6]. It shows that the participants can see the value of BPMLS for their learning purposes. This initial study has also given us good practical hints on the need for the users, and what to expect from them in a process-driven learning system such as our BPMLS.

In summary, the scope of our thesis progressed step-by-step. From providing the rationale for the need for the process-driven learning systems, we conducted a systematic research on the current trend on business process-driven e-learning. From proposing to enhance the business process models with learning models, we used them in our proposed BPMLS. From implementing a prototype of the BPMLS, we evaluated the technology acceptance of BPMLS. At the end of these steps, we provided an evidence-based, new approach to workplace e-learning. Now, we can conclude that the methods proposed in this thesis can be expected to contribute to the new direction in the development and integration of learning in the organizations.

[1] https://github.com/venkatapathy/bpmls-framework

While conducting our research, we also have identified many opportunities for future work. In the short-term, we would like to extend the pilot study that we carried out to understand the acceptance of BPMLS with more users from diverse groups. We also would like to see if we can implement more case studies tailored to the actual learning need of the users. We would also like to implement a modeling tool that will help integrate the design and implementation of the BPM and LPM. In the long-term, we would like to see how to incorporate the competencies to our model. This way, BPMLS can be used to map the profiles of employees and the organizational need for the competencies for those profiles. Over the long-term period, we hope to see BPMLS making a presence in the corporate learning culture both as a methodology and technology, and we hope that this will facilitate achieving knowledgeable employees and an efficient work-force, and productive organizations. One more area of research that we would like to focus in the future is on how we can derive the learning scenarios for the learning path specification based on already available business cases and how we can use the process mining techniques to assist in this regard.

# Appendix A

# XSD Schemas

## A.1 XSD Schema for the Learning Path Specification

Listing A.1 gives the XSD schema for the Learning Path Specification as defined in Section 5.2. The schema can also be downloaded from the following link: https://github.com/venkatapathy/bpmls-framework/tree/master/backend/src/main/resources/schema/LearningPath.xsd

```
1  <xs:schema targetNamespace="http://www.isti.cnr.it/research/unit.php?unit=SEDC" xmlns:xs="http:
     //www.w3.org/2001/XMLSchema">
2  <xs:element name="LearningPath">
3    <xs:complexType>
4      <xs:sequence>
5        <xs:element type="xs:string" name="learningcontexthint" maxOccurs="1" minOccurs="0"/>
6        <xs:element name="Prerequesties">
7          <xs:complexType>
8            <xs:sequence>
9              <xs:element name="PreLearningPath" maxOccurs="unbounded" minOccurs="0">
10               <xs:complexType>
11                 <xs:simpleContent>
12                   <xs:extension base="xs:string">
13                     <xs:attribute type="xs:string" name="refid" use="optional"/>
14                   </xs:extension>
15                 </xs:simpleContent>
16               </xs:complexType>
17             </xs:element>
18           </xs:sequence>
19         </xs:complexType>
20       </xs:element>
```

```
21        <xs:element name="Competencies">
22          <xs:complexType>
23            <xs:sequence>
24              <xs:element name="Competency" maxOccurs="unbounded" minOccurs="0">
25                <xs:complexType>
26                  <xs:simpleContent>
27                    <xs:extension base="xs:string">
28                      <xs:attribute type="xs:string" name="id" use="optional"/>
29                      <xs:attribute type="xs:string" name="name" use="optional"/>
30                      <xs:attribute type="xs:string" name="url" use="optional"/>
31                    </xs:extension>
32                  </xs:simpleContent>
33                </xs:complexType>
34              </xs:element>
35            </xs:sequence>
36          </xs:complexType>
37        </xs:element>
38        <xs:element name="LearningActivities">
39          <xs:complexType>
40            <xs:sequence>
41              <xs:element name="LearningActivity" maxOccurs="unbounded" minOccurs="0">
42                <xs:complexType>
43                  <xs:simpleContent>
44                    <xs:extension base="xs:string">
45                      <xs:attribute type="xs:string" name="id" use="optional"/>
46                      <xs:attribute type="xs:string" name="bpmn_activityid" use="optional"/>
47                      <xs:attribute type="xs:string" name="competencyid" use="optional"/>
48                      <xs:attribute type="xs:string" name="bpmn_activitylabel" use="optional"/>
49                    </xs:extension>
50                  </xs:simpleContent>
51                </xs:complexType>
52              </xs:element>
53            </xs:sequence>
54          </xs:complexType>
55        </xs:element>
56        <xs:element name="LearningGoals">
57          <xs:complexType>
58            <xs:sequence>
59              <xs:element name="LearningGoal" maxOccurs="unbounded" minOccurs="0">
60                <xs:complexType>
61                  <xs:sequence>
62                    <xs:element name="LearningScenarios">
63                      <xs:complexType>
64                        <xs:sequence>
65                          <xs:element name="LearningScenario" maxOccurs="unbounded" minOccurs="0">
66                            <xs:complexType>
67                              <xs:simpleContent>
68                                <xs:extension base="xs:string">
```

```
                                    <xs:attribute type="xs:string" name="lsid" use="optional"/>
                                  </xs:extension>
                                </xs:simpleContent>
                              </xs:complexType>
                            </xs:element>
                          </xs:sequence>
                        </xs:complexType>
                      </xs:element>
                      <xs:element type="xs:string" name="KPIs"/>
                    </xs:sequence>
                    <xs:attribute type="xs:string" name="id" use="optional"/>
                  </xs:complexType>
                </xs:element>
              </xs:sequence>
            </xs:complexType>
          </xs:element>
        </xs:sequence>
        <xs:attribute type="xs:string" name="competencyid"/>
        <xs:attribute type="xs:string" name="id"/>
        <xs:attribute type="xs:string" name="name"/>
        <xs:attribute type="xs:string" name="processid"/>
      </xs:complexType>
    </xs:element>
</xs:schema>

```

Listing A.1: XSD Schema for the Learning Path Specification

## A.2 XSD Schema for Learning Scenarios

Listing A.2 gives the XSD schema for the Learning Scenarios that will be referred in the Learning Path Specification. The schema can also be downloaded from the following link: https://github.com/venkatapathy/bpmls-framework/tree/master/backend/src/main/resources/schema/LearninScenario.xsd

```
<xs:schema targetNamespace="http://www.isti.cnr.it/research/unit.php?unit=SEDC" xmlns:xs="http://www.w3.org/2001/XMLSchema">
<xs:element name="LearningScenario">
  <xs:complexType>
    <xs:sequence>
      <xs:element type="xs:string" name="scenariocontexthint"/>
      <xs:element name="Trace">
        <xs:complexType>
```

```
8           <xs:sequence>
9             <xs:element name="vertex" maxOccurs="unbounded" minOccurs="0">
10              <xs:complexType>
11                <xs:simpleContent>
12                  <xs:extension base="xs:string">
13                    <xs:attribute type="xs:string" name="id" use="optional"/>
14                    <xs:attribute type="xs:string" name="bpmn_activityid" use="optional"/>
15                    <xs:attribute type="xs:string" name="bpmn_activitylabel" use="optional"/>
16                  </xs:extension>
17                </xs:simpleContent>
18              </xs:complexType>
19            </xs:element>
20          </xs:sequence>
21        </xs:complexType>
22      </xs:element>
23      <xs:element name="TargetVertexes">
24        <xs:complexType>
25          <xs:sequence>
26            <xs:element name="vertex" maxOccurs="unbounded" minOccurs="1">
27              <xs:complexType>
28                <xs:sequence>
29                  <xs:element type="xs:string" name="activitycontexthint"/>
30                </xs:sequence>
31                <xs:attribute type="xs:string" name="id" use="optional"/>
32                <xs:attribute type="xs:string" name="bpmn_activityid" use="optional"/>
33                <xs:attribute type="xs:string" name="bpmn_activitylabel" use="optional"/>
34              </xs:complexType>
35            </xs:element>
36          </xs:sequence>
37        </xs:complexType>
38      </xs:element>
39      <xs:element name="InitialValuation">
40        <xs:complexType>
41          <xs:sequence>
42            <xs:element name="DataObject" maxOccurs="unbounded" minOccurs="0">
43              <xs:complexType>
44                <xs:simpleContent>
45                  <xs:extension base="xs:string">
46                    <xs:attribute type="xs:string" name="id" use="optional"/>
47                    <xs:attribute type="xs:string" name="bpmn_camundaid" use="optional"/>
48                    <xs:attribute type="xs:string" name="bpmn_dolabel" use="optional"/>
49                  </xs:extension>
50                </xs:simpleContent>
51              </xs:complexType>
52            </xs:element>
53          </xs:sequence>
54        </xs:complexType>
55      </xs:element>
```

```
56        <xs:element name="ValuationOracle" maxOccurs="1" minOccurs="0">
57          <xs:complexType>
58            <xs:sequence>
59              <xs:element name="ValuationFunction" maxOccurs="unbounded" minOccurs="1">
60                <xs:complexType>
61                  <xs:sequence>
62                    <xs:element name="DataObject" maxOccurs="unbounded" minOccurs="1">
63                      <xs:complexType>
64                        <xs:sequence>
65                          <xs:element name="ExpectedValue" maxOccurs="1" minOccurs="0">
66                            <xs:complexType>
67                              <xs:simpleContent>
68                                <xs:extension base="xs:string">
69                                  <xs:attribute type="xs:string" name="id"/>
70                                </xs:extension>
71                              </xs:simpleContent>
72                            </xs:complexType>
73                          </xs:element>
74                          <xs:element name="DoHint" maxOccurs="1" minOccurs="0">
75                            <xs:complexType>
76                              <xs:simpleContent>
77                                <xs:extension base="xs:string">
78                                  <xs:attribute type="xs:string" name="id"/>
79                                </xs:extension>
80                              </xs:simpleContent>
81                            </xs:complexType>
82                          </xs:element>
83                        </xs:sequence>
84                        <xs:attribute type="xs:string" name="id"/>
85                        <xs:attribute type="xs:string" name="bpmn_camundaid"/>
86                        <xs:attribute type="xs:string" name="bpmn_dolabel"/>
87                      </xs:complexType>
88                    </xs:element>
89                  </xs:sequence>
90                  <xs:attribute type="xs:string" name="id"/>
91                  <xs:attribute type="xs:string" name="bpmn_activityid"/>
92                  <xs:attribute type="xs:string" name="bpmn_activitylabel"/>
93                </xs:complexType>
94              </xs:element>
95            </xs:sequence>
96          </xs:complexType>
97        </xs:element>
98      </xs:sequence>
99      <xs:attribute type="xs:string" name="id"/>
100     <xs:attribute type="xs:string" name="name"/>
101     <xs:attribute type="xs:string" name="bpmn_processlabel"/>
102     <xs:attribute type="xs:string" name="bpmn_processid"/>
103   </xs:complexType>
```

```
104   </xs:element>
105 </xs:schema>
106
107
```

LISTING A.2: XSD Schema for Learning Scenarios using in the Learning Path Specification Model

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