A HYBRID E-LEARNING FRAMEWORK: PROCESS-BASED, SEMANTICALLY-ENRICHED AND SERVICE-ORIENTED

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Abstract

Despite the recent innovations in e-Learning, much development is needed to ensure better learning experience for everyone and bridge the research gap in the current state of the art e-Learning artefacts. Contemporary e-learning artefacts possess various limitations as follows. First, they offer inadequate variations of adaptivity, since their recommendations are limited to e-learning resources, peers or communities. Second, they are often overwhelmed with technology at the expense of proper pedagogy and learning theories underpinning e-learning practices. Third, they do not comprehensively capture the e-learning experiences as their focus shifts to e-learning activities instead of e-learning processes. In reality, learning is a complex process that includes various activities and interactions between different roles to achieve certain gaols in a continuously evolving environment. Fourth, they tend more towards legacy systems and lack the agility and flexibility in their structure and design.

To respond to the above limitations, this research aims at investigating the effectiveness of combining three advanced technologies (i.e., Business Process Modelling and Enactment, Semantics and Service Oriented Computing – SOC–) with learning pedagogy in order to enhance the e-learner experience. The key design artefact of this research is the development of the HeLPS e-Learning Framework – Hybrid e-Learning Framework that is Process-based, Semantically-enriched and Service Oriented-enabled. In this framework, a generic e-learning process has been developed bottom-up based on surveying a wide range of e-learning models (i.e., practical artefacts) and their underpinning pedagogies/concepts (i.e., theories); and then forming a generic e-learning process. Furthermore, an e-Learning Meta-Model has been developed in order to capture the semantics of e-learning domain and its processes. Such processes have been formally modelled and dynamically enacted using a service-oriented enabled architecture. This framework has been evaluated using a concern-based evaluation employing both static and dynamic approaches. The HeLPS e-Learning Framework along with its components have been evaluated by applying a data-driven approach and artificially-constructed case study to check its effectiveness in capturing the semantics, enriching e-learning processes and deriving services that can enhance the e-learner experience. Results revealed the effectiveness of combining the above-mentioned technologies in order to enhance the e-learner experience. Also, further research directions have been suggested.

This research contributes to enhancing the e-learner experience by making the e-learning artefacts driven by pedagogy and informed by the latest technologies. One major novel contribution of this research is the introduction of a layered architectural framework (i.e., HeLPS) that combines business process modelling and enactment, semantics and SOC together. Another novel contribution is adopting the process-based approach in e-learning domain through: identifying these processes and developing a generic business process model from a set of related e-learning business process models that have the same goals and associated objectives. A third key contribution is the development of the e-Learning Meta-Model, which captures a high-abstract view of learning domain and encapsulates various domain rules using the Semantic Web Rule Language. Additional contribution is promoting the utilisation of Service-Orientation in e-learning through developing a semantically-enriched approach to identify and discover web services from e-learning business process models. Fifth, e-Learner Experience Model (eLEM) and e-Learning Capability Maturity Model (eLCMM) have been developed, where the former aims at identifying and quantifying the e-learner experience and the latter represents a well-defined evolutionary plateau towards achieving a mature e-learning process from a technological perspective. Both models have been combined with a new developed data-driven Validation and Verification Model to develop a Concern-based Evaluation Approach for e-Learning artefacts, which is considered as another contribution.

To my mother Amina and my father Khamis

To my wife Alaa and my children Mohammed, Layan, and Dania

To my brothers Raed and Mahmoud and sisters Reema and Safaa

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Glossary

A

Adaptive Hypermedia is the opposite of 'one-size-fits-all' approach used in the development of hypermedia systems. Adaptive hypermedia systems construct a model through interaction with the user with the purpose of adapting to the needs of that user.

Application Profiles refers to schemas which consist of data elements drawn from one or more namespaces, combined together by implementers and optimised for a particular local application.

Assessment refers to the process where instructors set specific tasks to judge the extent to which learners can demonstrate learning outcomes.

Artefacts refer to designed frameworks, models or other arrangements that are designed to fulfil a purpose or solve a problem. This arrangement could be software system, tool, theoretical framework, pedagogical model, or a combination of them.

B

Business Process is a process involves activities which are performed by people and/or machine working in collaborative groups to achieve specific business goals.

Behavioural Learning Theory which considers learner's minds as a black box while the focus always goes to the changes in learner's behaviour.

Business Process Enactment refers to the instantiation and execution of business processes using computing facilities.

C:

Cloud Computing (CC) is a large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet.

Cloud Learning Environment (CLE) is a learning facility enabled by learning services on the cloud. The users of cloud learning services are academics or learners, who share the same privileges, including control, choice, and sharing of content on these services.

Cognitive Learning Theory emphasis on modelling the processes of interpreting and constructing meaning inside the mind.

Constructivist Learning Theory focuses on how previous learner knowledge is used to either assimilate or accommodate new information into conceptual framework.

Cognitive Perspective that sees learning as a way to model the processes of interpreting and constructing meaning, and knowledge acquisition is the outcome of an interaction between previous learner structure for understanding and new experiences.

Completeness a response is specified for every possible input and input sequence, with respect to a set of criteria.

Consistency the degree of freedom from contradiction among the components of the system or its testing results.

D:

Dynamic Validation is the checking the correctness of the system semantics.

E:

e-Learning describes the use of innovative information and communication technologies (ICT) to support learning and its associated activities such as assessment and feedback.

e-Learning Model describes where technology plays a specific role in supporting learning.

e-Learning Meta-Model a meta-model that describes the e-learning domain, abstracts from technical details and can lead to different e-learning models.

Evaluation refers to judging how effective the design of the learning environment is for supporting learning.

I:

Interoperability refers to the ability of two or more systems or components to exchange information and to use the information that has been exchanged.

IEEE LOM is a multi-part standard that specifies a conceptual data schema that defines the structure of a metadata instance for a Learning Object, to describe the characteristic of Learning Object.

Intra-contextual reusability refers to the use of learning objects several times in similar contexts.

Inter-contextual reusability refers to the use of learning objects in domains other than that for which they were designed.

L:

Learning is the act or process by which behavioural change, knowledge, skills and attitudes are acquired. It is also used to refer to how experience produces long-lasting effects in the way that behaviour changes with variation in the environment.

Learning Theory provides empirically-based investigations of the variables which influence the learning process, and provide explanations of the ways in which that influence occurs.

Learner/e-Learner An actor who gains new knowledge and skills through interacting with his or her environment, mainly students.

Learning/e-Learning process is the acquisition of knowledge, behaviours, skills, values, preferences or understanding through interacting with the learning environment.

Learner/e-Learner behaviour is the sum of the interaction activities between learners/e-learners and the internet environment under the guidance of a motivation in order to obtain planned results.

P:

Pedagogy refers to the processes, experiences, contexts, outcomes and relationships of teaching and learning in higher education.

Pedagogical model usually aligns with a particular pedagogical approach or learning theory.

Pedagogical framework describes the broad principles through which theory is applied to learning and teaching practice.

Personal Learning Environment (PLE) is a facility for an individual to access, aggregate, configure and manipulate digital artefacts of their ongoing learning experiences.

R:

Reusability for LO is the property that allows Learning Objects to be used more than once in multiple instructional contexts, whether to be part of a larger Learning Object, or to be part of a course.

S:

Self-Regulated Learning SRL/Self-Directed Learning is a process in which learners/e-learners take the initiative, with or without the help of others, to diagnose their learning needs, formulate learning goals, identify resources for learning, select and implement learning strategies and evaluate their learning outcomes.

Static Verification and Validation techniques are concerned with the analysis and checking of software system representations, such as the requirements document, design diagrams and the program source code.

U:

Undecidability of a particular construct refers to the wide range of values of a certain construct so that they cannot be listed in one set.

V:

Validity refers to the correct value/behaviour (i.e., the actual behaviour is similar to the expected/specified behaviour) of a software system.

Acronyms

BPMN: Business Process Modelling and Notations

BPEL: Business Process Execution Language

CLE: Cloud Learning Environment

eLEM: e-Learner Experience Model

eLCMM: e-Learning Capability Maturity Model

eLMM: e-Learning Meta-Model

EL/ELT: Experiential Learning/ Experiential Learning Theory

HeLPS: Hybrid e-Learning Framework that is Process-based, Semantically-enriched, and Service-oriented

ICT: Information and Communication Technology

LMS: Learning Management Systems

LBD: Learning by Doing

MDE/MDA: Model Driven Engineering/Architecture

MOOCs: Massive Open Online Courses

Moodle: Modular Object Oriented Dynamic Learning Environment

OER: Open Educational Resources

OWL: Web Ontology Language

PLE: Personal Learning Environment

SME: Subject Matter Expert

SOA/SOC: Service Oriented Architecture/ Service Oriented Computing

SRL/SDL: Self-Regulated Learning/Self-Directed Learning

TEL: Technology-Enhanced Learning

UDDI: Universal Description, Discovery, and Integration

UML: Unified Modelling Language

VLE: Virtual Learning Environment

V&V: Validation and Verification

WBL: Web-Based Learning

WSDL: Web Service Description Logic

XML: eXtensible Markup Language

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Chapter 1:

Introduction

1.1 Background and Motivation

Learning is one of the very oldest human activities that have been practiced since the dawn of humankind. Throughout the course of history, learning has been approached in different ways according to surrounds environments, goals, available technologies and other contextual inputs. Learning took different forms, such as traditional schools/classrooms, learning discovery, e-learning and blended learning. A variety of terms, with different definitions, have been used in relation to utilising technology in learning such as e-Learning, Technology-Enhanced Learning (TEL) and Web-Based Learning (WBL). Similarly, tools used for this utilisation vary in their goals, scope, adopted strategies, etc. Examples of such tools include: Learning Management System (LMS), Virtual Learning Environment (VLE) and Adaptive e-Learning Systems. For the context of this research, e-Learning will be used to describe the use of innovative information and communication technologies (ICT) to support learning (Hammad, Odeh and Khan, 2013).

Over the last two decades, a substantial escalation in the use of technology in different domains such as e-learning, e-business and e-health have been evolved (Sun *et al.*, 2008). However, the effective application of technology in learning, which is a complex cognitive domain that is not totally discovered by scientists and psychologists, is more challenging (Wenger *et al.*, 2013). For instance, Wenger et al (Wenger, McDermott and Snyder, 2002) explained the complexity of learning as it cannot be reduced to a simple process of knowledge transmission. Learning is an inherent dimension of everyday life and is fundamentally a social process. Therefore, learning is a journey across various landscape of practices/contexts. Additionally, Dewey (Dewey, 1897) affirms the social aspect of learning. Such different conceptualisations of learning make the improvements of learning processes by using technology more challenging.

This alludes to the challenges faced to enhance learning through utilising technology. Therefore, critical investigations ought to be carried out to thoroughly understand learning and how to improve it first, and then introduce technology to enhance the learning process and increase its effectiveness. More specific, developing and effective e-learning artefact is challenging because of: (i) *the complexity of the target domain* (i.e., the learning domain), it is an implicit phenomenon where investigators try to explain external actions based on their assumptions, experiments or theories; (ii) the *inter-domain complexity* where it is challenging to draw a link between the learning domain and the technology domain. For instance, the proliferation of new or relatively new e-learning models such as the Connectivism and Community of Practices (Bell, 2011) has been influenced by the development of new technologies that facilitate better interactions, encourage self-regulated learning and offer a massive number of resources. Moreover, the e-learning is context-dependent, as it can perform and function differently based on the context. Therefore, there is a need to capture the continuously evolving contextual parameters and acting upon them to effectively meet the requirements of stakeholders.

1.2 The Research Problem

There exist a number of e-learning frameworks, models, tools, processes, and theories; however, there is a lack of research to investigate the suitability of different e-learning approaches using technological interventions and to assess the extent to which learning goals and outcomes of different e-learners are met. In this respect, key challenges are listed below. *First*, there is no satisfactory answer for why a particular e-learning approach can enhance the experience of a particular e-learner and cannot do that for another e-learner. In other words, which e-learning pedagogical approaches and technological interventions are most suitable to a specific e-learner? Limited evidence in the literature exists on the clear involvement of pedagogy in current e-learning artefacts. For instance, Mikroyannidis (Mikroyannidis, 2012) used Self-Regulated Learning (SRL) pedagogical approach, while Alagha and Burd (AlAgha and Burd, 2009) adopted the constructivist learning theory to learn from hypertext. These approaches are expected to enhance the e-learner experience, but literature shows that often it needs to be developed further (Hammad *et al.*, 2013). Since e-learning is conceived as a process through which e-learners achieve their learning goals by carrying out a number of e-learning activities and participating in interactions to reflect their understanding (Kahiigi *et al.*, 2007), this research intends to incorporate the pedagogy of learning as an intrinsic component of the proposed e-learning artefact/framework. To do so, learning theories will be investigated because they provide empirically-based investigations of the variables that influence the learning process and provide explanations of the ways in which that influence occurs (Mayes and De Freitas, 2004).

Second, current e-learning artefacts are deficient in matching the e-learner's requirements because they do not capture the context to the sufficient degree. For instance, semantic representation has been utilised to model: e-learners and their interests (Ehimwenma, Beer and Crowther, 2015), e-learning resources (Ghaleb *et al.*, 2006), and the e-learning domain (Mikroyannidis, 2012). Also, it has been used in recommendations systems (Peis, del Castillo and Delgado-López, 2008) and adaptive e-learning processes (Richter, 2011). Yet, the comprehensive and the coherent context of the e-learning process has not been sufficiently captured, and consequently recommendations need further enhancements. *Third*, the focus of the recommendations of the e-learning artefact shift from process towards activities. This entails that these e-learning activities are isolated, which leads to missing the coherence of the e-learning process. By e-learning process, we refer to the series of activities (e.g., interaction with the e-learning artefacts/environment) carried out by the e-learner and other relevant stakeholders to achieve certain learning goals and outcomes. In this context, artefacts refer to designed frameworks, models or other arrangements that are designed to fulfil a purpose or solve a problem. This arrangement could be a software system, a tool, a theoretical framework, a pedagogical model, or a combination of them. Putting the focus on the e-learning processes instead of activities will bring further coherence for the e-learning experience, and consequently decision on which e-learning approaches and technological interventions are most suitable for a specific e-learning process can be taken.

Fourth, the distributed computing paradigm has been utilised in the e-learning to add further flexibility to e-learning artefacts (Yang, 2011; Sagayaraj, Rajalakshmi and Poovizhi, 2012); however, this utilisation is rare and limited. For instance, Web Services have not been widely used in e-learning domain for various reasons (e.g., web services are not good in transmitting large amount of data). Most e-learning artefacts that dominate the e-learning applications are monolithic systems. Also, central concerns to applying distributed computing paradigm in e-learning such as: (i) enhancing data exchange and representation, (ii) automatic wrapping of existing e-learning contents in the form of web services, (iii) using Semantic Web Services for further annotations, and (iv) service identification and discovery are not well-investigated in the e-learning context.

Furthermore, the current artefacts are not comprehensive to the extent that they can effectively cover different e-learning models based on hybrid inputs from the context of e-learning. This context is not limited to e-learner preferences, learning styles or e-learning resources, but also in relation to pedagogical approaches underpinning the e-learning processes, organisational aspects, e-learning contents-related concerns and the type of skills to be taught. Evidence in the literature (Zhuhadar *et al.*, 2009) revealed that the hybrid e-learning artefacts/approaches are beneficial for both technology domain and e-learning domain, especially on extending the current pedagogical principles in order to accommodate the rapid technological changes. This is supported by the fact that e-learners' demand and quality of their educational experience should be the main derivers of e-learning development because e-learning is fundamentally about learning and not technology (SFEFC/SHEFC, 2013).

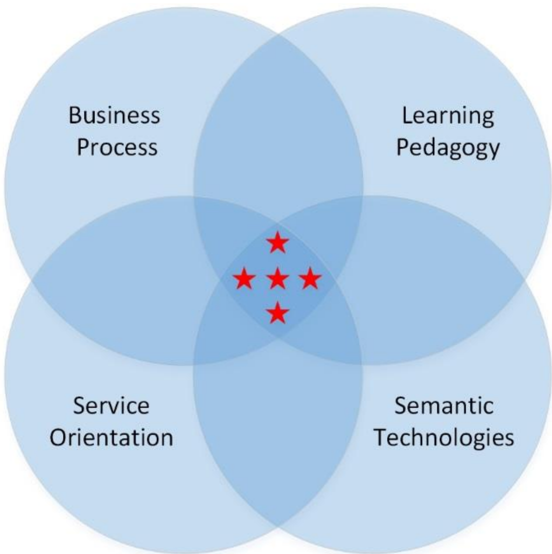


Figure 1.1: The Main Research Domains

This research is an attempt to build a framework for e-learning based on *learning pedagogy* and the *following technologies* as shown in Figure 1.1: the business process, semantics and service-orientation. *First*, this research will investigate learning theories and pedagogical models that are heavily adopted in the e-learning context and are sufficient to draw conclusions necessary to proceed to the subsequent research steps. *Second*, a business process will be used to model and enact various e-learning processes. These e-learning processes vary because: (i) they have different activities, and (ii) they might be individually or socially-oriented. *Third*, since the e-learning process is context-dependent to a large extent, semantic technologies will be used to capture context of e-learning processes and encode domain-specific rules to enrich the e-learning processes, and consequently tailor/customise e-learning processes according to the e-learner requirements to enhance his/her e-learning experience. *Fourth*, the semantically-enriched e-learning processes need to be dynamically enacted, so that their elements (e.g., activities, conditions, roles, etc.) can be mapped to software services. Therefore, Service-Oriented Architecture will be adopted to map e-learning processes to web services to respond to the e-learner's requirements. These requirements vary from simple e-leaning activities (e.g., reading a lesson web page) to more complicated and cooperative one (e.g., engaging with other users and responding to learning requirements). Moving towards automated e-learning solution is one of the main aim of this research, therefore once the e-learning contents designed and published by instructors, and supportive teams, e-learners are expected to practice their e-learning activities without much involvement from their instructors. Instructors role is expected to be limited to respond to e-learners' requests and help them to manage their learning journey.

1.3 Research Hypothesis and Questions

The research hypothesis in this thesis states that:

"A hybrid, semantically-enriched and process-based e-learning framework, when enacted using service oriented enabled e-learning services, results in enhancing the e-learner's experience."

Some of the above-stated research hypothesis aspects are further clarified according to the research context. *First*, hybrid means that the proposed e-learning framework will: (i) utilise different inputs, such as the e-learner's learning style, e-learner goals and skills, e-learning processes and learning resources, and (ii) combine different technologies and approaches (i.e., business process, semantics, and SOA) to enhance the e-learner's experience. *Second*, process-based e-learning framework is associated with business process modeling and enactment techniques to model and enact e-learners' learning processes.

In order to thoroughly understand the drawbacks of the existing e-learning artefacts/processes and the potential for developing a generic e-learning process model, a literature review must be carried out. In this context, a *generic e-learning process* means that the model should be capable of generating a wide range, not all, of specialised e-learning processes based on various contextual inputs. It is impossible to guarantee that the identified generic e-learning process can specialise to all possible learning processes due to the richness of learning domain; however, the most common e-learning processes must be covered. Therefore, the first research question is:

Research Question 1: What e-learning process models exist and how these models can be utilised to develop a generic e-learning model?

As mentioned earlier, e-learning processes need to be described and modelled in order to understand their activities, roles involved, produced artefacts and other related e-learning process constructs. In this research, Business Process Modelling and Notation (BPMN) will be utilised to capture and model e-learning processes. Hence, the second research question is:

Research Question 2: To what extent can the industry-standard Business Process Modelling and Notation capture e-learning processes?

As stated above, additional semantics can help in enriching the e-learner's behaviour and e-learning processes. The e-Learner's behaviour includes his/her interaction with e-learning artefacts, while an e-learning process is more comprehensive as it includes other roles involved in learning such as instructor and technician, actions specified by the instructor or organisation, etc. Therefore, the third research question is:

Research Question 3: To what extent can semantic-based approaches enrich e-learner's processes and accordingly the e-learner's behaviour?

After specifying the generic e-learning process and semantically enriching it, dynamically enacting the derived e-learning processes using service-oriented architecture is investigated in this research to enhancing the e-learner's experience. Therefore, the fourth research question is:

Research Question 4: Can the semantically-enriched generic e-learning process model and the e-learners' behaviour models be dynamically enacted using service-oriented enabled e-learning services?

As this research aims at enhancing the e-learner's learning experience, the impact of enacting the semantically-enriched e-learning processes in SOA-enabled environment needs to be assessed. Hence, the fifth research question is:

Research Question 5: What research evaluation methods/artefacts can be utilised to critically assess the enhancement of the e-learner experience using the e-learning research developed?

The above-mentioned research questions, listed in Table 1.1, have been identified based on the early-identified research hypothesis. Therefore, those research questions will be answered one by one in the coming chapters in order to prove or disprove the research hypothesis.

Table 1.1: Research Questions

RQ #	Research Questions
RQ 1	What e-learning process models exist and how these models can be utilised to develop a generic e-learning model?
RQ 2	To what extent can the industry-standard Business Process Modelling and Notation capture e-learning processes?
RQ 3	To what extent can semantic-based approaches enrich e-learner's processes and accordingly the e-learner's behaviour?
RQ 4	Can the semantically-enriched generic e-learning process model and the e-learners' behaviour models be dynamically enacted using service-oriented enabled e-learning services?
RQ 5	What research evaluation methods/artefacts can be utilised to critically assess the enhancement of the e-learner experience using the e-learning research developed?

After identifying the research problem, hypothesis, and questions, it will be useful to define the scope of this research as follows. *First*, e-learning processes include various types of processes, such as: (i) *learning processes* where e-learners interact with learning activities and submit their assignments, (ii) *management processes* where quality and accreditation concerns are handled, permissions are assigned to users according to their organisational roles, (iii) *design processes* where e-learning and e-assessment contents/activities are designed and published, to name but a few. This research is after the first type of processes, learning processes or learning-oriented processes and other activities that directly impact learning activities. Other processes (e.g., management, design, etc.) are outside the scope of this research. To better support e-learning processes, only fine-grained e-learning processes are considered. Fine-grained e-learning processes include certain flow of activities and interaction implemented by e-learners and other supportive stakeholders (e.g., instructor, teaching assistant, learning buddies, etc.) to achieve some short-term goals (e.g., mastering a topic/lesson). However, course-grained e-learning processes are more complex and could span over one or more academic term/year and require additional supportive processes, such as management, design processes, etc., which are out of the scope. Expanding the scope of this research to cover such processes remains for future work.

Second, as explained earlier this research will incorporate pedagogy/learning theories to develop more effective e-learning artefacts. However, it is beyond the scope of this research to delineate all learning theories used in e-learning contexts. Instead, this research will investigate the widely used learning theories and analyse them to design more effective e-learning artefact. *Third*, since business processes are used to model and enact e-learning processes, extensive comparison between current business process modelling notations and business process execution languages is out of the scope of this research. Instead, industry-standard modelling notation (i.e., Business Process Modelling Notation (BPMN) and Business Process Execution Language (BPEL)) will be adopted to model e-learning processes and dynamically enact them, respectively. *Forth*, as this research is limited to learning-oriented processes only, its outcomes (i.e., research artefacts) will be evaluated against e-learner-oriented concerns. This means that other concerns, such as institutional concerns (e.g., instructors are not responsive to their e-learners, which negatively impact their experience) are out of the scope. Similarly, other technical concerns such as Human Computer Interaction, interface design, usability concerns are not considered in this research.

1.4 Research Contributions

The principal contribution of this research is minimising the research gap, identified in Chapter 2, in enhancing the e-learner experience using a hybrid approach. In this approach, business process modelling notation has been used to model and enact the semantically-enriched e-learning processes in a service-oriented architecture. The following list summarises the main research contributions:

1- **The HeLPS e-Learning Framework**: the main design artefact of this research, which encapsulates: (i) a generic e-learning process model, (ii) a mechanism to semantically-enrich the early-identified e-learning process with various contextual inputs, (iii) a mechanism to transform the generic e-learning process to a specialised one, and finally (iv) dynamically enacting the early-specialised e-learning process in the SOA-enabled environment. The HeLPS framework has been proposed as a three-layered architecture, where the Core Business Logic layer is composed of the next main artefacts. *First*, **the e-Learning Meta-Model**, which allows generating various models (i.e., producing a specific model out of the generic one), captures a high-abstract view of learning domain, decouples e-learning processes from contents and tools utilised in e-learning, and provides an interoperable approach for the various e-learning components to exchange the proper information and work collaboratively to enhance the e-learner experience. Second, **the e-Learning Business Process artefact** acts as a transformation mechanism to transform the generic e-learning process (i.e., captured in the e-Learning Meta-Model) to a specific e-learning process for a certain e-learner. Third, **the Service-Orientation artefact**, which allows enacting the early-specified and semantically-enriched e-learning process in SOA-enabled environment.

2- The **Generic e-Learning Business Process and its Specialisation**, which has been developed via: (i) deriving, in a bottom-up approach, specifications for different e-learning process models from a thorough pedagogical analysis and e-learning models/framework review and (ii) semantically enriching these e-learning process models via the e-Learning Meta-Model to generate various specific models out of the generic one, and (iii) dynamically enacting these e-learning process models using BPEL execution engine.

3- The **Development of Rule-based Specialisation (Customisation) Mechanism** represented by the Semantic Web Rule Language (SWRL) in order to: (i) encode domain-specific knowledge (e.g., rules), and (ii) generate a specialised e-learning process from the generic e-learning process for a particular e-learner.

4- **Semantically-enriched Service Derivation** algorithms to derive relevant web services based on the behaviour encoded in the e-learning business process model and its constituent activities.

5- The **e-Learner Experience Model (eLEM)**. Despite the obvious claim of using ICT to enhance teaching and learning, a limited investigation of the term enhancement was found in the literature. Neither the e-learner experience nor what is meant by enhancement in the context of e-learning have been clarified. To respond to this gap, eLEM has been developed to act as a model that can measure the impact of adopting certain e-learning artefact in a certain context.

6- The **e-Learning Capability Maturity Model (eLCMM)** has been developed based on Systems and Software Engineering standards: Systems and Software Quality Requirements and Evaluation (SQuaRE) Product Quality (PQ), Quality in Use (QiU), and Data Quality (DQ) models due to their comprehensive list of qualities that are precisely defined. The aim of developing such a model is to respond to research gap in: (i) assessing the e-learner experience and (ii) providing a path for improvement of the current e-learning practices. The eLCMM provides a defined evolutionary plateau towards achieving a mature e-learning process.

7- **The e-Learning Evaluation Framework**, which includes, in addition to the early-mentioned eLEM and eLCMM, a data-driven Validation and Verification Model to test and verify e-Learning Software Systems. A spiral instantiation process for evaluating the HeLPS e-Learning Framework has been developed to facilitate the application of this evaluation framework in certain contexts.

8- **The e-Learning Meta-Model** as the current e-learning adaptation approaches are limited to recommending resources, peers or communities. However, learning is not limited to these constructs.

Learning is a process that includes further constructs such as the way of teaching and learning and its extended context. This entails that the e-learning context needs to be comprehensively specified through a mechanism that allows interoperable and flexible interactions between various constructs. So, adopting **Model Driven Engineering (MDE)** for the **e-Learning Meta-Model** that provides a hybrid approach to enhance the e-learner experience by capturing information about: (i) actors, (ii) e-learning pedagogy, (iii) content, (iv) process model, (v) external context, (vi) e-learning processes and activities, (vii) facilitating tools and (viii) presentation formats.

9- A **Methodological Approach to Generalise a Business Process Model** from a set of related business processes sharing the same goals and associated objectives. The proposed approach has been applied in the e-learning domain, which demonstrated its ability to develop a generalised e-learning business process model that is derived from the existing pedagogical models and technology-enhanced learning artefacts.

To facilitate these contributions, standard-based approaches such as Web Service Description Language have been adopted to describe learning/assessment web services. This makes it easier for such contributions to be applied by different researchers or organisations due to their implications on interoperability, flexibility, and agility. The above-listed contributions, especially the HeLPS e-Learning Framework, are important as they significantly expand the scope of learning process beyond resources recommendations. Learning is far complicated and needs to be investigated in many contexts, such as project-based learning and social learning, which is well considered in the above-listed contributions via modelling various detailed learning processes based on learning theories and abstracting them in one generic e-learning process.

Academic organisations, such as universities and colleges, deliver their teaching and learning services to a wide range of learners. Those learners are very different as they belong to different communities, have different background, skill, and preferences. Therefore, their needs/requirement are quite different and here is the main added value of this research. Furthermore, three of the above-mentioned contributions (i.e., the e-Learning Evaluation Framework, the e-Learner Experience Model, and the e-Learning Capability Maturity Model) have been designed and developed to evaluate the effectiveness of applying e-learning approaches at a certain organisation. e-Learning practitioner and experts are expected to find the above-listed contributions useful. Experts, in this context, refer to: (i) technological experts, who are looking for new developments in e-learning domain and (ii) educational experts who are looking after underpinning pedagogical theories and the best arrangements for effective learning environments.

1.5 Research Publications

The following papers stemmed from the work undertaken within the framework of this research:

R. Hammad, M. Odeh, and Z. Khan, "A Novel e-Learner Experience Model," International Arab Journal of Information Technology, (2017), Vol 14, Special Issue. pp. 586-597.

R. Hammad, "Game-enhanced and Process-based e-Learning Framework," In: El Rhalibi, A., Tian, F., Pan Z., (eds) Edutainment: The 11th International Conference on e-Learning and Games, Bournemouth, UK, 2017, Lecture Notes in Computer Science, Vol 9655, pp. 279 – 284, Springer.

R. Hammad, M. Odeh, and Z. Khan, "eLCMM: e-Learning Capability Maturity Model," The 15th International Conference on e-Society (e-Society), Budapest, Hungary, 2017, pp. 169-178.

R. Hammad, M. Odeh, and Z. Khan, "Towards a Generalised e-Learning Business Process Model," The 7th International Conference on Business Intelligence and Technology (BUSTECH), Athens, Greece, 2017, pp. 20-28.

R. Hammad, M. Odeh, and Z. Khan, "e-Learner Experience Model," The 17th International Arab Conference on Information Technology (ACIT16), Beni-Mellal, Morocco, 2016, pp. 86-94.

R. Hammad and D. Ludlow, "Towards A Smart Learning Environment for Smart City Governance," The 9th IEEE/ACM International Conference on Utility and Cloud Computing, Shanghai, China, 2016, pp. 185-190.

R. Hammad, M. Odeh, and Z. Khan, "Towards A Model-based Approach to Evaluating the Effectiveness of e-Learning," The 9th European conference on IS management and evaluation (ECIME), Bristol, UK, 2015, pp. 111-119.

R. Hammad, M. Odeh, and Z. Khan, "Towards a Generic Requirements Model for Hybrid and Cloud-based e-Learning Systems," The 5th International Conference on Cloud Computing (CloudCom), Bristol, UK, 2013, pp. 106-111.

1.6 Thesis Outline

After this chapter, the background and literature review are discussed in **Chapter 2**. In particular, the pedagogy underpinning e-learning artefacts which forms the base for identifying the research gap and deriving business process models for e-learning processes and their BPMN specifications. Furthermore, the extensive literature review for related work across all different domains is presented. **Chapter 3** presents: (i) the research method utilised in this research and (ii) the main research artefact "the HeLPS e-Learning Framework", its architecture, design choices and implications. Consequently, **Chapter 4** discusses the HeLPS e-Learning Framework detailed design and development. This mainly includes the framework instantiation process, the e-Learning Meta-Model, generating specific e-learning processes from the generalised one, and deriving e-learning services from e-learning business process models. **Chapter 5** presents the research evaluation design along with its constituent artefacts to answer research questions and to prove/disprove the research hypothesis. This evaluation framework is mainly based on the Data-driven Validation and Verification Model using a sufficient and representative case study. Also, this evaluation framework uses the early-developed models (i.e., the e-Learner Experience Model and the e-Learning Capability Maturity Model). Finally, a conclusion of this research outcomes along with suggested future research directions are presented in **Chapter 6**. To support this outline, various appendices (i.e., Appendix I – Appendix XIII) are presented at the end of the thesis.

Chapter 2:

Background and Literature Review

2.1 Introduction

As introduced earlier, this research is multidisciplinary as it combines the following research domains: (i) e-learning pedagogy, (ii) business process modelling and enactment, (iii) semantic representation and (iv) service-oriented computing. These domains belong to two different disciplines: (i) social science which includes learning pedagogy and (ii) technology which includes the rest of the three domains. In general, pedagogy provides the basis for the overall e-learning framework, while the three remaining domains are seamless technologies that contribute to specify a learning process, semantically enrich it and finally enact it using service-oriented enabled environment to enhance the e-learner learning experience. Therefore, this chapter introduces a background to these domains and reviews the relevant literature. Figure 2.1 shows the roadmap for the literature review carried out in relation to this research.

2.2 Literature Review Approach

To conduct a comprehensive literature review, the following three phases have been followed: (i) planning, (ii) conducting the review and (iii) reporting the review. The *Planning phase* answers the basic questions: what to be covered, why and how. In the planning phase, the researcher uses scientific databases, library and other sources to get relevant literature. The main criteria for selecting the literature are: (i) they represent successful e-learning models, (ii) they are related to the domain of this research, (iii) they have distinctive features (i.e., they significantly differ) and (iv) their implications on learning and teaching practices are important and relevant to this research context. A second-cut filtering has been performed to exclude unrelated research/sources.

To properly structure the review process, the selected and reviewed models were classified into the following categories, mainly, based on their salient features: (i) *common models* which refer to the most commonly used e-learning models in academic institutions, (ii) *process-based* and *service-oriented models* which refer to models adopting the service-oriented paradigm and formal process-based approaches, (iii) *semantically-enriched models* which refer to the use of semantic technologies such as ontology for contextualisation purposes, (iv) *theoretical and*

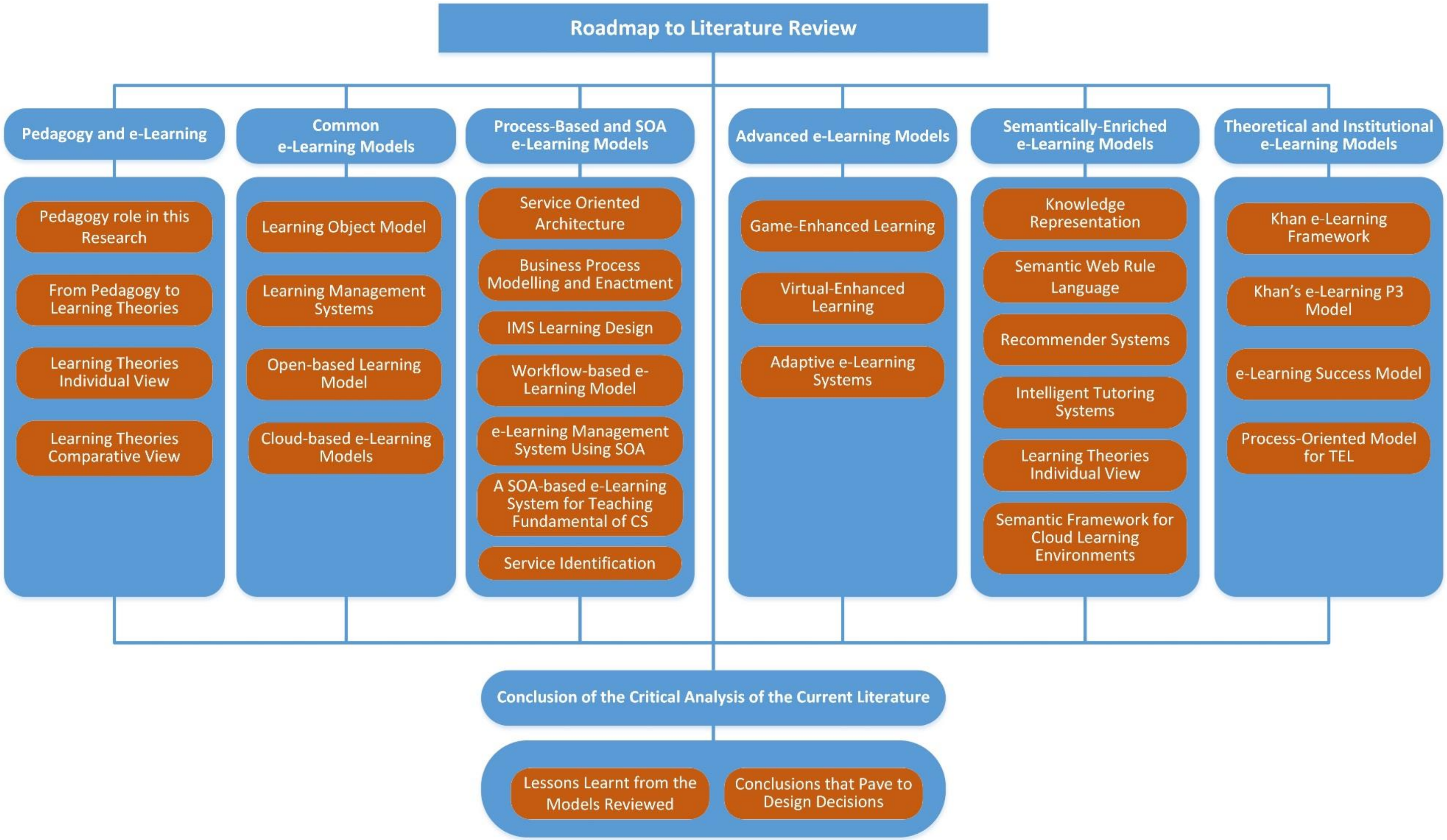


Figure 2.1: Roadmap to Literature Review

institutional models that set out general rules and framework for adopting e-learning, (v) *advanced models* that use unconventional techniques, such as adaptive systems and virtually-enhanced systems and (vi) *pedagogical models* that refer to the broad principles through which the theory is applied in learning context, they usually align with a pedagogical approach or learning theory (Conole, 2010).

For better investigation and analysis, the early-identified models have been labelled as: (i) *core model* which refers to models used in other e-learning models (e.g., Learning Objects), (ii) *standard-based* which refers to specifications adopted by internationally recognised bodies (e.g., IMS LD), (iii) *full system* which refers to systems applied and adopted by institutions (e.g., Blackboard), (iv) *concept* which refers to research-based models which could be abstract, design-based or proposed framework, (v) *prototype* which refers to pilot implementations rather than actual implementation (e.g., most of the adaptive systems), and (vi) *theoretical* which refers to models suggested to set up general e-learning settings (e.g., Khan e-learning framework). Table 2.1 lists all reviewed models, while Figure 2.2 reveals their differences/diversity.

Table 2.1: Selected e-Learning Models

#	Model Title	Code	Model Category	Artefact Lifecycle
1.	Learning Object - *Sub Model*: IEEE LOM and Extended Learning Object Model	C1	Common e-Learning Models	Core Model IEEE LOM is a standard model
2.	Open-based Models - *Sub Model*: MOOCs, OERs, OCWs, FutureLearn	C2		Sub/Full systems
3.	Learning Management Systems - *Sub Model*: e-Training	C3		Full systems
4.	Cloud-based Models	C4		Concept
5.	IMS Learning Design	PS1	Process-based and Service-oriented e-Learning Models	Standard
6.	Workflow enabled e-Learning Services	PS2		Concept
7.	e-Learning Management System Using Service Oriented Architecture	PS3		Prototype
8.	A SOA-based e-Learning System for Teaching Fundamental Information of Computer Science Courses	PS4		Prototype
9.	A Service-oriented Architecture for Adaptive and Collaborative e-Learning System	PS5		Prototype
10.	Intelligent Tutoring Systems	S1	Semantically-enriched e-Learning Models	Full systems and prototype
11.	ROLE	S2		Prototype
12.	Recommender Systems	S3		Full systems and prototype
13.	Game-based e-learning model	A1	Advanced e-Learning Models	Full systems
14.	Virtual-Enhanced e-learning models	A2		Full systems
15.	Adaptive e-learning model	A3		Prototype
16.	Khan's e-learning Framework	T1	Theoretical & Institutional e-Learning Models	Theoretical
17.	Khan's 3P Model	T2		Theoretical
18.	E-Learning Success Model	T3		Theoretical
19.	Process-Oriented Model for TEL	T4		Theoretical

#	Model Title	Code	Model Category	Artefact Lifecycle
20.	Kolb's Experiential Learning Cycle	P1	Pedagogical e-Learning Models	Theoretical
21.	Merill's Instructional Design Model	P2		Theoretical

Keys:

C 1..4 Common Models

PS 1..5 Process and Service Oriented Model

S 1..3 Semantically-enriched Models

A 1..3 Advanced Models

T 1..4 Theoretical Models

P 1,2 Pedagogical Models

The second phase is *conducting the review*. It includes: (i) reviewing the early-identified models via related sources to extract the appropriate information and (ii) analysing them using SWOT analysis to identify model's strengths (S), weaknesses (W), opportunities (O) and threats (T) that are related to this research scope (i.e., hypothesis and questions) (Ming *et al.*, 2014). All models have been compared against ISO 25010 and ISO 25012: Systems and software Quality Requirements and Evaluation (SQuaRE) Product Quality (PQ), Quality in Use (QiU) and Data

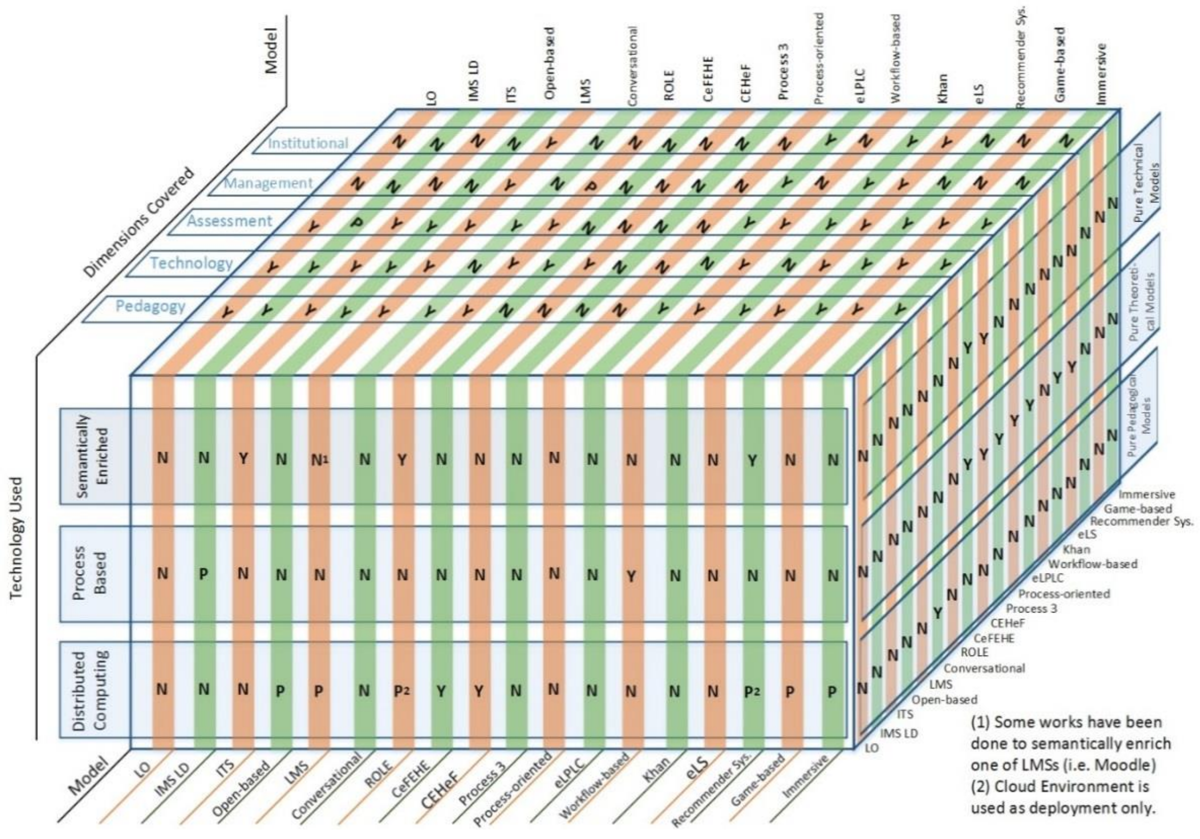


Figure 2.2: e-Learning Models Comparison

Quality (DQ) standards as they have a list of precisely defined qualities which provide consistent approach to perform comparative analysis. Additional qualities (i.e., pedagogically-based) to the early-identified PQ, QiU and DQ have been driven from literature to accommodate the particularities of e-learning domain/artefacts. Lessons learnt from this review will be inspire the design and instantiation of the proposed solution/artefact because the expected artefact should reinforce strengths, overcome weaknesses, facilitate or realise opportunities and mitigate/counter threats. The final phase is *reporting the results*. This phase manifested itself through documenting the reviewed literature in terms of (i) information supported by figures and proper visualisation and (ii) critical reflections on the gap in the existing literature. This will be used to rationalise the new proposed e-learning framework and pave the ground for the research design phase.

2.3 Pedagogy and e-Learning

Pedagogy is defined by the Cambridge Dictionary as '*the study of the methods and activities of teaching.*[1]' Also, it refers to '*the art or science of teaching*' (Beetham and Sharpe, 2007). Further investigation into pedagogy reveals the little consensus in the literature upon one definition. One reason for that is that pedagogy is an interrelated concept and should be considered within its larger context. This entails that ICT-based educational practices be considered as a larger framework that e-learning pedagogy may be explained within. Another reason for the little consensus is the dynamic nature of pedagogy because our understanding of pedagogy does not remain static (Webb and Cox, 2004). Consequently, our conceptualisation about pedagogy becomes more complex over time as a result of our growing understanding of theories underpinning pedagogy such as cognition and metacognition (Watkins and Mortimore, 1999). Nevertheless, the UK universities' research assessment exercise (RAE) developed a more generic definition for pedagogy to include reference to *the processes, experiences, contexts, outcomes and relationships of teaching and learning in higher education* (RAE, 2006). This definition affirms the dialogue initiated between learning and teaching in pedagogy (Beetham and Sharpe, 2007), where learning asserts the active participation of the learner instead of the passivity implied by teaching. This intimate connection between learning and teaching is more realistic from the researcher's point of view as real life learning could contain, even implicitly, some aspects of teaching.

So, this part of the research is an attempt to thoroughly understand the current conceptions of pedagogy in order to suggest how the new innovative technologies can be useful in the context of learning and teaching. In other words, developing a successful e-learning artefact requires establishing a proper understanding of pedagogy first and then making suitable technological interventions. Since learning differs from one learner to another and from one context to another, successful e-learning artefact should be generic in order to respond to different learning contexts, such as formal, informal, professional or lifelong learning. Such technological interventions can be realised in the form of e-learning models or frameworks. In this research, *models* and *frameworks* are used interchangeably. Although some researchers tend to use *frameworks* to express a more comprehensive artefact or technological interventions than models, evidence from literature shows that both terms can be used interchangeably (Conole, 2010).

2.3.1 From Pedagogy to Learning Theories

Learning environments/spaces have significantly evolved into complex, multipurpose, technology-intensive environments (Bonanno, 2010b). For instance, LMSs have strongly dominated the e-learning domain (Mikroyannidis, 2012), they integrate administrative and management capabilities, social tools, complex

[1] http://dictionary.cambridge.org/

architectures and course-based capabilities. This cross-domain, rapid and intensive development has led to complex learning environments/spaces, where learners need effective guidance based on careful consideration for the underlying complex pedagogical models. The incorporation or reconsideration of the pedagogical theories/models is required to enable technology to enhance the overall learning process and more specifically the e-learner experience.

The reviewed literature reveals two arguments regarding the use of learning theories in learning and teaching. The first is the anti-theory argument, which does not believe in theories at all. Robert Gagne and B. F. Skinner are examples of this approach, as they do not consider that a learning phenomenon can be explained by simple theories (Gagné, 1965). The second argument, adopted in this research, considers learning theories as an essential component of teaching and learning. Various researchers claim that following a learning theory approach is inevitable in any good pedagogy design (Conole, 2010; Schunk, 2012; Mayes and De Freitas, 2004). In this research, learning refers to the act or process by which behavioural change, knowledge, skills and attitudes are acquired (Boyd and Apps, 1980) based on external or internal stimuli (Susimetsa, 2006), while theory refers to a comprehensive, coherent, and internally consistent system of ideas about a set of phenomena (Knowles, Holton III and Swanson, 2011). This research investigates learning theories that provide empirically-based accounts of the variables which influence the learning process, and provide explanations of the ways in which that influence occurs (Mayes and De Freitas, 2004), but not e-learning theories that overlap with other categories of theories such as Human Computer Interaction (HCI) and Information Structuring theories (Hoadley, 2007). The next section will present an analytical review of learning theories that are widely utilised in e-learning contexts along with an attempt to adopt a taxonomy of the different schools of learning theories.

2.3.2 Learning Theories

In this section, first, the most common learning theories are presented, then the second part briefly discusses: (i) other learning theories within the context of specific learning approaches (e.g., Pinritch theories in the context of Self-Regulated Learning) and (ii) the two pedagogical models (Kolb's Learning Cycle and Merill's Design Principles) as examples to reveal their value in e-learning contexts. The third part presents one of the most adopted classifications for learning theories (i.e., Mayes and de Freitas classification) with some reflections. Finally, the fourth part concludes this section with a comparative summary of learning theories. It is essential to say that it is beyond the scope of this research to delineate all learning theories used in e-learning contexts. Full comprehensive coverage can be found in the literature (e.g., (Harasim, 2012; Knowles *et al.*, 2011; Schunk, 2012) and (Millwood, 2013)).

2.3.2.1 Learning Theories: the Individual Approach

Behaviourism

Behaviourism was initially developed in the 1920's with its golden age in the 1950's (T. Bates, 2015). Watson defined learning as a sequence of stimulus and response actions in observable cause and effect relationships (Watson, 1913; Chowdhury, 2006). Behaviourism considers the learner's mind as a black box while always focusing on the changes in the learner's behaviour (Kruse, 2009). Behaviourism is associated with a number of theorists such as: Pavlov, Watson, Thorndike, Skinner and Bandura; however, Skinner's view is currently the most dominant. Moreover, behaviourism is divided into two types: (i) classical conditioning, which refers to natural reflexes in response to various stimuli and (ii) operant conditioning, which refers to the reinforcement of these responses through the concept of extrinsic rewards/punishments so that such responses become more/less probable in the future (Susimetsa, 2006). On the one hand, behaviourism is attractive because it is simple and easily explains some learner actions or situations (Collins, 2002). Yet on the other hand, it has been criticised because it does not explain the internal learning processes or learners' reasoning and thinking, especially higher-level critical thinking skills and problem solving (Kruse, 2009; AlAgha, 2009). Behaviourism is tightly coupled with Instructional Design (ID) models such as Merrill First Five Principles model that: (i) engage learners in a problem, (ii) allow them to activate their knowledge, (iii) allow them to discover knowledge through demonstration, (vi) allow them to apply and (v) integrate knowledge in the wider context (Merrill, 2002). Additional ID models, also known as pedagogical models, exist such as: (i) ADDIE: Analyse, Design, Develop, Implement and Evaluate, (ii) Dick and Carey Systems Approach Model and (iii) Gagné's Nine Events of Instruction (Gagné *et al.*, 2005).

Direct Instruction

Direct Instruction (DI) refers to the academic focus, precise sequencing of content, high learner engagement, careful teacher monitoring, and specific corrective feedback to learners (p. 35) (G. G. Duffy and Roehler, 1982). This contradicts with exploratory models such as inquiry-based learning. According to Huitt et al, one of DI variant models, DI is composed of three main activities: (i) *presentation* which introduces knowledge, reviews new concepts, explains and reflect upon them, etc., (ii) *practice* which allows learners to practice learned knowledge under guided and independent practice schemes, and (iii) *assessment and evaluation* which include formative and summative assessment (Huitt, Monetti and Hummel, 2009). This model puts further emphasis on practice, close observation and feedback.

Cognitivism

Behaviourism's failure to explain different learning processes in a meaningful way led to the so-called cognitivist revolution which replaced behaviourism in the 1960's as the dominant paradigm (Watrin, 2012). Unlike behaviourism, cognitivists believe that mental processes are essential for explaining behaviour. More specifically, cognitive theories focus on how students make meaning out of new information and experience. According to Kruse, cognitive learning theories include: (i) constructivist learning theories, (ii) developmental learning theories and (iii) social learning theories. Each of these emphasises how meaning-making processes are affected by a given set of factors from its own perspective. However, Marko (Susimetsa, 2006) claims that cognitive psychology goes beyond this as it is associated with additional learning theories, such as Information Processing learning theory and constructivism. Simply, information processing theory considers the mind as a computer. Thus, both humans and computers accept input, process it and produce outputs (Mayer, 1996). On the one hand, cognitivism is a vital approach and led to different e-learning inventions such as: (i) ITSs that are based on analysing learner responses to questions and direct the learner to appropriate actions, and (ii) AI-based techniques that represent the mental processes used in human learning (T. Bates, 2015). On the other hand, and from an epistemological perspective, it belongs to objectivism which means that knowledge is absolute, matches reality (Harasim, 2012) and exists outside the human mind, independently of what an individual may or may not believe (A. W. Bates and Poole, 2003) which is not true for all kind of knowledge.

Social Learning Theory

Learning has been linked to its social perspective in many views. For instance, Wenger recognises learning as a social process (Wenger *et al.*, 2002). Moreover, Bates explains that knowledge is either acquired through: (i) a social process or (ii) institutions that are socially constructed, e.g., schools/universities. Consequently, knowledge is conceptualised as content plus the socially constructed value (T. Bates, 2015). In social learning theory, knowledge is constructed via social interaction, and learners are able to learn from observing and interacting within social and cultural contexts (Ruohotie, 2000; Kruse, 2009; Bandura and McClelland, 1977). Hence, social learning theory is related to cognitive learning theories because it admits the existence of individual intelligence and reasoning abilities (Susimetsa, 2006). The rapid developments in social tools influenced TEL and led to inventing social learning environments[2].

Constructivism

Constructivism is one of the main learning paradigms. Unlike the previous behaviourist and cognitivist paradigms, constructivism takes a holistic approach. In constructivism, each learner constructs his/her own knowledge for him/herself, each learner individually and socially constructs meaning while he/she learns (Hein, 1991). Hence, learners make sense of their external environments by a meaning-making process, which depends on previous and current internal experience (T. Bates, 2015). Constructivism assimilates most of the cognitive-based learning theories such as information processing and social learning theories (Susimetsa, 2006). Additionally, it is not as deterministic as behaviourism and some elements of cognitivism in terms of the predictable behaviour of learners (Susimetsa, 2006). Constructivists claim that it takes more realistic and logical perspective since it focuses on the uniqueness of learners. Humans are very dynamic in nature; their views and values change over time and this change reflects on the future knowledge. Moreover, the learner is at the centre of a continuously changing rich world of facts, experiences and knowledge. Hence, the learners perceive external knowledge/information and interpret it according to their internal understanding (Rogers, 1969; T. Bates, 2015).

So, learning is a complex recursive phenomenon, and every individual: (i) is unique in his/her own way of thinking, (ii) his/her behaviour is not predictable or deterministic and (iii) uses previous knowledge to make meaning of his/her environment. Constructivism is attached to the following two essential concepts: (i) assimilation, where learners fit new information within their existing mental framework and (ii) accommodation, where learners add to/modify their existing mental framework. Wadsworth nicely describes accommodation as a qualitative change while assimilation is a quantitative change (Wadsworth, 2004). Constructivism has been criticised because previous learner mental frameworks might be wrong, not easy to discover or modify (Kruse, 2009). This is related to

[2] http://c4lpt.co.uk/top100tools/

conceptual changes, misconception and missing conceptions (C. Chen, Cheng and Lin, 2012; von Aufschnaiter and Rogge, 2010; Chi and Roscoe, 2002; VanLehn *et al.*, 2002)).

Connectivism

As educational technology has evolved, new learning theories emerge and proliferate. Connectivism is a good example of complex circular interaction between learning and technology. Since knowledge is distributed across networks of interrelated connections, learning occurs through connections within networks (Bell, 2011). According to Siemens, the main drawbacks of the existing perspectives are: (i) their intrapersonal view of learning, (ii) their failure to address learning that is located within technology and organisations, and (iii) their lack of contribution to the value judgments that need to be made in knowledge-rich environment. Therefore, below are the key principles of connectivism as a new learning theory (Siemens, 2014):

1. Learning and knowledge rest in the diversity of opinions.
2. Learning is a process of connecting specialised nodes or information sources.
3. Learning may reside in non-human appliances.
4. The capacity to know more is more critical than what is currently known.
5. Nurturing and maintaining connections are needed to facilitate sustained learning.
6. The ability to see connections between fields, ideas, and concepts is a core skill.
7. Currency (i.e., accurate and up-to-date knowledge is the intent of all connectivist learning activities).
8. Decision-making is a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality, so correct answers may change from day to another.

To conclude, connectivism is the first theoretical attempt to radically re-examine the implications of technological innovations for learning (T. Bates, 2015). It creates an opportunity to understand new learning models emerged out of recent technological developments and it is controversial because it extends the learning view outside the learner. Additionally, Siemens's description of connectivism as a successor to behaviourism, cognitivism and constructivism (Bell, 2011; Siemens, 2014) can be challenged because it neither adds to the principles of existing theories (Verhagen, 2006) nor explains how learning can reside in non-human appliances (Engeström and Kerosuo, 2007). Further criticism exits in (T. Bates, 2015) such as participants struggling in unstructured learning environment, being overwhelmed by peer-generated content, the need for explicit support and so on.

Learning by Doing

Learning by Doing (LBD) is a broad paradigm or learning theory that describes learning by doing learning theory and theories established to support this theme such as Experiential Learning Theory (ELT) and situated learning (J. Y. Feng *et al.*, 2013). LBD requires the learner to perform tasks that have to be learned; in other words, learning takes place while performing tasks (Leyer, M., & Wollersheim, J., 2013). Evidence shows that LBD can (i) achieve results which are 20% better than other learning methods (i.e., behavioural approaches) (M. Leyer, Moormann and Wang, 2014), (ii) significantly minimises the cost of learning (Levitt and March, 1988), (iii) ideal with novice learners, (vi) a useful adjunct to traditional learning, and (v) context-dependent which limits its reusability in dissimilar contexts (J. Y. Feng *et al.*, 2013) and therefore, it is not highly useful for conceptual learning. LBD is linked with giant pedagogy/learning theorists such as John Dewey, David Kolb and Jean Piaget. In LBD/ELT, learning refers to the process, whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience (Kolb, 1984). Kolb expands on this combination of grasping and transforming experience which agrees with Roger's argument where he divides learning into (i) cognitive which corresponds to academic knowledge, for example learning vocabularies, and (ii) experiential which refers to applied knowledge such as learning how to repair PCs.

However, LBD needs the following qualities to maintain its success: (i) the quality of personal involvement, (ii) self-initiated, (iii) the pervasive effects on the learner, (iv) evaluation by the learner, and (v) its essence is meaning to the extent that the element of meaning to the learner is built into the whole experience (Rogers, 1969; McRae and Rogers, 2012). LBD is useful for teaching specific types of skills (e.g., motor skills – skills that are mainly attached to movements/actions by learners –, laboratory studies and medical internships); and better results are expected if learners are guided by instructors (T. Bates, 2015). However, LBD is not very widely adopted in e-learning because the majority of e-learning artefacts have been primarily produced to support schools-based learning, where instructor-led approaches are dominant (Tynjälä, 2008). LBD/ELT is described by the Kolb Experiential Learning Cycle shown in Figure 2.3 and its four stages as described below (Kolb, 1984):

1. *Concrete experience*, which refers to either (i) new experience encountered by individuals or (ii) re-interpretation of existing experience. This stage tends toward feeling.
2. *Reflective observation* which refers to observing the experience before making a clear judgment, finding out meanings of entities/elements or discovering inconsistencies between experience and understanding. This stage tends toward watching.

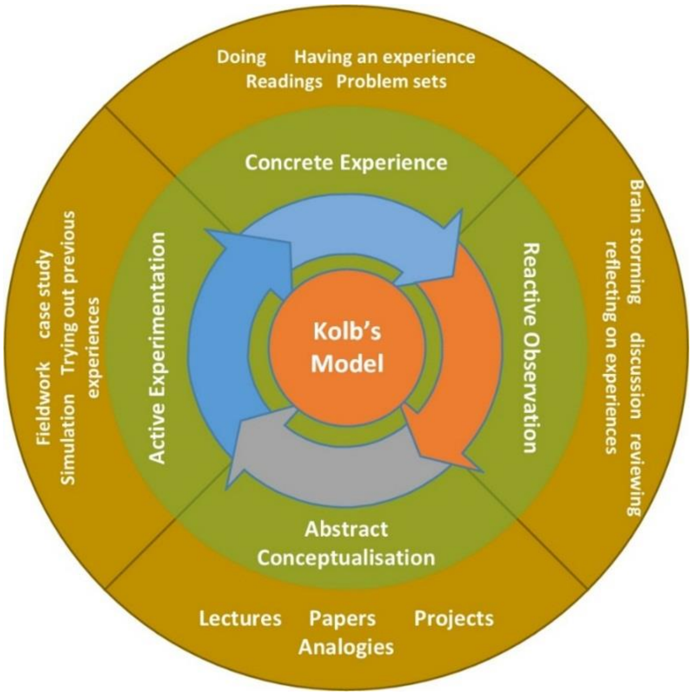


Figure 2.3: Kolb's Experiential Learning Cycle

3. *Abstract conceptualisation which refers to analysing different ideas to achieve a new abstract/intellectual understanding of a given situation or modify an existing abstract. This stage tends toward thinking.*
4. *Active experimentation which refers to applying what has previously been learned in real cases. This checks the learner's ability to get things done in the real world. This stage tends toward doing.*

Other approaches such as Problem-Based and Project-Based Learning are also classified as Experiential Learning techniques (Furman and Sibthorp, 2013). Problem-Based Learning uses learners' interest in a given problem to: (i) create an experiment to respond or answer a given question or (ii) develop a course of action that helps in resolving the problem (Haas and Furman, 2008). While project-based learning creates projects based on learners' interests; these projects must be rich in educational content to add value to the learner (Marienau and Reed, 2008). The added value in project-based learning is the ability to use the project as an authentic platform to learn many skills (Furman and Sibthorp, 2013). This enables learners to grasp a wide range of skills, for example time management, planning, decision making and group dynamics in addition to the subject-specific skills needed to solve problems presented in the project. However, ELT promotes an individualised perspective of learning at the cost of the social, cultural and non-cognitive aspects of learning phenomenon (Reynolds, 1999; Holman, Pavlica and Thorpe, 1997) and it does not reflect on the unconscious learning processes which might lead to or prevent learning activities (Vince, 1998). Finally, technology can facilitate LBD/ELT through simulation, immersive-based technologies (e.g., virtual/augmented reality and second life) (Gil-Ortega and Falconer, 2015).

Self-Regulated Learning (SRL)

Despite the potential of e-learning, diverse difficulties (e.g., cognitive overloading and disorientation) face practitioners when they learn from the web (Conklin, 1987). Therefore, Self-Regulated Learning (SRL), also known as Self-Directed Learning (SDL), gains more attention as it helps in regulating learning to avoid such difficulties. Although SDL tends to refer to more autonomous learning, more about their differences and similarities is shown in Table 2.2, both terms are used interchangeably in the literature (Bracey, 2010; Saks and Leijen, 2014).

Table 2.2: Self-Regulated Learning versus Self-Directed Learning

<table>
<tr><th>*</th><th>Self-Regulated Learning</th><th>Self-Directed Learning</th></tr>
<tr><td rowspan="5">Similarity</td><td colspan="2">Contains four principal activities/phases: Defining tasks, setting goals and planning, enacting strategies, monitoring and reflecting.</td></tr>
<tr><td colspan="2">Active participation of learner.</td></tr>
<tr><td colspan="2">Goal-directed behaviour</td></tr>
<tr><td colspan="2">Learners are intrinsically motivated</td></tr>
<tr><td colspan="2">Metacognition is an essential part</td></tr>
<tr><td rowspan="3">Differences</td><td>Originates from cognitive psychology</td><td>Originates from adult education</td></tr>
<tr><td>Practiced mainly inside traditional school environments</td><td>Practiced mainly outside traditional school environments (no facilitator/instructor)</td></tr>
<tr><td>Tasks usually set by teacher.</td><td>Involves planning a learning trajectory and involves designing a learning environment.</td></tr>
</table>

Various principal theories of SRL exist in literature, such as Pintrich (P. Pintrich, 2000), Winne and Hadwin (Winne and Hadwin, 1998) and Zimmerman (Zimmerman, 2000). The learner is self-regulated to the extent that he/she is a metacognitively, motivationally and behaviourally active participant in his/her own learning process (Zimmerman, 1989). This involves taking the initiative, with or without the help of others, to diagnose learning needs, formulate learning goals, identify resources, select and implement learning strategies and evaluate learning outcomes (Knowles, 1975; Saks and Leijen, 2014). Hence, self-regulated learners work on cognitive skills (e.g., analysis and reasoning) and meta-cognitive skills (e.g., reflection and self-assessment) (T. M. Duffy and Jonassen, 1992). SRL key phases are: (i) *cognitive planning and activation*, which includes: goal setting, activation of prior content knowledge and activation of metacognitive knowledge, (ii) *cognitive monitoring*, which involves awareness and monitoring of various aspects of cognition, especially metacognitive judgement of the learner herself, (iii) *cognitive control and regulation*, which includes cognitive and metacognitive activities that learners engage in to adapt and change their cognition, and (iv) *cognitive reaction and reflection*, which involves the learner's judgments and evaluation of their performance of the task and their attributions for performance (P. R. Pintrich, 2000). Several cognitive strategies such as: rehearsal, elaboration, organisation and critical thinking are used by SRL learners to plan, monitor and regulate their learning (P. Pintrich R. and McKeachie, 2000; P. Pintrich, 2000).

SRL increased the possibility of successful completion of online courses (Cennamo, Ross and Rogers, 2002) and the self-motivation of learners (M. M. Chang, 2005), but cognitive overloading and disorientation are not completely removed yet. SRL is considered as cognitive constructivism because learners use self-regulatory skills to control and direct their cognition (Susimetsa, 2006). In SRL, contextualisation is useful to stimulate prior knowledge activation on the content level and metacognitive knowledge level (P. R. Pintrich, 2000), which encourages adopting semantic technologies.

2.3.2.2 Learning Theories: Collective Approach

Various classifications for learning theories exist. This research adopts Mayes and de Freitas classification, with slight changes. According to Mayes and de Freitas (Mayes and De Freitas, 2004), learning theories are classified into the following three perspectives: (i) *Associationist*, where learning can be seen as an activity, (ii) *Cognitive*, where learning can be seen as achieving understanding and (iii) *Situative*, where learning can be seen as social practice. In the first category, knowledge is an organised accumulation of associations and skill components, and learning is the process of connecting the elementary mental or behavioural units through sequences of activity. Behaviourism, Direct Instruction and Instructional Design fall into this perspective. In the second category, learning is a way to model the processes of interpreting and constructing meanings. Knowledge acquisition is the outcome of an interaction between previous learner structures for understanding and new experiences. Mayes and de Freitas claim that constructivism fall into this perspective since understanding is gained through an active process of creating hypotheses and building new forms of understanding via activity, but we claim that constructivism assimilate most of the cognitive learning theories as will be explained below.

In the third category, learning is seen as situated within social and cultural contexts. Consequently, these contexts affect learning outcomes, knowledge, learner's ability to learn through participation and learner identity that is shaped by learner's relationship with the community. In this paradigm, knowledge is described as content plus socially-constructed value (T. Bates, 2015). Community, or Community of Practice, refers to groups of people who share

a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis (Wenger *et al.*, 2002). Hence, the quality of learning is the outcome of the participation of learners in their context (e.g., community, people, objects, artefacts, processes, cultural and social aspects) (Dawley and Dede. C., 2014). Virtual-enhanced learning, such as immersive-based, collaborative learning, authentic simulations and game-enhanced learning are examples on situated learning as long as they considerably embrace context (Gil-Ortega and Falconer, 2015; Gregory *et al.*, 2014; Hauge *et al.*, 2013).

Reflections on Mayes and de Freitas Classification

Mayes and de Freitas claim that many of the constructive-based approaches are indistinguishable from approaches derived from the associationist perspective, which we do not fully agree with. Instead, we argue that boundaries between learning theories, paradigms or perspectives are not clear to the extent that one learning model can be mapped to one learning theory. This is also valid on the domains where these theories are originally derived from. For instance, constructivism and cognitivism belong to different schools from an epistemological perspective but they can be classified into one perspective of learning theories. Therefore, a hybrid learning approach should be considered to comprehend different types of skills in various contexts. We argue that constructivism assimilate cognitivism since constructivism is not deterministic like some aspect of cognitivism. Constructivism considers individuals are unique and one's experience is continuously evolving which leads to different mechanisms for information processing and essentially meaning making. This seems very different from a cognitivism point of view.

Figure 2.4 depicts further reflections on the tangled boundaries between different learning theories. On the one hand, it shows how Behaviourism tends toward individualistic, instructor-centred, determinism, objectivism and

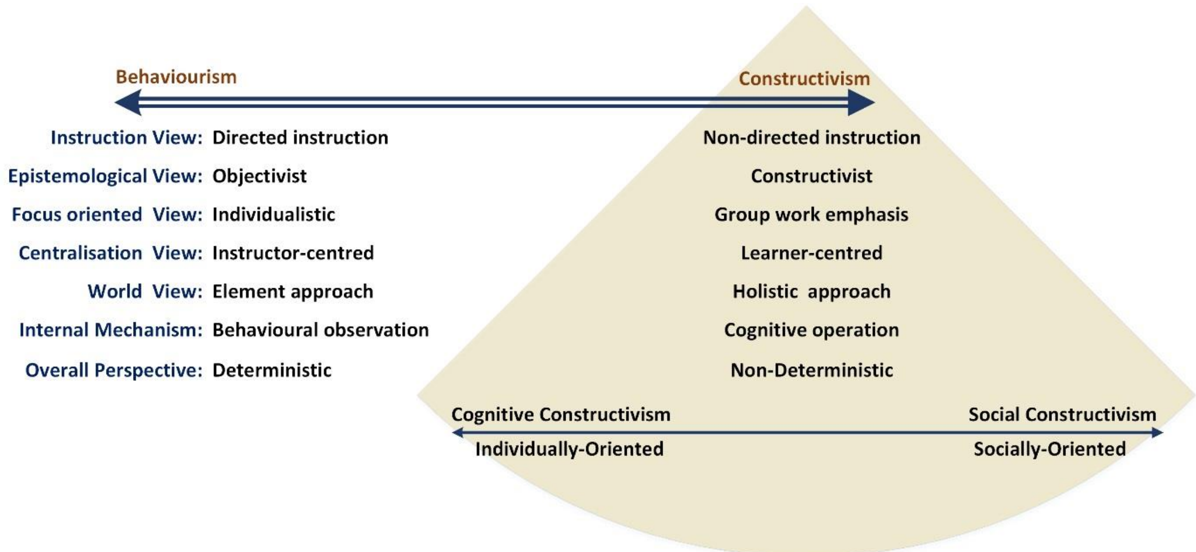


Figure 2.4: Learning Theories from Different View; (i.e., two extreme view)

direct instruction. It also reveals how behavioural observations work as the core internal mechanism for this learning paradigm. On the other hand, Constructivism, the other extreme, tends toward the opposite qualities (e.g., learner-centred) and covers a spectrum of learning approaches ranging from Cognitive Constructivism to Social Constructivism (B. G. Wilson, 1998; Gros, 2002; Cunningham and Duffy, 1996), which is wider than Collaborative Constructivism (Garrison, 1997). Constructivism can lean towards Behaviourism if the focus shifts towards feedback, and it can lean towards Situative if the focus shifts towards authentic learning activities. Finally, the above-classification and discussion helps to understand pedagogy, but further analysis/experiments are needed to understand learning, because fitting a flexible human creature into a simple and deterministic, to some extent, machine (i.e., computer) will not lead to a fully accurate understanding of learning phenomena. Also, considering pedagogical models (e.g., Instructional Design models) helps as they are in the middle between learning theories and e-learning models.

2.3.3 Learning Theories Comparative View

Table 2.3 shows a comparative summary of learning perspectives, theories and models used in e-learning. It extends the information shown above about common learning theories and links them up with an epistemological and world view since this supports the utilisations of these theories. Most of the literature cited above is used in the Table, however the main references are: (Conole *et al.*, 2005; Conole, 2010; Dyke *et al.*, 2007; Mayes and De Freitas, 2004; Harasim, 2012; Division of Learning andTeaching Services, 2011; Susimetsa, 2006; Hein, 1991; Conole *et al.*, 2004). To describe the world view of these models two terms have been introduced in Table 2.3: (i) *An Elemental Model*, that represents the universe as a machine composed of discrete pieces operating in a spatio-temporal field, and (ii) *A Holistic Model*, that represents the world as a unitary, interactive and developing organism (Knowles *et al.*, 2011). Furthermore, an *Epistemology View* has been addressed because it deals with the study of the origin, nature, limits and methods of knowledge (Schunk, 2012). Also, Table 2.3 shows the key figures of each theory including propounders (e.g., Piaget) and interpreters (e.g., Kilpatrick). Also, it uses different colours to differentiate between the two different types of the Cognitive Constructive approach.

2.3.4 Summary

This section concludes an extended review of e-learning pedagogy to: (i) understand the role of pedagogy in e-learning processes and (ii) conceptualise its best role in any proposed e-learning solution/artefact. Findings from the literature affirm the following three points. *First*, the deficiency of following one learning approach/theory to achieve comprehensive learning goals/outcomes (Dyke *et al.*, 2007; de Freitas and Jameson, 2012). *Second*, pedagogy, and its role in learning, is very dynamic and context dependent. Pedagogy evolves as technology evolves (e.g., connectivism learning theory), therefore an innovative and explicit consideration of pedagogy is needed to enhance the e-learner experience. Furthermore, pedagogy is context dependent and this context includes various human capabilities (e.g., learner reasoning and critical thinking) and broader contextual information that is related to the learning community and additional learning settings (e.g., institutional factors) (T. Bates, 2015). *Third*, learning theories are often presented as alternative interpretations of the same phenomenon. Nevertheless, we argue for more holistic approach where different learning theories are presented as compatible approaches to explain learning phenomenon. This means adopting a hybrid approach (i.e., combined of more than one learning theory) is necessary to fulfil e-learner needs. For instance, intellectual skills can be acquired through Gagne's bottom-up cumulative model, while top-down approach is preferred in teaching motor skills and higher order thinking skills (Mayes and De Freitas, 2004). Additionally, the hybrid approach considers the e-learner as both an individual and as a part of the social community to which the learner belongs, which adds further complications to the learning argument.

Developing a hybrid e-learning approach where different learning theories can be combined together, and various contextual inputs can be utilised entails the following: (i) the hybrid e-learning approach must be well specified and described so it cannot be confusing for the e-learner, and (ii) proper technologies need to be used in order to capture the required contextual information. The next section presents a thorough literature review for a wide range of e-learning models stretching from simple e-learning models such as Learning Objects through complex models such as Adaptive e-Learning Systems (AES). The overall aim of this review is to critically assess the current e-learning models and frameworks in order to discover the limitations as well as strengths and weaknesses of each e-learning model. Such findings will be used as a foundation for proposing a new e-learning artefact.

Table 2.3: Comparative Summary for Different Learning Perspectives, Theories and Models Used in e-Learning Contexts

#	Perspe-ctive	Metap-hor	World view	Influential figures	Epistemological orientation	Key characteristics	Key criticism	Main Approaches	Pedagogical models and frameworks	Potential e-learning models
1	Associationist	Learning as activity	Elemental model	John B. Watson, Ivan Pavlov, B. F. Skinner, Edward Thorndike, Edward Tolman	Objectivism: Reality is independent from human and external. Knowledge is absolute and matches reality	Learner's mind is a black box while the focus always goes to the changes in learner's behaviour. Learning is a sequence of stimulus and response actions in observable cause and effect relationships	Very simple and cannot explain complex learning processes. It refuses references to unmeasurable states such as feelings, attitudes, etc. which is not true for learning (T. Bates, 2015).	Behaviourism Instructional System Design e-Training Intelligent Tutoring Computer Aided Instruction (CAI)	Merrill's instructional design. Direct Instruction Model	Interactive content delivery system based on assessment and feedback.
2	Cognitive/Constructive	Learning as achieving understanding	Elemental model	*a) Cognitive learning theories:* David Merrill, Charles Reigeluth, Leslie Briggs, Albert Bandura, David Ausubel	Objectivism: Reality is independent from human and external. Knowledge is absolute and matches reality	Mental processes are essential for explaining behaviour. More focus on how learners make their own meanings based on the new information and experience. Learning as transformation of experience into knowledge, skills, attitudes, values and emotion.	Objectivism's view is that truth exists outs-ide the human mind or independently of what an individual may or may not believe (A. W. Bates and Poole, 2003), which is true some cases. Some knowledge and believes change over time which leads to different processing. Its elemental view (considering humans as machines) is also over simplistic. Humans are more dynamic and complex than machines. So, the analogy is mistaken, at least to some extent.	Constructivism Problem-based Learning Experiential Learning Learning by Doing SRL/SDL	Kolb's Learning Cycle Learning styles Laurillard's conversatio nal framework Community of inquiry framework	Adaptive and intelligent learning system Asynchronous and synchronous dialogue

			Holistic model	*b) Constructive learning theories:* Lev Vygotsky, Jean Piaget, Mitchell Resnick John Dewey, Jerome Bruner	Constructivism: knowledge is created to fit with reality. In other words, knowledge depends on the knower's frame of reference	Each learner individually and socially constructs meaning while he learns (Hein, 1991). Learners make sense of their external environments by a meaning making process which depends on previous experience. When learners see new information they either assimilate or accommodate it within their frameworks.	Does not consider emotional aspects, affective human characteristics and situations or experiences causing them. These factors may have significant influence on learners' ability to process and construct knowledge.			
3	Situative	Learning as social practice	Holistic model	John Seely Brown, Allan Collins, Paul Duguid, Jean Lave, Ettienne Wenger, George Siemens	Constructivism: knowledge is created to fit with reality. In other words, knowledge depends on the knower's frame of reference (Dabbagh, 2005; Dawley and Dede. C., 2014).	Consider social interaction. Learning is social participation within a wider socio-cultural context of rules and community. Learner knowledge and identity are affected by the community of practice	Context is important in situated learning, so understanding the design intentionality is inevitable (is it for education, fun, etc.?) (Dawley and Dede. C., 2014). Also, when education is the main target as opposed to fun or socialisation, learner motivation and engagement might decrease (Akilli, 2007) .	Cognitive apprenticeship Case-based learning Scenario based learning Collaborative learning Social constructionism	Wenger's community of practice Connectivi-sm Activity theory	Different tools that create opportunities for social interaction (e.g. forums, wikis) and creating or maintaining a community of practice.

2.4 Common e-Learning Models/Practitioner Perspective

This section discusses a group of e-learning models/frameworks that are commonly used by e-learning practitioners. These models include: (i) *Learning Object Model*, which is used almost in most of e-learning artefacts (Barker, 2005), (ii) *Learning Management Systems*, which are widely used by higher educational institutions (Mikroyannidis, 2012), (iii) *Open-based Learning*, that allow everyone to access learning contents and (iv) *Cloud-based Learning*, where recent cloud computing technologies have been adopted.

2.4.1 Learning Object (LO)

Learning Object (LO) refers to a digital entity that may be used for learning, education or training (Learning Technology Standards Committee, 2002). There are many variations stretching from simple Learning Object (e.g., power point presentation) through sophisticated Learning Objects (e.g., interactive LO). LO key components are: (i) learning objectives, (ii) a unit of instruction, to teach these learning objectives, (iii) a unit of assessment, to measure objectives achievement and (iv) metadata, to describe the object, its content and reuse process (D. A. Wiley, 2003). Different metadata initiatives emerged to promote LOs discoverability/reusability (Learning Technology Standards Committee, 2002), such as IEEE Learning Object Model – henceforth IEEE LOM or LOM–, IMS Learning Resources Metadata (Barker, 2005) and Dublin Core Metadata Initiative (DCMI) (McClelland, 2003). LOM, is an internationally recognised standard for describing LOs, as depicted in Figure 2.5 with LO title, language and vocabularies used for describing them (Barker, 2005). Since LOM is primarily designed for education, rich and extendable (Duval *et al.*, 2002), it is used as a base model for LO (Al-Khalifa and Davis, 2005) in this research. The LO Model strengths are: (i) reusability in different contexts, (ii) independent, (iii) self-standing unit of learning (Polsani, 2006), (iv) interoperability and accessibility, and (v) small or granular to the extent that it can be reused

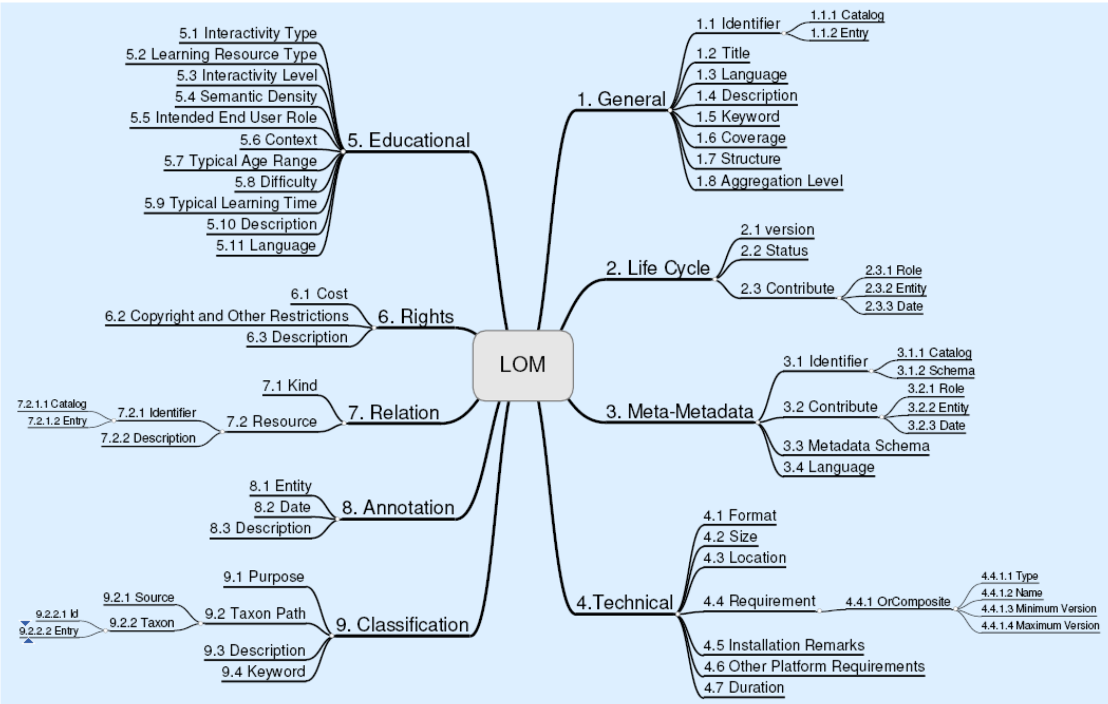


Figure 2.5: IEEE LOM Elements and their Hierarchy (Barker, 2005)

properly (Balatsoukas, Morris and O'Brien, 2008). Yet, LO Model shortcomings include: (i) its vagueness/abstraction, which is reflected on roles and their contribution, (ii) the lack of well-structured representation of learning and pedagogical concerns/information (Friesen, 2004), which limits the pedagogical value of LO, (iii) instructional model rather than learning model (Mayes and De Freitas, 2004; D. A. Wiley, 2003), (iv) content not process-oriented, where learning process is ignored or implicitly cemented into LO design, and (v) the required trade-off between LO granularity and inter/inter-contextual reusability (Currier and Campbell, 2005). So, the more contextualised LO is more likely to be less used. Various LO Content Models (LOCM) (e.g., SCORM Content Aggregation Model) appear to extend LO concept (Knight, Gasevic and Richards, 2006), yet they bring their own restriction to the LO Model instead of properly extending LO. For instance, SCORM is essentially about a single-learner, self-paced and pedagogically limited (Wirski, Brownfield and Oliver, 2004; Kraan, 2002).

2.4.2 Learning Management Systems (LMS)

Learning Management Systems are online portals that connect different roles (e.g., e-learner and instructor) and provide mechanisms for classroom materials/activities to be accessible, used and shared within flexible communication environment (Squillante, Wise and Hartey, 2014). LMSs are dominant e-learning tools used by universities worldwide (Walker *et al.*, 2014) because of: (i) their capabilities to facilitate learning and teaching activities which lead to user satisfaction (AbuShaban and Hammad, 2006), (ii) their adoption flexibility and integration/co-existence with other tools/packages, (iii) their long history of development, and (iv) their development model since most of proprietary LMSs have been acquired by the most dominant LMS (i.e., Blackboard and Moodle). Moodle is an example of open-source LMS that is leading the market as well. Both systems offer similar capabilities with marginal differences (AbuShaban and Hammad, 2006; Carvalho, Areal and Silva, 2011; Logan and Neumann, 2010).

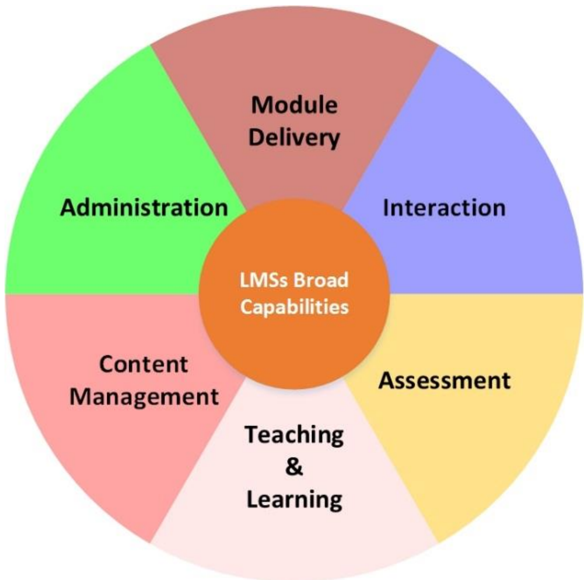


Figure 2.6: Broad Classifications of LMSs Capabilities

LMSs offer a wide range of capabilities which can be broadly classified into: module delivery, interaction, assessment, teaching and learning, content management or administration as shown in Figure 2.6.

Blackboard, similar to most LMSs, has been criticised to be supportive of linear pedagogy, system-wide and activity-integrated user profile (Logan and Neumann, 2010). Linear pedagogy refers to traditional approaches where repetitive instructions are given as answers to problems. This contradicts Moodle underlying pedagogy since Moodle supports social constructionist pedagogy by providing learners with more control on their activities and profiles, encouraging producing collaborative artefacts, providing potential for learning through observing peers (Dougiamas, 2010). LMSs are: (i) built around 'module' concept which makes it difficult to introduce flexible e-learning models such as social or informal learning models, (ii) turned to be complex and misleading environments for complicated pedagogical models, (iii) not generic to the extent that they can accommodate wide range of e-learning models (Logan and Neumann, 2010; Dougiamas, 2010), and (iv) classified as monolithic or legacy systems that cannot respond to the agility of e-learning requirements (Dagger *et al.*, 2007). The first LMS generation were black box, while the second generation manifests itself in more modular architectural design yet further shift towards a loosely coupled architecture is still required. Although LMSs have been used for e-training purposes, they are not sufficient enough (Bagnasco *et al.*, 2003) as they lack participatory learning (Nicholson, 2005) due to their underpinning philosophy to recursively decomposing knowledge and skills to simple and small units (i.e., associative approach), and may not be a suitable platform for complex topics that require advanced learning models (e.g., adaptive models) (Gagné, 1965).

2.4.3 Open-based Learning Model

Various open/distance learning initiatives (e.g., OpenCourseWare (OCW) and Open Educational Resources (OER)) appeared to provide learning without traditional restrictions such as entry requirements. OCW initiative started in 1990s aimed at offering online contents (Cormier and Siemens, 2010; Abelson, 2008). Later, OERs appeared to enrich it with further educational resources until the appearance of Massive Open Online Courses (MOOCs) in 2008. MOOCs model, as shown in Figure 2.7, extends OCW and OERs through offering entire courses instead of material or separated learning contents. MOOCs can be classified either as: (i) *connectivist MOOCs (cMOOCs)* which

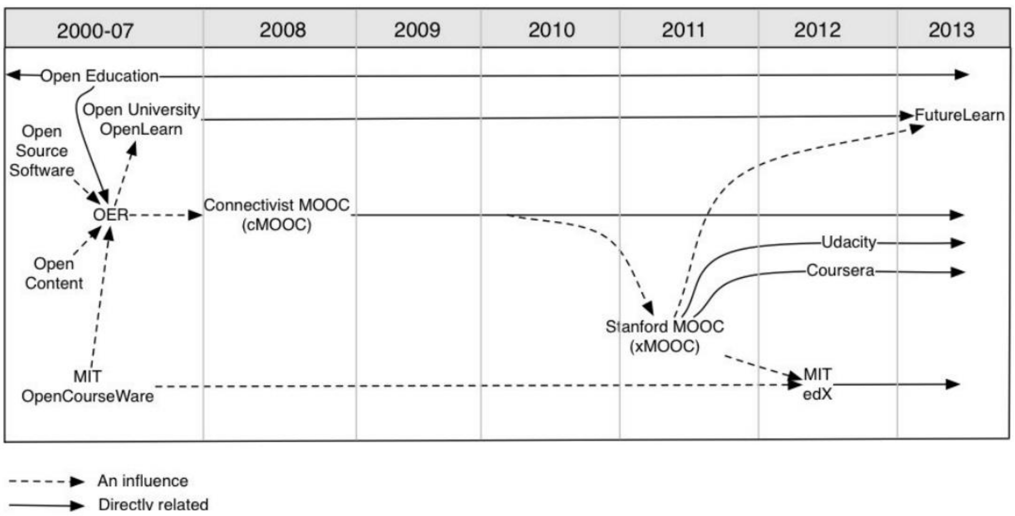


Figure 2.7: MOOCs and Open Learning Model Timeline (Yuan and Powell, 2013b)

offer e-learner-centred approach with limited institutional constraints (i.e., based on connectivism learning theory) to foster the affordances of social and participatory media (e.g., interaction with peers), or (ii) *content-based MOOCs (xMOOCs)* which adopts instructor-centred approach as the focus shifts towards instructor-designed contents/activities (i.e., behavioural learning theory) (Yuan and Powell, 2013a; Conole, 2013).

Pedagogically, the origin of MOOCs was bottom-up where the e-learner is encouraged to lead the learning process; however, recent initiatives promote a structured top-down approach (Conole, 2013). xMOOCs have been criticised for acting as traditional knowledge-transfer instead of knowledge-build model and promoting individualised learning experience (Larry, 2012; Larry, 2013). Although cMOOCs provide opportunities for non-traditional learning approaches that are almost unachievable in traditional classrooms (Yuan and Powell, 2013b), but it is not straightforward since learners use different channels (e.g. twitter) to exchange, collaborate, communicate and build knowledge via curation tools (e.g. scoop.it) to filter and aggregate resources (Conole, 2013). This may be very distracting, and learners find themselves in a learning environment that provides minimum constructive feedback and guidance to think creatively (Conole, 2013; Nkuyubwatsi, 2013). Additional MOOCS limitations include: (i) the high dropout (i.e., less than 10% (Liyanagunawardena, Adams and Williams, 2013)) which imposes questions on engagement methodologies and learning models/strategies, (ii) limited adaptivity to respond to the e-learner's heterogeneity based on their profiles (Haggard *et al.*, 2013; Daradoumis *et al.*, 2013) (iii) deficiency to hybrid model form (a mixture of cMOOCs and xMOOCS), and (iv) their superficial classification which ignores underpinning learning models (Conole, 2013). Hence, further contextualisation is needed to capture the semantics of learning and adoption of process-based approaches supported by various learning models to allow learners to control and enhance their own learning experiences.

2.4.4 Cloud-based e-Learning Models

Different cloud-based models appeared (e.g., (Saidhbi, 2012; Butt, 2013)) to extend educational networks or infrastructure capabilities in terms of sharing educational resources, collaborative data centre, e-library and technical support, and integration with other services for better resources utilisation taking into consideration the different business models of educational institutions. Therefore, (Butt, 2013) suggested a central hybrid framework that includes: (i) private cloud implemented and managed by the Ministry of Education in collaboration with higher education institutions and (ii) public cloud to provide access to extra services hosted by a certain university to serve multiple universities to reduce cost and increase efficiency (e.g., one registrar system to serve multiple universities). The proposed framework is composed of the following four layers: (i) a *user interface* that contains: (a) a user portal to access applications/services, (b) services catalogue to provide services along with their details, (c) services repository to provide a list of services, (ii) a *Software as a Service (SaaS) Layer* that provides access to cloud hosted applications (e.g., LMS), (iii) a *Platform as a Service (PaaS) Layer* that provides access to different platforms (e.g., programming languages), where users select capabilities to support their learning practices, and (iv) *Infrastructure as a Service (SaaS) Layer* that provides flexible access to virtualised hardware.

Such models adopt various cloud computing software platforms (e.g., OpenNebula, Aneka and Eucalyptus). Adopting OpenNebula cloud platform reveals proper supports for cloud features in IaaS (e.g., on-demand virtual machine provisioning) and enhances the integration of external providers' services with internal ones (i.e., hybrid approach). In (Sempolinski and Thain, 2010), Aneka has been adopted, on the top of OpenNebula, to give developers the ability to run their application on a local or remote distributed infrastructure. However, certain limitations have been reported including the high technical administration overhead due to manual configuration and the absence of learning/educational aspects of these cloud platforms (i.e., they are pure technical platforms). Other cloud-based models (e.g., (Butt, 2013)) have been developed as a three-tier framework through a combination of Eucalyptus, Aneka and OpenNebula. Despite its capabilities to form a hybrid model, this hybrid nature remains at the technology level only. Learning/educational models, theories and considerations are completely missing in such frameworks. This affirms the previous conclusion that learning can't be simply achieved by combining different software and hardware components.

2.5 Process-Based and Service-Oriented e-Learning Models

This section introduces the application of Business Process and Service Orientation in the e-learning domain. To do so, a brief background to both Business Process domain and Service Orientation has been presented, followed by key e-learning models and in particular: (i) *IMS Learning Design*, (ii) *Workflow-based*, (iii) *eLearning Management System* Using Service-Oriented Architecture, and (iv) *SOA-based e-Learning System* for Teaching Fundamental Information of Computer Science.

2.5.1 Business Process and Learning

A business process refers to a set of collaborative and transactional activities that are complete, dynamically coordinated and deliver value to customers (Smith and Fingar, 2003; Ould, 1995). Modelling business processes helps to understand processes, improve their performance and provide abstraction from technical details (Aguilar-Saven, 2004). Theoretically, process-based approaches fit e-learning because learning by itself is a process, as shown in Figure 2.8, and it cannot be limited to resource or peer recommendation. It is a coherent set of interactions, resource management and development activities in a continuously changing environment. Practically, process-based approaches are rarely adopted in e-learning due to: (i) the implicit nature of the learning phenomenon because it happens inside the e-learner's mind, and hence not straightforward to model and enact e-learning processes, (ii) it is very challenging to accurately specify e-learning processes because they vary significantly. Traditional e-learning processes classification, shown in Table 2.3, (i.e., Behavioural, Cognitive Constructive and Situative) can be changed depending on processes implementation. For instance, simulation-based learning processes are classified in the cognitive perspective; however, they can be situated if the focus is on the social affordances, such as interacting with peers and instructors.

Different modelling notations with their comparison exist in literature (Z. Khan, 2009). Researcher adopts industry-standards Business Process Modelling Notation (BPMN) for modelling purposes and Business Process Execution Language (BPEL) for enactment purposes, due to their expressiveness, interoperability and provided support. Semantic technologies will be used to enrich the modelled e-learning processes and minimise their ambiguity.

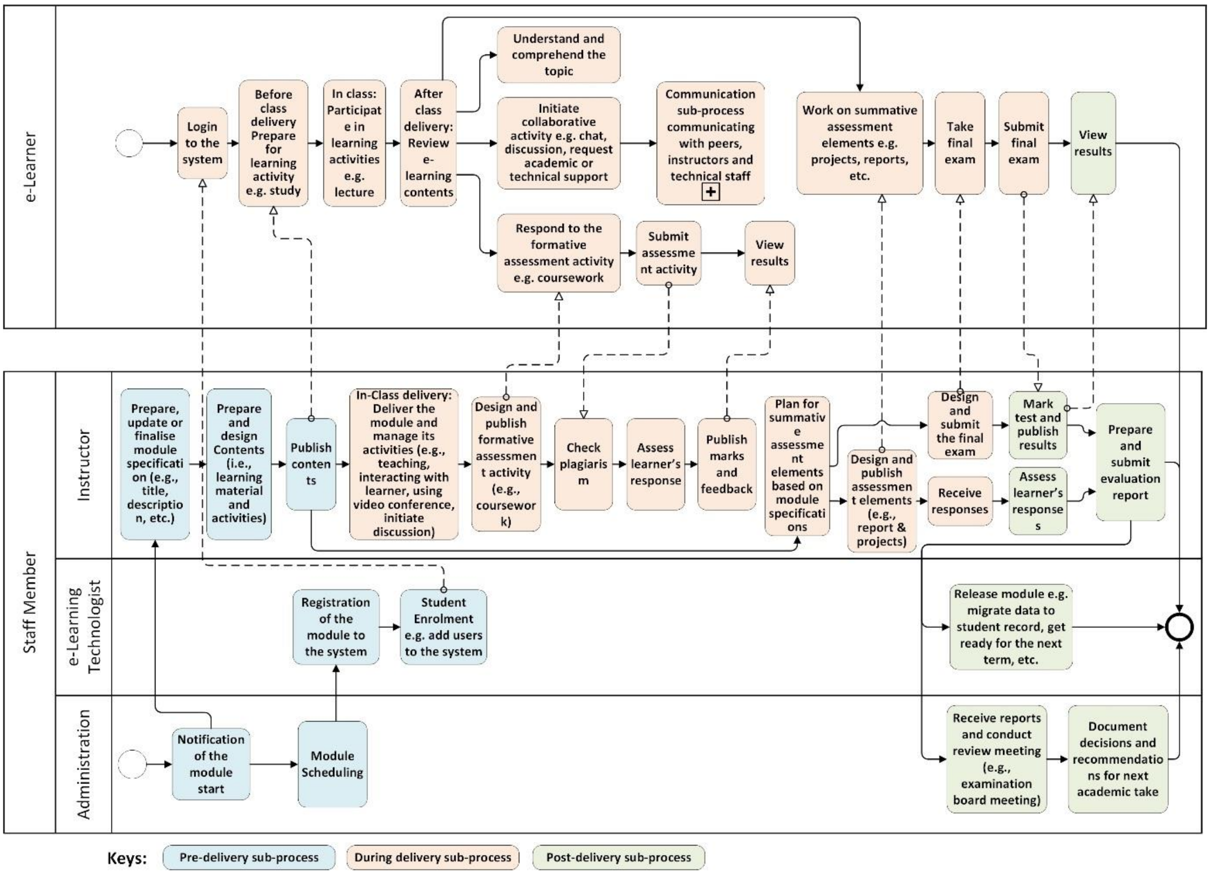


Figure 2.8: Module-scale e-Learning Process

e-Learning processes vary notably in terms of lifetime, scale and type. For instance, Figure 2.8 models e-learning process in pre-module delivery, during delivery and post-delivery phases where different actors are involved, Figure 2.9 shows an e-learner-oriented process which conforms to the scope of this research. This research mainly handles learning-oriented processes and aspects from other processes that are tightly connected to learning.

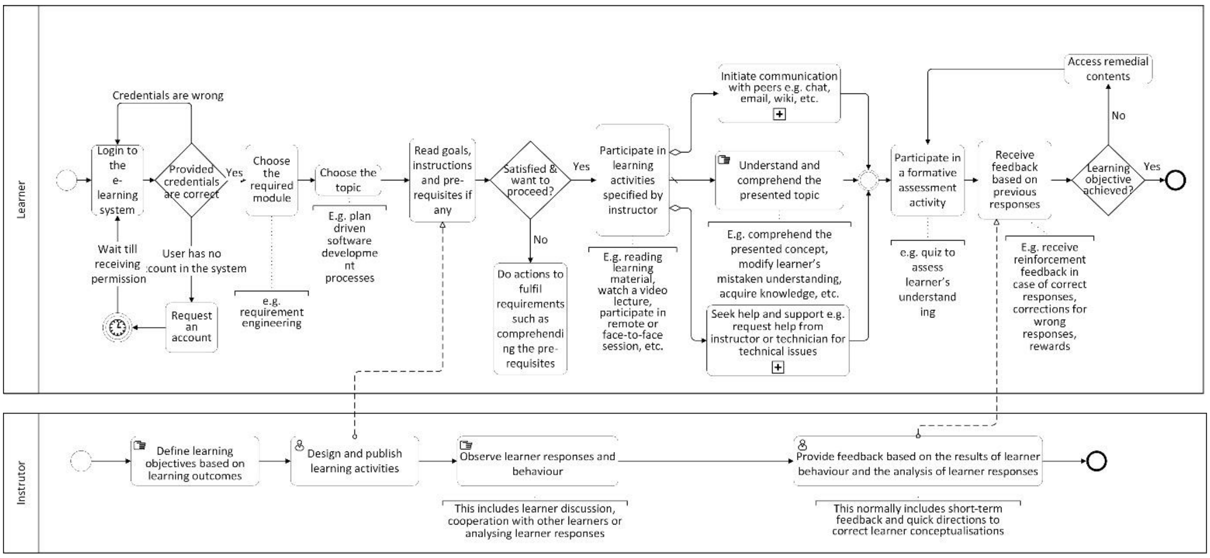


Figure 2.9: Learning-Oriented e-Learning Process

2.5.2 Service-Oriented Computing (SOC)

Adopting the Service-Oriented Computing/Architecture (SOA/SOC) in e-Learning is essential to respond to the continuously evolving e-learning requirements that cannot be met by the current legacy e-learning solutions due to their monolithic design (M. Papazoglou, 2012). It allows discovering and composing the suitable software services, henceforth services, to satisfy software system requirements. It changes the way that software systems designed, architected, developed, delivered and consumed (M. P. Papazoglou *et al.*, 2007; Sagayaraj *et al.*, 2012). SOA is a software architecture style that defines the utilisation of loosely coupled and interoperable services to satisfy the requirements of users or business processes (Meccawy, 2008). Resources in SOA-enabled environments are offered as independent services that can be accessed through interfaces which hide the implementation of these services (Erl, 2008). SOA model, as depicted in Figure 2.10, comprises the following three roles: service provider, service requester/consumer and service registry/broker (Sagayaraj *et al.*, 2012; M. Papazoglou, 2012). SOA relies on certain enabling technologies, depicted in Figure 2.11, such as: eXtensible Markup Language (XML), Simple Object Access Protocol (SOAP) or Representational State Transfer (REST), Web Service Description Language (WSDL) and the Universal Description, Discovery and Integration (UDDI) specification.

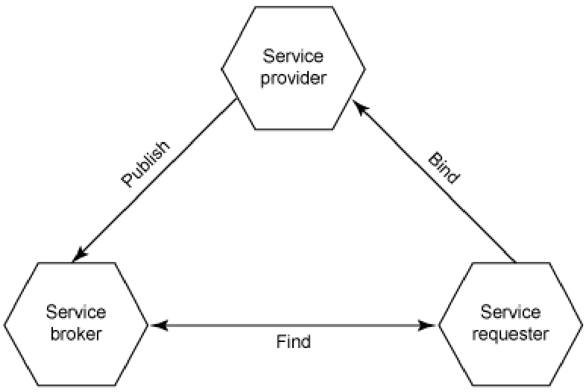


Figure 2.10: Service Oriented Architecture Model (Newcomer and Lomow, 2005)

Web services are self-describing and self-contained software modules that can be published, located and invoked across SOA-enabled environment to perform a certain task on behalf of a given role that could be a machine or user (M. P. Papazoglou *et al.*, 2007). The key advantages of web services include: loose coupling, reusability, interoperability, statelessness, describeability and discoverability (Erl, 2008; Newcomer and Lomow, 2005; M. Papazoglou, 2012).

SOAP is a lightweight XML-based protocol for exchanging information in distributed environments. SOAP as a protocol states the messaging between provider and requester. A SOAP message is composed of: (i) SOAP envelop, (ii) SOAP body and (iii) SOAP header. SOAP has different advantages, for instance its use for the

Figure 2.11: The Web Service Technology Stack

namespace and XML data types, transport flexibility, its high level of abstraction to stay away from technical details, it can use other protocols such as SMTP in addition to the HTTP (W3C,). **REST** is an alternative software architectural style for distributed computing. It also adopts a stateless client-server architecture style where web services are considered as resources identified by their URIs (X. Feng, Shen and Fan, 2009; Erl *et al.*, 2012). Despite the advantages of REST, it needs to be configured manually and consequently requires extended time and detailed technical knowledge for implementation (e.g., in REST, developers need to track, and handle messages failed to be delivered) (Meccawy, 2008). For this research, SOAP-based approach is chosen due to its strengths such as its customisability, the availability of open source libraries that allow further realisation steps, available tools, among others.

2.5.3 IMS Learning Design (IMS LD)

IMS Learning Design (IMS LD), among other standards (e.g., Content Packaging (CP) and Simple Sequencing (SS)), has been developed by the IMS Global Learning Consortium to develop and promote the adoption of open technical specifications for interoperable learning technology (Stracke, 2006). It evolved from Educational Modelling Language (EML) developed at Open University of Netherland to provide a containment framework of elements that can describe any design of a teaching-learning process or learning scenario in a formal way (Stracke, 2006; Jeffery and Currier, 2003). So, IMS LD is an e-learning specification that allows designers to describe Units of Learning (UOL), where UOL is the smallest unit providing learning events for learners, satisfying one or more interrelated learning objectives. UOL cannot be broken down into its components without losing its semantic and pragmatic meaning and its effectiveness towards the attainment of learning objectives (Koper and Van Es, 2003; Tattersall *et al.*, 2005).

IMS LD is the only existing interoperability specification that supports the definition and orchestration of learning activities involving multiple roles and complex activity flows (Derntl *et al.*, 2012). IMS LD elements, as shown in

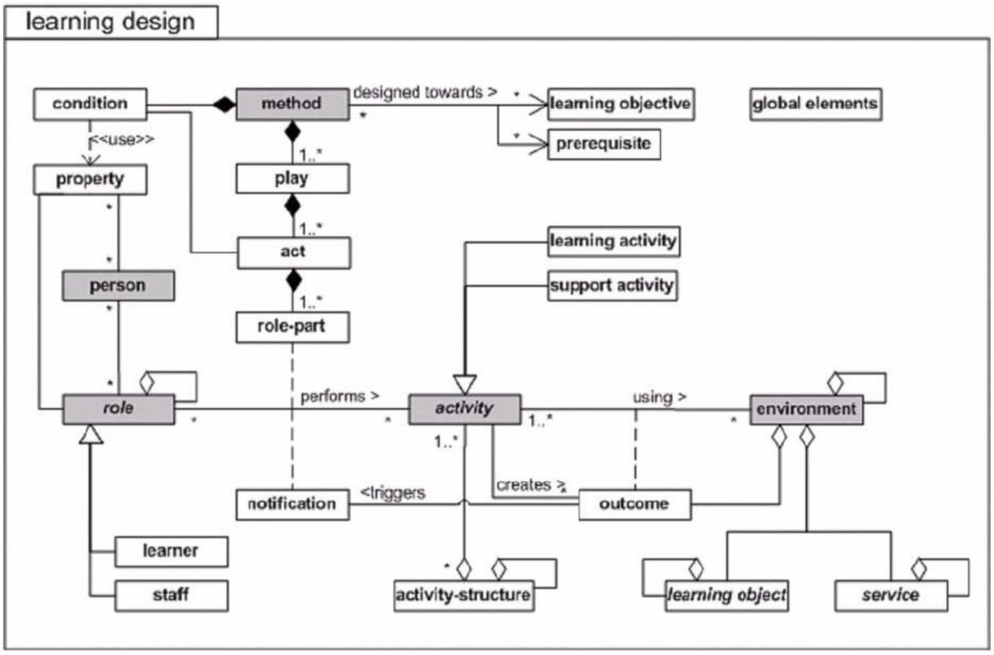


Figure 2.12: IMS LD Conceptual Model (Koper *et al.*, 2003)

Figure 2.12, are: *components* that refer to the basic design elements, and *method* which describes how to combine components together. The core components are: (i) role to define the functions carried out by a person, (ii) activity to define actions performed during learning and teaching process, (iii) activity structure includes several activities to create a sequence for all of them or to create a selection between them, (iv) environment which represents the container that holds learning contents, and (v) property to store data in order to keep, update and display it when required (Derntl *et al.*, 2012). It has three levels: A, B and C, each of these levels has different level of details, where level B is the most detailed one.

Despite IMS LD strengths (i.e., goes beyond content-oriented models), it has been poorly adopted, mainly in pilot projects, due to many shortcomings reported in (Derntl *et al.*, 2012; Neumann *et al.*, 2009; Griffiths and Liber, 2008). Key shortcomings include: (i) lack of flexibility (e.g., tiny changes to contents such as lesson order are not possible unless essential modifications to the activity structures, act, role-part, method, properties and conditions are done, no flexible inputs management) (Caeiro-Rodríguez, Anido-Rifón and Llamas-Nistal, 2010; Caeiro-Rodrıguez *et al.*, 2007), (ii) interoperability-oriented (e.g., does not allow saving or retrieving information to/from external sources), (iii) dynamic grouping for users is not possible, (iv) user behaviour is not recorded, (v) adaptation is limited (i.e., lack of rich adaption conditions, no adaption based on previous user behaviour) (Burgos, 2010), (vi) complex since it works as an integrative layer with other specifications (e.g., CP and SS) (Koper, Olivier and Anderson, 2003), (vii) package lifecycle, and (viii) limited work with collaborative learning and IMS Learning Design-Level B notation issues (e.g., how acts are synchronised, conditions utility) and other limitations related to interactions, execution control of activities and document transfer between activities (Neumann *et al.*, 2009; Griffiths and Liber, 2008).

2.5.4 Workflow-based e-Learning Model

Workflow-based e-Learning Platform (WeLP) has been proposed to analyse current e-learning systems and enhance its performance throughout the use of workflow concept (Yong, 2005). The core idea of this model is to design a better e-learning platform that can facilitate smooth implementing and use of different e-learning procedures. To do so, e-learning procedures have been divided into the following four aspects: (i) *teaching* that targets lecturers/instructors, (ii) *learning* that targets students, (iii) *administrator* that targets administration and personnel and (iv) *infrastructure* that targets infrastructure, technical experts and technicians. These four aspects represent four sub-workflows that will be used to plan and design the process of various e-learning aspects. Each workflow represents one aspects and has a list of activities that ensure its successful implementation. However, WeLP did not sufficiently specify the list of activities that constitutes each workflow (e.g., material delivery could be a huge process not only one activity), intuitively analyses the relationships between these activities, remains at the very high level of abstractions, leans toward design and lacks real evaluation that can prove its impact in terms of developing better e-learning platforms.

2.5.5 e-Learning Management System Using Service-Oriented Architecture

Jabr and Omari (Jabr and Al-Omari, 2010) proposed an e-Learning Management System using SOA to address various concerns especially including: (i) *interoperability* throughout integrating widely disparate web-based applications regardless of their implementations choices, (ii) *durability,* and (iii) *personalisation* among others. The proposed system provides a general approach on how to utilise SOA in e-learning with rich technical implementation (e.g., use cases and package diagrams) explanations but it lacks essential related aspects such as follows. First, there is no explanation for learning personalisation mechanisms. Second, web service identification process is not described despite the fact that web services are essential in such a system. Third, business process is mentioned in their architecture without further details. Generally, this system is focused around implementation rather than targeting certain concerns such as personalisation, privacy, durability to mention but a few. Also, it does not cover the underpinning learning models/theories to the sufficient level.

2.5.6 SOA-based e-Learning System for Teaching Fundamental Information of Computer Science

Another SOA-based e-learning system (C. C. Chang and Hsiao, 2011) has been developed to promote the reusability of e-learning components and contents and consequently reduce the cost and the interchangeability. According to Chang and Hsiao (C. C. Chang and Hsiao, 2011), they claim that such model accelerates the development of e-learning systems in the future. This model provides various functions stretching from course material through online test and assignments. However, both SOA-enabled e-learning models summarised in Sections 2.5.5 and 2.5.6, and other examples in the literature, moved towards implementation and technical concerns rather than addressing the core technical and learning concerns. Examples on these concerns include: service identifications based on e-learner's profile. Additional example is the web services limitation in transferring e-learning contents, as web services are not good in transmitting large amount of data. There is no discussion on how to handle this particular concern in the context of e-learning, where we have very rich contents such as videos and various illustrations artefacts. Furthermore, there is a lack in the discussion on reusing e-learning contents that are published online (e.g., html or jsp pages) through automatic wrapping of the currently-published contents in the form of web services. Additionally, web services are not utilised to the sufficient extent in the e-learning domain. Such discussion requires classifying the services into different categories such as utility services and content services, granularity of web services, and approaches to discover and identify services.

2.6 Semantically-Enriched e-Learning Models

This section briefly introduces the main technology underpinning this type of e-learning models, which is the ontology and its supportive technology (i.e., Semantic Web Rule Language (SWRL). Then, it reviews the following e-learning models: (i) Recommender Systems models, (ii) Responsive Open Learning Environment (ROLE) and (iii) Intelligent Tutoring Systems.

2.6.1 Ontology

Web evolved from web 1.0, mainly read-only information vehicle, to web 2.0, mainly about connecting users, to web 3.0 that aims at connecting intelligence through the semantic web (Ifenthaler, 2010; Ifenthaler, 2012), which requires effective knowledge/semantic representation. Ontology refers to "a specification of a conceptualisation" (Gruber, 1993). Conceptualisation refers to an abstract and simplified view of the modelled domain. Such specification should be formal (i.e., machine-readable) (Gaševic, Djuric and Devedžic, 2006). Ontology can be used in various ways (e.g., define hierarchies or formal vocabulary with axioms defined on such vocabulary) (Guarino, 1998). For this research, ontology is utilised to capture the logical structure of the e-learning domain, its concepts, relationships, rules, and contexts of use. It will work as a meta-model which: provides a mechanism to abstract from technical details, allows dynamic reasoning about certain instances (i.e., e-learners), allows more effective knowledge representation (e.g., management, discovery, and retrieval), makes domain assumptions explicit, and most importantly is necessary for a generic and hybrid e-learning solution. In other words, this meta-model will allow generating specific models for certain contexts, because meta-model is an explicit model of the constructs and rules needed to generate specific models for a certain domain. Such ontology could be specified using different languages such as RDF, RDFS, and OWL). Due to OWL 2.0 expressiveness as explained in Table 2.4, it will be selected for specifying the meta-model.

Resource Description Framework (RDF) affords a domain neutral mechanism to describe individual objects via XML-based serialisation syntax to represent information about resources in 3-triples format (i.e., subject, predicate/property and object) (Soomro, 2015; Wang *et al.*, 2004), while RDF Schema (RDFS) is the RDF vocabulary container that provides the capabilities of describing properties, classes of resources and relationships between them (Pan, 2009). Yet RDFS is limited (e.g., cannot specify cardinality and relationships between properties like symmetric, inverse and transitive) compared to other knowledge representation languages, such as OWL (Gil and Ratnakar, 2002; Munir, 2011). OWL vocabulary includes a set of well-defined XML elements and attributes that are used to specify domain concepts as well as their relationships and consequently capture the semantics of the target domain. Notable examples on some of the OWL vocabularies include: relations between classes, cardinality, property characteristics and enumerated classes. OWL is a combination of a layered structure comprising three expressive sublanguages which are: OWL Lite, OWL Description Logic (OWL DL) and OWL Full (Antoniou and Van Harmelen, 2004; AlAgha, 2009).

Table 2.4: Comparison of Different Ontology Modelling Languages

Characteristic	RDF(S)	OWL 1.0	OWL 2.0
Datatypes	✓	✓	✓
Cardinality restriction	×	✓	✓
Domain and Range	✓	✓	✓
Disjoint classes	×	✓	✓
Enumeration	×	✓	✓
Complementary classes	×	✓	✓
Property chains	×	×	✓
Asymmetric properties	×	×	✓
Reflexive properties	×	×	✓
Qualified cardinality restriction	×	×	✓
Class punning	×	×	✓

Table 2.4 summarises the differences between RDF, OWL 1.0 and OWL 2.0 to justify OWL 2.0 utilisation in this research. Semantic Web Rule Language (SWRL) has been developed to extend OWL expressiveness and its capability to model complex problems. SWRL is an expressive rule language that combines Horn clauses with concepts specified in OWL (Orlando *et al.*, 2012). SWRL rule is composed of antecedent/body and consequent/head. Once the antecedent atoms are true certain semantic reasoner (e.g., Pellet or Fact++) fires the SWRL rule and executes the atoms on the left-hand side (LHS). Such rules are inevitable because they allow reasoning about a certain e-learner in order to recommend a learning process/approach including: resources, peers, activities, etc. Below is an example of a simple SWRL rule that tells the system if there is a person (p) and a woman (w) where (w) is sibling of (p) then (w) is a sister for (p). OWL DL 2.0 and SWRL have been used in this research to achieve its final goals.

Person (?p), Woman (?w), sibling (?p,?w) → sister (p, w)

2.6.2 Recommender Systems

The success of Recommender Systems (RecSys) in various domains (Park *et al.*, 2012; Lu *et al.*, 2015) increased their potential to be applied in e-learning (Manouselis *et al.*, 2013). RecSys produce individualised recommendations and guide the e-learner in a personalised way to interesting/useful learning objects in a large space of possible options (Burke, 2002). These recommendations can be based with reference to: (i) contents previously-revealed to or studied by the e-learner, (ii) profile of the e-learner and his peers, (iii) demographic/personal data, (iv) utility function, (v) knowledge-based inference, or (vi) hybrid approach (Konstan, 2004). Successful application for RecSys in e-learning is challenging due to: (i) the richness of e-learning models and their underpinning pedagogical theories, (ii) learners vary significantly in terms of their time frame, strategies adopted (e.g., linear vs accumulative learning approach), (iii) recommendation lifetime is longer than its counterparts in other domains (e.g., watching a movie lasts for about an hour or so) and hence, evaluating the successfulness of these recommendations (e.g., the rate given by the user to the movie he/she watched) may lead to sparse or inadequate feedback, (iv) the different settings of learning (e.g., collaborative filtering techniques are more appropriate for informal not formal learning settings), (v) the heterogeneity of learning resources and their lifetime and (vi) the proper capture of contextual information to enrich the recommendation process because e-learner's skills, activities and approaches are continuously changing (Manouselis *et al.*, 2013; Manouselis *et al.*, 2011).

Limitations of TEL RecSys include: (i) the majority operate utility function to calculate value based on a single attribute (e.g., lessons rank or number of downloads) and rarely multiple attributes (Manouselis *et al.*, 2011) to find novel sources, peers or proper pathways or predict e-learner performance (Manouselis *et al.*, 2013), (ii) the majority do not fully capture learning process (e.g., from (82) RecSys surveyed in (Drachsler *et al.*, 2015), the vast majority (61) RecSys recommend learning resources, few (9) RecSys recommend peers, and very few only (4) RecSys recommend learning activities, (iii) limited accommodation of various learning settings (e.g., appropriate for informal settings since they shift responsibilities a way from domain experts and evaluate content quality based on e-learner collective behaviour instead of formal evaluation procedures (Manouselis *et al.*, 2013), (iv) deficient in critically responding to learners' metacognitive skills (Zhou and Xu, 2012), effective communication skills (Abel *et* *al.*, 2010) and capturing intrinsic factors such as e-learner motivation (Manouselis *et al.*, 2013), (v) presenting and visualising recommendations to learners need further enhancement (Manouselis *et al.*, 2013) and (vii) the limited number of reports on real-life deployment which disallows critical evaluation with actual experimental settings (Manouselis *et al.*, 2013) based on various technical, educational, pedagogical and psychological considerations (Buder and Schwind, 2012).

2.6.3 Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITS) are didactic, content specific and Artificial Intelligence (AI)-based instructional artefacts (Harasim, 2012) that encompass very different components to enhance learning (Keleş *et al.*, 2009). ITSs distinguish from their counterparts because they specify what to teach and how (i.e. teaching strategies) (Murray, 1999). ITSs consist of the following four components: (i) *domain model*, to model the subject being taught, (ii) *student model*, to represent e-learner, understanding, skills, etc., (iii) *teaching model*, to represent the methods of teaching, and (iv) *user interface*, to manage interaction with users (Freedman, Ali and McRoy, 2000). Combining the previous

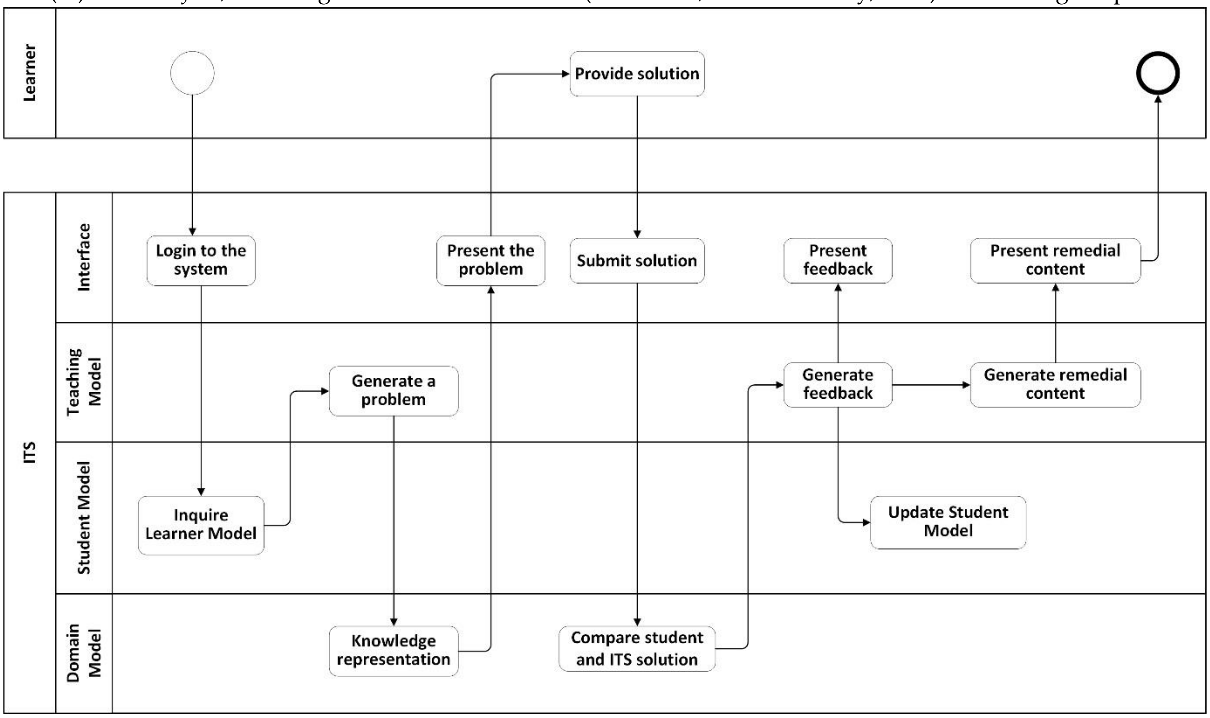


Figure 2.13: The Simplified Internal Mechanism of Problem-Solving Oriented ITS

four components allows: (i) analysing e-learner understanding to discover his/her *missing conception* (i.e., knowledge items existed in the domain model but not in the student model) and misconception (i.e., knowledge items existed in student model not the domain model) and (ii) adapting proper instructional methodology to achieve learning goals (Polson and Richardson, 2013). Analysis of the e-learner model differs according to the type of ITS which include: model-tracing cognitive tutors, constraints-based tutors, example-tracing tutors (Vandewaetere and Clarebout, 2014), underpinning theories, adopted techniques, classifications, authoring tools (e.g., D3-Trainer), teaching scenarios (e.g., drill and practice) (A. C. Graesser *et al.*, 2005; Murray, 1999; Keleş *et al.*, 2009; Stankov *et al.*, 2008; Frasson, Mengelle and Aimeur, 1997; Siemer and Angelides, 1998).

ITSs key shortcomings include: (i) its instructivist/behavioural approach (Harasim, 2012; Mayes and De Freitas, 2004), (ii) individual way of teaching, (iii) internal components are difficult to reuse (e.g., methods/analogies are domain-specific) (Freedman *et al.*, 2000), (iv) black box and expensive to build as 100-1000 hours of authoring are required per hour of instruction (Mitrovic and Koedinger, 2009), (v) no standard language for knowledge representation for interfaces to allow components talk to each other or to provide accessibility to data for external tools (El-Sheikh and Sticklen, 1998), (vi) authoring tools provide excellent visual interface but insufficient representation of knowledge, content and pedagogy (Murray, 1999), (vii) not accessible to instructors in terms of what is available, how to access and utilise (C. Graesser, Chipman and King, 2008), (viii) not pedagogical neutral/expressive as they are dominated by problem-solving oriented approaches (i.e., procedural rather than conceptual) (Brusilovsky and Millán, 2007)). Figure 2.13 shows a simplified internal mechanism of problem-solving oriented ITS. It reveals that ITSs are limited to specific types of learning models, and cannot successfully represent certain learning models (e.g., student-led models). Due to ITS underpinning model (i.e., direct teaching), learners miss the chance of exploring concepts of interest. Also, inefficient use of time has been noticed when using ITSs inspired by Piaget exploratory school of discovery learning (Clancey, 1986; Papert, 1980).

2.6.4 Semantic Framework for Cloud Learning Environments

Cloud Learning Environments (CLE) is an extension to Personal Learning Environments (PLE) that enable learners to compose their own learning environments while considering the cloud as a huge autonomous space (Malik, 2013). Nevertheless, learners face difficulties in allocating suitable resources from the abundant amount of resources available on the web due to the absence of semantic descriptions of learning services/resources (Mikroyannidis, 2012). Therefore, a four-layer semantic knowledge base has been developed in (Mikroyannidis, 2012) to capture the semantics of such learning resources as shown in Figure 2.14. Such knowledge base is composed of four layers to model e-learner, learning resources, learning domain and lexical-oriented concerns,

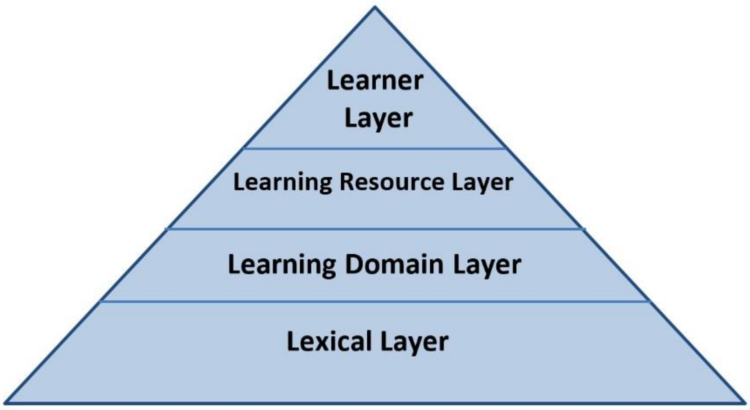


Figure 2.14: CLE Semantic Knowledge Base

respectively. This knowledge base represents the core of Responsive Online Learning Environment (ROLE). Through this knowledge base, ROLE *first* extracts e-learner's profile (e.g., preferences, goals and skills) from e-learner layer. *Second*, CLE matches e-learner's information with the appropriate learning resources layer, which is built out of metadata associated with learning content and user-generated tags. *Third*, results will be used by the learning domain and the lexical layer to link them with customised resources for certain domain/e-learner and to recommend the proper learning services to the e-learner and to suggest learning buddies who have similar profiles.

However, the ROLE framework does not comprehensively capture learning domain concerns, such as pedagogy. Learning is not only concerned with suggesting suitable resources/services and learning buddies. It is an ongoing process that changes e-learner's behaviour, attitude, believes and knowledge status (Kruse, 2009; Schacter, Gilbert and Wegner, 2011). In contrast, ROLE: (i) is limited to SRL-oriented approaches (i.e., single-model view), learning services have been used in a way that is limited to content-oriented resources and web 2.0 tool functions, and (iii) cloud has been used as a deployment environment as it did not propose a suitable model of cloud cross-platform in order to satisfy authors' claims (e.g., promoting scalability) when adopting cloud learning environment. Additional observations have been raised regarding the use of a flat-based privilege scheme that gives tutors and learners the same permissions. For instance, both tutors and learners have the same permission on this collaborative learning space, which may lead to some conflicts as learners might have mistaken information. This might have significant implications on knowledge base validity and consistency.

2.7 Advanced e-Learning Models

This section reviews the most advanced and complicated models which include: Game-Enhanced Learning (GEL), Virtual-Enhanced Learning (VEL) and Adaptive e-Learning Systems (AES).

2.7.1 Game-Enhanced Learning

Recently, the use of games in education and other domains gains momentum. This is described in different terms in the literature. For instance, "Gamification" refers to the use of game design elements in non-games contexts (Deterding *et al.*, 2011) or, in a border sense, refers to the use of game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning and solve problems (Kapp, 2012). Nonetheless, "Serious Games" refer to games designed for specific pre-defined purposes (Kiryakova, Angelova and Yordanova, 2014). Serious games repurpose games in order to offer activities that go beyond entertainment, but gamification use game design to enhance stakeholder's willingness to participate to originally non-playful experiences (Boughzala, Michel and Freitas, 2015). Therefore, this research uses the term "Game-Enhanced Learning (GEL)" as an umbrella to cover the above-mentioned models. Game creates a flow (e.g. goals, rules and feedback) that is necessary for learning. Psychologically during such flow learners experience gratification and their immersion in the experience are at peak creativity and performance which is an ideal situation for learning (Miller, 2013; Csikszentmihalyi, 1990).

Motivating learners and engaging them are the two key derivers behind GEL development. Games ability to reframe learners' failure as a part of learning experience is an example on motivation (Lee and Hammer, 2011). The continuous feedback and joyful experience to develop positive learners' qualities, such as: persistence and discovery is another example (McGonigal, 2011). Key GEL advantages are classified as: (i) *cognitive*, where games provide adaptive routes to success based on complex rules through active experimentation and discovery

(Domínguez *et al.*, 2013), (ii) *emotional*, as they induce frustration, curiosity, etc. and can transform from one emotional state to another and (iii) *social*, because learners continuously try to find new identities suitable for them (Lee and Hammer, 2011). Literature evidence in (Giang, 2013) reveals how GEL can positively impact e-learner's experience while (Hamari, Koivisto and Sarsa, 2014) empirical evidences reveal GEL positive impact on behavioural and psychological outcomes. This explains why GEL techniques have been embedded in different e-learning models such as ITSs (McNamara, Jackson and Graesser, 2010; Jackson and McNamara, 2013) and LMSs (Kiryakova *et al.*, 2014).

However, gamifying learning is challenging and not straightforward. Its limitations include the following. *First*, it requires heavy involvement by instructor and other team members in complex gamification stages, such as understanding audience/context and structuring the experience (Huang and Soman, 2013). *Second*, it might absorb instructor resources and teach learners to learn based extrinsic rewards (Lee and Hammer, 2011). *Third*, evidences from literature reveal mistakes in applying gamification concepts (e.g., instructors try to gamify outcomes instead of behaviour (Huang and Soman, 2013)), which requires close monitoring during the development (i.e., time consuming process) (Hammad, 2017). *Fourth*, it requires long-time of fine-tuning of course contents, teaching scenarios, learning processes, assessment strategies and feedback. *Fifth*, the currently adopted design approach is not user-centred, and consequently instructors are neglected from design which lead to poor adoption rate (Kiili and Arnab, 2013).

2.7.2 Virtual-Enhanced Learning (VEL)

Adopting virtual world (VW) and immersive technologies (iMT) in education increased in the last decade (Johnson, Levine and Smith, 2008); consequently, terms such as virtual/augmented reality, virtual world and immersive technologies flourished. Virtual worlds are simulated environments in which an actor uses an avatar to interact with digital entities in a certain environment (Dawley and Dede. C., 2014), where immersive technologies refer to the subjective impression that one is participating in a comprehensive and realistic experience. Technologies can induce immersion in number of ways such as: (i) the use of sensory stimuli, (ii) participants' abilities to influence actions happen in the surrounded environment, and (iii) the use of narrative and symbolism (Witmer and Singer, 1994; Dawley and Dede. C., 2014). Different tools exist in the world of VWs and iMTs stretching from complex environments (e.g., Second Life (SL)) through simple tools (e.g., such as 3D printers). The interaction between different VELs constituent resources/elements (e.g., sensors, video/sound, immersive tools) (Shuster, 2013) leads to various affordances such as: (i) enhancing the explored subject knowledge representation, (ii) greater chances for practicing authentic/experiential learning (Wood, 2014), (iii) increasing e-learner motivation and engagement, (iv) effectively facilitating collaborative learning tasks, (v) improved contextualisation of learning activities (Dalgarno and Lee, 2010) and (vi) stimulating e-learner creativity (Love, Ross and Wilhelm, 2009).

Recent VWs advancements go beyond the social affordances and pay more attention to their educational value. Examples include the virtual intelligent pedagogical agent developed in (Soliman and Guetl, 2010) that improve interactivity, provide narrative and dialogue to keep e-learner motivated, and engaged and link learners with their pedagogical goals. Furthermore, practical application of SL in educational contexts reveal its effectiveness in supporting constructivist based learning approach (Girvan, Tangney and Savage, 2013), learning by doing (Gil-Ortega and Falconer, 2015) and situated learning (Dawley and Dede. C., 2014) and more capabilities are expected to appear as reported in the 3D humanoid research (Korolov, 2014). Yet VEL's shortcomings include: (i) their complex interface/content which might be considered as uncomfortable for learners, (ii) learners often are overwhelmed with basic operational functions at the expense of proper VEL's utilisation to advance learning, (iii) institutional managers, educators and designers become more dissatisfied due to the little/ineffective use of VELs (C. Graesser *et al.*, 2008), (iv) usability aspects need further considerations, (v) lack of support at the institutional level, (vi) limited sustainability as projects/artefacts are created, used and disappear based on initiatives and funding therefore effort is lost and consequently educators start from scratch rather than building on others' work (Gregory *et al.*, 2014). Hence, VW/VEL initiatives require adopting more effective design approaches such as Model-Driven Engineering (MDE) to abstract from technical and domain/subject considerations. Moreover, it should be simplified and explained to stakeholders (e.g., staff and learners) through training or similar approaches in order to encourage their contributions. Finally, it needs further enhancements to respond to the collaborative work through allowing users to backup, restore and share artefacts developed or created by others. VEL's limited interoperability and the missing of standard-based approaches to represent knowledge and scenarios are the main reasons behind such problems. Nevertheless, VEL is still promising and needs further development and testing to get mature.

2.7.3 Adaptive e-Learning Systems (AES)

One-size-fits-all model deficiencies has led to the emergence of adaptive systems where e-learning contents, activities and services are adapted to e-learner based on his/her characteristics such as prior knowledge, cognitive abilities and affects; and learning context (Graf and Kinshuk, 2014). Intelligent adaptive/adaptable systems, adaptive educational systems and personalised learning systems are used interchangeably in literature to describe AES. Nonetheless, a considerable difference exists between an adaptable and an adaptive system since the former indicates users-initiated adaption technique, while the latter indicates system/automatic-initiated adaptation techniques without direct user intervention (Weibelzahl, 2005). Adaptive systems first capture data required (i.e., user modelling) and second act upon the captured information (i.e., adaptation process) to provide individualised learning experience (Graf and Kinshuk, 2014).

User Modelling can be done either by: (i) *collaborative* approach, where e-learner explicitly provides information about himself to be used in modelling process; and (ii) *automatic* approach, where systems monitor the e-learner behaviour/actions to build user model (Brusilovsky, 1996). Adaptation can be classified into: (i) *adaptive navigation support* that provides different ways to navigate contents (e.g., sort or hide) and (ii) *adaptive presentation* that targets how to present contents (e.g., video and text) (Brusilovsky, 2001). AESs reveal promising results in terms of achieving e-learner's goals and minimising time required by learners to master a topic (Graf and Kinshuk, 2007).

However, AES limitations include, *first*, the dominant use of collaborative e-learner modelling (Graf and Kinshuk, 2014), which raises considerable concerns on its validity (Jonassen and Grabowski, 2012). Other approaches (e.g., test-based, decision tree, machine learning) have been used to model an e-learner but still need further evaluation.

Second, most adaptive systems use limited contextual information or static modelling approach for large number of e-learner's characteristics such as learning style, which may not be true in all cases. *Third*, it is very challenging to measure some of e-learner characteristics especially the cognitive abilities such as working memory capacity are reasoning. Some of these cognitive abilities cannot be inferred from learning behaviour due to the insufficiency of these models (i.e., there is no enough reliable information to build a robust model). *Fourth*, it is not clear what kind of contextual information is necessary and therefore should be captured (Graf and Kinshuk, 2014). *Fifth*, despite of the AES relatively long history, they are mostly research prototypes rather than sustainable large-scale systems which prohibits evaluating them in real/authentic settings (Graf and Kinshuk, 2014). Furthermore, obtaining the accurate information to build an e-learner model, maximising the benefits of using e-learner models, minimising the cost of adaptive systems and addressing privacy are still valid concerns and under research (Shute and Zapata-Rivera, 2008), which will be investigated in this research (Chapter 3 and Chapter 4).

2.8 Theoretical and Institutional e-Learning Models

This section reviews three main theoretical e-learning models that can be used by academic institutions for general e-learning settings, planning, delivery, quality assurance, etc. These models are: Khan's e-Learning Framework, e-Learning P3 Model, e-Learning Success Model and Process-Oriented Model for Technology-Enhanced Learning.

2.8.1 Khan's e-Learning Framework

Khan's e-Learning Framework (KeLF) is a very generic e-learning framework. It presents eight dimensions view for e-Learning, as shown in Figure 2.15, which includes the following dimensions: (i) *pedagogical,* concerned with teaching and learning aspects (e.g., audience analysis), (ii) *technological*, concerned with technical aspects (e.g., infrastructure), (iii) *interface design,* concerned with interface (e.g., usability), (iv) *evaluation*, concerned with assessment/evaluation, (v) *management,* concerned with maintaining e-learning settings, (vi) *resource support,* concerned with resources and support needed for e-learning, (vii) *ethical*, concerned with cultural and ethical considerations and (viii) *institutional*, concerned with administrative affairs, student services and so on (B. H. Khan, 2005).

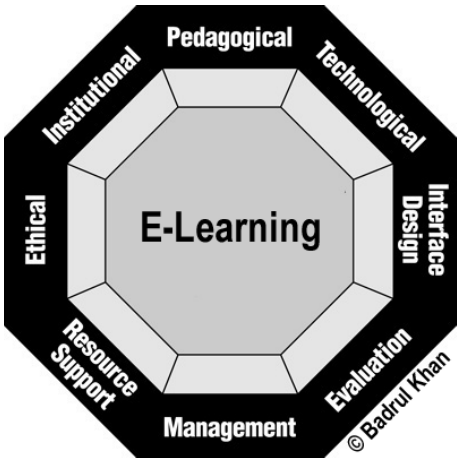


Figure 2.15: Khan e-Learning Framework (B. H. Khan, 2005)

2.8.2 e-Learning P3 Model

Khan presents the P3 Model: "People–Process–Product" to add further reflections to KeLF. In this model, different personnel perform actions in processes to produce products over two phases. However, P3 reflects a rigid, tutor-centred instructional-design approach, lacks underpinning processes as it handles pre- and post-learning processes. Furthermore, collaborative and participatory learning approaches are not represented and finally separating development from delivery does not reflect the agility of recent e-learning artefacts (i.e., modifiability). Such model cannot effectively guide various e-learning models, such as participatory learning and social learning.

2.8.3 e-Learning Success Model

e-Learning Success Model (eLSM), shown in Figure 2.16 (Lee-Post, 2009), explains what constitutes success in e-learning in order to guide e-learning initiatives over different phases. Six e-learning success factors grouped in three main clusters were proposed as follow: (i) *system design* which includes: a) system quality, b) information quality and c) service quality, (ii) *system delivery* which includes system use factor and (iii) *system outcomes* which includes a) net benefit and b) user satisfaction. eLSM has been used to evaluate the success of e-learning courses. However, eLSM detailed criteria are only mainly evaluated by surveying learners (i.e., mostly e-learner-oriented) which provides a single view on the systems success and cannot be as effective as required. Also, eLSM is static and ignores recent e-learning models, such as collaborative-based e-learning models.

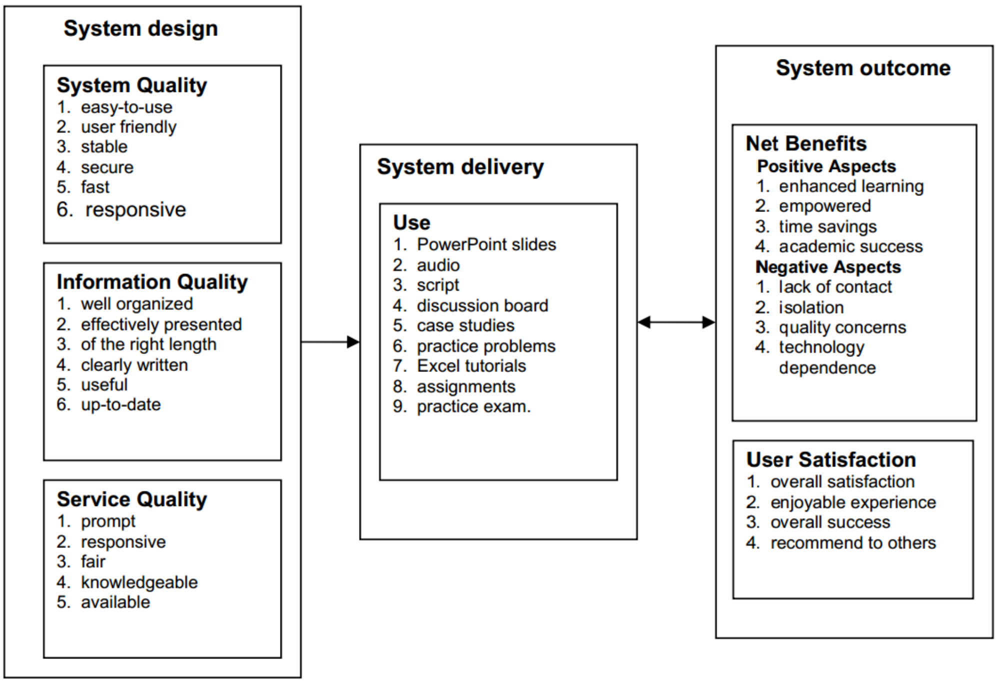


Figure 2.16: e-Learning Success Model (Lee-Post, 2009)

2.8.4 Process-Oriented Model for Technology-Enhanced Learning

A process-oriented model for TEL has been developed to consider different e-learning requirements and to offer flexible and e-learner-centred learning approach. Its key added value is conceiving learning as a process composed of activities happening in three-main levels as shown in Table 2.5. In each level, learners are interacting with domain (i.e., subject being taught), technology and community. Acquisition is the most salient feature for novice learners because they learn from experiences around them. However, in the experienced level learning is participatory and issues of affiliation and intimacy to groups and community of practice are more obvious. Finally, the last level embraces contributory and mediation forms of learning and knowledge building [78]. This model is a descriptive theoretical framework where no connections with realisation mechanisms exist (e.g., processes are not formed of clear activities). In addition, the used pedagogical terms (i.e., novice, experienced and expert) need to be precisely defined, linked with criteria and dynamic or responsive to various contexts.

Table 2.5: Summary of Process-Oriented Model for TEL

	Domain	**Technology**	**Community**
Acquisition Novice (Competence)	Knowledge and skills	Knowledge and skills in use of tools	Interactional skills
Participation Experienced (Affiliation)	In Affinity spaces and community of practices	Learning with others in use of tools for communication, group management and sharing	Experiencing different roles in contiguous and virtual communities
Contribution Expert (Self-actualisation)	Creating, designing and evaluating	Developing/using tools for mediation and knowledge building	Managing, leading, facilitating and evaluating contiguous and virtual communities

Summary

In summary, although a plethora of e-learning models and frameworks exist, they are used in different contexts for different purposes (e.g., direct representation to the learners, a guide for learning environment development, a schema to align to a given pedagogical approach or learning theory). Additionally, they describe complicated inter-relationships and inter-dependencies between learning and teaching components which cannot be easily understood by e-learning stakeholders (Conole, 2010). Therefore, it is not clear what could be the appropriate model for each learning scenario, which may lead to ineffective application for these learning models by e-learning stakeholders. The previously-discussed learning models cover several learning approaches/contexts, and hide various underpinning pedagogical theories and models behind their interfaces. Due to the particularities of the target domain (i.e., learning) such as its richness, its diverse stakeholders, the unique approaches needed for each e-learner, the continuously evolving learning requirements, among others, developing effective e-learning artefacts becomes more challenging. The next section critically analyses the research gap, provides key lessons learnt from this review, and concludes the chapter to pave the ground for the research design.

2.9 Critical Gap Analysis, Lessons Learnt and Conclusions

Findings from the above literature review reveal a list of limitations (i.e., research gap) that need to be addressed to have an effective e-learning artefact. These limitations are focused around as the following point: (i) adopted e-learning models, theories and pedagogical approaches underpinning them, (ii) guidance provided to e-learners to allow them to achieve their goals, (iii) mechanisms used to capture and interpret the overall context of the e-learning process including the e-learner behaviour and his/her broader context, (iv) the agility/legacy nature of the existing e-learning models, and (v) the practices or engineering approaches used in developing e-learning artefacts and how they can be improved in order to respond to the current software engineering challenges (e.g., reusability). Discussion about the above-mentioned findings are detailed below.

In the above sections, e-Learning models have been classified into six different categories based on their salient features as well as their main focus, where pedagogical models are at the heart of that classification. First, pedagogical models differ in terms of their scope and objectives, some of them are comprehensive such as Kolb's experiential model, while some others are specific to particular parts of the learning. Examples of such specific models include: (i) *constructionism* that emphases learning by doing, (ii) *constructivism* that focuses on building on prior knowledge (Conole, 2010), (iii) Gagne's model for learning contents orders (Gagné, 1965), and (iv) Doignon's knowledge space model to correct learners' misconceptions and fill learning deficiencies (Doignon and Falmagne, 1999). Understanding pedagogical models is crucial because e-learning practices are always driven by pedagogical principles and thus developing e-learning practices necessitates well understanding of principles underpinning them and any changes that could happen as response to the development process (Mayes and De Freitas, 2004). The literature reveals deficiency of adopting only one particular approach because different skills need different approaches. For instance, the bottom-up learning approach (i.e., mastering smaller units is a prerequisite for mastering more complex units, such as behavioral approaches) is good for intellectual skills while top-down approach is better for motor skills, attitudes and higher order thinking skills (Gagné *et al.*, 2005; Mayes and De Freitas, 2004). Similarly, e-learning models differ significantly in terms of their goals, key target audience, underpinning learning approaches, adopted technical mechanisms, etc. (Hammad *et al.*, 2013). This suggests an explicit adoption of a hybrid and rich learning and pedagogical model where top-down and bottom-up approaches are mixed together in alignment with different learning theories to respond to learners' requirements (***lesson learnt #1: adopting a hybrid model (pedagogical theories) to develop a rich e-learning model that fulfils the requirements of a wide range of e-learners***).

Second, Common e-learning models are either: (i) content-oriented models such as LO and OERs or (ii) semi process-based models such as LMSs, where system behaviour is hardcoded. Content-oriented models have limitations because they cannot coherently capture e-learning experience (Bonanno, 2010a; Marjanovic, 2007; Bonanno, 2010b). Learning is more than contents consumption as it involves participation, interactions with actors, and contribution in learning activities that constitute together a learning process. This suggests adopting a process-based approaches to guide learners and to allow them to achieve their goals (***lesson learnt #2: adopting process-based approach***). With content-oriented models, learners follow ad hoc approaches to achieve their learning goals.

Consequently, learners might be misled since current e-learning artefacts are complex, require further guidance (Polsani, 2006; D. A. Wiley, 2003; Friesen, 2004) and separating the learning process from the learning contents to support flexibility and agility features. Extended LO model evolved as a response to the absence of process concept or to provide guidance to leaners, but it is less effective since it restricts the LO with a pre-defined process behaviour. Similar to LO model, OERs have their shortcomings such as localisation, sustainability and discoverability (D. Wiley, Bliss and McEwen, 2014). Such shortcomings can be partially resolved through adopting the process concepts, where OERs becomes connected to specific context and part of learning processes that ensure the existence of a continuous maintenance and support for learners.

As mentioned earlier, semi process-based models such as LMSs and MOOCs have their processes cemented/codified in the system which works well in particular situations (e.g., informing learners about the release of assignment marks), but also imposes further restrictions on learning. For instance, these models adopt one-size-fits-all strategy, which means the absence of adaptivity (Vogten and Koper, 2014). Consequently, learners are less engaged due to system inability to respond to different learners' needs (Graf, 2009; Graf, 2005; Despotović-Zrakić *et al.*, 2012). According to Conole (Conole, 2013) and Nkuyubwatsi (Nkuyubwatsi, 2013), the limited constructive feedback provided to learners is a key reason for the high dropout rate in MOOCs e-learning model. This suggests adopting effective teaching and learning strategies through providing relevant feedbacks to learners based on their knowledge level. Additionally, this requires adopting effective knowledge representation techniques to capture, model and extract e-learner behaviour and e-learning contexts in order to recommend effective learning approaches, engage learners via suggesting peers, activities, and resources, and providing collaborative learning approaches to meet e-learner's expectation (***lesson learnt #3: adopting effective techniques for modelling e-learner behaviour and e-learning contexts through semantic representation techniques e.g., Ontology***).

Despite LMS tendency towards more modular approaches, they are described as legacy and monolithic systems which adds further restrictions on their flexibility and extensibility (Dagger *et al.*, 2007). Adopting flexible architectural style such as Service Oriented Architecture (SOA) allows incremental, dynamic and flexible application integration in a cost-effective manner regardless of platforms, technologies or languages used in current systems (***lesson learnt #4: adopting SOA-based model***). Also, the SOA model flexibility supports adopting more effective and hybrid pedagogical models instead of adopting rigid pedagogical models such as linear pedagogy (Logan and Neumann, 2010) or behavioural approaches (Gagné, 1965) (***affirms lesson learnt #1: hybrid pedagogical model***). Such hybrid models embrace single or combined learning theories to meet e-learner's requirements and apply learning approaches that are relevant to learning contexts (i.e., subject being taught, e-learner and environment). This suggests as well embracing effective techniques to dynamically derive relevant e-learning services based on the hybrid information captured from e-learner's behaviour, subject being taught and external environment (***affirms lesson learnt #3***). Most importantly, LMSs are built around 'module' concept which restricts accommodating additional e-learning models such as social or informal learning models, adaptive or learning analytic-based model (Dagger *et al.*, 2007; Vogten and Koper, 2014). This also suggests adopting a mixed and hybrid approach where different learning approaches can be accommodated (***affirms lesson learnt #1 and #3***).

Third, Formal process-based techniques (i.e., business process modelling and enactment) is rarely adopted in e-learning due to e-learning particularities such as the implicit nature of learning activities. For instance, in cognitive information processing pedagogical model, learning is a process of encoding information into long term memory (Dabbagh, 2005), which is challenging to be assessed. Additionally, the lack of standards to specify learning processes makes the automated execution of these processes from their specifications unfeasible. Current business process modelling standards are limited in capture contexts as they mainly depend on process elements (e.g., activity) text description. In this respect, semantic representation can be used to enrich the e-learning process models and consequently minimise models' ambiguity (***affirms lesson learnt #3*). Different educational modelling languages have been developed to specify a particular learning unit. IMS LD evolves from Netherland Open University Educational Modelling Language which has been standardised to specify the definition and orchestration of learning activities (Derntl *et al.*, 2012). Despite its rich approach, shortcomings exist such as: (i) has limited interoperability because saving or retrieving information to or from external sources is not allowed, (ii) it lacks flexibility (e.g., changes after UoL is packaged are not possible (Caeiro-Rodrıguez *et al.*, 2007)), (iii) e-learner behaviour is not recorded, (iv) adaptation is limited (i.e., lack of rich adaption conditions, no adaption based on previous user behaviour) (Burgos, 2010) and (v) complexity, since it works as an integrative layer to other specifications (e.g., IMS CP and IMS SS) (Koper *et al.*, 2003).

In addition, workflow enabled e-learning environment has been suggested in (Lin *et al.*, 2001), but still in very abstract form and needs further development. Linking a learning design scenario with services is not feasible because it is not possible to express the way in which elements in services have to be managed and controlled (e.g., if a car simulator has been linked to IMS LD, it is not possible to get information about what the e-learner does in the simulator) (Caeiro-Rodríguez *et al.*, 2010). Therefore, one possible solution is using industrial standard Business Process Management tools, such as Business Process Modelling and Notation (BPMN) and Business Process Execution Language (BPEL) to respectively model and enact e-learning services in SOA-enabled computing paradigm (***affirms lesson learnt #2***). On the other hand, service-oriented e-learning systems exist (e.g., (Jabr and Al-Omari, 2010; Sagayaraj *et al.*, 2012; Meccawy, 2008)) but are mainly proof of concepts. Most of the work extends the current LMSs to add SOA-architecture rather than developing algorithms to derive services from a certain e-learning scenario. Furthermore, UDDI along supportive technologies such as: XML, SOAP, RESTful and OWL have been suggested as implementation choices. Also, semantic web, OWL-S and WSDL-S have been used, to a limited extent. The common shortcoming between the previously-mentioned models is the limited number of contextual variables captured by these models, which might lead to learning resources/services that do not match e-learner interest. This requires further contextualisation techniques (***affirms lesson learnt #3***).

Fourth, semantically-enriched models reveal high capabilities in capturing contextualised information, yet their pitfalls are reported in the literature. For instance, the majority of Recommended Systems do not fully capture the thoroughness of learning domain (Drachsler *et al.*, 2015). Moreover, they are more suitable for informal learning since it shifts responsibilities away from domain experts and thus evaluate content quality based on e-learner collective behaviour instead of formal evaluation procedures (Manouselis *et al.*, 2013). In addition, RecSys are deficient in responding to metacognitive skills (Zhou and Xu, 2012), effective communication skills (Abel *et al.*,

2010) and capturing intrinsic factors such as e-learner motivation (Manouselis *et al.*, 2013). Lessons learnt from RecSys is to combine this model, or part of its techniques, within the overall proposed e-learning framework. For instance, using RecSys to help in informal learning and at the same time focus on other approaches such as SRL to strengthen metacognitive and critical thinking skills (***affirms lesson learnt #1***). Another model in this category is the Intelligent Tutoring Systems. It suffers from different drawbacks such as: (i) low reusability because two of its internal components (i.e., *domain model* and *teaching model*) are domain-specific, vendor-locked and not reusable (Freedman *et al.*, 2000), (ii) black box due to the absence of standardised approach for knowledge representation as well as competition between vendors, (iii) expensive to build and not easy to access and (iv) time and effort consuming (Nye, 2014). This affirms adopting flexible and standard architecture (i.e., process-based and SOA) (***affirms lesson learnt #2 and #4***).

Fifth, lessons from adaptive e-learning models are also important and lead to significant conclusions. For instance, adopting advanced techniques (e.g., learning gamification and virtual world) is not straightforward and consumes lots of resources (Lee and Hammer, 2011; Huang and Soman, 2013). So adopting (i) user-centred design approach (Kiili and Arnab, 2013) and (ii) model driven engineering (MDE) approaches (Kent, 2002; Siegel, 2014) to deal with complexity, abstracting away from platform-specific detail and to ensure integration and interoperability considerations (***lesson learnt #5: adopting model-driven engineering approaches is recommended***). Additionally, such advanced techniques require long-time of development and refinement (Hauge *et al.*, 2013). This suggests planning for collaborative and sustainable arrangements where produced artefacts can be created, used and shared with other colleagues (Gregory *et al.*, 2014) (***affirms lesson learnt #2 to support artefacts automatic or semi-automatic creation, sharing, etc.***). Adopting all of the previously-mentioned techniques should not be at the cost of artefact simplicity (e.g., scenarios and interfaces), because learners get confused in such complex e-learning environments (C. Graesser *et al.*, 2008). Finally, combining entertainment and pedagogy in game-based learning reveals significant weaknesses in providing effective feedback, supporting student assessment and personalised learning (Hauge *et al.*, 2013). This suggests careful consideration for pedagogical models underpinning e-learning practices (***affirms lessons learnt #1***). **Sixth**, theoretical e-learning models assert the e-learning comprehensiveness. This requires promoting and strengthening the hybrid approach to capture the e-learning contexts, utilise the captured information to form a hybrid e-learning model, specify it a process based format, and enact this process in SOA-enabled environment (***affirms lessons learnt #1, 2, 3 and 4***).

To conclude, an effective e-learning framework should be pedagogically neutral to the extent that it can speak differently to different learners in different contexts. This allows accommodating adaptive e-learning models, where e-learner's needs, learning context and learning pedagogy are the key derivers behind deriving proper e-learning services. To accommodate these needs, a new e-Learning Framework is needed. This framework should establish an explicit and comprehensive link between pedagogy and its sub components (i.e., learning theories) from one side and e-learning models from the other side. This explicit link in cooperation with semantic representation will help in minimising the ambiguity and overlapping between existed models. This is challenging since models are not easy to effectively apply because they describe complicated inter-relationships and inter-dependencies between learning and teaching components, which cannot be approached straightforwardly

(Conole, 2010). Combining the above-mentioned components (i.e., learning pedagogy, process-based, semantics, and SOA) is useful in this research context. For instance, process-based can replace individualised learning processes by cohort one, where collaborative activities between peers can be carried out. Furthermore, process-based approaches can contribute to solving roles problem in e-learning (Seale and Rius-Riu, 2001) by assigning particular tasks to specific users in an automated or semi-automated approach. This can be applied in learning processes and others as well, such as management processes, course design, etc. Also, process-based approach has the potential to guide learners to automatically derive proper services.

Furthermore, using ontology to semantically enrich the proposed framework helps in modelling the e-learning domain (i.e., including the subjects to be taught, e-learners and their behaviour, overall e-learning process context), which is inevitable for effective adaptive systems. Such model describes how the e-learning domain conceptual representation is structured. This normally includes: (i) concepts and (ii) concept relationships (Ramos, 2014), rules, and assumptions. Having an effective semantic representation in place allows: (i) making adaptive decisions about certain e-learners, (ii) tailoring the generic e-learning process to a customised e-learning process for a certain context, and (iii) abstracting from various details. Such details could be technical-oriented (e.g., related to platforms used) or domain oriented (e.g., different pedagogical analogies used in mathematics domain might be not useful in history domain) (Bromme, 1995). This use of ontology is expected to be effective in specialising the generic e-learning process according to the e-learner context, which makes his/her goals more achievable. This elaborates the centric role of semantic representation in the new e-learning framework as it describes the semantics of the e-learning process and classify/structure its contextual constructs (Snae and Brüeckner, 2007).

In summary, this analysis states the importance of developing a new e-Learning framework that affirms: (i) the necessity of paying more attention to the pedagogical side of e-learning because pedagogy helps learners to make sense of the educational value of e-learning, (ii) the potential of adopting process-based, service-oriented and semantic representation, and (iii) embracing effective software engineering approaches such as model-driven engineering approach to minimise complexity and conform to the agility of e-learning technologies. In the next chapter, a detailed research design will be presented.

Chapter 3:

The Research Framework Design

3.1 Introduction

After having reviewed the state of the art in the fields of Semantics, Business Process, SOA and e-Learning, a number of research gaps have been identified. To systematically respond to the early-identified gaps, the overall research design is presented in Section 3.2. By *research design*, we refer to the methods followed by the researcher for the development of a research framework. It informs how the goals of this research can be accomplished by explaining this research phases according to their sequence as well as their outputs. A key artefact of this research is the HeLPS: Hybrid e-Learning Framework that is Process-based, Semantically-enriched and Service Oriented-enabled, introduced in Section 3.3. A detailed description of the proposed e-learning framework along with its modules and component is presented and justified. It also presents the e-Learning Meta-Model (eLMM), which is a key component of the HeLPS e-Learning Framework. Finally, Section 3.4 concludes the chapter and paves the ground for the HeLPS e-Learning Framework development process.

3.2 Research Design

Various research methods exist such as case study (Yin, 2013), experimental (Penny, 1974) and design science (Peffers *et al.*, 2007). Although design science research method facilitates building and evaluating purposeful and novel IT artefacts to address business needs (Hevner *et al.*, 2004), it needs to be implemented in an iterative approach which does not fully suit this research. Since this research aims at enhancing the learning experience of the e-learner, an integrated research methodology has been devised based on case study (Yin, 2013) and experimental approach (Penny, 1974). The case study method suits this research because it is an empirical method that thoroughly investigates contemporary phenomenon within its actual context, particularly when the boundaries between phenomenon and context are not obvious (Yin, 2013). Literature evidence shows the rise of adoption of the case study approach in Software Engineering domain due to its suitability to establish context-related understanding for the phenomenon under investigation (Runeson and Höst, 2009). In addition, the case study method allows more explanatory approach to answer how, what and why questions (Crowe *et al.*, 2011). It is related to other methods, especially experiment-based (Runeson and Höst, 2009). Experimental research refers to methods developed for testing the causal relationships (i.e., cause-effect relationship) (Dane, 2010). Moreover, experimental-based research is subjected to sequential pattern of planning, implementation and evaluation (Penny, 1974). As part of experiments, a data-driven design approach is used to assess the effectiveness of various e-learning processes (e.g., e-learning contents, process-based approach, hybrid learning model, service orientation, etc.) In this research, the experimental approach complements the case study method. Figure 3.1 explains the five phases of the adopted research design framework. These phases are: (i) inception, (ii) research framework design, (iii) framework instantiation and prototyping (i.e., detailed design and development), (iv) evaluation, and (v) reflections and dissemination. These phases are explained as follows:

- In the first phase, related literature will be critically reviewed in relation to e-learning theories/models, e-learning business process modelling and enactment into software services (i.e., SOA), semantic enrichment and ontologies. This has resulted in affirming the research gaps in e-learning domains and the significant importance for developing an effective e-learning framework that can adaptively respond to the various needs of the e-learners and enhance their e-learning experience.
- In the second phase, potential solutions will be investigated and analysed. During the initial analysis and design, further insights will be acquired into the problem domain, solution will be proposed as a high level conceptual e-learning framework. Also, in this phase, different trade-offs between different design choices have been made. Some of these trade-offs are related to the incompatibility between different specifications, tools, platforms, etc. (e.g., Jena API does not support OWL 2.0 used in this research). Appendix VI discusses HeLPS related design choices.
- In the third phase, modular design for the proposed e-learning framework will be produced and a prototype will be implemented as proof of concept. This phase will also introduce new approaches for deriving services from business process models and their enactment in a SOA-enabled environment.
- In the fourth phase, the proposed e-learning framework will be evaluated to answer the research questions in order to prove or disprove the research hypothesis. The evaluation will be based on: (a) human expert validation of the derived e-learning process models, (b) the development of metrics: (i) *The e-Learner Experience Model (eLEM)*: to quantify the e-learner experience and measure the impact of the proposed solution on this experience and (ii) *The e-Learning Capability Maturity Model (eLCMM)*: to assess the maturity of the proposed technological artefacts, and (c) the development of data driven/offline experiment to evaluate the hybrid e-learning framework. These experiments will be utilised to provide insights into research questions. The above-described research design works as a framework that encapsulates a hypothetical case study that is sufficient for answering the research questions and experimenting the actual behaviour of the proposed e-learning framework. This hypothetical case study will be developed based on a relevant sufficiency analysis in order to ensure the validity of the evaluation results. It will be built using the bottom up approach to test the proposed e-learning framework capability to develop the best e-learning process to enhance the e-learner experience.
- In the fifth phase, further reflections on the accomplished research will be conducted in order to answer the early-identified research questions, and consequently the research hypothesis, disseminate the

research conclusions via thesis chapters and various publications – some of the future/potential publications are detailed in Appendix XI –, and finally propose future research directions.

As described above, these research phases contribute to a comprehensive research framework starting from identifying a certain research problem up to solving the problem and proposing future research directions. Various research limitations have been identified in relation to e-learning domain. However, the most critical one, from the researcher point of view, is the decontextualisation of learning processes and shifting the focus of applying technologies towards isolated learning activities at the expense of inclusive and integrated learning process. Involving learning pedagogies in this research attracted many researchers, as it was obvious in the literature and discussion with various educational experts. Also, investigating and modelling the learning theories used in e-learning processes is challenging due to the implicit nature of learning phenomena, which requires thorough analysis and synthesis of the current literature and models.

Furthermore, considering the input, recommendations, and feedback of academics and organisational bodies (e.g., committees, research groups, etc.) entails adopting flexible and quantifiable approaches so that their impacts can be measured. Looking at this specific concern from evaluation perspective, this research aims at developing concern-based evaluation framework that can assess the impact of applying the introduced e-learning framework on: (i) e-learners (i.e., via the e-Learner Experience Model), and the technology capabilities (i.e., via the e-Learning Capability Maturity Model), and the overall organisation (i.e., via the e-Learning Evaluation Framework). This research opens valuable opportunities for researchers from both domains (i.e., technology and learning) to test our understandings for the learning phenomena and the current application of educational technologies. This will evolve as we progress in the research as will be explained in the coming chapters.

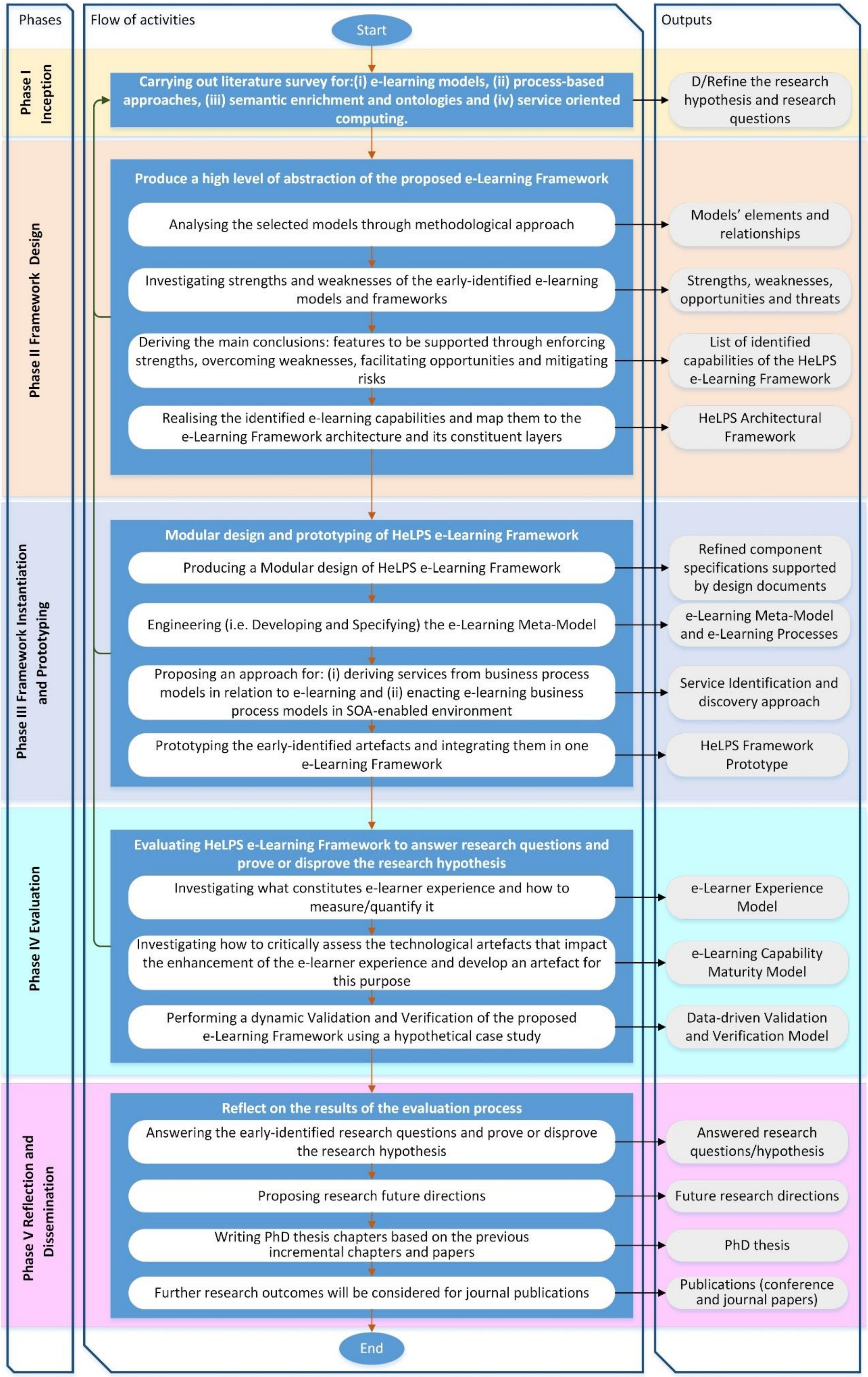


Figure 3.1: Research Design Along with its Five Phases

3.3 Introducing the HeLPS e-Learning Framework

In order to respond to the early-identified research gaps a new e-Learning Framework "HeLPS" needs to be developed. HeLPS refers to Hybrid e-Learning Framework that is Process-based, Semantically-enriched and Service-oriented Enabled. HeLPS is designed in a layered architecture to promote reusability, scalability, separation of concerns principle, and abstraction (i.e., through meta-modelling) (Siegel, 2014). HeLPS adopts a hybrid approach because it: (i) integrates various technologies (i.e., Business Process Modelling and Enactment, Semantics and Service Orientation) and (ii) utilises a wide range of different inputs (i.e., contextual parameters that are related to the e-learner, his/her e-learning process, and the surrounded context) is considered in order to enhance the e-learner experience. The adopted layered architecture is composed of the following layers: presentation, business logic, data layer, e-Learner Experience Model, and e-Learning Capability Maturity Model. Business Logic Layer represents the core of HeLPS e-Learning Framework as shown in the architectural framework design depicted in Figure 3.2 and as will be explained below.

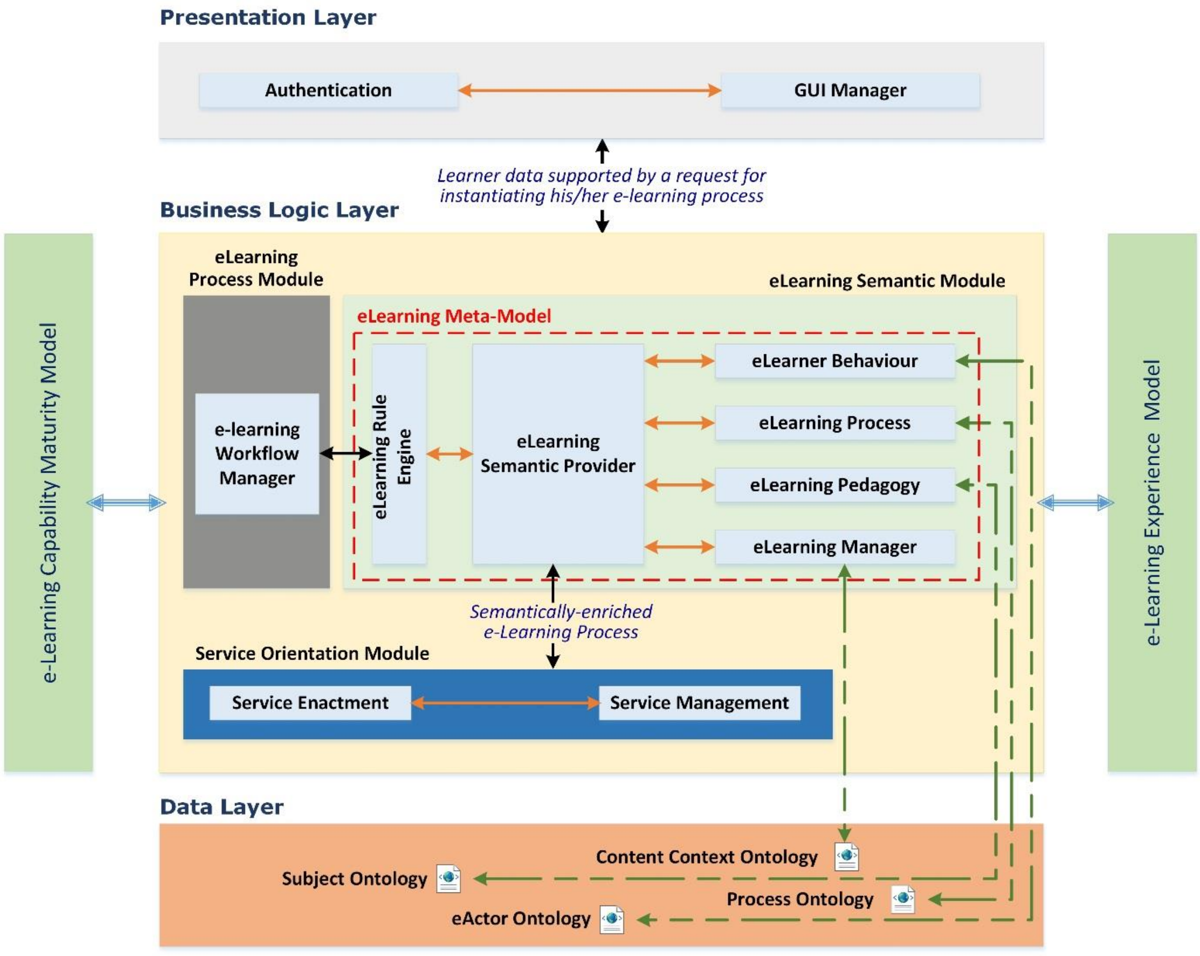


Figure 3.2: The HeLPS Framework Architectural Design

Below is a top-down description for the above-mentioned framework:

The Presentation Layer: provides relevant information related to end user interaction with the system such as browsing the contents, getting directions on what to do, when, and how. In addition, it communicates with other layers, by which it: (i) passes the required information to the Business Logic layer and (ii) represents the results of the interaction with the internal framework layers, module and components. Only throughout this layer, the end user will initiate, directly or indirectly, the required system functionalities (e.g., Login to The System function can be directly initiated, while Decide Learning Approach function is indirectly initiated by the internal framework business logic layer). This layer is responsible for connecting the end user with the core business capabilities encapsulated in the business layer or external applications (e.g., web2.0 tools, e-libraries, social networks, e-surveys, etc.) for integration purposes. It is composed of the following two components:

- *Authentication Component*: this component is responsible for normal login capabilities. Successful login attempts will trigger the process of instantiating an e-learning process for the specific e-learner through the underlying business logic.
- *Graphical User Interface (GUI) Manager Component*: this component is responsible for visualising e-learning processes and presenting the overall system results and recommendations/directions for e-learners. This includes interaction with the system, stakeholders, such as: learning peers, instructors, and external relevant tools such as e-surveys.

The Business Logic Layer: encapsulates the main capabilities of the HeLPS e-Learning Framework as it consists of the following three modules:

a. ***The eLearning Semantic Module***: the essence of contextualisation of the proposed framework. It uses ontology to represent and extract information about e-learners, learning processes, topics to be taught and so on. **eLearning Semantic Provider** is the key component of this module that is responsible for managing and communicating with the following components in order to extract data from a certain ontology.

    i. *eLearner Behaviour*: interacts with the eActor ontology that models actors, mainly the e-learner, in terms of his/her goals, preferences, learning progress, learning style, skills, etc. By the term "e-learner behaviour", we refer to the collection of the interaction activities between the e-learners and the system to obtain planned results. Modelling the e-learner behaviour is so intrinsic for the HeLPS e-learning framework to make it adaptive and responsive to various e-learners' needs.

    ii. *eLearning Process*: interacts with the BPMN Ontology, which models the elements of any business process model. Such elements include: (i) *flow objects* such as events and activities, (ii) *data objects* such as data inputs and data stores, (iii) *connecting objects* such as sequence flow (e.g., default or conditional flow between activities) and messages flow, (iv) *swimlanes* such as pools and lanes, and (v) *artefacts* such as group and text annotations. This component is based on the BPMN Ontology that has been developed in (Rospocher, Ghidini and Serafini, 2014) and reused in our research project. It has been used to abstract the detailed e-learning business processes and allow further enrichment of the various business process elements based on the e-learner behaviour and other ontological concepts.

    iii. *Learning Pedagogy*: interacts with the e-learning pedagogy ontology as well as the e-Learning Process Activity Ontology. The latter is different from the business process modelling notation ontology because it models e-learning process-oriented constructs such learning objectives, contents, prerequisites, type of learning activities, etc. Throughout this component, the framework can formulate the current e-learning processes used by a certain e-learner and retrieve relevant information about his/her previous e-learning processes.

iv. *eLearning Manager*: interacts with the wider scope of the e-learning ontology, which includes the concepts that are related to organisation, programme, module, context of use, facilitating tools, presentation format of the e-learning contents, etc. Through this component, the wider context of the e-learning process can be retrieved. For instance, this may include the type of learning units in a certain subject, the common misconceptions of a certain topic, the environment providing this content, etc.

v. *eLearning Rule Engine*: interacts with the Semantic Web Rule Language (SWRL) rules encoded in the eLearning ontology, referred to as the e-Learning Meta-Model (eLMM) in this research as it conceptualises the e-learning model in relation to the scope of this research. These rules have been identified based on a thorough literature review, and encapsulate domain-specific considerations/rules. Therefore, this component provides the information, i.e., based on inference, that is necessary to generate a special/customised e-learning process for a certain e-learner from the generalised e-learning process.

b. ***The eLearning Process Module***: This module is completely responsible for instantiating an instance of the generic e-learning process for a certain e-learner. Its main component, eLearning Workflow Manager, becomes triggered when any e-learner uses his/her credentials to log into the system. Once the login sub-process is successful, the component targets the e-learner profile to extract his/her related information and then to specify the suitable e-learning activities and assessment activities. The e-learning process will be completed based on the assessment results as this will lead to update the e-learner behavioural model, whether his/her attempt was successful or not. The specified e-learning process will appear as a BPEL (Business Process Execution Language) Script (Object Management Group, 2011). BPEL is an XML-based language to define and execute business processes using web services. BPEL scripts is capable of invoking web services to achieve the business process goals and consequently to fulfil the e-learner needs, but this cannot occur unless the required web services have been identified. Therefore, an essential step here is to identify and discover the proper web services based on the business process specifications. These web services vary between utility services (e.g., extract e-learner goals) and core web services (e.g., services that have e-learning contents).

c. ***The Service Orientation Module***: The main aim of this module is to enact the semantically-enriched e-learning processes to service oriented-enabled e-learning web services. This module is composed of the following components:

vi. *Service Enactment:* ensures the proper execution/enactment of the specified BPEL scripts. This requires passing BPEL scripts to certain business process execution engine. This component is also concerned with necessary tasks related to enactment such as inputs and outputs of the web services, which can be useful in the case of assessment e-learning web services/operations.

vii. *Service management*: Successful enactment for e-learning process requires careful considerations, named "management", of the BPEL scripts and the invoked web services along with their requirements (e.g., parameters). Such management includes getting/providing the necessary parameters to the web services or other data sources (e.g., assessment mark for the e-learner). It is also concerned with identifying missing web services and incomplete e-learning processes (i.e., if the e-learning process has been terminated before its end) because all processes need to be recorded. Such service-related concerns should be handled by this component.

The Data Layer: stores and provides access to the data hosted by the software system and also data that could be shared with other external applications, if any. Such data includes, but are not limited to, database servers, owl files, WSDL files, etc. Data sources existing in this layer should be accessible to other layers and their constituent components through standard mechanisms (e.g., API in the case of the proposed e-Learning Framework).

The e-Learner Experience Model (eLEM): which is concerned with the e-learner experience. Since HeLPS aims at enhancing the e-learner experience, there should be an artefact (i.e., model) that informs to what extent the experience of a certain e-learner has been improved. eLEM has been derived from a thorough investigation of e-learning and user experience research, which has led to define the e-learner experience as a special type of user experience where the cognitive aspects such as knowledge and values acquired; socio-cognitive aspects such as relationship with the community; and the mechanism of learning (i.e., learning processes along with their pedagogy) form the foundation of the e-learner perception and responses. To quantify the e-Learner Experience and devise the proper measurement metrics, the e-learner experience has been divided into the following constructs: (i) knowledge and skills, (ii) misconceptions, (iii) the overall assessment results, (iv) interaction with learning community, (v) social presence of the e-learner, (vi) academic support provided to the learner, (vii) engagement, and (viii) critical thinking. Capturing the values of the above-mentioned constructs for a certain e-learner allows HeLPS to measure the e-learner experience.

The e-Learning Capability Maturity Model (eLCMM): provides a critical assessment to what extent the Hybrid e-Learning Framework, HeLPS in this research, is mature. The eLCMM, inspired by the Capability Maturity Model developed by the Software Engineering Institute (SEI) (Paulk *et al.*, 1995), is composed of the following five maturity levels: (i) initial, (ii) repeatable, (iii) defined, (iv) managed and (v) optimising. Each of the previously-mentioned maturity level represents a well-defined evolutionary plateau towards achieving a mature e-learning process. The eLCMM is divided into the following Key Process Areas (KPA): (i) product quality, (ii) quality in use, (iii) data quality, and (iv) pedagogical quality (Hammad, Odeh and Khan, 2017a). Each KPA is divided into a list of processes (i.e., 26 processes in total) that are supported by a list of key practices and five-level maturity scale. Hence, the eLCMM assesses the maturity of the HeLPS e-Learning Framework in the above-mentioned KPAs (e.g., product quality) and suggests ways to improve the current e-learning practices to move from initial/ad hoc level towards the optimising or continuously improving e-learning processes. To conclude, the above-described e-Learning Framework has been introduced to respond the research gap analysis presented in Chapter 2. The e-Learning Meta-Model is an essential part of this framework; therefore, it will be further explained in the context of the MDE approach in the next sections.

3.3.1 Model-Driven Engineering in the Context of the HeLPS e-Learning Framework

As indicated in Chapter 2 (section 2.9), various aspects of Model-Driven Engineering (MDE) techniques have been utilised in this research. The MDE can be applied in various ways, such as: modelling and meta-modelling, decoupling domain model from technical domain, ensuring process automation to generate one model from another model that has different level of abstraction, performing multiple variants of the system while sticking to the same system behaviour specifications and maximising interoperability on different platforms and describe system behaviour easily. In this research, there is a need to use domain concepts to derive the solution (e.g., to use learning outcomes, module structure, e-learner knowledge and other concepts/relationships in order to recommend an e-learning process that is more suitable to the e-learner). Ontology can be used to design a solution and automatically facilitating inferences which could be used for generating specific models from a generic model. Since ontology defines the domain concepts/vocabularies, scope, constructs/entities, and relationships (i.e., capture the domain-specific knowledge), it can be used to specify the e-Learning Meta-Model (eLMM). As this research aims at developing a generic e-Learning Meta-Model, this model should be independent of any pedagogical e-learning model. This implies that the proposed e-learning meta-model should be capable of equally modelling various e-learning models (e.g., constructive or behavioural e-learning model). Also, this eLMM, as depicted in Figure 3.3, should be Computational/Platform Independent (CIM/PIM), where various technologies can be effectively used without impacting the overall framework behaviour.

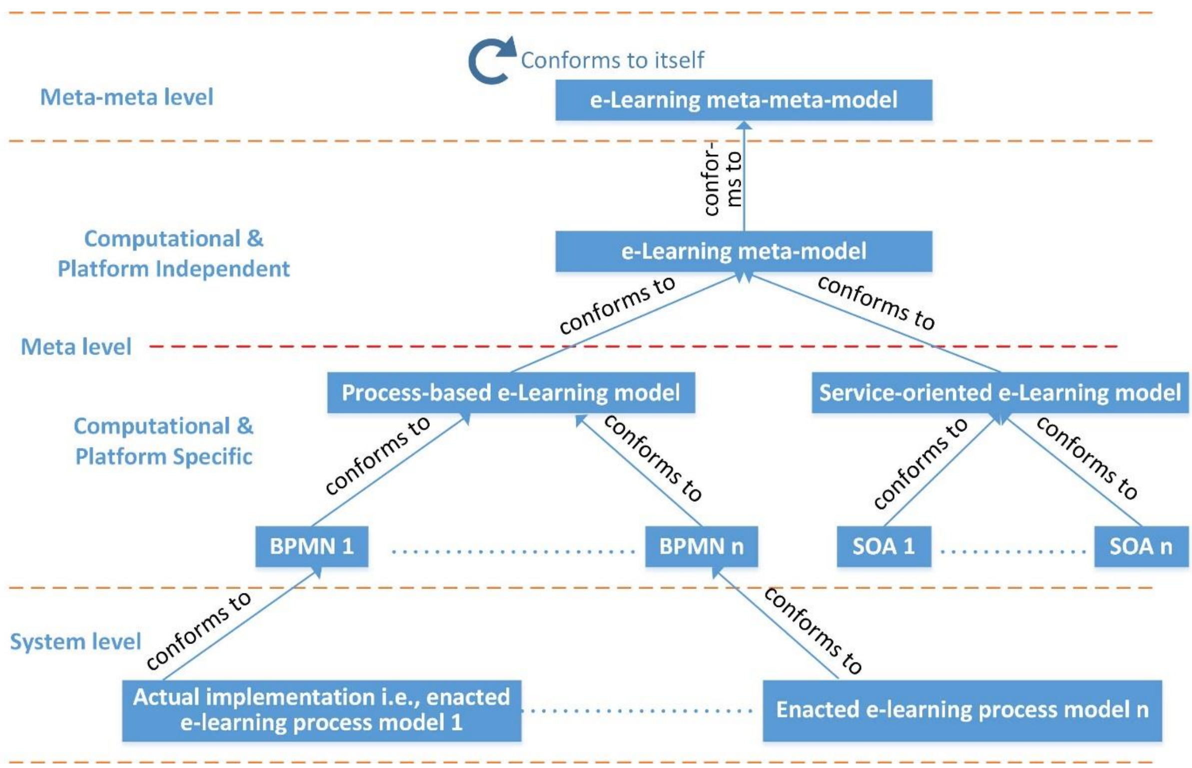


Figure 3.3: MDE in the Context of HeLPS eLearning Framework

One additional reason for using a meta-modelling approach is the capability of the proposed eLMM to pave the ground for a sufficient level of compatibility with other meta-models that represent specific conceptualisations. For instance, the proposed e-Learning Meta-Model will facilitate the interaction with one of the essential external conceptualisations (i.e., the Business Process meta-model, BPMN 2.0 ontology). Another example is the subject/domain ontology, which models/represents the subject (e.g., Mathematics or Physics) to learn. The main aims of the subject ontology are: (i) showing the sequence of concepts/topics, (ii) types of concepts (i.e., core concepts or supportive concepts), and (iii) the common misconceptions in certain topic that need to be resolved (e.g., agile software development process is linked with unplanned projects or less-documented software products). Transforming the generic e-Learning Meta-Model, that is computational and platform independent, to a specific e-learning model for a certain e-learner, that is computational and platform specific, is another key reason for applying MDE in HeLPS e-Learning Framework. As illustrated in HeLPS architecture, Figure 3.2, and its description, the **eLearning Process Module** is responsible for instantiating a generic e-learning process for a certain e-learner, and consequently transforming this generic e-learning process (i.e., which is computationally and pedagogically independent) to a more specific process that is tailored to certain pedagogy and specific platform considerations (i.e., Java in the context of this research).

3.3.2 The Process of Developing the e-Learning Meta-Model

Very different e-learning models exist in the world of technology-enhanced learning. These models evolved over a range of time to meet specific users' requirements. These requirements might be learner needs, technologies needed to facilitate specific e-learning activities, pedagogical affordances, etc. This has led to high demand for adaptive and flexible e-learning models, where knowledge is always accessible in ways that are convenient to different e-learners in different contexts. However, developing a hybrid e-learning framework that can adapt strengths of those different models is not a straightforward task as summarised and discussed in the conclusion of the literature review (Section 2.9). To systematically handle this problem, a generic e-learning model needs to be developed based on the research gap analysis identified in relation to e-learning, business process, semantics, and service-oriented architecture to provide the basis for a hybrid e-learning framework.

Generally, a meta-model defines: (i) structure, (ii) semantics and (iii) constraints for a family of models (Mellor, 2004). In this research, the *e-Learning Meta-model (eLMM)* refers to a platform, technology and pedagogy independent specification that describes the e-learning domain by defining its structure, semantics and constraints. This meta-model is a computational-independent model (CIM) and platform-independent model (PIM) that can be transformed into platform-specific models (PSM) having different bindings to particular implementation platforms or environments (e.g., SOA, Business Processes). The eLMM includes the following three main aspects: (i) *structure* that represents basic elements/constructs and their hierarchy, (ii) *semantics* that represent rules and relationships between constructs and (iii) *constraints* that could be technical constraints (e.g., data type) or domain specific (e.g., achieve a learning goal). In order to derive the e-learning meta-model in a consistent way, the following process-based approach has been applied on the early-identified and reviewed e-learning models:

1- Determine the boundary of the model under review, that only relevant aspects that are related to research scope are covered.
2- Identify main, generic and independent elements (i.e., building blocks) of the model. These elements characterise the model (e.g., the learning objective is one of the building blocks for the Learning Object Model). Elements are entities or constructs, and possess certain features (e.g., content is an element while reusability is a feature). Synonyms should be grouped to identify different terms with same semantics.

3- Elaborate the selected model using different perspectives (e.g., model behaviour, interaction, flow, interaction, etc.) or refer to the existing literature and apply verb-noun analysis technique in order to:

   i) Identify model attributes, such as eLearner ID, background, etc. **These attributes are labelled as tags.**

   ii) Identify relationships between elements (e.g., learning objectives describe learning object). This would result in a list of basic relationships between model elements. ***These relationships are meta-association.***

   iii) Identify constraints between elements and their associations (i.e., cardinality, conditions, attributes and formats if any). ***These rules and constraints constitute the semantics of the e-learning domain/models.***

4- Repeat steps 2 and 3 for all selected models related to the research scope.

5- Use appropriate notation to visualise and represent the final output.

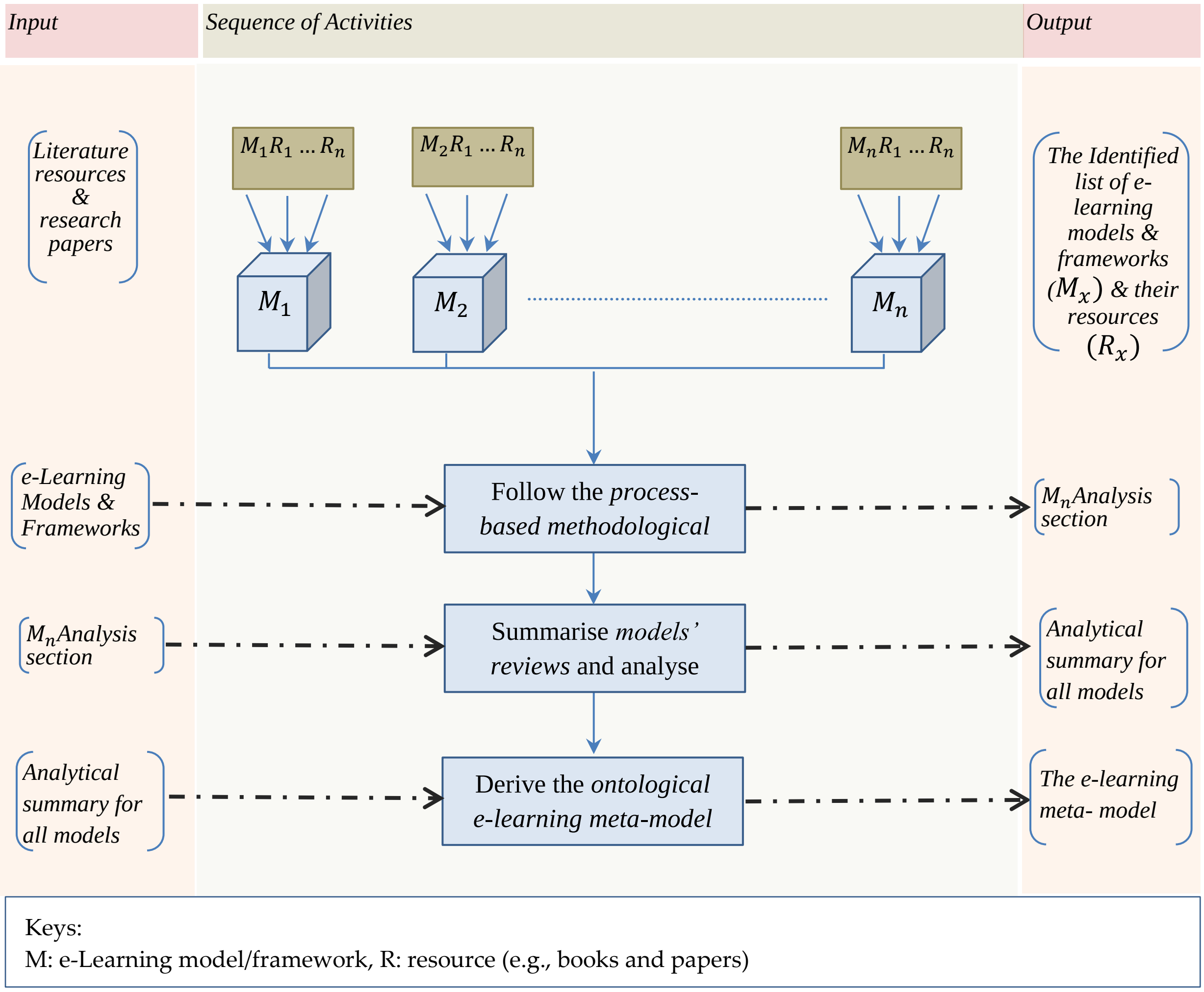


Figure 3.4 The Process of Deriving the Hybrid e-Learning Meta-Model

Figure 3.4 visualises the process of deriving the e-Learning Meta-Model, the left column reveals the input of each step, the middle column shows the sequence of activities, and finally the outputs are shown on the right-side column. This Figure represents the road map for deriving the e-Learning Meta-Model. Applying this process on the selected e-learning models available in the literature is not straightforward due to the: significant differences between these existing models (e.g., model granularity, scope, capabilities, dimensions covered, etc.). However, for cross-verification of the newly developed ontological e-learning model, this model is verified by reverse traceability approach (i.e., the ontological model concepts will be traced back to their original elements). In the next section, the result of applying this process will be presented.

3.3.3 The e-Learning Meta-Model Description

The above-described process has been applied on the early-identified e-learning models, which has led to a large number of concepts, relationships, rules, and constraints from each e-learning model. Some of these concepts, relationships and rules are common, while some other are specific to certain e-learning models. Also, some of these concepts are ill-defined, interrelated to each other, and have been used in different ways. So, it was challenging to derive an eLMM that enables the HeLPS addressing the identified research gaps sufficiently. For instance, Appendix I shows the log of applying the above-described process-based approach (Section 3.3.2) on the Learning Object Model, and similarly for the rest of e-learning models. Responding to the early-performed research gap analysis was the key deriver for synthesising the resulted the output of applying the process-based approach on all e-learning models. Also, various Software Engineering concepts such as: loose coupling, high cohesiveness, separation of concerns, and modularity have been utilised to ensure a good-enough design for the eLMM. Since HeLPS aims at enhancing the e-learner experience (i.e., research hypothesis) through providing adaptive and highly responsive e-learning processes that match his/her preferences (i.e., stated in the research gap analysis), the e-learner and his/her information, henceforth the e-Learner Behavioural Model, is an essential part of the eLMM. This has been driven by literature as well, because adaptive e-learning artefacts require capturing the e-learner related information, modelling his/her information and acting upon the modelled information, as depicted in Figure 3.5.

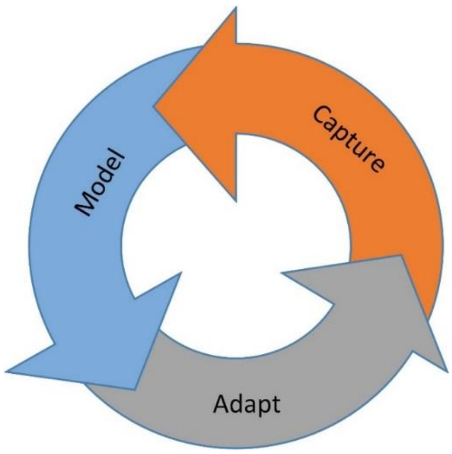


Figure 3.5: Adaptation Lifecycle

The e-Learner behavioural modelling refers to the process of gathering relevant information to infer the current cognitive state of the e-learner, and to represent it to be accessible and useful to the artefact for offering adaptation (Thomson and Mitrovic, 2009). The capability of e-learner behavioural models depends on the extent of the precision of the information collected about the e-learner behaviour. This requires handling the key challenges of e-learner modelling such as the inadequacy of data, improper use of modelling techniques, noise within the data, and the imprecise nature of the e-learner behaviour (Sinha and Potey, 2015). As indicated in (Sinha and Potey, 2015), a proper e-learner model answers: what to model (i.e., information captured)?, how to represent captured information (i.e., structure)?, and how to maintain the model (i.e., modelling techniques)?. Selecting information to be modelled in the e-learner behavioural model depends on: (i) the goal of the modelling process (i.e., advanced adaptation vs. simple adaptation) and (ii) the nature of the context and knowledge of the subject to be taught (conceptual vs. procedural, complex vs. structural, limited amount of content vs. large one).

Generally, the e-learner's knowledge is a common construct of the e-learner behavioural model due to its importance in developing an adaptive system. According to (Brusilovsky and Millán, 2007), the e-learner behavioural model consists of: (i) e-learner knowledge in terms of subject being taught, (ii) interests represented as keywords or concept-based list, (iii) goals and tasks which represent the immediate/short-term purpose of learner actions, (iv) background in terms of previous experience outside the core domain being taught, (v) individual traits which refer to cognitive style as well as learning style, and (vi) context in terms of platform used, location, affective state, etc. Other researchers (e.g., (Chrysafiadi and Virvou, 2013)) have extended the e-learner models to include: skills, learning preferences and styles, errors and misconceptions, motivation, affective features (e.g., emotions and feelings), cognitive aspects (e.g., memory, attention, solving, making decision and analysing abilities, critical thinking and communication skills), and meta-cognitive aspects (e.g., self-regulation, self-assessment, self-explanation and self-management). This alludes to the complexity of building the e-learner model, and the eLMM in general, and the need for appropriate trade-offs.

Recalling the early-performed research gap analysis, the e-learner is considered as the key actor in the HeLPS e-Learning Framework. Each e-learner: (i) can join/belong to various groups according to HeLPS underpinning logic and (ii) has an e-Learner Behavioural Model that is composed of (a) *static information* or less dynamic (e.g., gender and disability) and (b) *dynamic information* (e.g., skills, goal and metacognitive skills). This e-Learner Behavioural Model provides the e-Learning Framework with the required information so that the e-Learning Framework can generate a customised/specialised e-learning process for this e-Learner based information provided by the eLMM. Due to space limitation, the full description of the eLMM, including the e-Learner Behavioural Model, cannot be shown here yet it can be found in Appendix II. The selected information to be modelled in the e-Learner Behavioural Model allows the HeLPS e-Learning Framework to generate a specialised e-learning process from a generic e-learning process. Key e-Learner Behavioural Model information/constructs include: the e-Learner skills, goals, misconception, knowledge level, peers and so on. Using these constructs, HeLPS can customise an e-learning process that will include, for instance, recommending e-learning activities, e-learning contents, and peers in order to achieve the final e-learner goals and consequently enhance his/her experience.

Some of the e-Learner Behavioural Model constructs such as emotions (e.g., happy and angry) and physical context parameters (e.g., temperature, light, etc.) either need: (i) further equipment to precisely capture them or an explicit request to be manually provided by the e-learner, which may lead to e-learner disappointment due to the repeated requests of providing further information. Hence, a trade-off is needed to decide what to model where preciseness of information captured and their usefulness in adapting learning processes are key factors in this trade-off. The word *usefulness* here refers to the added value of this specific construct/information that will allow the HeLPS e-Learning Framework to respond to the early-performed research gap analysis. Also, some of the e-Learner Behavioural Model constructs lack the consensus in the literature. For instance, motivation, emotions, and affective states are ill-defined terms as some researchers consider them the same, others consider motivation subsumed by emotions or vice versa. According to this research's view, emotions are constituted by the dynamic interplay of cognitive, physiological and motivational processes in a given context (Op't Eynde, De Corte and Verschaffel, 2006). Literature evidence reveals that capturing the e-learners' emotions, feelings and affects and acting upon them improves the effectiveness of learning (Lehman *et al.*, 2008) and enriches the e-learning process and the e-learner motivational and psychological presence (Picard *et al.*, 2004), because emotions can alters the way of information storing and retrieving (Linnenbrink, 2006) and the way of organising memory during the time of information receiving or retrieving and e-learner's cognitive state (e.g., cognitive overload (Kim and Pekrun, 2014)). Hence, this research adopts a view where emotions and motivations are inseparable. They are described in the eLMM according to the three-state Russell's model for emotions, which consists of the following states: excited/positive, neutral, and bored/negative (Shen, Wang and Shen, 2009).

To conclude this part of the eLMM, the e-learner and his/her behavioural model is an essential part of the eLMM. To properly structure the large number of concepts, relationships, and rules discovered in the reviewed e-learning models, various Software Engineering concepts such as modularity and separation of concerns have been utilised. This has led to organising the eLMM as a meta-model that is constituted of smaller parts (i.e., eight sub meta-models), which maximises the reusability feature of the eLMM. Therefore, the e-Learner Behavioural Model and its related aspects belongs to the eActor part of the eLMM. These eight parts of the eLMM are described below, as depicted in Figure 3.6:

1- *eActor* a person or system that interacts with the software application in support of a specific process or to perform a specific operation or related set of operations (Zoltai, 2005). This includes two main types: staff and e-learner. The former can be classified into: (i) academic staff such as instructor, module leader, and facilitator and (ii) management and technical staff such as technical support, instructional designer, and system administrator. These are the common actors in e-learning. This conceptualisation is shown in Figure 3.7.

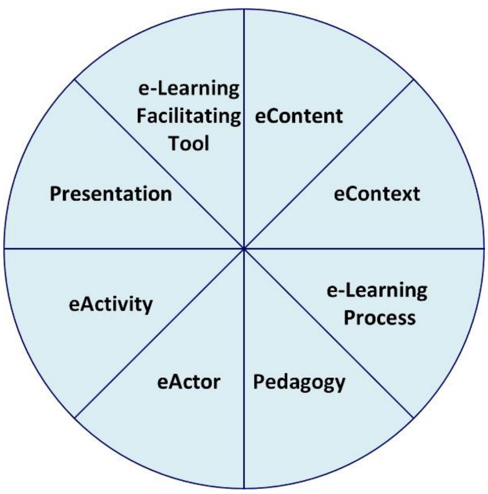


Figure 3.6: The Main Eight e-Learning Concepts

2- *e-Learning Facilitating Tool* refers to the wide range of software tools used in e-learning context to facilitate and support e-learners either by helping them to achieve a given goal or to perform a given task. Examples on these facilitating tools are: To Do List, Email, Wiki, file sharing, etc. These tools can enhance e-learner experience if they have been used and organised in planned approach, and here where pedagogy plays an important role. Facilitating tools can be classified into many classifications, such as: (i) personal (e.g., To Do List) and (ii) social/collaborative (e.g., wiki, chat, etc.)(Dalsgaard, 2006). In this research, facilitating tools are classified into the following two types: (i) content-free tools such as communication tools email, chat, forums, etc. and (ii) content-based tools where contents are codified into one of the available tools such as lessons presented in web page, case study interactive tutorial, experiment in video file, etc. Content-based tools are also described in the literature as mediating artefacts which refer to the different forms of representation of e-learning activities, where e-learning activity is codified in narrative, table and metrics, visualisation, vocabulary or model (Conole, 2009).

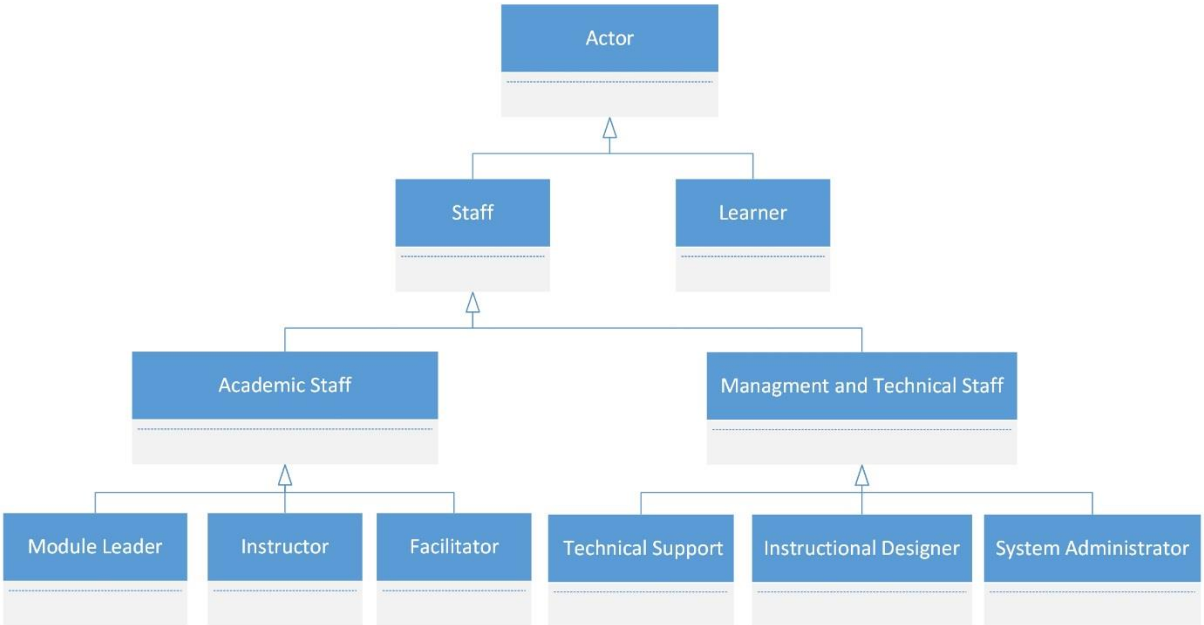


Figure 3.7: Conceptualisation and Classifications of e-Learning Common Actors

3- *Pedagogy* relates to processes, experiences, contexts, outcomes and relationships of teaching and learning in higher education (RAE, 2006). Pedagogy, in this research, is based on learning theories used in e-learning context. These learning theories are divided into behaviourism, cognitivism/constructivism, and situated-based learning theories.

4- *e-Learning Process* involves activities which are performed by people and/or machine working in collaborative groups to achieve specific learning goals (Ould, 1995). As introduced earlier, learning is a social process, which links this process with the wider context that surrounds learning. Even though defining learning as a process is a simplification of what some educational psychologists claimed. For instance, Gagne defines five different domains of learning processes each of them has its own approach (Knowles *et al.*, 2011; Gagné, 1972). This affirms the need for capturing the contexts of this e-learning process via semantic representation techniques.

5- *eActivity* refers to actions done by a specific actor (e.g., e-learner) using a facilitating tool or combination of more than one to achieve a goal. This includes activities done to support e-learners whether this support is academic, technical, or logistic. Hence, the process which is composed of activities requires using one or more tool to achieve a goal. However, a process cannot do this without the help of pedagogy since pedagogy helps the e-learning artefact and its actors, more specifically e-learners, to make sense of learning and teaching. Consequently, process cannot afford what e-learners need without including the sixth concept which is the *eContext*.

6- *eContext*: information that can be used to characterise the situation of an entity which can be a person, a place, an object that is considered relevant to the interaction between the actor and the system (Dey, 2001), such as location, environmental attributes (e.g., motion, noise level, etc.), people, devices, objects and software agents that it contains. It might be extended to contain activities and tasks in which user and computing entities are engaged, and their situational roles, beliefs and intentions (Knappmeyer *et al.*, 2013). Literature evidence (Mikroyannidis, 2012) reveals that enriching the e-learning process with its wider context (e.g., e-learner previous knowledge and learning peers) helps in customising the e-learning process according to the e-learner's requirements and goals. Such contextual inputs differ from one e-learning process to another. For instance, if the e-learning process aims at teaching intellectual skills then the e-leaner prior learning experience is important to be known by the e-learning artefact. However, if the aim is to teach motor skills, which can be obtained via practices or learning by doing approach (Knowles *et al.*, 2011), then the focus should go to the contextual inputs that allow further customisation of the e-learning approach (e.g., learning style).

7- *eContent* refers to subject domain contents and materials that are published in different format and made available for e-learners. They represent the resources prepared to convey knowledge and information to e-learners, in relation to: (i) topic (e.g., introduction to reading skills), (ii) subject that covers a given domain (e.g., Math), (iii) module which represents a form of formal/semiformal setup of learning normally covering parts of a given subject or combination of more than one subject, (iv) programme that consists of more than one module and leads to an award or certificate, and (v) informal learning-based contents which may be a selected piece of information about topic(s).

8- *Presentation* refers to the way chosen by a specific actor (e.g., instructional designer, subject matter expert, instructor, etc.) to deliver content which may be narrative, textual, graphical, audio/visual, immersive technologies or hybrid. Usually, Content and Presentation elements are highly coupled, which negatively impacts the agility of e-learning systems, and their ability to respond to the continuously evolving learning models.

In summary, these eight core elements of the eLMM are inter-related to each other to a larger extent. Underneath these eight core elements, various supportive elements, attributes, and characteristics exist. For instance, each e-learning process has learning objectives, pre-requisites and so on. Figure 3.8 depicts a high-level abstraction of the e-Learning Meta-Model and its constituent eight elements and their basic structure, semantic/relationships. For instance, it shows that e-learner (i.e., the main actor in the HeLPS) follows an e-learning process situated in a certain context. Also, e-Learning Process is composed of a list of eActivities. These activities are orchestrated according to the e-learning process specification, which ensures the coherence of the learning experience (i.e., identified in the early-performed research gap). Furthermore, these activities are facilitated by e-Learning Facilitating tools. Such facilitating tools are based on or contain eContents, which are presented in a certain Presentation Format. Learning theory (i.e., the main concept of the pedagogy) generates an e-Learning Process. This means that any e-Learning Process must be based on a learning theory or combination of learning theories according to context as indicated in the research gap analysis.

As stated previously, the e-Learning Meta-Model will be specified/encoded using ontology, and therefore, the two terms (i.e., the eLMM and the ontology) might be used interchangeably. Further rules and relationships of the eLMM will be explained later, yet a final explanation in relation to Figure 3.8 is needed. It is related to the concept "*Thing*", which acts as the most abstract concept in ontology. Therefore, all other concepts (e.g., eActor, eActivity, and eContext) will be sub-concepts of it. To ensure the validity of the eLMM, a traceability matrix of the eLMM constructs/elements is provided in Appendix IV. For instance, it shows if a certain element (e.g., eActor) exist in a certain e-learning model. Actor refers to the existence of an identity for the e-learner ranging from simple user account to advanced user profile. In most of the reviewed e-learning models, both content and presentation elements exist but tightly coupled to each other. Moreover, the e-learning process aspect is either missing or mostly implicit and cemented into the e-learning model behaviour. The full e-Learning Meta-Model is represented in Figure 3.9 as a class diagram.

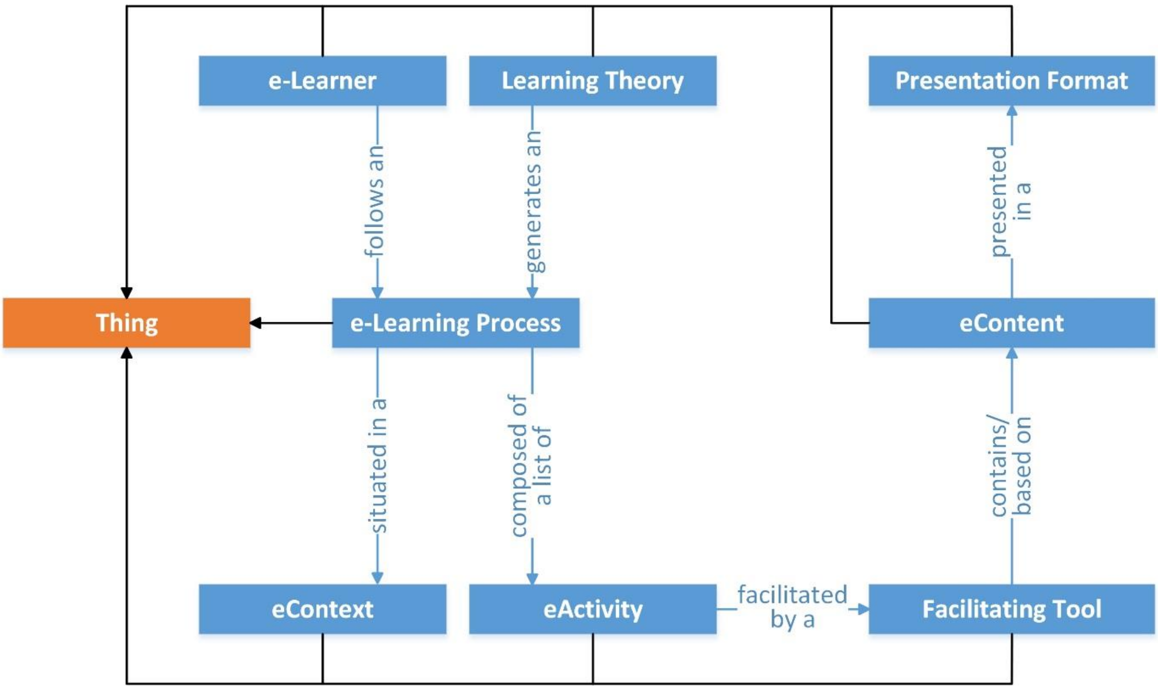


Figure 3.8: High Level Abstraction of the e-Learning Meta-Model

To conclude, the above-described detailed eLMM constructs requires carful approaches to structure and maintain its data. Different e-learner modelling techniques exist in the literature such as: overlay model, stereotyping model, perturbation model, machine learning techniques, cognitive theories, constraint-based model, Fuzzy learner model, Bayesian network model, ontology-based learner model, data and text mining, evolutionary and genetic representation model, decision tree, etc. (Chrysafiadi and Virvou, 2013; Sinha and Potey, 2015; Brusilovsky and Millán, 2007; Romero and Ventura, 2007; Baker and Yacef, 2009; W. Chen and Mizoguchi, 2004). Each modelling approach has its own strengths and weaknesses as well as ability to ideally model a specific set of information, as

Figure 3.9: Class Diagram Representation of the e-Learning Meta-Model

shown in Table 3.1 (Brusilovsky and Millán, 2007; Chrysafiadi and Virvou, 2013). For instance, in the overlay model the subject being taught is modelled via a set of interrelated concepts, where the learner's knowledge is a set of masteries over these concepts. These masteries can be represented in Boolean or qualitative measures. Overlay is one of the simplest modelling techniques, but it is not sufficient since it does not represent misconceptions (i.e., learner's incorrect understanding), different cognitive needs, preferences, etc.) (Chrysafiadi and Virvou, 2013). Therefore, a hybrid e-learner models where two or more modelling techniques are combined together has been adopted in this research to respond to the demand of modelling a wide range of e-learner characteristics. For instance, the stereotype model can be used in combination with the overlay to initialise learner model in order to avoid "one e-learner" problem, where all students have the same characteristics.

Table 3.1: Ideal Uses of Learner Modelling Approaches

Model Title	Ideal Use
Overlay Model	Representing learner's mastery based on the domain knowledge
Stereotype Model	Representing learner's learning styles
Perturbation Model	Detecting learner's misconceptions
Cognitive Theories	Recognising learner's emotions
Constraint-Based Modelling	Identifying learner's knowledge
Fuzzy/probabilistic Models	Representing abstract and subjective aspects of the learner's characteristics such as affective, cognitive and meta-cognitive features.

3.4 Conclusion

In this chapter, the research design framework has been introduced. Then, the need for a new architectural framework to enhance the e-learner experience has been identified and discussed with the introduction of the HeLPS e-Learning Framework. As enhancing the e-learner experience is not a straightforward task, a combination of technologies (i.e., semantics, business process and SOA) has been established, where each technology has a specific role in the introduced HeLPS Framework. HeLPS e-Learning Framework consists of five layers, where each layer has certain number of modules and components. This chapter elaborated on how the early-identified technologies can work together to respond to the early-performed research gap analysis. Further focus has been given to the e-Learning Meta-Model, the essence of the HeLPS e-Learning Framework. This includes why this e-Learning Meta-Model is needed and the process-based approached utilised to derive it from various e-learning models.

The eLearning Meta-Model is the key artefact in the HeLPS e-Learning Framework because it is used to generate a specialised e-learning process model for each e-learner based on his/her context. In other words, eLMM is a generic e-learning model, which uses ontology-based technique to model the e-learner's knowledge, errors, learning styles and preferences, affective states, metacognitive features and other cognitive aspects. The introduced eLMM has been used as a conceptual model to abstract from technical details and generate a special e-learning process from a generic e-learning process based on the information, rules, and context specified in the eLMM. Additional models (i.e., the e-Learner Experience Model and the e-Learning Capability Maturity Model) have been designed to support HeLPS e-Learning Framework design and development and to guide its evaluation process. The HeLPS e-Learning Framework aims at providing automated e-learning artefact, and consequently minimise the human intervention in learning processes to make the best use of instructors' time. Hence, once the e-learning contents designed and published by instructors, and supportive teams, instructors are not expected to be involved in deciding what is the appropriate learning/assessment contents for a particular e-learner. They are expected to help e-learners to manage their learning process by responding to their questions and providing further support.

This chapter, more specifically the e-Learning Meta-Model, is an attempt to respond to the second part of the first Research Question (i.e., whether existing e-learning process models can lead to the development of a generic e-learning model?). The proposed approach to develop the eLMM shows that it is possible to construct a generalised e-learning model that: (i) brings the commonalities of other e-learning models together, and (ii) considers the special features of these e-learning models based on certain conditions. The introduced eLMM is expected, at least theoretically up to this stage, to meet the various needs of a wide range of e-learners, and therefore to be considered as a generic e-learning model that can lead to many specialised e-learning models. However, this will be further tested in Chapter 5 based on the instantiated proof of concepts introduced in Chapter 4. Similarly, the proposed HeLPS e-Learning Framework responds to, theoretically, the second, the third and the fourth research questions by explaining, in abstract way, how these technologies (i.e., business process, semantics and SOA) can be utilised in the e-learning domain in order to enhance the e-learner experience. This framework design needs to be instantiated, in Chapter 4, and evaluated, in Chapter 5, to fully respond to the second, third and fourth research questions.

Chapter 4:

Design and Development of the HeLPS e-Learning Framework

4.1 Introduction

After having briefly introduced the HeLPS e-Learning Framework in Chapter 3, this chapter instantiates this framework and presents its design specification. To achieve this goal, an instantiation process has been defined and applied to the HeLPS architectural framework as detailed in Section 4.2. In Sections 4.3 to 4.7 the HeLPS architectural layers and components are detailed. This particularly investigates: (i) the potential of specifying e-learning processes based on pedagogical theories and models underpinning e-learning artefacts, (ii) how e-learning processes can be contextualised to enrich the e-learner experience, and (iii) mechanisms to dynamically enact these e-learning processes. This hybrid approach will be examined in the context of the e-Learner Experience Model and the e-Learning Capability Maturity Model that have been developed to critically assess the impact of HeLPS e-Learning Framework on the e-learner experience and the maturity of the HeLPS e-Learning Framework, respectively. Finally, Section 4.8 concludes this chapter.

4.2 The Process of Instantiating the HeLPS e-Learning Framework

The following steps formulate the instantiation process of the HeLPS e-Learning Framework, depicted in Figure 3.2:

Step 1: Instantiating the e-Learning Meta-Model of the HeLPS e-Learning Framework as per the following perspectives (i.e., Section 4.4.1):

1. **The organisational perspective**, which includes information about the organisation, its programmes, modules, regulations, policy, staff members (both academic and non-academic) and students. This is achieved through the following steps:
    a. Defining the organisation, faculty, department and programme.
    b. Selecting the information needed to be instantiated (i.e., only the relevant part of the organisation, such as certain department and modules).
    c. Specifying the selected information.

2. **The e-Learner perspective**, which includes: (i) static information about e-learner (e.g., name and date of birth) and (ii) dynamic information (e.g., e-learner's goal, skills and knowledge levels). This is achieved through the following steps:
    a. Developing a set of e-learners' profiles to be used during the design and development process.
    b. Specifying the early-developed e-learners' profiles.
3. **The content level**, which includes the modules offered by the organisation as well as their contents such as lessons, supportive materials in different formats video, audio or text-based. This is achieved through the following steps:
    a. Choosing the selected modules, or part of them, needed to instantiate the model. In our case, the Software Engineering module has been chosen along with three essential topics (i.e., Waterfall software design process, Agile process and Validation and Verification).
    b. Specifying the above-identified information.
4. **Technical level**, which includes the environment, used platforms, requirements for advanced or custom e-learning processes (e.g., behavioural or virtual world/second life-based e-learning process models).

Step 2**:** Instantiating the e-learning processes used by the organisation, its instructors, modules and learners (in Section 4.4.2). This is achieved through the following steps:

a. List the early-identified e-learning processes used by the institution and its instructors as well as the generic e-learning process.
b. Model/Specify these e-learning processes based on BPMN 2.0 standard using the appropriate tools to produce xml-based serialisation and readable business process models.
c. Instantiating the BPMN 2.0 Ontology within the selected e-learning processes, as mentioned earlier.

Step 3**:** In case of the absence of a sufficient set of web services that could meet the e-learners' demands, similar to this research, a Service Orientation component needs to be deployed and configured in order to get the services registered, described and published in a given Service Registry, such as the UDDI: Universal Description, Discovery and Integration (in Section 4.4.3). This will be done through the following steps:

a. Selecting, installing and configuring the appropriate service registry.
b. Developing the web services underpinning the HeLPS e-Learning Framework.
c. Publishing the services using the configured UDDI.
d. Check whether the services can be enacted within the context of HeLPS e-learning framework.

Step 4: Developing and specifying a set of domain-specific rules (SWRL rules), which will be fired based on the e-learner preferences and the overall context to produce a specialised e-learning process model for that learner (in Section 4.4.1.3). These SWRL rules support the HeLPS e-Learning Framework to unambiguously instantiate the generic e-learning process for a certain e-learner. In other words, generating a specialised e-learning process from the generalised one. This is achieved through the following steps:

a. Identifying the rules needed to satisfy the early-performed research gap analysis.
b. Specifying these rules using the appropriate tools.

c. Testing the rules ability to be fired automatically based on the appropriate inputs.

Step 5: Enacting the semantically-enriched e-learning processes through the Service Orientation module and derive the web services to the e-learner, so that he/she can go through a specific e-learning experience. This is accomplished through the following steps:

a. Extracting the required e-learner information (i.e., from the ontology) to specialise the generic e-learning process for that e-learner.
b. Getting the Business Process Execution Language (BPEL) script for that e-learning process.
c. Enact it using the Business Process Execution Engine (i.e., WSO2).

Step 6: Update the e-Learner Behavioural Model, which represents a subset of the e-Learning Meta-Model that models the e-learner preferences and his/her interaction with the HeLPS, at the end of the e-learning process. This will be done through the following steps:

a. Tracking the e-learner interaction with the HeLPS framework (e.g., recording his/her attempts).
b. Automatically updating the e-Learner Behavioural Model.
c. Exit the e-learning process.

The above-mentioned steps represent the process of constructing the various components of the HeLPS e-Learning Framework and reflect the complexity underpinning such a framework. The next sections will describe how the proposed instantiation process is applied in the context of the HeLPS e-Learning Framework, with a substantive focus on the three key modules of the Business Logic Layer including eLearning Semantic, eLearning Process, and Service Orientation Modules.

4.3 The Presentation Layer

This layer is the first layer of the HeLPS e-Learning Framework, as shown in Figure 3.2. The two key purposes of this layer are: (i) to create the relevant user interface for each user and consequently display the appropriate contents and data, and (ii) handling the user interaction with the framework according to the early-specified logic. This layer has two components as explained below:

1- Authentication Component**:** This component aims to identify, authenticate, and authorise users. It does this by, *first*, checking the provided credentials against the information stored in the eLearning Meta-Model about all users (i.e., authentication). The *Second* step is to ensure that all identified/authenticated users are allowed to access the resources they are asking for (i.e., authorisation). For example, to differentiate between *e-learner user* and *instructor user* when they provide their credentials using the HeLPS e-Learning Framework interface. This role of this component is essential as it initiates/triggers the e-learning process for a certain e-learner. Consequently, this particular instance of the e-learning process consults the e-Learning Meta-Model to verify his/her details. This might lead to requesting an account if this e-learner has no account, re-typing his/her credentials in case of errors, or going to the next activity in the e-learning process if he/she is an authorised e-learner/user. In case of successful login attempt, the e-learner's details will be sent to the GUI Manager Component, explained below.

***2- Graphical User Interface (GUI) Manager Component*:** After receiving a notification from the above-introduced Authentication Component about a successful login attempt, this component manages the user-oriented functionalities. By the term "*manage*", we refer to sending the users' data to the underpinning HeLPS processes/activities including fetching the data from the underneath layers, handling them according to rules, procedures, etc. that are encapsulated in the Business Logic Layer, getting the results and visualising them to the user. This includes various activities/processes such as validating users' credentials, responding to user interactions and graphically facilitating the e-learning process interaction with the e-learner. HeLPS functionalities are briefly represented in the use case model shown in Figure 4.1, which includes, but not limited to, the following functionalities: (i) *Login/Logout:* to perform the action of login or logout for a certain user, (ii) *Get Learning:* to allow e-learners to participate in learning activities according to HeLPS designed processes, (iii) *Assess My Learning:* to assess the progress of a certain e-learner in a specific module/unit of learning, (iv) *Interact with Peers*: to allow e-learners to interact with each other in various mechanisms, (v) *Capture the e-Learner Model:* to extract the required information from the e-Learner Behavioural Model, (vi) *Update Learning Model* to update the e-learner behavioural model after the end of his/her e-learning processes, and (vii) *D Specify the e-Learning Process*: which is an essential part of HeLPS, that encompasses various functions such as recommending peers and resolving misconceptions in order to specialise the generic e-learning process for a particular e-learner. Additional feature of this component is to represent data/contents extracted from external resources/tools such as e-library and e-survey. In the next section, the Business Logic Layer is presented in detail.

Figure 4.1: HeLPS Use Case Diagram

4.4 The Business Logic Layer

As introduced earlier in Chapter 3 (i.e., Figure 3.2), this layer is the core layer of HeLPS e-Learning Framework. It consists of the following three modules: (i) the eLearning Semantic Module, (ii) the eLearning Process Module, and (iii) the Service Orientation Module. In this section, we explain these modules and their internal structure in relation to the HeLPS e-Learning Framework capabilities.

4.4.1 The e-Learning Semantic Module

This module describes the utilisation of semantic technologies in the context of the HeLPS e-Learning Framework. The eLearning Meta-Model (eLMM), briefly described in Chapter 3, is the core of this module. As introduced before, the eLMM represents knowledge about e-learners (e.g., goals, learning styles and preferences) and other context details (e.g., regulations and institutes) and assists in making decisions (i.e., through reasoning) in certain cases. Moreover, it encapsulates domain-specific knowledge (e.g., e-learning pedagogy) and rules/relations (e.g., John "eLearner" is enrolled in Software Engineering "Module"). Such features allow the development of knowledge-based artefacts, making domain assumptions explicit, reusing domain knowledge, separate domain knowledge from operational knowledge, which are necessary for the MDE approaches and consequently for HeLPS development. In this respect, this section explains the eLMM elements, their datatypes, constraints and illuminates certain modelling concerns, specifications and rules. Figure 4.2 depicts a snapshot of the eLearner Behavioural Model, part of the eLMM due to space limitation. As introduced earlier (Section 2.7.3), eLearner Behavioural Model (eLBM), User Model/Profile in the literature, is essential for adaptive e-learning system because it represents the user (i.e., e-learner) in a certain way so that the system can be adapted to reflect the user requirements (Graf and Kinshuk, 2014).

The e-learner can be modelled in different ways according to the system goals. For instance, if the system goal is to recommend e-learning content, then the key eLBM constructs are the e-learner knowledge and previous

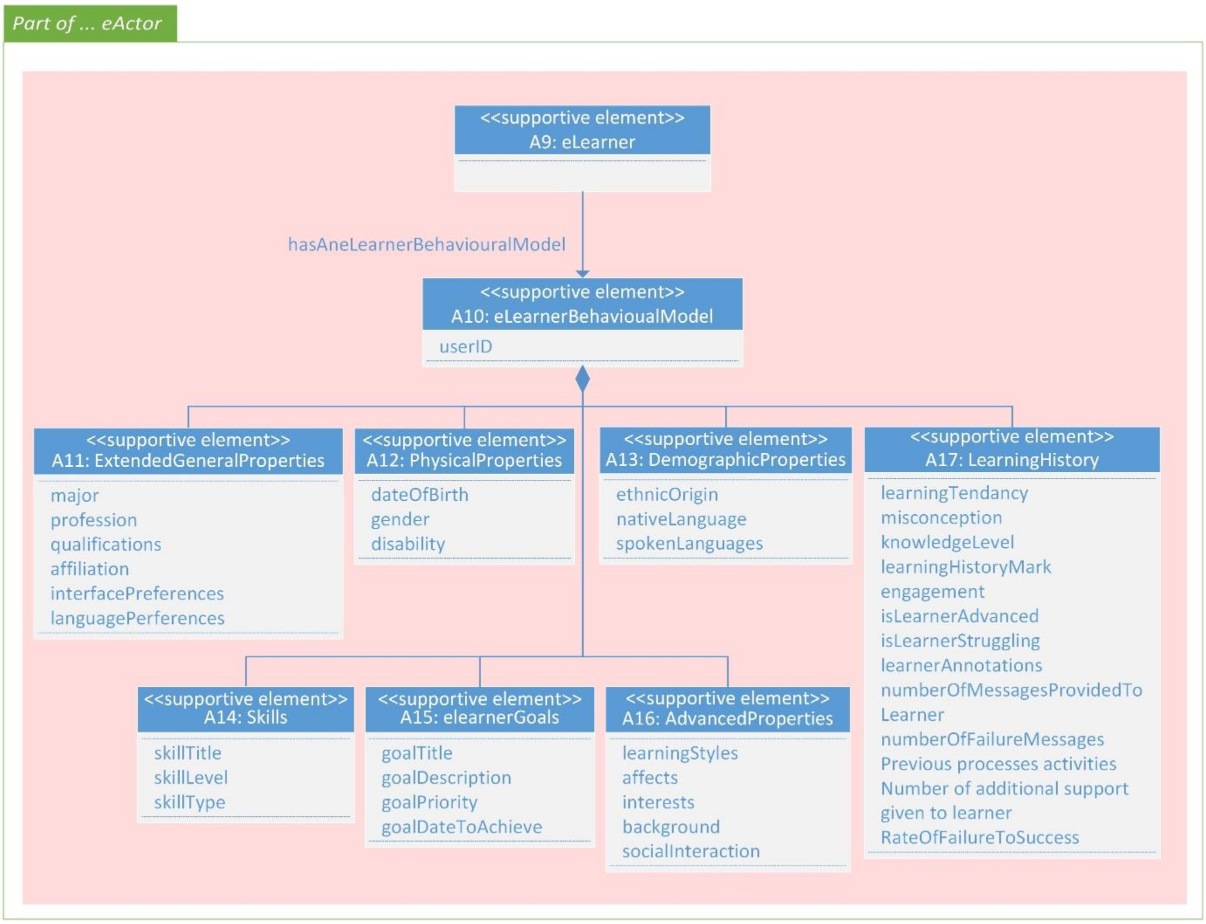


Figure 4.2: Visualisation of the eLearner Behavioural Model

formative assessment results. However, if the system goal is to recommend peers then, the focus will be the e-learner history of interaction with the system (Albert and Tullis, 2013). Consequently, the eLBM has been developed based on the HeLPS purpose. Figure 4.2 shows that eLBM is composed of a wide range of constructs including: goals, skills, knowledge level, misconceptions, to mention but a few. It also reveals, as an example, one of the relationships, which is: each eLearner has an eLearner Behavioural Model. To promote eLBM reusability, modularity and agility, it has been divided into the following sub-concepts: extended general properties, physical properties, demographic properties, learning history, skills, e-learner goals, and advanced properties. Various constructs exist underneath these sub-concepts.

For the above-mentioned reasons (i.e., reusability, modularity and agility), the eLMM has been divided into the following constituent sub-ontologies: (i) eActor, (ii) ePedagogy, (iii) ActivityProcess, (iv) ContentContext and (v) LearningProcessModel. The first four sub-ontologies, i – iv, have been developed, while the latter (i.e., the LearningProcessModel ontology) has been reused from a previous research project (Cabral, Norton and Domingue, 2009). Various rules have been designed and developed for a better conceptualisation of e-Learning domain. For instance, the rule: hasFolloweLearnereLearningProcess, where the e-Learner is the domain and the eLearningProcess is the range. As a convention, only the first word of the rules starts with a small letter, the relation (i.e., hasFollow) is specified and will be followed by the domain (i.e., eLearner) and the range (i.e., eLearningProcess). This will make rules understandable, especially when the eLMM becomes more complicated. Such rules are used to specify relationships between ontologies concepts. Other rules, which will be further explained later to maximise the eLMM added values include: isFormedBasedOnLearningProcessLearningTheory, isPresentedInaEcontentPresentationFormat, to mention but a few. There is another type of dynamic rules that will be used for dynamic reasoning/decision making regarding HeLPS behaviour for a certain e-learner (e.g., to show the e-learner the best web service based on his/her eLBM) that will be discussed later in this section.

#	Concepts	Definition/Sub concepts	Data properties	Datatype	Constraints	How to capture
Actor Ontology *(ActorOnt)*						
1	eActor (A1)	Represents human or software agent performing some action in the e-learning system to achieve a given purpose.				
		1.1 MachineActor (A2): Non-human actor e.g. service				
		1.2 HumanActor (A3)				
			Identifier	String	Obligatory	Implicit
			User ID	String	obligatory	Explicit via learner sign up
			Password	String	obligatory	Explicit via learner sign up
			First name	String	obligatory	Explicit via learner sign up
			Last name	String	obligatory	Explicit via learner sign up
			Email address	String	Obligatory	Explicit via learner sign up
			Address	String	Obligatory	Explicit via learner sign up
			Phone number	Integer (14) digits	Optional	Explicit via learner sign up
		1.2.1 Staff (A4)				
			Staff qualification	String	Obligatory	Explicit based on user data
			Contract type	Enumerated, Controlled list: FT fixed, FT Temp, PT	Obligatory	Explicit
			Employment date	Date	Obligatory	Explicit
		1.2.1.1 Non-academic staff (A5)				
		1.2.1.1.1 Technical staff (A6)				
		1.2.1.1.2 Admin staff (A7)				
		1.2.1.2 Instructor (A8)				
		1.2.2 e-Learner (A9): The main actor in the system, the student.				
2	eLearner Behavioural Model (A10)	is a representation of information about an individual user that is essential for an adaptive system to provide the adaptation effect in order to behave differently for different users [200].				
		2.1 Extended general properties (A11)	Programme = Major	String	Obligatory	Explicit via learner sign up
			Profession=occupation = career = vocation	String	Optional	Explicit via learner sign up, e.g. web developer

Figure 4.3: Sample of the e-Learning Meta-Model Description

Due to space limitation, a detailed list of all eLMM constructs are specified in Appendix II, with further explanations on models common and specific features in Appendix VII. Figure 4.3, reveals a sample of the eLMM concepts, sub-concepts, definitions, data properties, data types, constraints and how to capture related information. For readability purposes, **Bold** constructs (e.g., Human Actor) refers to inherited relationship, while cells with shade/dark background (e.g., Actor) refers to an aggregation relationship of its sub concepts. For example, the human actor has the following data properties: User ID, password, first name, etc.

4.4.1.1 e-Learning Meta-Model: Modelling Considerations

Based on the purpose of this research and the early-deduced conclusions and lessons learnt, eLMM concepts (i.e., constructs) have been decomposed into simpler constructs to avoid complexity of the hybrid e-learning conceptualisations. For instance, the construct "*rateOfFailureToSucess*", which refers to the rate of failed to success attempts of passing a quiz on a specific learning topic is different from the construct "*numberOfFailureMessages*", which relates to project-based, ongoing activities or learning activities that are under direct support from the instructor (i.e., used in Direct Instruction based eLearning). Similarly, *"spokenLanguages"* has a list of languages up to five, is different from *"nativeLanguage"*. The former is used to support the e-learner with other resources in different languages in case of language-oriented struggling, while the latter is used to group e-learners with similar profiles. Also, *"skills"* is divided into: metacognitive, cognitive and intellectual skills, where every skill type might lead to different e-learning process type considering the topic being taught and the approach of learning/teaching. Such e-learning processes are complicated and have multiple variants, for instance a certain e-learning process may be a combination of two elementary/detailed e-learning processes (i.e. behavioural and self-regulated e-learning processes), where any of those two variants can be individually or collaboratively oriented, text or video based contents format and so on. So, a wide range of factors have been modelled and used to precisely specify the e-learner learning processes.

Additional challenge in modelling the eLMM relates to measuring of certain eLMM constructs, for instance the *Learning Style*, which refers to the physical qualities, thoughts and feelings that the e-learner uses to perceive, respond, and interact with a stable environment (Pantho and Tiantong, 2015). This is a must condition to promotes the e-learner motivation and performance (Koorsse, Cilliers and Calitz, 2010). Different learning styles classifications (approximately one hundred) have been developed over the last three decades, yet VARK (Visual, Aural, Read/Write, Kinaesthetic) is one of the most popular models used in e-learning domain, where a well-established questionnaire or method may be utilised to decide which of the four learning styles is preferred by the e-learner. The four learning styles in VARK are described as follows. First, ***Visual***, which refers to learners who prefer learning through provided demonstrations and descriptions. e-Learners in this style use videos, graphics or other visualisation tools (e.g., lists) to organise their learning processes. Second, ***Aural***, where e-learners prefer more to learn by listening, and hence the aural discussion or dialogue represents a good opportunity for those e-learners. Third, ***Read/Write***, which refers to e-learners who prefer taking notes whenever they are exposed to a learning experience, (e.g., lectures). Fourth, ***Kinaesthetic***, where e-learners prefer learning by doing and hands-on learning experiences. Those learners like to be linked to their environments via movement and interaction rather than watching or listening to a lecture. Similarly, to capture the e-learners' affects or emotional states, the 3-state Russell's model for emotion (i.e., positive, neutral, negative) is adopted as explained in the meta-model description.

4.4.1.2 e-Learning Meta-Model Specifications

This section presents the formal specification of the eLMM with the objective to capture the semantic, rules, constraints, etc. in a machine-understandable format using a suitable language. Among XML, RDF, DAML+OIL and OWL, this research opted for Web Ontology Language (OWL) as a specification language for this eLMM. OWL is written in XML and it offers all required capabilities for modelling the proposed e-learning model. OWL has three variants: (i) OWL Lite, (ii) OWL DL and (iii) OWL Full. OWL Lite is useful for classification hierarchy and simple constraints which is not the case in our model. Nonetheless, OWL DL has the sufficient level of required expressiveness and capabilities. OWL has been utilised in this research as a specification language for the eLMM due to the following: (i) OWL is designed to provide a common way to process the content of web information instead of displaying it (i.e., XML main role), (ii) OWL facilitates greater machine interpretability than supported

```
<!DOCTYPE rdf:RDF [
<!ENTITY owl "http://www.w3.org/2002/07/owl#">]>
<rdf:RDF xmlns:owl ="http://www.w3.org/2002/07/owl#"
xmlns:rdf ="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
<owl:Ontology rdf:about="">
<rdfs:label>My Ontology</rdfs:label>
<rdfs:comment>Generic e-learning Model</rdfs:comment>
</owl:Ontology>
<owl:Class rdf:ID="Actor" />
<owl:Class rdf:ID="Learner" />
<rdfs:subClassOf rdf:resource="#Actor" />
<owl:Class rdf:ID="Staff Member" />
<rdfs:subClassOf rdf:resource="#Actor" />
</owl:Class>
</rdf:RDF>
```

Figure 4.4: Sample of OWL-DL Specification

by XML, RDF and RDF Schema by providing additional vocabularies, (iii) OWL is more expressive and interoperable than RDF and RDF Schema (e.g., cardinality constraints, value constraints, inference are not supported in RDF and RDFS while OWL offers these capabilities, and (iv) XML is deficient when it comes to exchanging highly structured data between applications (Gaševic *et al.*, 2006). To conclude, OWL is more expressive and has greater machine interoperability than RDF, larger vocabulary. Figure 4.4 shows a snippet of OWL based specification of the eLMM and full specification is attached in Appendix II. This ontology has been developed and specified using the Protégé 4.3 tool [3], Figure 4.5 visualises part of the hierarchy of the developed eLMM. Mainly, it shows the ProcessActivity sub-ontology). This eLMM consists of a large number of concepts/classes, data properties, object properties as shown in Figure 4.6 (a), (b) and (c), respectively. Full e-Learning Meta-model traceability at the level of core and supportive concepts is shown in Appendix III.

[3] https://protege.stanford.edu/

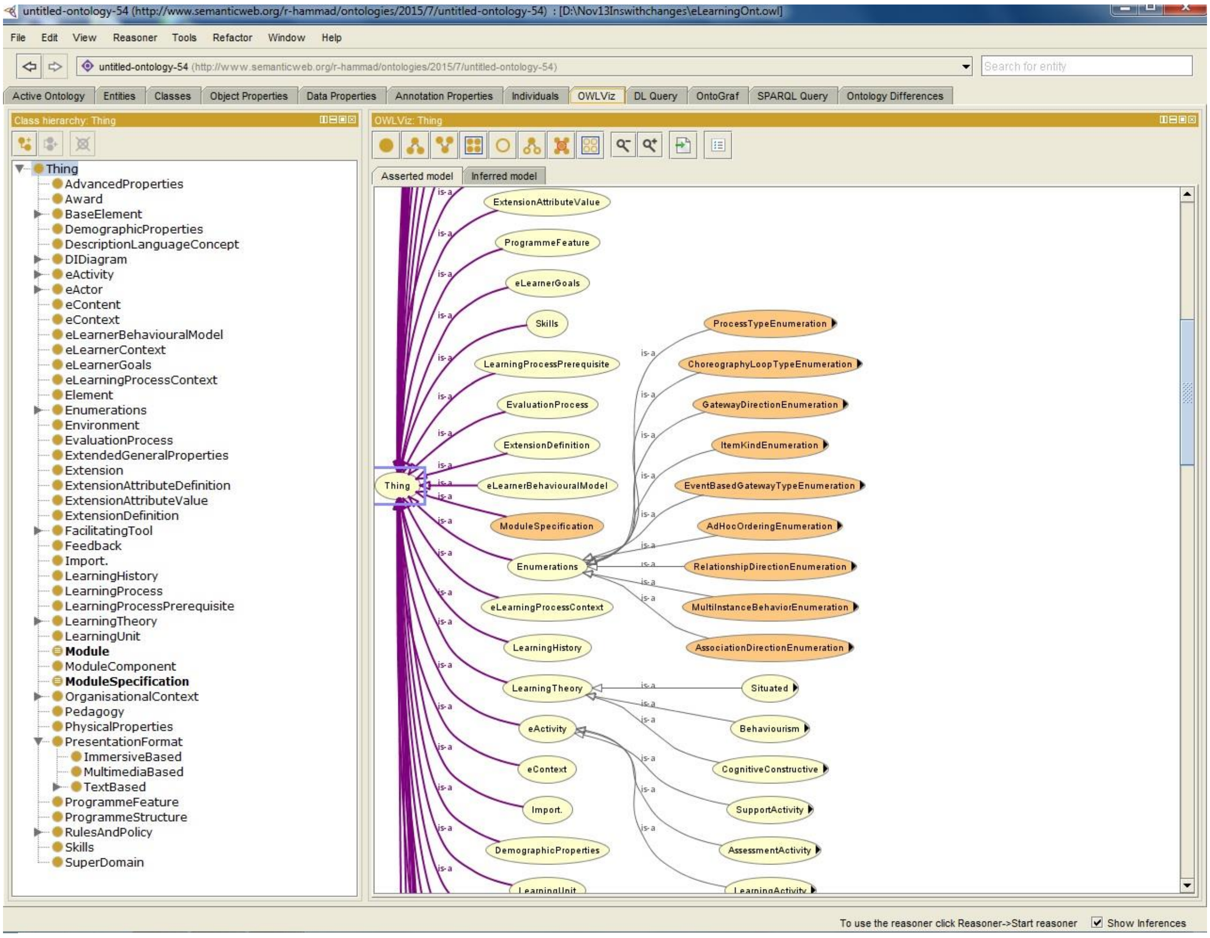
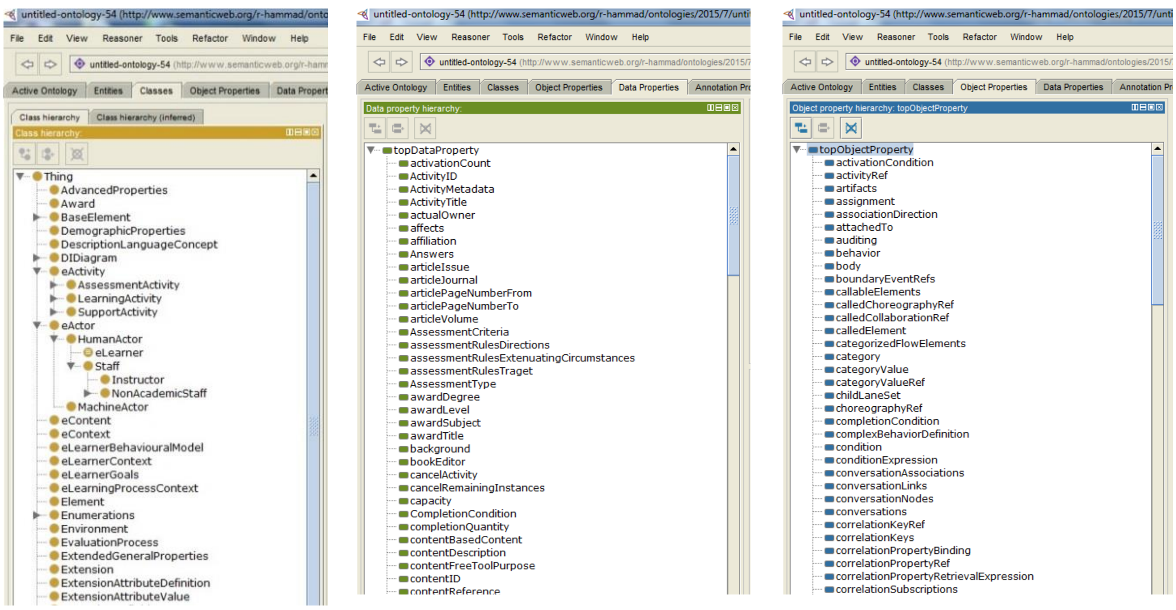


Figure 4.5: Part of ProcessActivity Ontology



(a) Class Hierarchy (b) Data Object (c) Object Property

Figure 4.6: e-Learning Meta-Model in Figures

4.4.1.3 Semantic Web Rule Language (SWRL) e-Learning Rules

OWL's ability to define axioms to ontological concepts and their relationships adds further advantage to its expressiveness because these axioms specify how to interpret concepts and infer information from them (Orlando *et al.*, 2012). To process OWL based elements, SWRL is utilised to define processing rules. SWRL has been developed to extend OWL expressiveness. An SWRL rule is composed of two parts: (i) *antecedent* or body and (ii) *consequent* or head. Once the antecedent atoms are true, the SWRL rule fires and execute the actions on the Right-Hand Side (RHS). Both antecedent and consequence are composed of *Atoms* connected with conjunctions, where a conjunction is represented as (,), formerly caret symbol (^). *Atoms* can be a class, an individual property atom, data valued property atoms, different individual atoms, same individual atoms, built-in atoms or data range atoms[4]. These SWRL rules have been specified to enrich the generic e-learning process for a given e-learner and align with e-learner experience. Table 4.1 proves a simple example of SWRL based rule with explanation and full SWRL specification is listed in Appendix III.

Table 4.1: Examples of HeLPS e-Learning Framework SWRL Rules Specification

#	Rule
1.	e-Learning process combines SRL elements for those e-learners who have metacognitive skills. **IF THEN Translation:** If the e-learner has metacognitive skills, then suggests SRL elements for his/her e-learning process. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), Skills(?s), LearningProcess(?lp), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelSkill(?lbm, ?s), hasFollowLearnerLearningProcess(?x,?lp),skillType(?s, ?str), matchesLax(?str, "Metacognitive") -> recommendedProcessElement(?lp,"SRL")
2.	Module pass mark is the sum of module component pass marks. **IF THEN Translation:** If a module has more than one components, then module pass mark is the summation of its component pass marks.
3.	***Struggling e-learner in a topic*** is an e-learner who did not pass two assessment unit for that particular concept. **IF THEN Translation:** If the e-learner did not pass two assessment elements for the same topic (his mark<50), then he/she should be recognised as ***struggling learner in a topic*** to give further support later.
4.	***Struggling e-learner in a topic*** should be given extra support (e.g., instructor-centred approaches). **IF THEN Translation:** If the e-learner is ***struggling in a topic,*** then provides less-controlled approaches such as direct instruction.

[4] http://protege.cim3.net/cgi-bin/wiki.pl?SWRLLanguageFAQ

5.	***Struggling e-learner in a module*** is the e-learner who is struggling in two or more core learning topics of the module and should be given extra support e.g. instructor-centred approaches and join group to get help from talent/advanced learners. **IF THEN Translation:** If the e-learner is *struggling in a module,* then provides direct instruction and join him to groups of advanced learners.
6.	*Advanced e-learner* is a learner that already finished two or more learning topics and achieved 85% or more in their assessment units and their grade point average (i.e. overall mark average) is above 70%. **IF THEN Translation:** If the e-learner achieved 85% or more in two learning topics of a module and his/her grade point average is greater than 70%, then he/she is an advanced e-learner.
7.	*Advanced e-learners* are encouraged to help struggling learners e.g. publish supporting contents, interact with them **IF THEN Translation:** If the e-learner A is struggling in a module and another e-learner B is an advanced e-learner in that module, then e-learner B leads the support-based group and e-learner A joins the support-based group to learn from the advanced e-learner.
8.	Presentation format of a learning content should be suitable for learner's learning style. The system should provide video-supported material for those learners who would like to learn by video-based contents. **IF THEN Translation:** If the e-learner's learning style is video, then show him/her video-based learning processes
9.	Presentation format of a learning content should be suitable for the e-learner's learning style. The system should provide audio-supported material for those learners who would like to learn by audio-based contents. **IF THEN Translation:** If the e-learner's learning style is audio then show him/her audio-based learning processes
10.	Presentation format of a learning content should be suitable for the e-learner's learning style. The system should provide read/write-supported material for those learners who would like to learn by read/write-based contents. **IF THEN Translation:** If the e-learner's learning style is read/write, then show him/her read/write-based learning processes
11.	Presentation format of a learning content should be suitable for the e-learner's learning style. The system should provide Kinesthetic-supported material for those learners who would like to learn by Kinesthetic-based contents. **IF THEN Translation:** If the e-learner's learning style is Kinesthetic, then show him/her Kinesthetic-based learning processes
12.	Bored e-learners want to see interesting and motivating learning processes such as game-enhanced approaches. **IF THEN Translation:** If the e-learner's affect state is bored, then recommend interesting learning approaches such as game-enhanced learning approaches.

13.	Bored e-learners with related background should see learning processes related to their background *. (*) *Background refer to e-learner's knowledge outside the module being taught. For instance, if a learner's background is good in Math then he/she might be taught the "Validation & Verification" topic with more focus on formal verification.* **IF THEN Translation:** If the e-learner's affect state is bored and he/she has related background, then recommend background-oriented learning process
14.	Excited e-learners are eager to learn more so recommend enrichment learning contents. **IF THEN Translation:** If the e-learner's affect state is excited (i.e., positive), then recommend enrichment learning contents.
15.	e-Learners with visual disability should be treated in a way that is suitable for their visual conditions. **IF THEN Translation:** If the e-learner has a visual disability, then recommend alternative learning contents. For instance, contents supported by alternative text-based (ALT).
16.	e-Learners with hearing disability should be treated in a way that is suitable for their hearing conditions. **IF THEN Translation:** If the e-learner has hearing disability, then text-based learning contents. For instance, contents without sound material (e.g. podcasting), video material should be supported by scripts.
17.	An e-learner masters a learning topic when he/she gets 50% or more in the assessment part of that learning topic. **IF THEN Translation:** If the e-learner gets 50% or more in a given learning topic, then he/she mastered that topic.
18.	The e-learner cannot access a learning topic unless he/she fulfils its prerequisites. **IF THEN Translation:** If the e-learner masters a prerequisite for a learning topic, then he/she can access the required learning topic.
19.	e-Learning process should be directed towards the pre-requisite of a learning topic instead of the learning topic itself if the prerequisite is not fulfilled by the e-learner. **IF THEN Translation:** If the e-learner does not master the prerequisite of a given learning topic, then show the content for that prerequisite.
20.	e-Learners with misconception should be exposed to a learning process that resolve the identified misconception. **IF THEN Translation:** If the e-learner has a specific misconception, then provides a learning process that can resolve the specified misconception.
21.	Collaborative-oriented learning approaches should be recommended for learners who are highly engaged with collaborative and social activities (*). For instance, their learning processes involve

	obvious recommendations for peers and collaborative tools that allow more interactions such as commenting on the work of others, tagging, sharing and so on. (*) *Engagement,* as defined in the meta-model specification, refers to the time spent on social tools and interactions with actors. **IF THEN Translation:** If the e-learner is highly engaged with in social interaction (i.e., 30% of the learning process time is spent on social activities), then recommend collaborative learning approaches.
22.	Individual-oriented e-learning approaches should be recommended for e-learners who spend minor time in social tools interacting with peers and instructor (*). (*)Such e-learners will be able to interact with others and use the social tools but those tools (e.g. peers recommendations) are not highlighted to them as per collaborative approaches. **IF THEN Translation:** If the e-learner is not highly engaged with social interaction (i.e., less than 30% of the e-learning process time is spent on social activities), then recommend individual learning approaches.
23.	e-Learners with 30% or more *academic support failure messages* (e.g. 3 out of 7 messages) are recommended to take direct instruction e-learning process i.e. under observation and support. **IF THEN Translation:** If the e-learner has 30% or more failure messages in his/her behavioural model, then recommend direct instruction-based e-learning process.
24.	e-Learners who are skilled in SRL and have their own goals should be offered more flexible environment where they can find the appropriate content. **IF THEN Translation:** If the e-learner has SRL skills and has specific goals, then suggests processes that meet his/her goals(*). (*) goalTitle data property is represented by keyword (i.e., topic title).
25.	e-Learners are grouped in peers based on their commonalities in goals, interests, social interaction or annotations so they become more motivated to interact with each other. **IF THEN Translation:** If e-learner A and e-learner B have common factors (i.e., goals, interests, social interaction or annotations), then group them together.
26.	For those e-learners who preferred situated e-learning approaches (i.e., collaborations with instructor and others learners is an indicator) recommend situated learning approaches **IF THEN Translation:** If the e-leaner is highly interacting with the community (i.e. instructor and other learners), then recommend situated approaches.
27.	For those e-learners who preferred situated learning approaches and their learning style is kinaesthetic, recommend virtual world-oriented learning approaches. **IF THEN Translation:** If the e-leaner prefers situated learning approaches and his/her learning style is kinaesthetic, then recommend virtual world-oriented situated learning approaches.

4.4.1.4 Reflections on Underpinning Modelling Limitations and Challenges

Despite the proposed meta-model expressiveness as a result of adopting OWL-DL and SWRL rules, some limitations exist due to the fact that OWL and SWRL rules have their own limitations stemming from underpinning logics, such as First Order Predicate logic. OWL-DL 2 is a decidable portion of first order predicate logic, with some decidable extensions that goes beyond First Order Logic. First Order Predicate logic is sound and complete but not decidable. For instance, OWL 2 cannot specify non-monotonicity (e.g., "Birds fly, penguin is a bird, but penguin cannot fly.[5]"). This stems from the fact that there is a need for a trade-off between expressiveness and decidability. Such limitations affect the capabilities of the eLMM, and in certain cases had led to different design choices (i.e., using OWL API programmatically instead of SWRL reasoner) in order to realise the desired system behaviour. On the other side, the published e-learning contents/services are usually poorly described. There is a lack of evidence to what extent IEEE LOM and similar standards attributes have been actually used in real systems. For instance, we were not able to find evidences on the use of IEEE LOM attributes (e.g., interaction level) in actual e-learning settings, which makes the process of finding suitable learning resources more challenging.

4.4.2 The e-Learning Process Module

This module describes the utilisation of Business Process in the context of HeLPS. To do so, it describes the process of deriving the e-Learning Business Process Models from the literature, the proposed approach to create a generic business process model from a set of related business processes having the same goals, the generalised e-learning process model and finally the enactment of e-learning business process models in the context of HeLPS.

4.4.2.1 Deriving Business Process Models from e-Learning Literature

Modelling e-learning scenarios is central for the e-learning domain. This has been manifested in the proliferation of the different Educational Modelling Languages (EML) such as Open University Netherland EML, PALO EML and the e-Learning Material Markup Language (LMML). Later on, OU-EML was approved as an IMS Learning Design specifications. Despite IMS LD expressiveness, a considerable number of deficiencies have been reported in the literature (e.g., (Burgos, 2010)). Hence, an alternative approach to identify e-learning processes has been proposed. This approach is informed by the performed literature survey of a wide range of e-learning artefacts as well as the pedagogical and learning models underpinning these artefacts. Going back to pedagogy of learning (Section 2.3), learning processes are classified into the following three main categories: Behavioural, Cognitive/Constructive and Situative as shown in Figure 4.7. Therefore, in this researcher bottom-up approach has been adopted which resulted in the following: (i) modelling nine different e-learning processes, as shown at the bottom of Figure 4.7, based on the identified literature, (ii) developing a generalisation approach to generalise the detailed e-learning processes into one generic e-learning process, (iii) applying the early-developed generalisation approach to the nine detailed e-learning processes, which has led to three generic e-learning processes – named as Upper e-Learning Process (ULP) –, as shown in the middle layer in Figure 4.7 and finally (iv) applying the generalisation approach to the three ULPs, which has led to a generalised e-learning process – named as

[5] http://dior.ics.muni.cz/~makub/owl/#limits

Generalised e-Learning Process (GLP)–, shown at the top of Figure 4.7. These e-learning processes have been driven by pedagogical analysis and informed by the literature review of the current e-learning models. In the next section, these models are discussed and modelled using BPMN business process modelling notation.

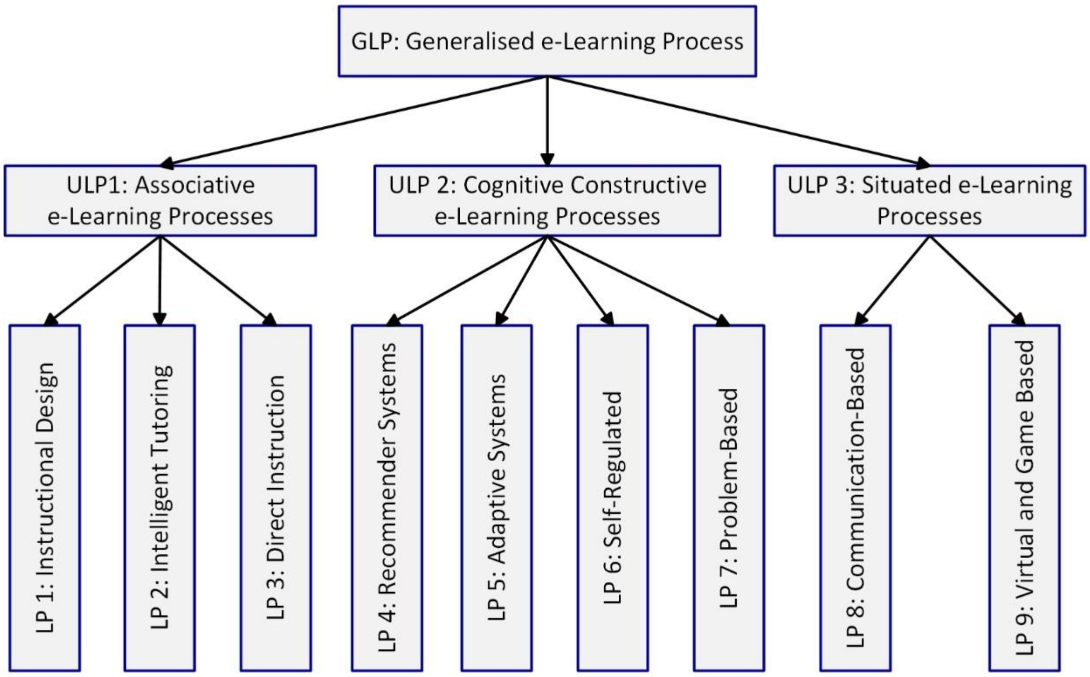


Figure 4.7: Classification of e-Learning Processes

4.4.2.2 Associative or Behavioural e-Learning Processes

The most noticeable examples in this perspective are: (i) instructional-design e-learning process, (ii) intelligent tutoring e-learning process and (iii) direct instruction. Since the modelled processes are self-explanatory through the annotations, only the first process will be described in detail; however, the most significant difference will be mentioned in the description of the rest of the e-learning process models.

4.4.2.2.1 Instructional Design e-Learning Process

Figure 4.8 represents a typical behavioural e-learning process. The process starts with the common login activities; this includes filling in security credentials in a form, and then exploring the learning space which is the space provided by the e-learning system for the e-learner to interact with the system and perform all the tasks to accomplish his/her goals. This is followed by selecting the topic required to study. Then the core learning activities follow where the e-learner chooses the topic, reads the predefined learning objectives and pre-requisites that are predefined by instructor. If the e-learner is happy, then he/she can proceed and participate in learning activities that could be reading a paper, reviewing a written piece of essay or information, etc. During the last step, the learner may find it useful to initiate collaborative activities with her peers (i.e., initiate communication with peers using communication tools such as chat, email, wiki, etc.) or seek help and support (e.g., request help from instructor or contact technician for technical issues). Understanding the e-learning contents/material presented to the e-learner is a manual (or supposed to be performed by the e-learner in his/her own time) activity, and this is why it is followed by an assessment activity which is also specified by the instructor. Then, the e-learner should receive the feedback for his/her answer and end the process if learning objectives are fulfilled otherwise he/she will go back to the e-learning process with remedial contents to accomplish the early-specified learning objectives. Usually, the assessment activity uses simple approaches (e.g., multiple choice questions because it be marked by the system and correct options are provided to the e-learner as feedback). Similarly, the feedback provided is general, in most of the cases, and designed to provide general directions rather than responding to a single learner.

4.4.2.2.2 Intelligent Tutoring e-Learning Process

Intelligent Tutoring Systems (ITS) represents a massive area of research, where thousands of systems evolved in very different ways. Different approaches, mechanisms and types exist in literature (Nye, 2014), and examples on these types are: expectation and misconception tailoring, constraints based modelling and model tracing. Similarly, instruction approaches include a considerable number of different approaches such as separate in class instruction and integrated class instruction. Also, mechanisms used to provide feedback or model misconceptions vary as well. Hence, it is very challenging to model all of these approaches and processes. Since modelling the expectation and misconception based on principal instruction is very common and a key feature for ITSs as shown in recent studies (e.g., (Ma *et al.*, 2014)), intelligent tutoring e-learning process based on misconception modelling is modelled to represent ITS-based e-learning processes. The main added value of ITS e-learning process is its ability to deliver, in an intelligent (i.e., customised) way, a specific e-learning to each e-learner based on his/her behavioural model as well as the mechanism utilised to provide a customised feedback to the e-learners.

Intelligent tutoring e-learning process, as shown in Figure 4.9, is considered as an advanced behavioural e-learning process, because it depends on the stimulus-response analogy. Similar to the Instructional Design-based e-learning process model, ITS e-learning process starts with common login activities. This will be followed by intrinsic activities to be done behind the scene by the ITS itself, such as extracting the e-learner model (e.g., his/her knowledge, learning styles, emotions, etc.), discovering his/her misconceptions, deciding the best teaching approach, and then revealing the e-learning contents/activities to the e-learner. The contents will be presented to the e-learner according to the ITS design principles and approaches, but will be followed by an assessment element to test the e-learner understanding and update his/her model accordingly.

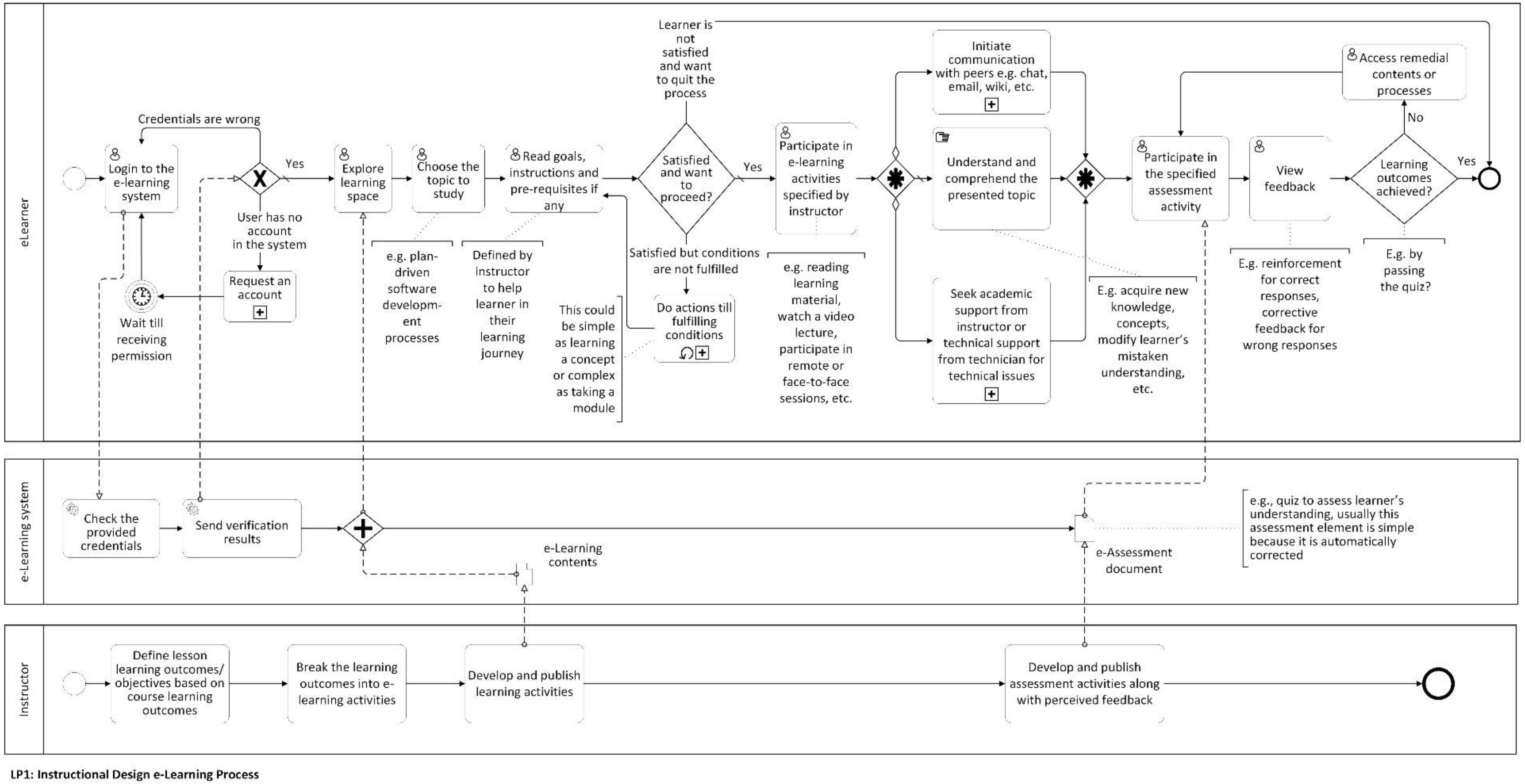


Figure 4.8: Instructional Design-based e-Learning Process Model

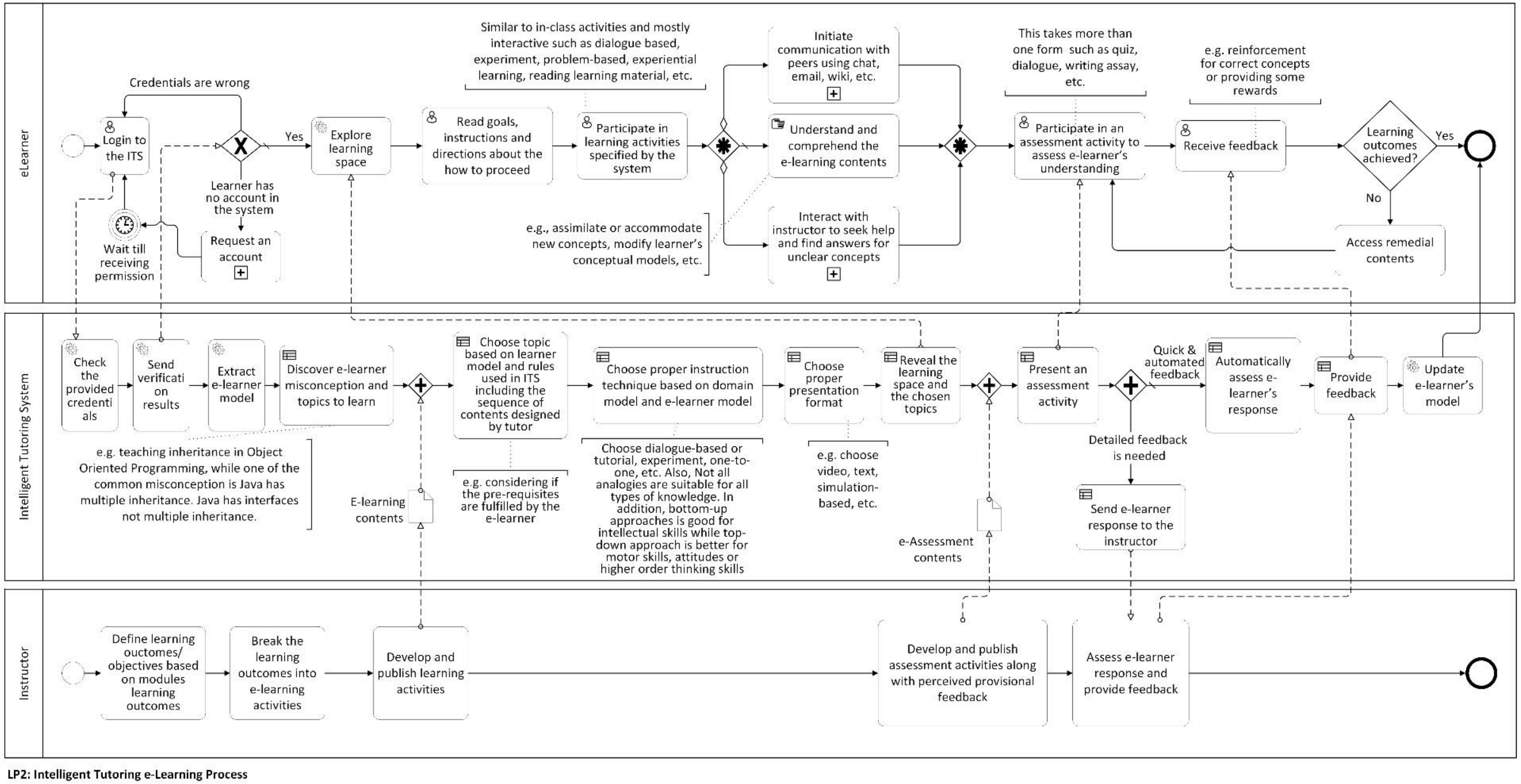


Figure 4.9: Intelligent Tutoring e-Learning Process Model

4.4.2.2.3 *Direct Instruction e-Learning Process*

The direct instruction e-learning process is almost equivalent to other behavioural e-learning process models. However, it provides more emphasis on the practice, and consequently acting upon this practice via feedback. Therefore, the e-learner behaviour is observed by the instructor in order to provide the relevant feedback that is suitable to the e-learner and his/her progress towards the attainment of the learning outcomes/objectives. Observation can take different forms such as observing the e-learner behaviour in an experiment, checking results produced by the e-learner, or reviewing his/her submitted reports. Similarly, feedback takes different forms as well. Feedback represents all post-response information that is provided to the e-learner to inform his/her actual state of learning or performance. It consists of the following two main parts: (i) the evaluative, which is related to the learning outcome and indicates the performance level achieved; for instance, the response is correct or incorrect or the correctness percentage, and (ii) the informational component, which consists of additional information relating to the concept, task, mistakes or how to proceed. Combining the evaluation and information components allows feedback to function as reinforcing, informing, motivating, regulating, etc. (Narciss, 2008). Figure 4.10 depicts the model of the direct instruction e-learning process.

4.4.2.3 *Cognitive Constructive e-Learning Processes*

Hereafter by Cognitive Constructive e-Learning Process we mean that any e-learning process that is classified either as a Cognitive or Constructive learning process. This includes large number of processes from social constructionism to cognitive constructivism. Below are some common examples on these processes:

4.4.2.3.1 *Problem-Based e-Learning Process*

Problem-based e-learning process (PBL) is defined as a learning and teaching method which puts a problem first, and in which further learning is conducted in the context of that problem (York Law school, 2007). PBL is not problem solving, but it ensures that learning happen in the context of problem solving or real-world scenario. The problem-based learning approach, as depicted in the context of e-learning process model in Fgiure 4.11, is composed of the following steps (York Law school, 2007): (i) identify concepts and parts of a problem that needs clarification, (ii) define the problem, (iii) analyse the problem, brainstorm about solutions or causes, (iv) structure solutions or causes, (v) state learning objectives, (vi) self-study to gain further knowledge towards learning objectives and problem solving, and (vii) report lessons learnt and the way of applying the problem-based approach. Different forms of assessment can be applied in the framework of PBL. In ideal cases, assessment is not done on a problem for problem basis, but on the competencies which should be acquired to show mastery in the field.

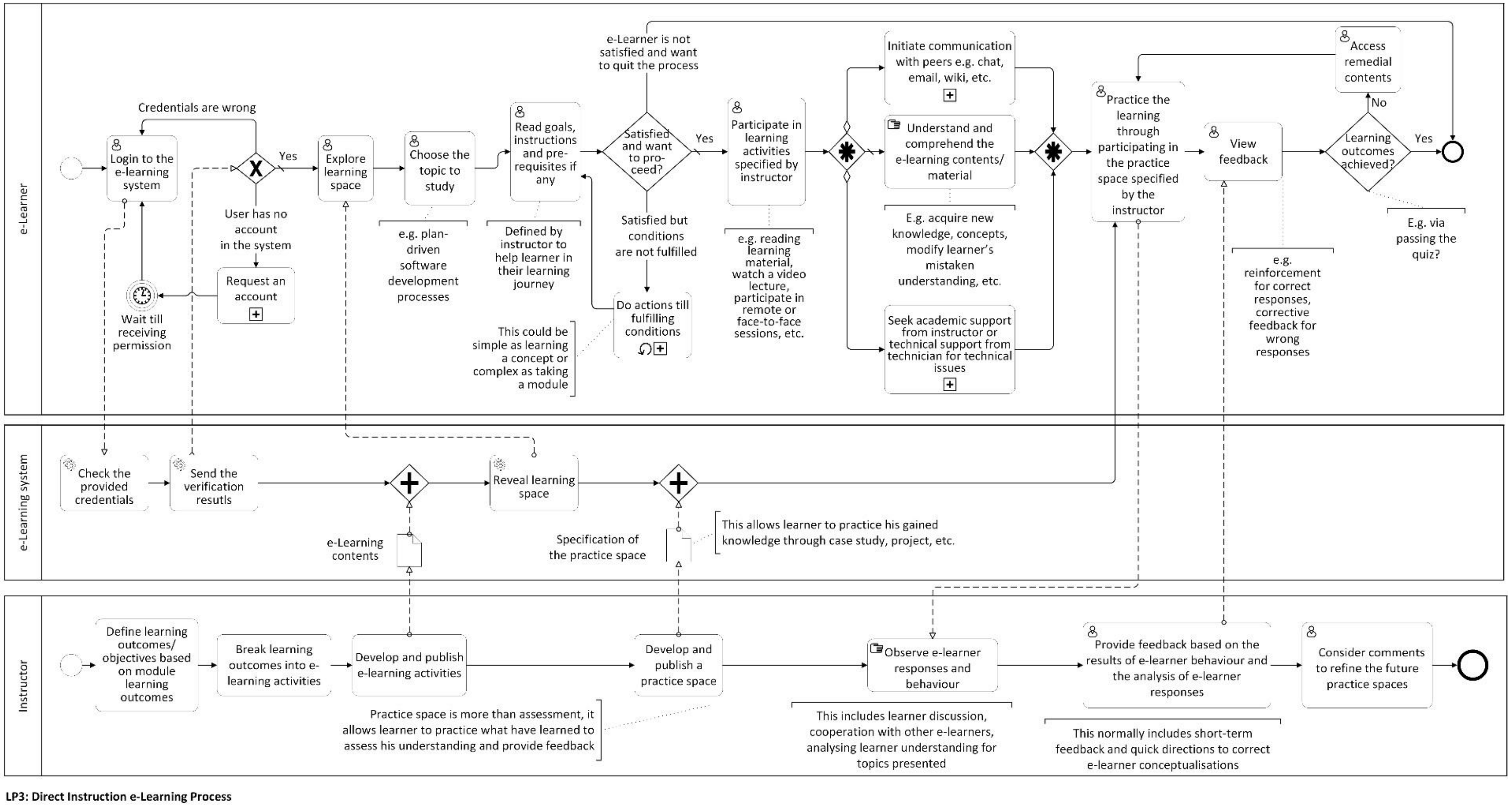


Figure 4.10: Direct Instruction e-Learning Process Model

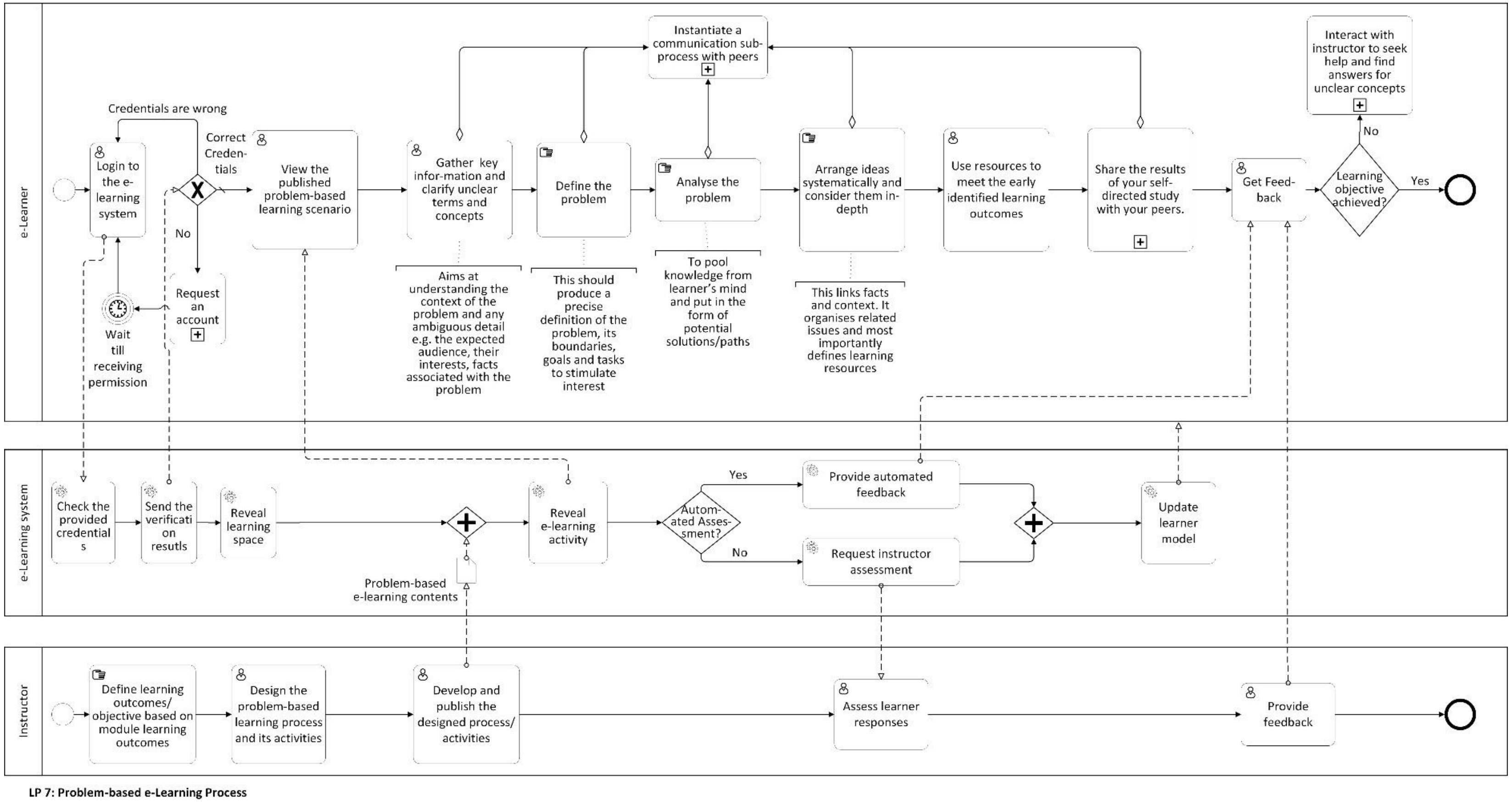


Figure 4.11: Problem-Based e-Learning Process Model

4.4.2.3.2 Self-Regulated e-Learning Process

The self-Regulated Learning (SRL) process takes place when the e-learner takes the initiative, with or without the help of others, to diagnose their learning needs, formulate learning goals, identify resources for learning, select and implement learning strategies and evaluate their learning outcomes (Knowles, 1975). SRL is challenging because it is not easy to be applied by learner due to common difficulties, such as cognitive overloading and disorientation (AlAgha, 2009). Also, it is domain-specific which means it is affected by practitioners, instructor, organisation and other contextual information. In other words, learners can practice different SRL activities (e.g., plan or control their learning) to different extents based on the settings of their learning processes. For instance, learners are allowed to setup their own goals in formal learning, in this case they are called proximal goals, with a greater control from their instructors. Such goals could be related to figuring out what learning strategies work better for them or when to seek help and how. Despite the fact that learning objectives are defined by the instructor, SRL comes into play when learners need to participate in various learning activities. This echoes the fact that SRL can be used in formal learning settings. However, learners will have a greater control over their learning processes in informal learning and consequently can use SRL at a higher level (i.e., self-assessment, self-reflection, learning process goals identification). So, SRL is more structured and well-defined in formal learning settings, while it is more ill-structured in informal learning.

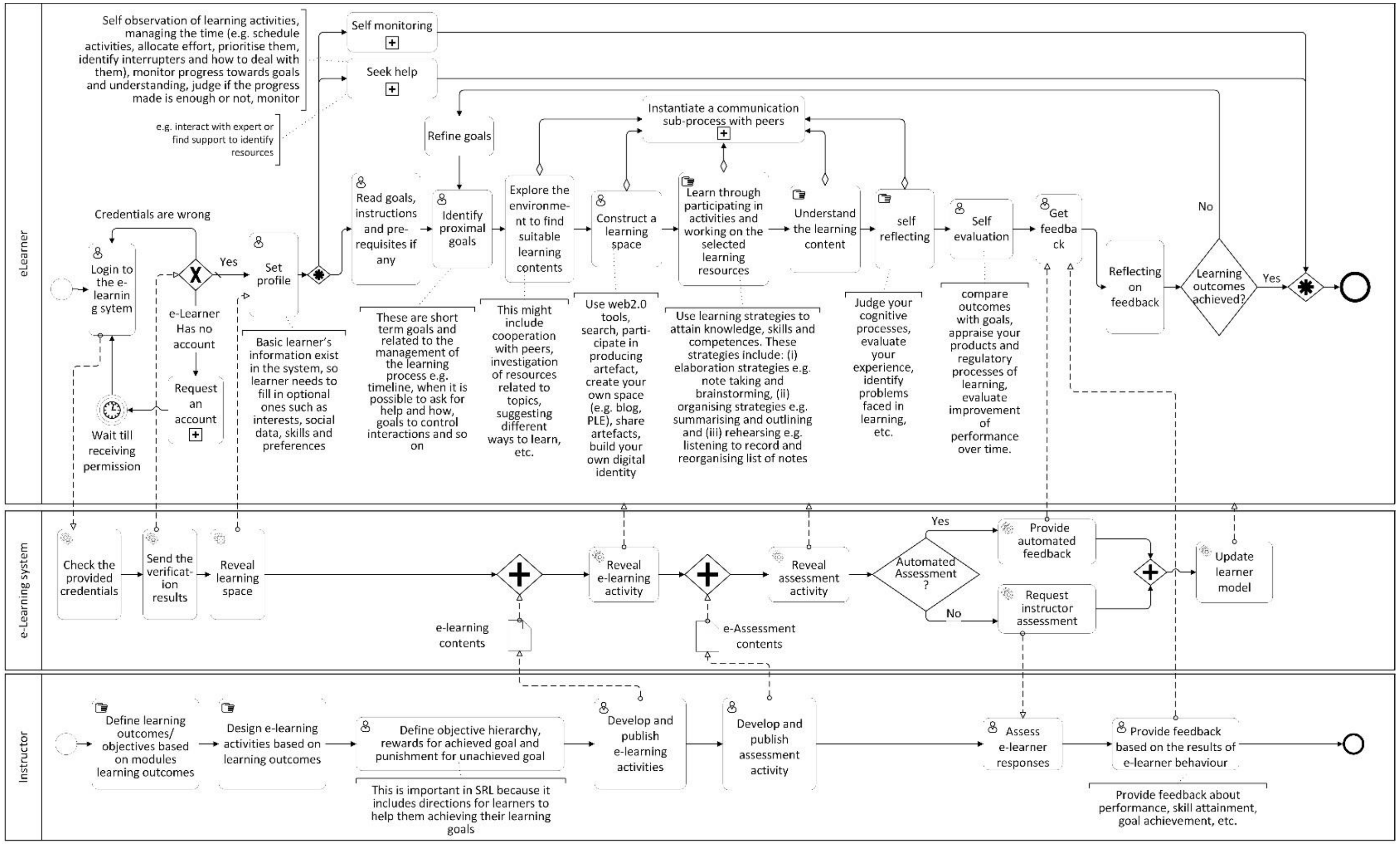
Therefore, it is important to examine SRL in various settings or combined with other e-learning processes. Literature evidence shows that SRL is rarely investigated from collective view and mostly from individual view (Margaryan *et al.*, 2009). Additional challenges appear when it comes to SRL evaluation. Also, comprehensive strategies to evaluate and manage e-learning processes are needed because in SRL e-learners can construct their own learning spaces (some other researchers call them learning environments or personal learning environment), and use their components differently. Examples on this include using blogs and wikis for personal information management purposes (i.e., the simplest level of usage), for social interaction and collaboration (i.e., more complicated level of usage), or for information aggregation and management (i.e., the most complicated level of usage) (Dabbagh and Kitsantas, 2012). Each of the previously-presented cases impacts e-learner experience differently, and therefore different assessment approaches are needed. SRL process model is shown in Figure 4.12, which is a representation of the following set of activities devised from (Nussbaumer, 2013; Kiefel, Govaerts and Palmér, 2012; Gagné *et al.*, 2005):

1- ***Plan*** e-Learner provides input regarding goals, preferences, etc.

Key Activities phase: Profile-setting, goal-setting, time-managing.

2. ***Prepare***: e-Learner finds and selects e-learning resources and creates their own Learning Spaces/Environments.

Key Activities: Explore or find contents, debate with other peers/mates, and construct his/her Learning Space.



LP6: Self-Regulated e-Learning Process

Figure 4.12: Self-Regulated e-Learning Process Model

3. ***Learn***: the e-Learner works on the selected e-learning resources, attains knowledge, skills and competences using learning strategies and techniques.

> ***Key Activities***: 8LEM (exploring, imitating, exercising, receiving, experimenting, creating, debating), cognitive task-strategies (elaboration, organisation, rehearsal), domain-reflecting (assessment and self-assessment), time-managing.

4. ***Reflect***: the e-Learner reflects and reacts on strategies, achievements and usefulness, gets feedback from different sources, does self-evaluation.

> ***Key Activities****: Self-reflecting, self-evaluating, feedback-providing, reflecting on feedback.*
>
> ***Key Activities relevant for all phases****: Self-monitoring and help-seeking.*

4.4.2.3.3 Recommender Systems e-Learning Process

The successful application of Recommender Systems (RecSys) in different domains (e.g., e-commerce and e-tourism) (Lu *et al.*, 2015; Park *et al.*, 2012) increased the potential of applying RecSys in education in order to offer better searching capability for learning resources, which is an essential problem (Manouselis *et al.*, 2013). Recommender systems can mainly help in recommending learning resources or finding peers who share interests, goals and characteristics with the e-learner. Hence, the system first decides its goals (i.e., what to do) and acts upon it. For instance, if the purpose is finding learning peers then check the history of similar e-learners and classify them based on custom-made criteria and make the recommendations. If the purpose is resources recommendations, then this requires further check for both e-learner model and domain model, and at the same time prioritising resources used by peers. In addition, it builds on the e-learner's feedback to enhance future recommendations. The RecSys e-learning process model is depicted in Figure 4.13.

4.4.2.3.4 Adaptive Systems e-Learning Process

In such systems, learning contents, activities and other e-learning services are adapted to each e-learner based on: (i) e-learner characteristics including prior knowledge, learning styles, cognitive abilities, effectiveness and motivation; and (ii) e-learning context (Graf and Kinshuk, 2014). Adaptation techniques differ from one system to another, but they generally extract learner model, check which learning goal, objectives or task need to be accomplished, check domain model to capture the proper content suitable for that learner as well as proper presentation techniques, present contents, and finally update learner model based on feedback. This process is shown in Figure 4.14. This kind of e-learning process is the most advanced e-learning process found in the literature, yet it is usually investigated based on a small number of factors (e.g., learning styles or prior knowledge) and it is not combined with learning theories underpinning different learning approaches.

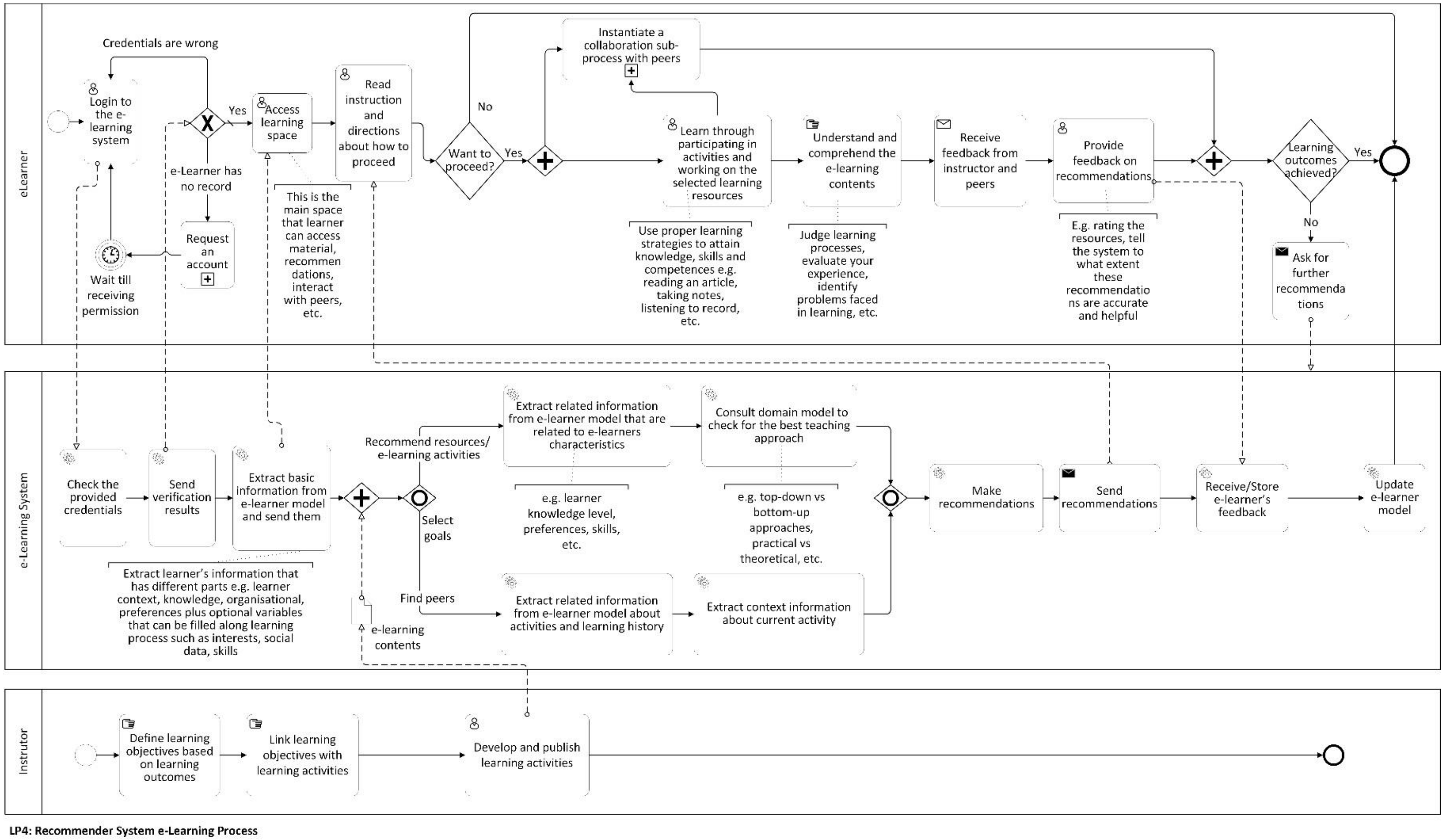


Figure 4.13: Recommender System e-Learning Process Model

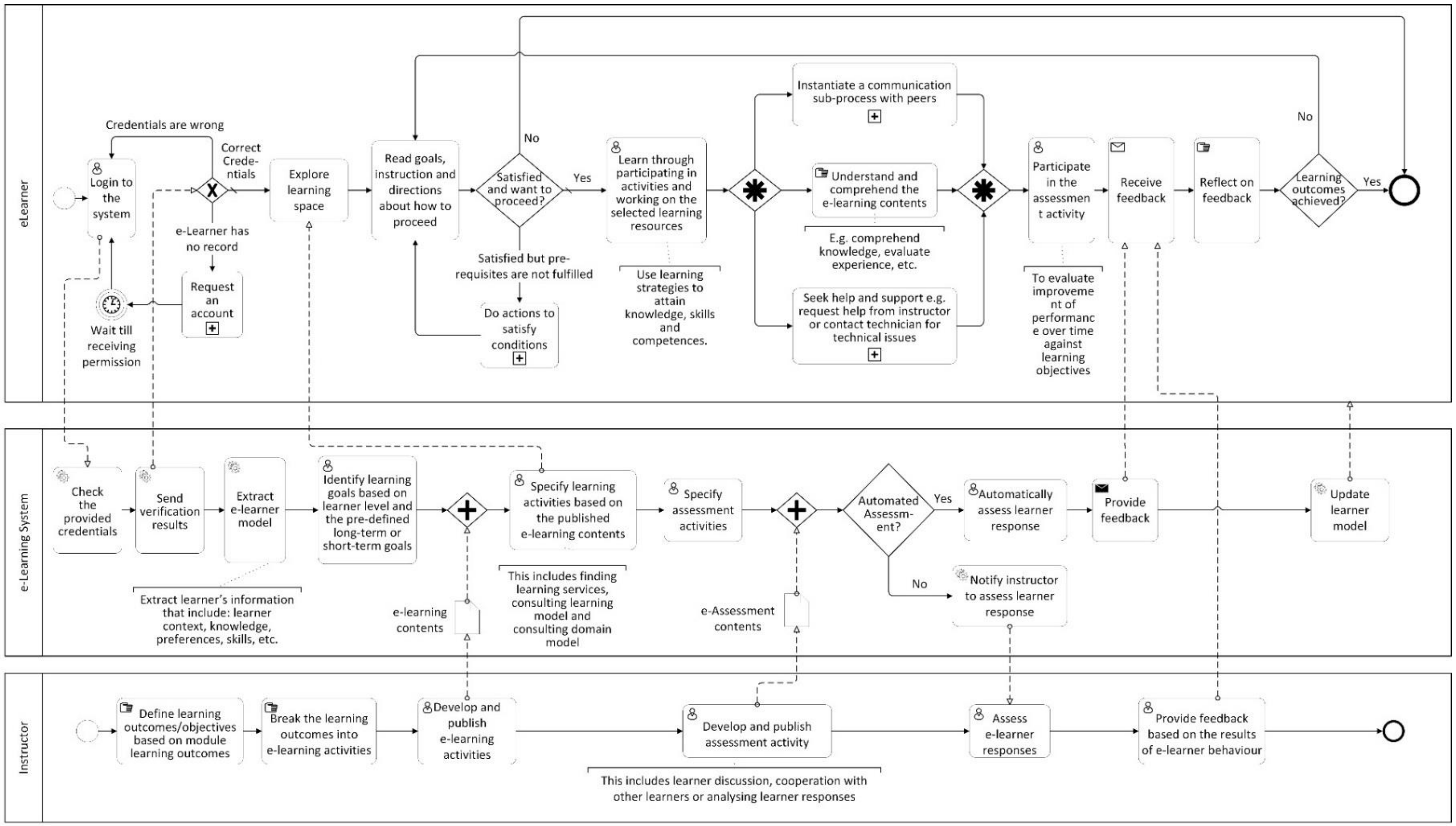


Figure 4.14: Adaptive System e-Learning Process

4.4.2.4 Situated e-Learning Process

Modelling situated e-learning processes is challenging because learning is seen as social participation, which means complicated interrelations between different actors. Although, collaborative approaches exist in social constructionism and constructivism learning theories, but they are not dominating current learning processes as in the situated learning perspective. Connectivism and Community of Practices are two models that embrace the situative perspectives. In such collaborative approaches, the e-learner can take different roles such as: master (i.e., guiding other learners), anchored instructor (i.e., advising learners), apprentice (i.e., imitate other), peer tutee (i.e., explains something he knows to other learners), etc. (Inaba and Mizoguchi, 2004). Since this process is mainly driven by interactions between different roles, the context becomes very crucial for situated learning because it is the main vehicle used in the e-learning process (Dawley and Dede. C., 2014). Two examples on this category of e-learning processes are discussed in this section.

4.4.2.4.1 Virtual-Enhanced e-Learning (VEL)/Game-Enhanced e-Learning (GEL) Process

This process represents the use of Virtual World (or Reality) and Game-Enhanced e-Learning Systems. Such models establish an identity for each e-learner, allow e-learner to explore the whole learning environment (i.e., the e-learning system interface, but the term environment is used here because the e-learner is immersed in the presented interface), plan for his progress, work according to his/her plan, gain some achievements as a result of understanding the concepts or the knowledge presented, and then proceed to next steps. This type of e-learning processes is driven by the visual interaction between actors (e.g., avatars that represent different e-learners), and therefore the way of interaction is taking different form (i.e., event-based interactions instead of textual or conversational form). This kind of interaction is challenging to follow and analyse if we compare it with other kinds of interactions, such as email or chat which can produce good indications with simple analytical tools. Consequently, the gained knowledge and experience become more implicit (e.g., analysing the chat of two e-learners can indicate how learners learn from each other's spelling mistakes, while this is more challenging in VEL processes). Also, an e-learner can spend two hours using a game-based learning approach on how to drive a car without achieving his/her goal, unless well-designed indicators are in place (e.g., the number of hitting other cars or breaking the rules). Such indicators are not easily developed and can be very difficult in the case of teaching critical thinking skills. Figure 4.15 shows a generalised process for the virtual/game-enhanced e-learning process.

4.4.2.4.2 Communication/Participation-based situated e-learning process

The process shown below in Figure 4.16 presents the situated e-learning process that is dominated by e-learner participation and communication with peers and instructors to learn new concepts. It shows how interactions can be done in situated learning environments. In such e-learning processes, the instructor mainly takes a facilitator role. Connectivism learning theory is an active example on this category because it shows the roles of the non-human appliances in e-learning processes. This is useful because Connectivism theory has not been fully tested and is still under investigation. In the next section, a process-based approach is proposed to develop a generalised e-learning process model from the early-identified nine detailed e-learning processes.

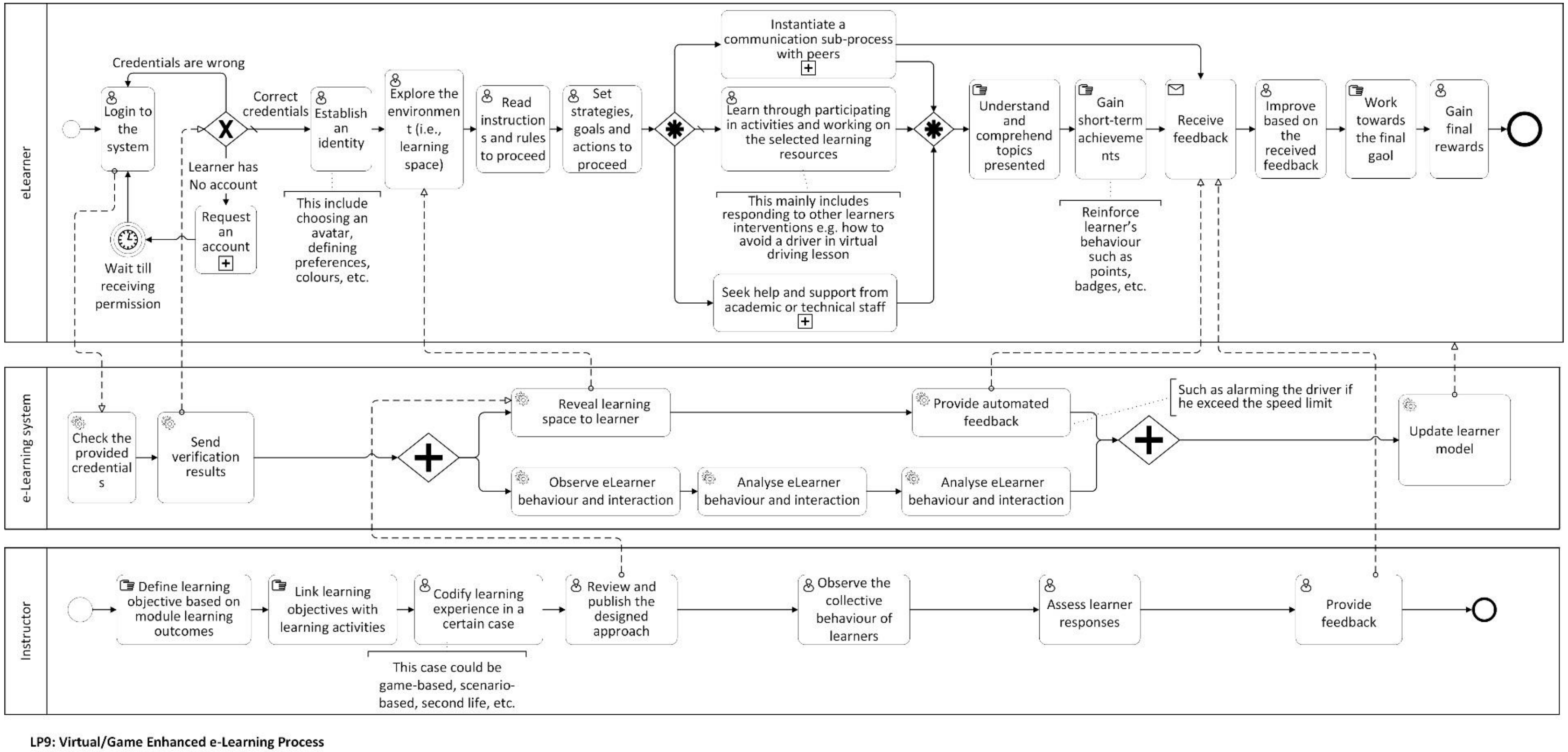


Figure 4.15: VEL/GEL Situated Learning Process

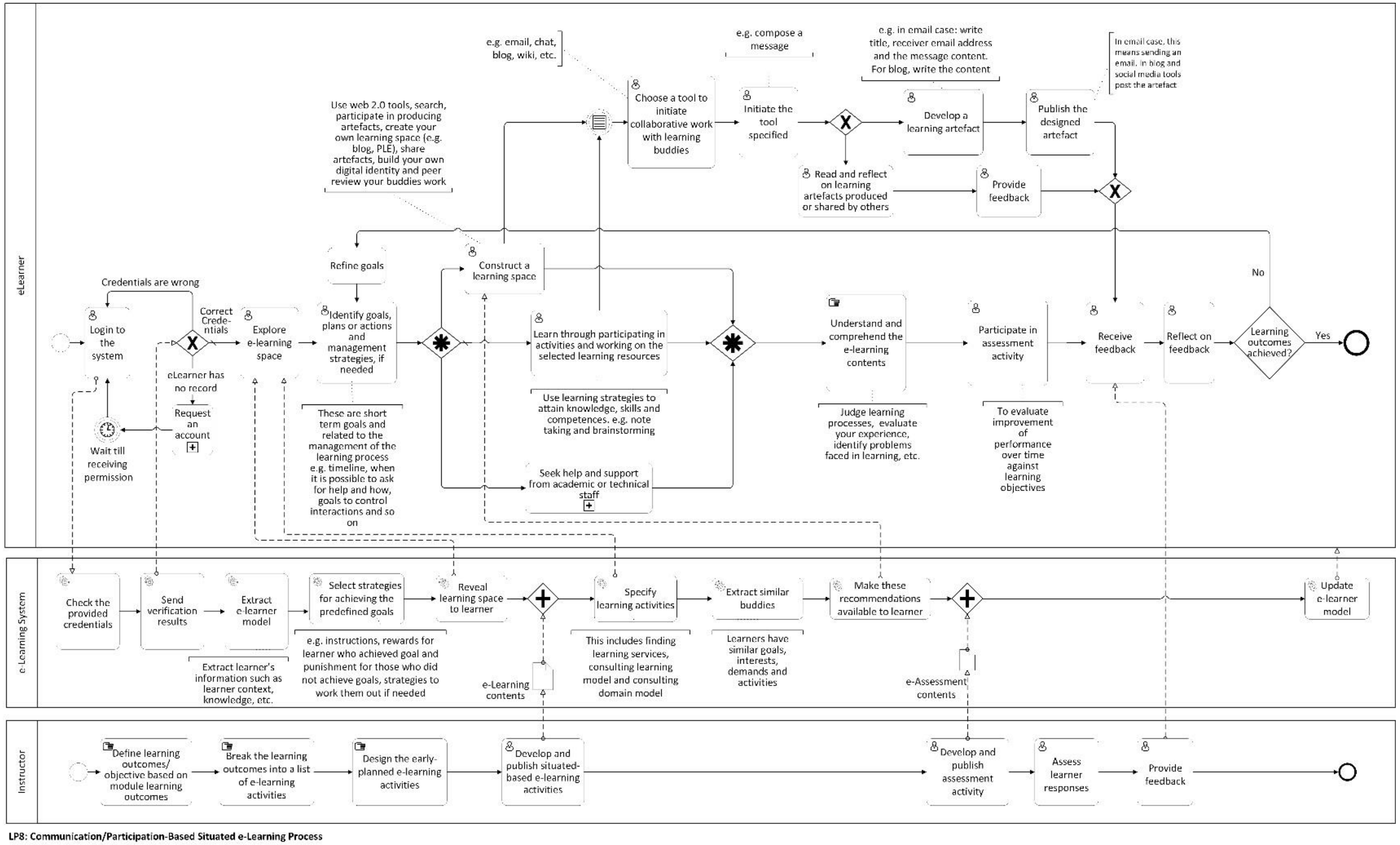


Figure 4.16: Communication/Participation Situated e-Learning Process

4.4.3 The Proposed Approach to Developing a Generalised e-Learning Business Process Model from a Set of Related Business Processes

Process-based systems are composed of business processes, which are collectively aimed at achieving the same business goals and objectives, but they may vary in design of process details (e.g., workflows, interactions, concurrent or sequential flow of activities, means of achieving the same objectives and approaches to attend tasks, etc.). Often domain specific business processes possess common characteristics, which can be generalised to promote reusability, consistency and interoperability amongst different business organisations. For instance, the Direct Instruction e-learning process refers to learning by following instructor-designed learning processes, whilst the Self-Regulated e-learning process refers to e-learner-oriented learning processes which include self-planning, self-monitoring and self-assessment. So, the goal of both processes is the same, but they use different mechanisms to achieve the same goal. This suggests that generalising these processes will provide the commonalities as well as ways to accommodate all other process variations. However, this requires an effective generalisation approach. The following process has been synthesised to derive the generalised e-learning business process model from the e-learning process models introduced in the previous section:

1. Analyse all available business processes, their goals, activities, underpinning pedagogic models/theories and determine the boundary of these processes. This allows getting insights about the different e-learning processes, their scopes and whether they can be formally modelled using BPMN visual notations and the corresponding machine-readable formats (e.g., XMI and XSD). The output of this step is the analysis of the nine e-learning business process models shown in Figure 4.7.
2. If necessary, classify the early-identified business processes based on domain-specific concerns to bring further coherence to the proposed processes/activities (e.g., as depicted in Figure 4.7: e-Learning Process LP1 to LP 9 have been classified into three different categories). This classification can help in capturing the semantics of these e-learning processes, because categorised processes share certain underpinning logic or features.
3. Identify all processes elements which include: (i) flow objects (events, activities and gateways), (ii) data (data objects, inputs, outputs and data stores), (iii) connecting objects (sequence flows, message flows, associations and data associations), (iv) swimlanes (pools and lanes) and (v) artefacts (group and text annotation). Some of these elements (e.g., text annotations) help to capture semantics of specific activities, which can be useful later on for business process enactment and execution in a Service-Oriented Architecture (SOA) environment.
4. Identify the common process elements and the special/unique ones from the early-identified process elements (i.e., the outcome of step 3). For instance, "user login" and "set profile" are common activities, while for example "plan your e-learning" activity is not.
5. Generalise the special/unique process elements (e.g., the following two activities: (i) "study a particular learning lesson" and (ii) "perform the following instructions" can be generalised to the following activity: "participate in the specified learning activity"). Careful considerations for the terms used is needed as they reflect different underpinning learning approaches (e.g., "perform" usually entails participatory learning while "study" does not).

6. Define, from the literature appropriate sources, and specify the rules and the conditions that are essential to customise the generic e-learning process for a certain e-learner (i.e., generate a specialised business process from the generic one). For instance, define the following rule: e-learning process combines Self-Regulated Learning (SRL) elements for those e-learners who have metacognitive skills. Such rules allow selecting the suitable process elements from the generalised business process elements. Specifying this rule requires adopting certain specification/standard that is suitable for this research context.
7. Make the information required to execute the early-specified rules available. For example, to execute the above-mentioned rule, the type of e-learner skills (i.e., metacognitive) should be modelled in the e-learner behavioural model.
8. Identify, if any, potential contradiction between process elements (e.g., SRL e-learning processes contradict with Direct Instruction especially in selecting learning goals). This has essential consequences on the process's roles and their actions.
9. Resolve the discovered contradictions through introducing intermediate process elements, further rules or making assumptions necessary to accurately specify the business process. For instance, to resolve the above-mentioned contradiction between activities in step 8, "Decide Learning Approach" activity has been added to the generic e-learning process model, where this activity is supported by certain rules to check the e-learner's skills and context and decide the best learning approach for this particular e-learner.
10. If the early-identified business processes have been classified, then make one level of generalisation for each category. For instance, in Figure 4.7: LP1, LP2 and LP3 have been generalised and led to Upper-Level eLearning Process (ULP1) and similarly LP4 to LP7 have been generalised and led to ULP2 and so on).
11. Perform another level of generalisation for the outcome of the previous step (i.e., the early-generalised processes) using steps 4 to 10. For instance, ULP1, ULP2 and ULP 3 have been generalised and led to the Generalised e-Learning Business Process appeared at the top of Figure 4.7.

In the next section, the above-proposed approach is applied to the nine e-learning process models to develop a generalised e-learning process model with the objective to achieve the e-learner's requirements in these processes. Appendix IX reveals the log file of the applying the above-proposed generalisation methodological approach on the detailed e-learning processes.

4.4.4 The Generalised e-Learning Processes for the HeLPS Framework

Using the generalisation approach (Section 4.4.3), two levels of e-learning process generalisation have been introduced. One level is composed of the three Upper Level e-Learning Processes and the second level is the final Generalised e-Learning Process.

4.4.4.1 ULP1: The Generalised Behavioural e-Learning Process

The Generalised Behavioural e-Learning Process shown in Figure 4.17 is derived from the previous detailed e-learning processes (i.e., LP1, LP2 and LP3), where the first group of activities refer to common login process. The process includes filling in security credentials in a form, and then selecting the module required to study. Then, choosing the topic and finally participating in an assessment activity. The process allows e-learner to initiate collaborative activities with peer (e.g., chat, email, wiki, etc.) or seek help and support (e.g., request help from instructor or contact technician for technical issues). However, these activities are not the core activities in behavioural e-learning processes as they are in the case of situative-based e-learning processes.

4.4.4.2 ULP2: The Generalised Cognitive Constructive e-Learning Process

Similarly, a generalised cognitive constructive e-learning process has been driven based on the previously-modelled and described four processes (LP4, LP5, LP6 and LP7). Figure 4.18 shows the generalised cognitive constructive process. Detailed investigation of this generalised cognitive constructive-based e-learning process shows that it covers a wide range of e-learning processes that could lean towards certain types of behavioural e-learning process or situated-based e-learning processes. The key deriver in such processes is the participation of the e-learners as they need to interact with the learning environment, and in some cases, they build their own learning environment by constructing what we call Learning Spaces.

4.4.4.3 ULP3: The Generalised Situated e-Learning Process

Figure 4.19 reflects the generalised situated e-learning process which shows the commonalities of the two early-identified situated e-learning processes. The key aspect in such processes is the ability to perform learning in unconventional ways, where e-learners and instructor almost have the same level of publishing contents and creating artefacts. This puts additional effort on the instructor to verify and follow up published contents or to have a more restricted version of these processes, where control is retained in the hand of instructor or his/her representatives.

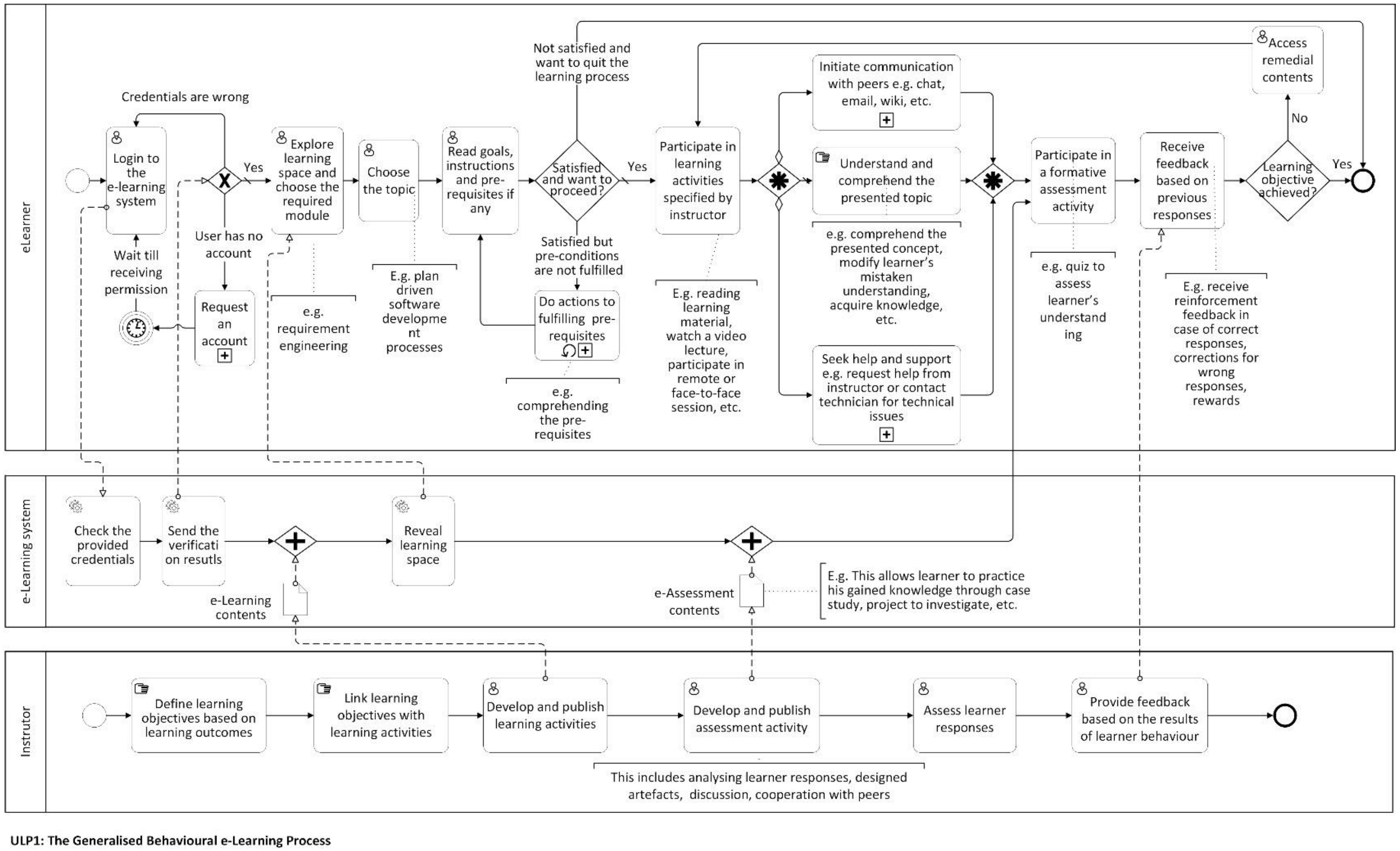


Figure 4.17: ULP1: The Generalised Behavioural e-Learning Process

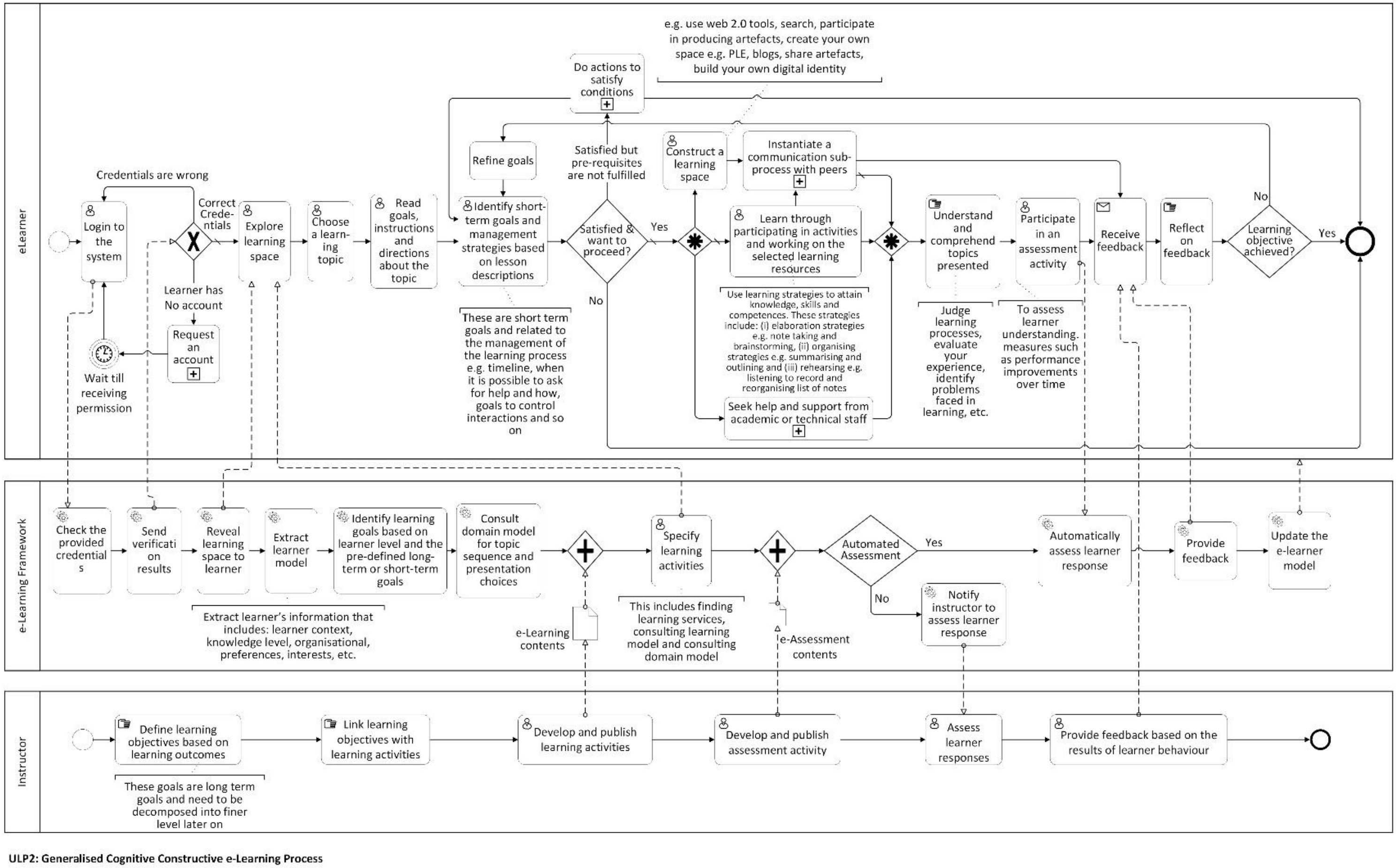


Figure 4.18: ULP2: The Generalised Cognitive Constructive e-Learning Process

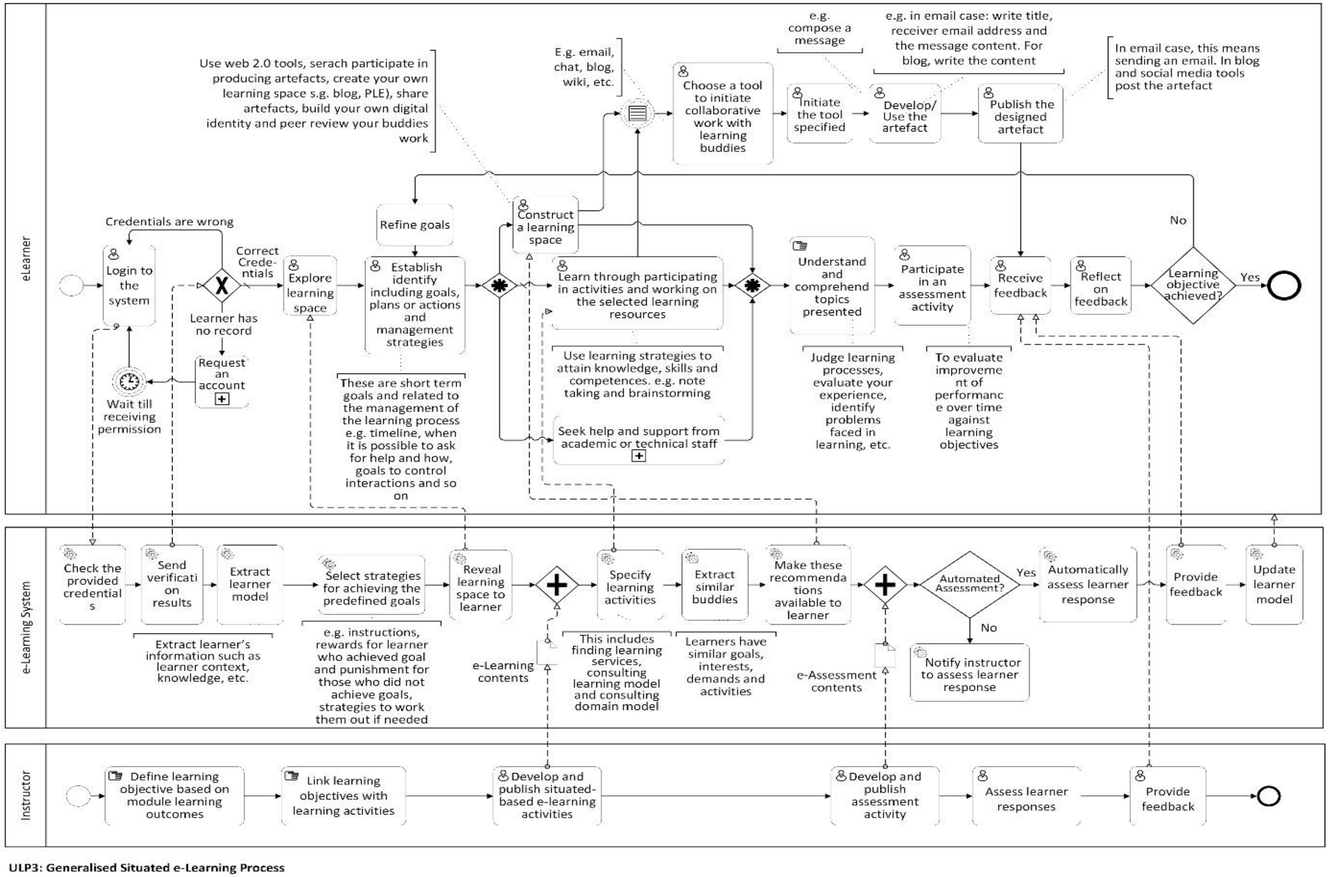


Figure 4.19: ULP3: The Generalised Situated e-Learning Process

4.4.4 GLP: The Generalised e-Learning Process

Figure 4.20 shows the main generalised e-learning process. This can lead to different e-learning processes based on the hybrid inputs (i.e., eLearner Behavioural Model and eLearning Context) to the proposed e-Learning Framework. This generalised e-learning process affirms the analysis and conclusions in Chapter 2, that e-learning can take different forms, depending on the inputs coming from the adopted e-learning environment. Deriving the generalised process is not straightforward as the generalised e-learning process model covers the two extreme learning processes (i.e., learner-centred and instructor-centred). It also covers individually-oriented and socially-oriented e-learning processes. Additionally, the timeframe of various e-learning activities impacts the overall process. Therefore, self-regulation and self-monitoring processes have been broken into different sub-activities (e.g., identifying management strategies and refining goals) to make the process more traceable and achievable. This generalised e-learning process needs to be supported with a source of information about e-learners and their contexts, which is the eLMM in our case. This is clarified in the operationalisation scenario shown in Appendix V. It is also necessary to affirm that the generalised e-learning process model reflects only learning-oriented fine-grained e-learning processes that occur by a certain e-learner to learn a concept or a learning topic. A coarse-grained e-learning processes that can cover programme scale is not covered in this research and will remain for future work. Basically, course-grained e-learning processes can be decomposed into a series of fine-grained e-learning processes.

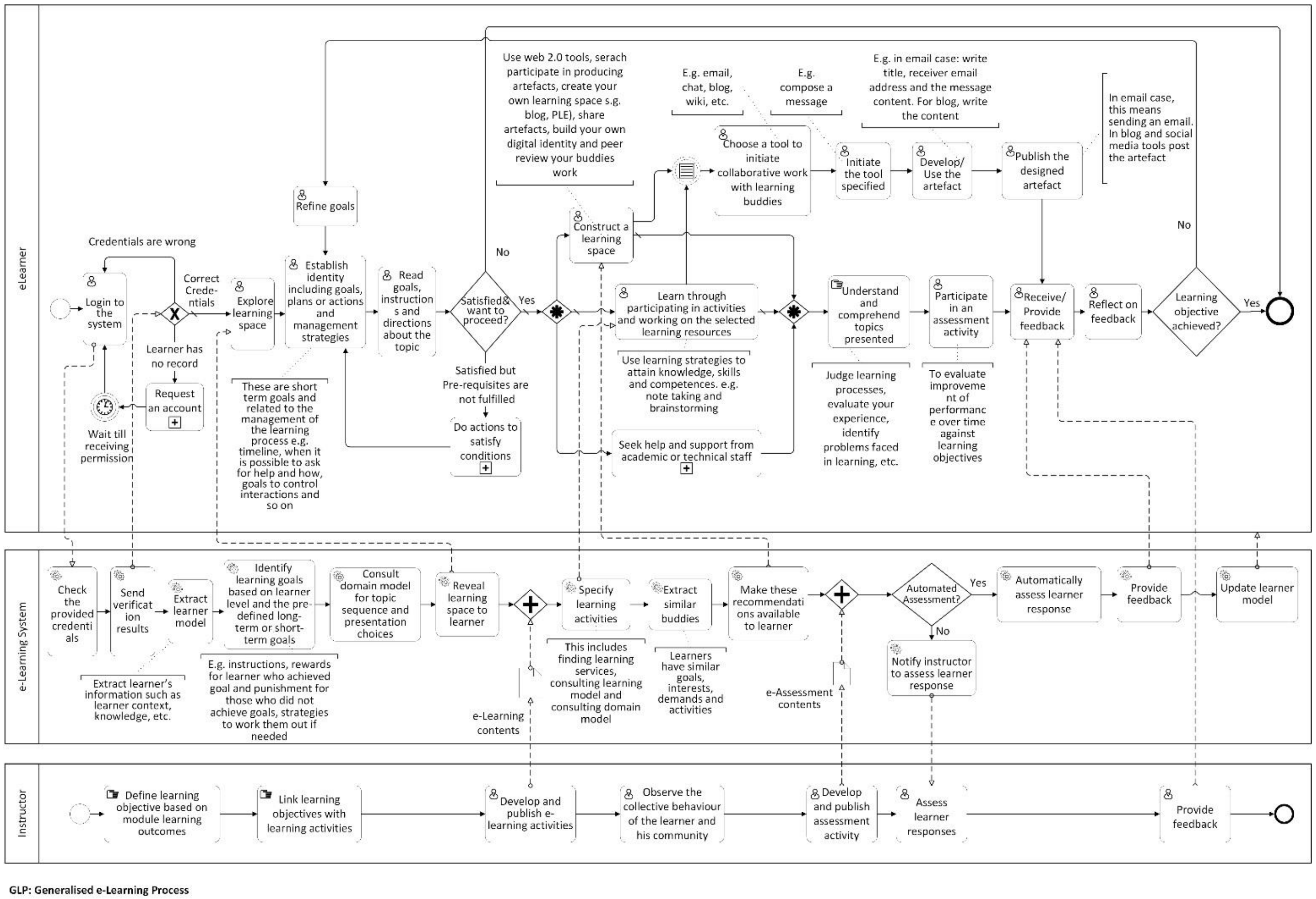


Figure 4.20: GLP: The Generalised e-Learning Process

4.4.5 Business Process Modelling and Execution in the HELPS Framework

The emergence of Business Process in developing and maintaining large enterprise process-based software systems necessitates the need to enact business processes in a computer-based system. A standard approach for this enactment is to start with BPMN models and to translate these models into correspondent executable process definitions (Ouyang *et al.*, 2009). BPMN is a standard for capturing business processes and similarly BPEL is the de-facto standard for implementing business processes (Ouvans *et al.*, 2006). However, translating a BPMN model to a BPEL correspondent is not straightforward. The main reason behind this is that they are based on different formal models since BPMN is a graph-based, while BPEL is a block-structured. This does not abandon BPEL ability to produce graph-oriented constructs, to a limited extent. Also, BPMN supports arbitrary control flow structures where BPEL supports only restricted control flow structures in addition to the 'control link' to connect a collection of activities.

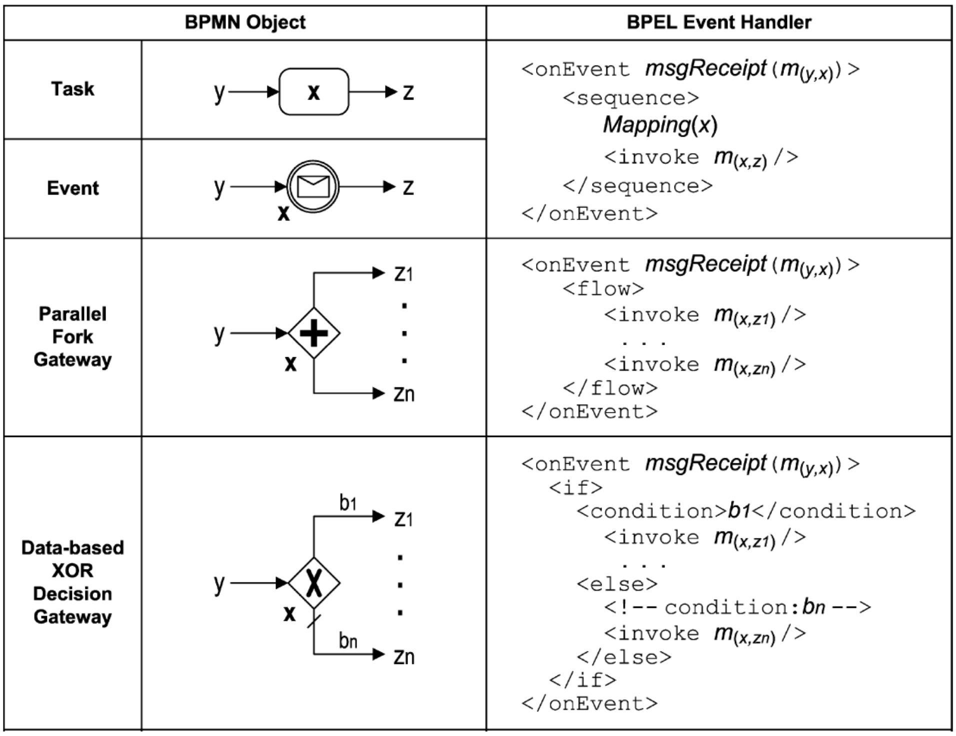


Figure 4.21: Mapping BPMN Objects onto BPEL Event Handlers: Example (Object Management Group, 2011)

Translating a BPMN model to BPEL has been approached by many researchers. Some of the translation approaches are restricted to certain types of BPMN models (e.g., well-structured models), while some other tools need human interventions to produce the correspondent BPEL script. In addition, the readability of the produced BPEL script is investigated as well. Furthermore, OMG specifications for BPMN contains some directions on how to map tasks and events into BPEL as shown in Figure 4.21. All of these factors make BPMN translation to BPEL achievable in different ways. The main mechanism applied in order to map BPMN models to BPEL is to map Business Process Diagram (BPD) component onto suitable BPEL block, and incrementally using this mechanism to translate every BPD into BPEL bock structure. BPMN component can be: (i) well-structured which can be translated easily, (ii) not well-structured but acyclic where control link-based BPEL code work or (iii) neither well-structured nor can be translated by control links where event-actions rules can be the solution in this case (Ouyang *et al.*, 2009).

BPMN2BPEL plugin has been utilised in this research because it does not impose restrictions on the BPMN model. This plugin has been tested in the context of the proposed e-learning framework and proved its ability to translate the identified e-learning process models to their BPEL counterparts.

4.4.6 The Service Orientation Module

In order to derive e-learning web services derived from the HeLPS e-learning processes, Service Identification (SI) and Discovery (SD) algorithms/approaches are essentials (Klose, Knackstedt and Beverungen, 2007). Service Identification is the act of identifying process elements (or candidate services) from business process models, and service discovery is the process when identified HeLPS candidate services mapped to existing e-learning web services (Bennett, 2012). A Candidate service is a term used to distinguish a conceptualised service from an actual implemented service, because candidate service is the set of functions that have been recommended for reuse (Bennett, 2012; Erl, 2008). Figure 4.22 depicts the sequence of SI and SD processes and their outputs for HeLPS. In summary, it reveals how the HeLPS e-Learning Framework starts with a business process model for a particular e-learner, identifies services from that model, discovers the services, and finally orchestrate them.

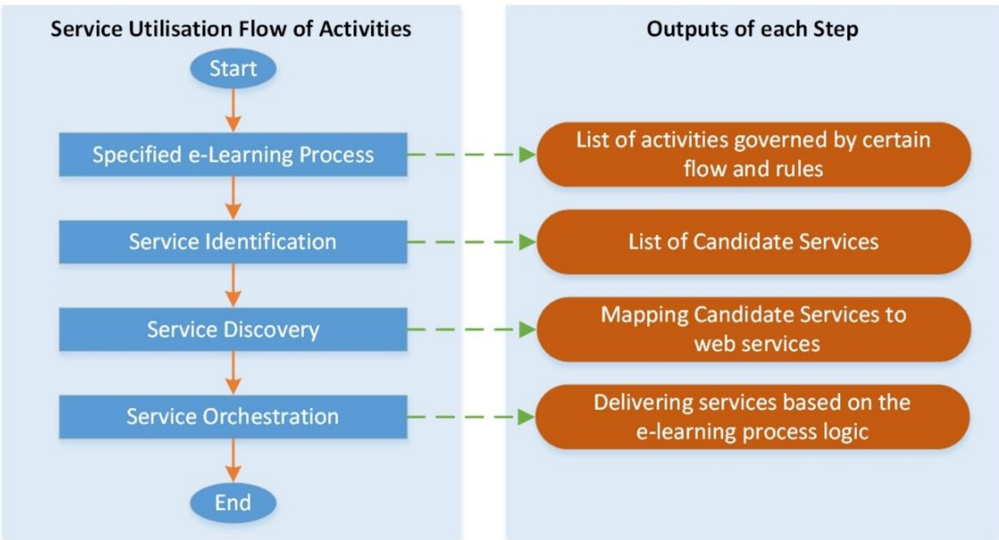


Figure 4.22: Service Utilisation in the context of HeLPS

Various Service Identification approaches ranging from top-down to bottom-up approaches exist in the literature (e.g.,(Jamshidi *et al.*, 2012)), such as: (i) *goal-driven approach,* where enterprise goals are identified and broken into a level that can be automatically realised or supported, (ii) *business process decomposition approach,* where the business process is partitioned into sub-processes or activities that can be handled as services, (iii) *business functions approach,* where the most detailed business functions in the functional decomposition are mapped to services and (iv) *existing supply approach,* where the requirements/functions are given the highest priority (Hubbers, Ligthart and Terlouw, 2007). Examples on identifying services from business process models approaches include: (i) SI approaches such as: ASIM (Automated Service Identification Method) (Jamshidi *et al.*, 2012), (ii) establishing a service model from business model (Jamshidi, Sharifi and Mansour, 2008), (iii) designing and defining SOA solutions (Dunnavant and Johnston, 2014), (iv) identification and analysis of business and software services (Kohlborn *et al.*, 2009), (v) a method for service identification from business process model (Azevedo *et al.*, 2009),

(vi) SOMA: a method for developing SO solutions (Arsanjani *et al.*, 2008). However, Service Orientation has not been widely adopted in the e-learning domain, and therefore needs further investigation. For instance, Dagger (Dagger *et al.*, 2007) introduced the utilisation of Service Orientation in e-learning without explaining how services could be identified or discovered. Similarly, Honghui (Honghui and Xiaojun, 2010) did not discuss technical issues, such as service identification. Other initiatives (i.e., e-Learning Framework (S. Wilson, Blinco and Rehak, 2004)) aimed at providing a flexible infrastructure for e-learning by using Service Orientation but it has not been taken forward.

None of the attempts cited above provide detailed procedures for automatic service identification and discovery in the e-learning domain with acceptable measures that explain whether the educational goals have been achieved or not. For instance, the main aim of the work presented in (Azevedo *et al.*, 2009) is to help the service designer to better design and plan service implementation, and it is not fully automated. Similarly, Jashmidi's work (Jamshidi *et al.*, 2008) is abstract, does not consider various process model elements (i.e., business rules, business requirement, process flows (Azevedo *et al.*, 2009), ignores service discovery issues, and needs considerable customisations to consider the e-learning particularities for service identification and metrics. Additionally, it is not straightforward to define metrics and measurement tools because service identification is a multi-objectives optimisation concern (Jamshidi *et al.*, 2008), objectives could be meeting users' requirements, performance optimisation, quality of service, to mention but a few. Also, these approaches do not consider e-learning particularities in relation to service orientation, which can be summarised as follows. *First*, the dependency between different types of e-learning services (e.g., *learning service* that is designed to teach topic A and *assessment service* that is designed to assess the e-learner's achievements in relation to topic A must be related to each other (e.g., cover the same concepts to the same depth). *Second*, relationships/dependencies between services from different categories of e-learning process, depicted in Figure 4.23, might be complicated because e-learning can be applied differently, and its processes/activities might be interpreted differently by stakeholders. *Third*, different priorities for e-learning services should be given. For instance, the priority of *learning services*, designed to teach certain lessons/topics, should be higher than the priority of supportive services (e.g., chat or communication services) despite the fact that communication services can be more or less important to the e-learning process based on the pedagogical approach underpinning this e-learning process. *Fourth,* the intended learning outcomes of any e-learning process need to be considered in judging the success of SI approaches. Other factors such as performance might be considered, but they are not the only factor to judge the successfulness of SI approach. Additional e-learning particularities in relation to service orientation exist such as the difficulty of representing and consequently identifying the learning concerns (e.g., learning theories) in web services.

4.4.6.1 Service Orientation in the e-Learning Domain

Generally, the e-learning domain includes a wide range of processes/services as shown in Figure 4.23. It includes (i) learning processes, where e-learners practice learning and assessment activities, (ii) management processes, where programmes/courses are planned, managed and evaluated, (iii) design processes, where instructors design their learning objectives, contents, plan for delivery and so on. These three categories are not firmly fixed in the e-learning literature and further categories, such as logistic processes or quality assurance may be found in the literature. Additionally, activities inside different categories of processes are not isolated and may have interdependency. For instance, designing a module affects the types of learning services provided to learners and the possible ways to assess their progress. Since this research aims to enhance the e-learner experience, the e-learning processes will be considered, while the remaining categories and their processes remain for future work.

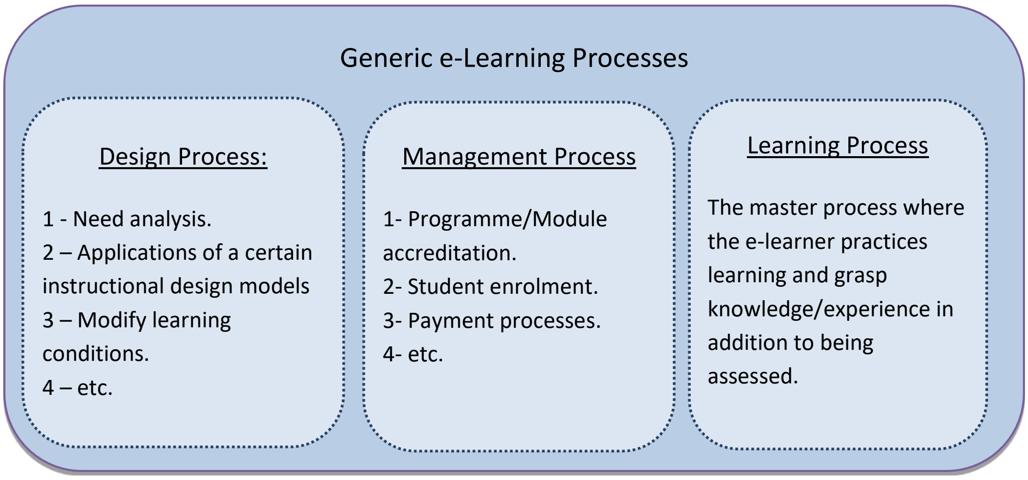


Figure 4.23: Generic Categories of e-Learning Processes

This research, based on its scope (i.e., Section 1.2) and hypothesis and questions (i.e., Section 1.3), aims at deriving (i.e., identifying and discovering) services form learning-oriented e-learning business process models. Therefore, management or design-oriented e-learning processes are not in the scope of this research. Based on the e-learning literature, HeLPS underpinning services have been divided into the following types: (i) *utility services*, which represent common and cross-cutting functionalities that are useful for various service compositions (e.g., login service and update e-learner behavioural model service), (ii) *application/business role services*, which represent application-oriented services (e.g., decide learning approach service) and (iii) *core services*, which represent essential business functions in the e-learning domain (Erl, 2008), (e.g., services that shows e-learning contents). Similarly, the activities of the early-identified e-learning processes are categorised in the same way (i.e., utility, application, and core activities). Table 4.2 shows a selected list of examples of the services underpinning or provided by HeLPS.

Table 4.2: Selected HeLPS Underpinning Web Services

Service ID	Service Title	Service Type	Description	Operations
WS_1^c	WaterfallTextbased	Core	To teach waterfall software process by text	getLearn() getQuestion() getTitle()
WS_2^c	WaterfallVisualbased	Core	To teach waterfall software process by visual contents	
WS_3^c	WaterfallProblembased	Core	To teach waterfall software process by problem-based learning approach	
WS_4^c	AgileTextbased	Core	To teach agile software process by text	
WS_5^c	AgileByDoing	Core	To teach agile software process through learning by doing approach	
WS_6^c	AgileByGame	Core	To teach agile software process through game-based approach	
WS_7^c	VerificationValidationText	Core	To teach validation and verification by text-based approach	

WS_8^c	VerificationValidationByDoing	Core	To teach validation and verification through learning by doing approach	
WS_9^c	VerificationValidationColaborative	Core	To teach validation and verification by collaborative-based approach	
WS_1^u	LoginService	Utility	To perform login action	loginResponse()
WS_2^u	UpdateLearnerModel	Utility	To update the e-learner behavioural model	updateModel()
WS_1^a	CheckStudentGoal	Application	To check the e-learner goal	checkGoal()
WS_2^a	CourseManagementModule	Application	To manage the course contents	courseManagM()
WS_3^a	DecideLearningApproach	Application	To decide learning approach based on a set of constructs from the ontology	decideApproach()
WS_4^a	LearningSearch	Application	To search for learning contents	searchLearning()
WS_5^a	RecommendPeers	Application	To recommend peers	reommendPeers()
WS_6^a	SupportiveContent	Application	To show contents to solve misconceptions	showContents()

4.4.6.2 Criteria for the Service Identification Approach

In this research, a hybrid approach has been utilised to decompose e-learning processes into simple activities. Generally, the purpose is to identify services based on the following criteria: (i) meeting the user requirements (i.e., mainly the e-learner) (McBride, 2007) to enhance his/her experience, (ii) the reusability of these services (Marks and Bell, 2008), (iii) the low coupling and (iv) high cohesion (Klose *et al.*, 2007). More specifically, the mentioned-below concerns have been considered in the developed Service Derivation approach:

1. The first priority of the proposed SI approach is to meet the user requirements because enhancing the e-learner experience is the main objective of this research. So, decomposing an e-learning process into the most detailed capabilities (e.g., extract the e-learner's preference, decide the learning approach, provide learning contents, assess the e-learner behaviour, etc.) is necessary.
2. Service derivation (i.e., identification and discovery) from e-learning processes must be automated.
3. Only learning-oriented processes/activities will be considered, so design or management-oriented e-learning processes/activities are not covered in this research. Consequently, this will lead to a relatively simplified SI/SD approach because the remaining activities (e.g., learn, find e-learning contents, plan for learning, communicate, etc.) belong to the same actor (i.e., e-learner), have a clear time frame, limited contradictions and so on.
4. The proposed SI approach is based on the e-learning Meta-Model (i.e., Ontological model along with SWRL rules), so inputs from the e-learning ontology are used to minimise the ambiguity of the specified e-learning processes and consequently enhance e-learning derived services.
5. Since course grained services depend on the services they use, and the more dependencies a service has, the higher is the susceptibility of failures (Azevedo *et al.*, 2009). So, the decision here is to opt for fine-grained services rather than coarse-grained services to minimise dependency.

6. It is recommended to avoid the complexity in the proposed service identification approach because a complex SI process may lead to wrongly-identified services and hence obstructing the e-learner aims.

4.4.6.3 The Service Derivation Process

This service identification process is composed of two consecutive steps. The first step takes the e-learning process as input and identifies its required activities (i.e., associated with capabilities) as output. The second step takes the output of the previous step and consolidate these activities into a set of candidate services. Consequently, the early-identified candidate services are passed into the HeLPS service discovery algorithm to deliver web services to e-learners. Hence, this section introduces the following two algorithms: (i) the Capability Identification Algorithm and (ii) the Candidate services Consolidation Algorithm.

Step I: Capability Identification Algorithm

Algorithm ID: 4.1

Algorithm Title: Capability Identification Algorithm

Input:

(i) Pi: An instance of a certain e-learning process, which has all the activities governed by a certain flow and rules for a selected e-learner to achieve specific goal(s).
(ii) e-Learning Meta-Model with the HeLPS instantiated e-learning ontology and SWRL rules.

Restrictions:

Out-of-Scope Activities: activities that are not classified as learning-oriented such as design/publish a lesson and assessment unit.

Output:

PiList: a list of capabilities that need to be consolidated as candidate services before passing them into the service discovery algorithm.

Algorithm:

Start
Create PiList;
For each element in Pi do
    Read the activity specified in Pi;
    Label the activity with its lane title; // e.g., read the lesson: eLearner, design lesson: Instructor
    Ignore out-of-scope activities; // e.g., management or design-oriented tasks, develop contents from instructor lane
    Exclude the manual activities; // e.g., read the learning objectives of a certain lesson
    Store the activity in PiList;
End for
Call candidate service consolidation algorithm;
End

Relationship to other algorithms:

This algorithm calls the Candidate Service Consolidation Algorithm;

As mentioned above, the output of this algorithm is the list of capabilities which are passed as output to the second algorithm: candidate services consolidation algorithm as explained below.

Step II: The Candidate Service Consolidation Algorithm

Mapping each single capability from the capability list (i.e., PiList) onto one candidate service leads to incorrect level of granularity (i.e. fine-grained), which negatively impacts the overall performance and the reusability of services. Alternatively, related capabilities will be clustered together based on certain criteria, where each cluster is considered as a candidate service. This clustering can be static (i.e., services are clustered in a static way) or dynamic (i.e., during the runtime). Static clustering of e-learning services has been used in the e-Learning Framework (S. Wilson *et al.*, 2004), since it groups services with similar capabilities in one cluster (e.g., assessment, marking and grading services are in one cluster; similarly chat, email and forum services are grouped together and so on). Applying this static clustering approach leads to the following clusters: (i) *learning services*, (ii) *assessment services*, (iii) *communication services*, (iv) *e-learning process customisation services* to host HeLPS core logic such as decide learning approach and plan for e-learning process, and (v) *utility services* that are common and highly reusable across HeLPS such as authentication and authorisation.

The static clustering approach lacks agility and flexibility. Alternatively, dynamic clustering approaches allow further flexibility and respond to new emerging e-learning services. Therefore, this algorithm utilises the early-developed e-Learning Meta-Model (eLMM) to consolidation candidate services, because the eLMM encapsulates domain-specific knowledge that allows merging related services together in one cluster (i.e. candidate service). For instance, if a particular e-learner uses a self-regulated e-learning process, then activities/services related to this e-learning approach (e.g., set your own learning goal, prioritise the early-identified goal, and reflect on your achievements in relation to the early-identified goals) will be grouped together in one candidate service. Utilising a semantically-enriched service identification approach enhances the engineering of SOA-enabled artefacts because it depends on domain-specific logic encoded in the early-developed e-Learning Meta-Model. This approach will also allow HeLPS to accommodate additional e-learning services from different perspectives (e.g., management, quality assurance and financial), or new emerging services such as social learning-based services (e.g., annotate, rate, share and like activities/contents). In summary, this research adopts semantically-enriched clustering technique to: (i) abstract the detailed business functions in candidate services, (ii) avoid the incorrect level (i.e., very fine-grained) of granularity and (iii) maximise the level of service reusability.

Candidate Service Consolidation Algorithm

Algorithm ID: 4.2

Algorithm Title: Candidate services Consolidation Algorithm

Input:
(i) PiList: A list of capabilities or potential candidate services passed from Algorithm 4.1 based on the enactment of the Pi e-learning process.
(ii) e-Learning Meta-Model with the HeLPS instantiated e-learning ontology and SWRL rules.

Output*:* SCList which is a consolidated list of clusters (i.e. candidate services and their members) that need to be mapped to web services in a subsequent service discovery algorithm.

Relationship to other algorithms:

This algorithm is called by Capability Identification Algorithm to merge abstract capabilities in one candidate service

```
Start
For each element in PiList
  Read the PiList element;
  if PiList.element is utility activity then
       Create a Cluster;                          // add a new member in the SCList
```

```
        Add the current PiList.element to the current SCList cluster;
    end if
    if PiList.element is application activity then
        Check the eLMM (i.e., ontology) if the PiList.element and      // e.g., SRL activities such as set a goal
        the PiList(-1).element belong to the same e-learning           and prioritise a goal will be classified in
        approach then                                                  one cluster.
        Add the current PiList.element to the current SCList cluster;
    else
        if PiList.element and the PiList(-1).element do not belong to
         the same e-learning approach then
            Create a Cluster;                                           // add a new member in the SCList
            Add the current PiList.element to the current SCList cluster;
          end if
    else
    if PiList.element is core activity then
        Check the eLMM (i.e., ontology) if the PiList.element and      // such as having the following two
        the PiList(-1).element target the same learning topic then     activities: "reveal the e-learning content
                                                                       for agile process" and "assess the e-
                                                                       learner's understanding for agile process"
        Add the current PiList.element to the current SCList cluster;
        else
        if PiList.element and the PiList(-1).element do not belong to the same e-learning approach then
            Create a Cluster;
            Add the current PiList.element to the current SCList cluster;
        end if
      end if
     end if
   end for
 End
```

Discussion on the Proposed Service Identification Algorithms

The previously-proposed SI algorithms satisfy the simplicity criteria because the variety of services suitable for this research are limited, they could be utility services, application/business rules or core services. Nonetheless, the role of the e-Learning Meta-Model (i.e., ontology) is essential in this step to: (i) capture the semantic of the e-learning process and its activities, (ii) cluster similar activities (e.g., communication-oriented services such as discussion and wikis can be allocated in one cluster, SRL-oriented activities such as setting a goal and finding resources in another cluster), (iii) incorporate SWRL rules which encapsulate a considerable amount of HeLPS logic, and (iv) assist in solving semantic heterogeneity, where two different terms are used interchangeably such as discuss with peer and discuss with your colleagues.

In addition, from the e-learning literature, certain domain-related assumptions are derived. For instance, learning and assessment are considered as two different activities in the modelled e-learning processes, but it is recommended to have them in the same candidate service, because e-learners need to be assessed against learning objectives addressed in the learning unit. It is very challenging to find an assessment unit that matches exactly a certain learning unit in terms of addressing the same learning objectives in the same depth because such detailed descriptive information cannot be found in most published e-learning services. So, choosing learning and assessment activities from two different sources will lead to inaccurate assessment. In addition, certain good practices have been used in the proposed SI approach, for instance to start with top-down approach, then goal-service and finally bottom-up analysis of the currently existed learning assets (Arsanjani, 2004). Finally, the SI approach should be assessed/evaluated against its main goal, which is enhancing the e-learner experience through meeting recommending e-learning process that meets his/her requirements. Other concerns/criteria (e.g., reusability) have been considered as well. For instance, utility services are frequently used in the HeLPS e-Learning Framework and therefore, they have been separated from other services (i.e., application and core services). Also, application services have been clustered together to save the coherence or cohesiveness of the e-learning process. As explained earlier, HeLPS aims to provide the best experience for e-learners by selecting the appropriate services amongst various alternatives. This decision is supported by multiple criteria such as learning topic requested, learning style, disability, etc. in the next paragraph, this multiple-criteria decision-making approach is explained according to its priorities.

Multiple Criteria Decision Making (MCDM)

Discovering web services amongst available web services occur according to the following priorities:

Priority #1: discover the web service based on the e-learner recommended learning topic:

```
For all services available in the registery do
        discover web services where service learning topic = learningprocessTopic;
        return services;
End for
```

Priority #2: discover the web service based on the e-learner learning style:

```
For all services discovered in the previous step (i.e., #1) do
        discover services where web service learning style = learningContentStyle;
        return services;
End for
```

Priority #3: discover the web service based on the e-learner disability status:

```
For all services identified in the previous steps do
        If disability = visual Then
                discover services where assistive technologies (e.g., ALT or podcast is utilised);
        End if
        If disbaility = hearing Then
                discover services where assistive technologies (e.g., scripts for video contents is utilised);
        End if
        Return services;
End for
```

Priority #4: act upon the recommended process element (based on SWRL rule deduced value):

```
Switch (recommended Process Element){
  Case1: Problem-Based Learning:
          discover services where learning approach = problem-based learning;
          return services;
          break;
  Case 2: Self-Regulated Learning:
          allow the e-learner to set and manage his/her goals;
          discover services based on the goals selected earlier;
          allow the learner to regulate his/her learning procsses;
          return services;
```

break;
Case 3: Instructional Design:
discover services where Instructional Design-based approach is utilised;
return services;
break;
Case 4: Intelligent Tutoring:
discover services where learner misconceptions are handled;
return services;
break;

Case 5: Direct Instruction:
discover services where more instructor support is proiveded (e.g., contents are instructor-led, services for instructor notification about e-learner progress, etc.
return services
break;
Case 6: Recemmendor System:
discover services where more instructor support is proiveded (e.g., scripts written for the video contents is utilised
return services
break;
Case 7: Hearing Communication-based:
discover services where assistive technologies e.g. scripts written for the video contents is utilised
return services
break;
Case 8: Hearing Game-based or Virtual-based:
discover services where Game/virtual-based e-learning approaches are utilised;
return services
break;
Case 9: Adaptive based processes:
discover services where contents, learner peers, emotional, formative assessment elements are utilised;
return services
break;
}// End Case

Priority #4: provide assessment element to assess learner understanding:

reveal the associated assessment element to the learner;
capture his/her behviour during the assessment process;
act upon learner behaviour by showing the proper feedback or providing guidelines if needed;

Priority #5: update learner model:

commit changes to the e-learner model;
end the learning process;

After identifying the services from e-learning business process models and explaining the priorities of decisions to be taken by the framework, the next step is to discover the web services from available service registry using keyword matching approach. This is presented through the Service Discovery Algorithm.

Service Discovery Algorithm

This algorithm discovers the web services from the services published in a service directory as explained below.

Algorithm ID: 4.3
Algorithm Title: Service Discovery
Input: (i) Li: an instance of e-learner

(ii) eLMM: e-Learning Meta-Model and SWRL rules.
(iii) SCList: a list of the final and consolidated candidate services produced by algorithm 4.2.
(iv) Web Services published in service registry.

Output: WSDL files for the discovered web services.

Start

```
1: For all elements in SCList do
2:          If SCList.element is utility or application candidate service then
3:                   Match SCList.element with services in the service registery using keyword-based approach
4:          Else // core services
5:                   discover services where eLMM.learningprocessTopic = learning service topic;
6: End for
7: For all services discovered in line 5 do
8:          discover services where eLMM.learningContentStyle= learning service learning style
9: End for
10: Switch(eLMM.recommendedProcessElement) {//"recommendedProcessElement" refers to the decided learning approach
11:    Case 'InstructionalDesign':
12:    From services discovered in line 5, discover services where behavioural/text based content is presented;
13:    break;
14:
15:    Case 'SRL':
16:    From services discovered in line 5, discover services where SRL is endorsed;
17:    discover utility services that allow planning for learning e.g. define a goal;
20:    break;
21:
22:    Case 'DirectInstruction':
23:    From services discovered in line 5, dicover services where simplified content is presented;
24:    discover utility services that initiate dialogue with instructor;
25:    break;
26:
27:    Case 'SituatedBased':
28:    From services discovered in line 5, discover services where situated e-learning process is presented;
29:    discover utility services that initiate dialogue with peers and instructor;
30:    break;
31:
32:    Case 'ProblemBased':
33:    From services discovered in line 5, discover services where problem-based approach is utilised;
34:    break;
35:
36:    Case 'VirtualWorld':
37:    From services discovered in line 5, discover services where virtual-based content is presented;
38:    break;
39:
40:    Case 'GameBased':
41:    From services discovered in line 5, discover services where Game-based approach is endorsed;
42:    break;
43:
44:    Default: eLMM.learningprocessTopic = learning service topic; break;
45: }
46:
47:  Switch (recommendedAssistiveElement){
48:     Case 'Visual':
49:     From services discovered in line 5, discover services designed for visually impaired audience;
50:     break;
51:
52:     Case 'Hearing':
```

```
    From services discovered in line 5, discover services designed for deaf audience;
    break;
}

Switch (eLMM.recommendedProcessContent){
    Case 'Enrichment':
    discover services that has similar learning contents to enrich learner's learning process;
    break;

    Case 'MisconceptionResContent':
    discover services designed to resolve the assigned misconception;
    break;
}

if eLMM.recommendedProcessBackground is not Null
     From services discovered in line 5, discover services designed based on background value;

if eLMM.learningTendency is Collaborative  then
     discover "recommend peers" utility service to establish communication with peers;
else
 learningTendency = Individual
End
```

In this section, the above-mentioned approach to derive (i.e., identify and discover) services from e-learning business process model has been introduced. This approach works well the following two essential artefacts: the eLearning Meta-Model and the Generalised e-Learning Business Process Model. The generalised e-learning process explains the generalised behaviour of the HeLPS e-Learning Framework, while the eLearning Meta-Model (i.e., Ontology) encodes a significant amount of knowledge about the e-learner behaviour, history, context, and processes which will be used to transform the generic process to a specialised one. Full example-based scenario on the interaction between these artefacts is explained in Appendix V.

4.5 The e-Learner Experience Model

4.5.1 Background

The intrinsic aim of adopting e-learning technologies is enhancing the learning process and increasing its efficiency, effectiveness and flexibility (Hammad *et al.*, 2013). The frequent use of technology-enhanced learning (TEL) term, which is another term used to describe e-learning, reflects the strong link between e-learning and the notion of enhancement in the e-learner's experience. However, literature evidence shows that it is not clear what is meant by enhancement as well as the components targeted by this enhancement (Kirkwood and Price, 2014). Furthermore, it is not obvious how to measure the proposed enhancement in TEL. Is it related to technology, institutional, processes, stakeholder (i.e., e-learner and instructor) or content aspects?). Though the e-learner experience has been researched in a number of studies (e.g., (Sudhakar, Tyler and Wakefield, 2015)), it has been restricted to certain aspects such as student perceptions or usability. More comprehensive evaluation approaches have been proposed such as (Hammad, Odeh and Khan, 2015) but they lack the precise definition of what constitute an e-learner experience model. In this regard, this part of the research is an attempt to clarify and present e-learner experience model that can be used to assess the effectiveness of a particular e-learning approach. **First**, it discusses the concepts of the e-learner experience model along with its roots; **second** it describes the constructs of the proposed e-learner experience model; **third**, it elaborates further on two main aspects of the model to suggest weights to different model constructs; **fourth**, it proposes a scale for those constructs to measure the overall effectiveness of the model; **fifth**, it reflects on some modelling issues and finally summaries the section.

4.5.2 The e-Learner Experience Model

Investigating the e-learner experience has its roots in two different research domains: (i) e-learning and (ii) user experience or usability. From the e-learning perspective, different researchers pay attention to the added value of e-learning. In most cases, researchers use the results of assessment elements (e.g., exams) and other tools (e.g., self-completion surveys) to measure the enhancements brought by a technology to the learning domain. Moreover, they combine different e-learning aspects such as the quality of learning (Conole, 2013), currency of e-learning contents (Gilbert, Morton and Rowley, 2007), supporting students and student perceptions, which impacts the respective evaluation efficiency. In contrast, from user experience or usability perspective, researchers commonly ignore the particularities of e-learning research and focus on user experience, and hence the objectives of e-learning are often not considered. In addition, user experience research focus moved towards leisure; and, therefore, factors such as context of use and anticipated use are rarely investigated (Bargas-Avila and Hornbæk, 2011), pp.2689.

The previous introduction shows that user experience and usability have been researched for a long time. However, these aspects have not been investigated as holistic approach in e-learning domain. Usability, as defined in ISO 9241, refers to "the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments" (International Standard Organisation, 2015). While user experience (UX), as defined in ISO 9241-210, refers to "a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service" (International Standard Organisation, 2010). Two schools of thought exist in the literature regarding the relationship between usability and UX. The first school considers the user experience as an elaborated form of one of the usability metrics which is the user satisfaction, while the second school of thought, adopted in this research, affirmed that usability is subsumed by user experience. Nonetheless, user experience includes usability, cognitive, socio-cognitive and affective aspects of users' experience such as users' enjoyment, desire to repeat the system use, and enhanced mental models (Law and van Schaik, 2010). This suggests that there is a need of e-learner experience model (eLEM) that is based on combination of UX and e-learning. This model should define what constitutes the e-learner experience and how it can be evaluated or measured. For instance, building on the metrics defined to assess e-learner's behaviour and attitude. Such e-learner experience model will be useful for assessing to what extent a given e-learner has benefited from certain e-learning settings.

The difference between applying UX research in e-learning and other domains is obvious. For instance, applying UX in e-commerce aims to increase product efficiency and support the user in his actions (e.g. purchasing a DVD). But, in e-learning the e-learner is expected to spend time to learn, communicate and share experiences and values with others, face challenges and may struggle to achieve her/his final learning goals. Hence, it is quite challenging to measure e-learner achievements, especially if we consider the different possibilities/paths (i.e., learning process) e-learner can take during her/his learning journey (Scanlon, McAndrew and O'Shea, 2015). The e-Learning research is best described as a complex system, which includes communities, technologies and practices that are informed by pedagogy (i.e. theory and practice of teaching, learning and assessment). This is a combination of technology and pedagogy that allows experimentation to generate further insights and willingness to engage different learning communities in a set of e-learning practices (Scanlon *et al.*, 2013).

In light of the previous discussion and for the purpose of this research, the e-learner experience is defined as a special type of user experience where the cognitive aspects such as knowledge and values acquired; socio-cognitive aspects such as relationship with the community; and the mechanism of learning (i.e., learning processes along with their pedagogy) form the foundation of the e-learner perception and responses (Hammad, Odeh and Khan, 2016). The previously-mentioned definition of e-learner experience needs to be decomposed in order to identify the constituent constructs of the e-learner experience model as well as the potential approaches to measure the changes (i.e. enhancements or descents/declines) that could happen during a learner's learning journey. The importance of this model stems from its role in the process of e-learning research and innovations. As explained in Figure 4.24, the process starts with identifying the limitations in current approaches, which could be considered as drivers/motivations for the new research, then making the technological interventions through research, design and development phases. Applying research outcomes (i.e. artefacts) should bring certain enhancements to learning experience that need to be measured or proven by some evidences.

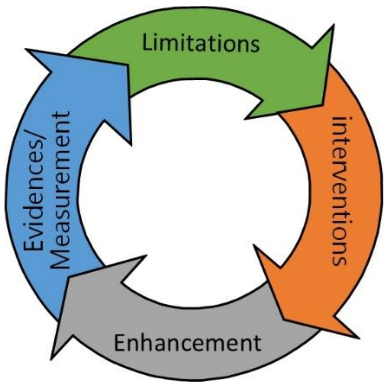


Figure 4.24: The Cycle of e-Learning Research and Innovations

Generally, the enhancements technology brings to learning can be classified into different clusters. For instance, they could be related to: (i) information and support provided to learners, (ii) e-learner performance or (iii) e-learner satisfactions (Antonis *et al.*, 2011), or they could be classified into: (i) operational improvements such as flexibility, (ii) quantitative changes in learning such as test scores or (iii) qualitative changes in learning such as reflections and critical awareness (Kirkwood and Price, 2014). For the sake of this research, enhancements is classified into two categories as shown in Figure 4.25: (i) e-learner-oriented which includes enhancements that are directly related to e-learner experience.

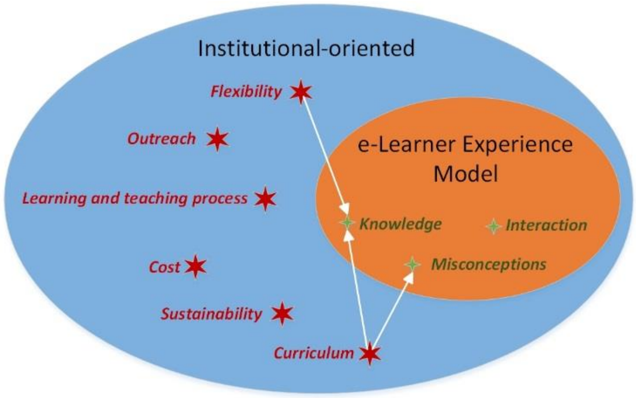


Figure 4.25: The classification of the enhancements of e-learning

and (ii) institutional-oriented which includes enhancements that are related to the institution or any of its components such as technology applied, instructors, teaching/learning process, regulations, its relationship with the community, etc. This research is mainly concerned with the first category, i.e., e-learner-oriented enhancements, which will be called e-Learner Experience Model. This is based on the finding that putting e-learner and his experience at the centre of active e-learning process results in better learning practices (Graf and Kinshuk, 2014). Restricting this part of the research to e-learner-oriented enhancements does not controvert the fact that some of the institutional-oriented enhancements influence the e-learner experience model such as technology, curriculum and flexibility, while some others such as the cost does not have that impact on the e-learner experience. Further institutional-oriented enhancements remain for future research.

4.5.3 e-Learner Experience Model Constituent Constructs

Findings from current e-learning literature artefacts explain that e-learner experience is conceived, to large extent, as quantitative changes in (i) e-learner's knowledge that is assessed by assessment elements such as exams or (ii) e-learner behaviour and satisfaction that is assessed by self-completion surveys (Ramos, 2014). However, the proposed e-learning experience model is an attempt towards identifying an extended list of constructs and potential approaches to measure them. To achieve this goal, a wide range of e-learning models have been investigated. These models stretch from simple models (e.g., Learning Objects (Balatsoukas *et al.*, 2008)) to complicated systems (e.g. Intelligent Tutoring Systems (Nye, 2014; Ma *et al.*, 2014), Adaptive System (Ramos, 2014; Ciloglugil and Inceoglu, 2012)) and from classical systems (e.g., Learning Management System (Despotović-Zrakić *et al.*, 2012)) to research-based artefacts (e.g., Recommender Systems (Drachsler *et al.*, 2015; Park *et al.*, 2012; Khribi, Jemni and Nasraoui, 2008; Buder and Schwind, 2012), Game-based(Hauge *et al.*, 2013), Immersive-based system (Dawley and Dede. C., 2014)). This investigation leads to identifying eight main concepts for the e-learner experience model as they are detailed in the next paragraphs.

The **first** construct is the knowledge and skills. In most e-learning settings such as universities, module learning outcomes form the base for the expected e-learner's behaviour after completing the module. Learning outcomes are combinations of knowledge to be acquired and skills/competences to be developed. Knowledge refers to the mastering, understanding or the state of knowing a particular concept of the module being taught, while skills reflect the e-learner's abilities to apply acquired knowledge in actual case. Differentiating knowledge and skills is important because they usually represent theory and practice, respectively. For instance, effective writing of a computer programme that needs analytical, logical and integration abilities (i.e., skills) differs from knowing how to write a programme in a certain programming language (i.e., knowledge). The e-learner goals are enclosed as well, because learners' goals are focused around acquiring knowledge and skills. This includes goals identified by instructor in formal settings or by learners in self-regulated learning (SRL) settings (i.e., they are named as proximal goals because they represent the breakdown of goals set by instructors) (Dabbagh and Kitsantas, 2012).

Second, the overall assessment results of learning outcomes which can be done through exams, projects, essays or similar comprehensive assessment elements. These comprehensive assessment elements can provide reasonable results however and for the purpose of improved adaptive e-learning processes, fine-grained modelling techniques for e-learner experience are needed so that generating flexible learning paths to learners becomes possible. This is based on the assumption that exams and other comprehensive assessment elements (i.e. course-grained) assess the overall learning outcomes attained by a particular e-learner, but simpler and fine-grained assessment elements such as quizzes that follow each learning unit are used to assess e-learner understanding for that particular topic/concept. **Third**, the e-learner misconceptions represent errors/mistakes inside the e-learner's mind. They will be stored in his model as a subset of the overall misconceptions modelled about a topic.

The previously-identified three constructs are the basic individual constructs that constitute the e-learner experience model. The remaining constructs are either related to the social dimension or the advance individual perspective. The social dimension of learning is an important factor because it deals with the social interaction of the e-learner and his relationship with the learning community. The importance of the social dimension differs according to the learning approach followed by the e-learner. For instance, it is crucial in situated learning where the e-learner knowledge is shaped by his relation to the community. The latest top 100 tools[6] used in education survey reveals the high use of social tools (e.g. social networking, podcasting, RSS feeds, blogging and sharing) in e-learning. But due to the scope of this research, this social dimension cannot be fully analysed and measured. Instead, it will be broken into the following two sub-constructs: (i) *e-learner interaction with the community* (i.e. the **fourth** construct of the model) and (ii) *the social presence* (i.e. the **fifth** construct of the model) which has been simplified to annotations that represent comments, tags, shares, and likes e-learner gets when publishing her/his artefacts.

Six, the support provided to the e-learner should be taken into account as well. Support can be technical to help the e-learner accessing the system capabilities. Referring to this research scope, technical help has no considerable impact on the e-learner experience model since it will be measured by other metrics/attributes stemming from user satisfaction. The other type of support, which is important in this research, is the academic support which is an intervention to help an e-learner to progress in her/his learning journey. This academic support can be divided into two types: (i) *negative-based academic support* which is made by instructors, or other academic roles such as facilitators, based on negative assessment indicators e.g. to correct an e-learner misconception and (ii) *positive-based academic support* which is made by instructor or other academic roles to encourage advanced learners to progress

[6] http://c4lpt.co.uk/top100tools

(e.g., providing additional resources for learners who are eager to learn more, faster or in a reflective way). The negative-based support decreases e-learner's skills and knowledge, while positive-based support gives an indicator for reflective e-learner skills.

Seventh, time-on-task construct is divided into the following sub-constructs: (a) *interaction activities* where learners are encouraged to spend more time in a meaningful way to build knowledge through participation (i.e. named as engagement, the more time spent by an e-learner to use the interaction tools the more engaged with the system he is) and (b) *learning speed* which refers to the time of consuming a learning unit by a particular e-learner. There is a time period identified by the instructor for each learning unit, so the e-learner is expected to approximately use that time. Two different indicators can be taken from this construct. If a large number of learners exceeded the specified time limit of a given learning unit, then this learning unit might be difficult or not well-designed, so there is need to re-design it again by the instructor and with the help of other supportive team members such as instructional designers. However, if an e-learner: (i) consumes a particular learning unit in less than the specified time and (ii) scores high in the assessment element, then he is an advanced e-learner. The main criteria here is to achieve the goals of the learning unit rather than time spent to do so.

Eighth, the e-learner ability to think critically. This includes higher order thinking skills such as meta-cognitive skills that help e-learner to regulate her/his learning and to be more reflective (Saks and Leijen, 2014). A limited number of researchers (e.g., (King, Goodson and Rohani, 1998)) use *critical thinking* as a form *of higher order thinking* or *problem solving*. However, in this research, *critical thinking* and *higher order thinking* are used interchangeably in this research since they refer to skills that include critical, reflective, metacognitive and creative thinking skills (King *et al.*, 1998). This construct is a pure qualitative one and will be evaluated by instructors or tutors in face-to-face learning settings. However, considering the automation level of the HeLPS e-Learning Framework, this will be automatically evaluated by: (i) the e-learner meta-cognitive skills stored in his/her e-learner model and (ii) the number of positive/negative support, done by instructors, to deal with complex learning problems (Kirkwood and Price, 2014; King *et al.*, 1998). So, the more successful self-regulated learning processes followed by a particular e-learner the more critical thinking skills he/she has, because an e-learner cannot have reflection qualities unless he/she masters metacognitive skills (e.g., self-management, self-reflection, allocating suitable resources, etc.) (Zimmerman, 2000).

In this regard, effective modelling for learning and assessment contents is necessary, because learning/assessment activities need to be linked with the skills (e.g., cognitive skills, meta-cognitive skills) that should be conveyed to e-learners. Hence, the number of meta-cognitive skills and the number of positive/negative support, in relation to these skills, can provide a base line for evaluating the e-learner critical skills. As a final remark, the proposed e-learner experience model focuses on the following two aspects:

- *The objective data* rather than subjective and this is the reason for excluding some of the e-learner self-completion constructs such as affects (e.g., boredom). These constructs can be used to provide different treatments for the e-learner but not to evaluate her/his experience (e.g., providing game-based learning approach or some other interesting material for bored e-learners). However, e-learner will be judged based on the achievement of the learning outcomes not her/his affects.

- *The quantitative data* rather than qualitative. Quantitative data includes: e-learner behaviour, such as grades, assessment results, system usage data, completion rate, etc. Other qualitative data such as open-ended questions in surveys, interviews or observations should be quantified to help in producing suitable conclusions. In this way, the proposed e-leaner experience deal with objective and quantitative data. Table 4.3 describes the constituent constructs of the e-learner experience model, the tendency for each of construct which summarises the aim of the ideal system whether to increase this construct or to decrease it, quantification approach and measurement consideration.

Table 4.3: e-Learner Experience Model Constituent Constructs

#	Construct	Tendency	Quantification approach	Key methods to measure
1	Knowledge: understanding of a particular concept and Skills: e-learner's ability to act upon the acquired knowledge to achieve a goal.	Increase	The percentage of known to the unknown concepts in a scale from 1, the least, to 10, the best.	Concepts of a module are modelled in a certain way (e.g. subject ontology) and e-learner knowledge is modelled as an overlay model with percentage of understanding of each concept. Evaluation results come from the assessment construct of the learning unit.
2	Misconceptions: errors in e-learner's conceptualisation	Decrease	Percentage of the e-e-learner misconceptions to the overall misconceptions modelled in the system.	Modelled misconceptions are stored in the subject ontology.
3	The overall assessment results (e.g. exams) which is suitable for comprehensive assessment	Increase	The results of the assessment element are modelled in the e-learner model from 1 to 10.	Results come from comprehensive assessment elements that assess e-learner's learning outcomes.
4	Interaction with learning community that includes learners and instructor	Increase	This includes: (i) the number of actions performed by the e-learner to interact with learners and instructor via different tools e.g. email, forums, and other web 2.0 tools; and (ii) the quality of e-learner interaction.	For simplicity the quality of e-learner interaction is not considered in this research because it needs further details such as using education data mining (EDM) techniques, e.g. to extract the most written words by an e-learner in the forum and analyse them to get some quality indicators.
5	Social presence of the e-learner: it is an indicator on the use of the learning environment by the e-learner.	Increase	The number of annotation the e-learner has. Annotation refers to the number of comments, shares, likes, tags, the e-learner get from the	The use of annotation encourages learners to work in groups and to be socially active, but further analysis techniques are left for future research.

			member of his learning community when he produces an artefact.	
6	Academic support provided to the e-learner			
6.1	Negative-based academic support: interventions based on negative assessment indicators	Decrease	Number of negative-based academic interventions.	Should be linked with the concept that e-learner is working on at the time of providing support.
6.2	Positive-based academic support: interventions to encourage advanced learners to progress	Increase	Number of positive-based academic interventions.	This gives an indicator for reflective e-learner which is considered as a way to quantify the e-learner reflection abilities.
7	Time-on-task: time spent by a given e-learner on a specific task (learning or interaction tasks). This gives indication for engagement and learning speed.			
7.1	Learning speed: time spent by the e-learner on a specific learning task	Stable	The time span with which the e-learner is involved in consuming a learning unit. This can be measured by comparing the time of use with the time attached to every learning unit.	Learning speed is not the criteria for to judge to what extent this learning content is understood by the e-learner. But it will be used to give indications regarding the learning content design.
7.2	Engagement: time spent by the e-learner on participatory learning approaches such as blogging, interacting with the learning community.	Increase	Time-on-task can be calculated by minutes or other time units to measure the use of collaborative activities such as discussion, wiki, etc. where the aim is to increase.	For the context of this research, engagement attribute has been separated from the interaction and social presence (i.e. annotation) of the e-leaner. Further future research is recommended to investigate the correlation between these attributes specially the quality of e-learner interaction. This requires the use of specific learning analytics and EDM techniques in the context of big data or large data set.
8	Critical thinking: e-learner ability to reflect and learn thoroughly.	Increase	This is a qualitative construct, but it can be quantified by the assessment results of the advanced questions and the number of successful SRL processes taken by an e-learner.	The relation between SRL (i.e. metacognitive) skills and high-quality learning (i.e. higher order thinking process or skills) is based on the assumption that both of them are tightly coupled to each other.

4.5.4 e-Learner Experience Model: Structural and Measurement Perspectives

Combining both measurement and structural perspectives is inevitable to bring success to technological artefacts especially if they incorporate user behaviour (Law and van Schaik, 2010). Simply, measurement perspective is concerned in defining model's qualities (e.g., interoperability) along with rigorous measures to allow measuring the overall user experience or other aspects that model would like to measure. While the structural perspective is of explanatory or predictive models that are established to understand and predict the relations between the model's constructs (Edwards and Bagozzi, 2000). For instance, the less misconception the e-learner has the better for her/his knowledge and skill constructs. Similarly, the less negative-based support is the better for her/his experience model. *First*, knowledge and skills gained through the e-learner's learning journey represent the backbone of the e-learner experience, therefore all other constructs are investigated in terms of their impacts on knowledge and skills. The rest of the model's constructs (i.e., interactions, social presence, positive-based support, engagement, critical thinking and overall assessment results) are positively impacting the knowledge and skills construct. For instance, the better assessment results are the best for the e-learner experience model and so on. Based on the explanatory investigation of e-learning literature, especially e-learner modelling, the eight constructs of the e-learner experience model along with their relationships are represented in Figure 4.26.

Analysing the relationship between these eight constructs helps, in support with proper literature, in assigning proximate weights for each construct. Due to the importance of the first construct, knowledge and skills, the approximate weight that will be given to this construct is 0.3 and it will come from the quizzes given to e-learner after each learning unit. *Second*, the misconception which comes from repeated mistakes of the e-learner minimises the e-learner abilities to act up on the learnt knowledge. For instance, one of the misconception in the confusion between area and perimeter. So, the e-learner still has a level of knowledge and skills, but he/she fails to correctly respond to questions until the misconception is being resolved. Therefore, misconception is assigned the value 0.1. *Third*, assessment results that come from comprehensive assessment elements such as exams and projects, mostly give indicators to coarse-grained or high-level of the e-learner understanding. Therefore, it is assigned 0.2. *Fourth*, the social dimension of the learning process which includes both interaction and social presence contributes to the socially-constructed and shaped knowledge and experience. Findings show that the usefulness of this dimension if it has been managed and monitored well. Hence, this construct is assigned 0.1. *Fifth*, the academic support, both

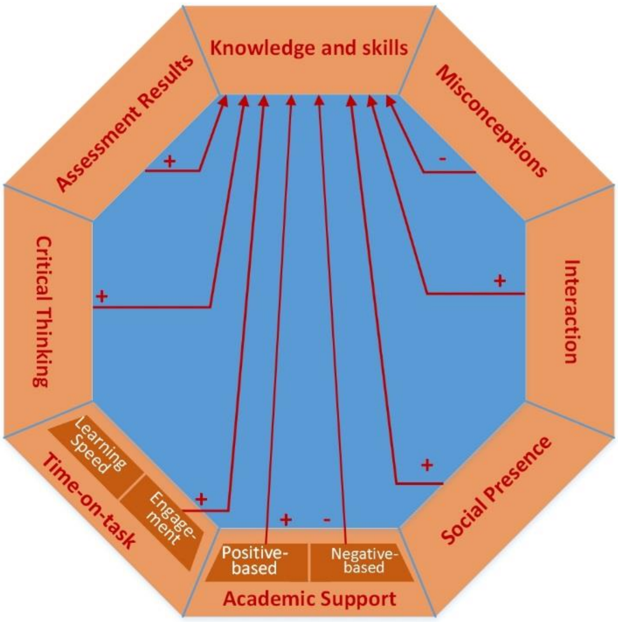


Figure 4.26: e-Learner Experience Model: A Structural View

negative and positive-based, affects the e-learner knowledge in different ways. Positive-based support indicates the well-progress of the e-learner and should increase the e-learner's knowledge and skills and consequently the e-learner experience. Yet the negative-based support indicates some of the misconception or missing conceptions that the e-learner has. This construct (i.e., academic support) is assigned 0.1. *Sixth*, time-on-task is also divided into: (i) learning speed, and (ii) engagement. Only engagement is assigned 0.1 and it has been treated separately from the social dimension for the sake of data objectiveness. This decomposition allows better future investigation of correlation between different constructs. *Finally*, the critical thinking which also contributes positively to the e-learner knowledge and skills and consequently his experience model is assigned 0.1. Table 4.4 shows the proposed weights and collection methods.

Table 4.4: Model Constructs Proposed Weights and Collection Methods

#	Construct	Weights %	How to be measured
1	Knowledge and skills	30	Quizzes delivered to learners after e-learning services
2	Misconceptions	10	Question answer, feedback session
3	Assessment results	20	Exams, assignments or other overall assessment tools
4	Interaction	5	System collected data of the number of interactions with learning community members
5	Social presence	5	System collected data of number of the e-learner's annotations
6	Negative-based academic support	5	Number of instructor or system interventions based on negative indicators
7	Positive-based academic support	5	Number of instructor or system interventions based on positive indicators
8	Engagement	10	Time spent on interaction
9	Critical thinking	10	Instructor assessment and successful SRL processes

4.5.5 e-Learner Experience Model: A Proposed Scale

In order to allow a clear measurement mechanism, there is a need to adopt or define a scale where the previously-presented criteria can be measured. One of the widely-adopted scales for this purpose is Likert scale. This scale refers to a set of statements to which the respondents rate their own degree of agreement or disagreement. More specific, 5-point scale is one of the variations of Likert scale that is commonly used. It is composed of: (i) strongly disagree, (ii) disagree, (iii) neither agree nor disagree, (iv) agree and (v) strongly agree. Some researchers prefer 7-point scale but this makes it harder to find proper descriptive terms for each degree (Albert and Tullis, 2013). Likert scale is adopted in this research because: (i) it is simple to construct, its neutrality due to the use of odd numbers of responses and (iii) can produce a highly reliable scale despite of some limitations in specific cases such as avoiding extreme response categories.

Consequently, the following paragraphs address how each of the previously-identified constructs such as knowledge and critical thinking will be assigned a certain value (e.g., 3 out of 5). Both knowledge and assessment will use the results of quizzes and exams, respectively, converted to a scale ranging from 1, the least, to 5, the highest degree. In addition, the proposed e-learner experience model consists of three socially-constructed constructs which are: interaction, social presence and engagement. As a way to make this experience model generic so it can be used in different modules or courses, these three constructs work on the base of thresholds that are defined by the instructor or other concerned roles. For instance, instructor has to assign the suitable level of interactions (i.e. number of expected messages to be sent by the e-leaner, expected number of annotations and time spent on interactions). The identified thresholds are rated 3, while 1 and 2 refer to less than this threshold and 4 and 5 are above the threshold. For instance, if the number of the emails that should be sent by the e-learner is 10, then 1 refers to leaners who send one email, 2 refers to learners who send two or three emails, 3 refers to learners who send four or five emails, 4 refers to learners who send six or seven emails, 5 refers learners who send eight emails or more. This threshold can be general per all interaction tools (i.e., email, wiki, forum, etc.) or specific per each tool (e.g., 10 email messages and 5 posts on discussion forum). This customisable threshold allows more flexibility as instructors know the best suitable techniques for their own modules, whether a considerable or minimal emphasis should be placed on communication and other social tools. In such way, instructor, or other concerned technical and academic staff, can maximise, minimise or even eliminate (i.e., zero-threshold) the role of social dimension in their modules. Adopting zero-threshold means that this module/course focus goes away from situative-based learning approaches towards pure behavioural ones.

Similarly, a threshold should be assigned by the instructor for positive-based and negative-based academic support attributes. Again, this allows flexible learning management and interpretation for the results of the e-learner experience model. For instance, assigning a high number to the positive-based support, which is related to e-learner reflection, indicates that this module needs critical thinking skills. Hence, it is not expected to see the same positive-based academic support threshold for two different modules whereas the first one is first-year module and the second belongs to MSc programme. Finally, the critical thinking/learning skills construct is quantified by the percentage of successful SRL processes to the overall successful learning processes taken by a particular e-learner. The threshold here is the number that represents half of the successful learning processes for a particular e-learner. For instance, if an e-learner has 20 successful learning processes in his behavioural model then 10 is the threshold for the critical thinking attribute. Hence, if that e-learner has 3 SRL successful processes then he will be given 2. This proposed scale is shown in Table 4.5.

Table 4.5: e-Learner Experience Model Proposed Scale

#	Construct	1*	2	3	4	5*
1	Knowledge and skills	0-19 %	20-39 %	40-59 %	60-79 %	80-100 %
2	Misconceptions	100-80 %	79- 60 %	59-40 %	39-20 %	19-0 %
3	Assessment results	0-19	20-39	40-59	60-795	80-100
4	Interaction	0-19 %	20-39 %	40-59 %	60-79 %	80-100 %
5	Social presence	0-19 %	20-39 %	40-59 %	60-79 %	80-100 %
6	Negative academic support	100-80 %	79- 60 %	59-40 %	39-20 %	19-0 %
7	Positive academic support	0-19 %	20-39 %	40-59 %	60-79 %	80-100 %
8	Engagement (part of time-on-task)	0-19 %	20-39 %	40-59 %	60-79 %	80-100 %
9	Critical thinking	0-19 %	20-39 %	40-59 %	60-79 %	80-100 %

* *(1)* equals strongly disagree, poor or the least while *(5)* equals the highest level of achievements, discussion and reflections.

The proposed e-learner experience model is an attempt to understand the behaviour of e-learners by modelling the constructs that affect her/his experience. One of the challenges here is the external influences of the e-learner experience. For instance, developing the learning and teaching processes taken by a specific institution or adopting advanced innovations in teaching will impact the e-learner experience in a way or another. Additional challenge is the difficulty of deciding which construct affect the others and how because of mixing different concerns in learning processes. For instance, some e-learners may spend extra time on a specific e-learning task not due to bad content design consideration but because of some usability issues. It is challenging to isolate these concerns from each other's and consequently it is difficult to act upon the evaluation results, do is it the issue of content design or interface?

Furthermore, focusing on the quality instead of quantity of data is problematic in such distributed environments. This is due to the difficulty of collecting quantitative and objective data and to the nature of data itself. Some data constructs require different treatment techniques/scales. For instance, e-learner interaction with tools might be taking different time intervals due emotional reasons or e-learner's willingness to learn this topic. Additionally, tracking every single action done by the e-learner will complicate analysing his/her data and consequently taking the right decision. For instance, there could be a possibility for enhancing the quantification approach of the higher order/critical thinking skills through assigning a specific attribute for each question in any online assessment element, so the system can have a better idea about e-learner's reflection abilities (e.g., adding this pair {skill: reflection, topic: requirement analysis} to each question in the exam/quiz). Yet this will increase the load and effort on the instructors in designing assessment elements and may stop them from using these advanced technologies.

4.5.6 Summary

This section introduces an e-Learner Experience Model to understand the impact of e-learning on e-learner experience. The proposed model combines both e-learning literature with User Experience research in order to develop a model that addresses the research concerns and at the same time responds to the particularities of e-learning domain. Hence, the unique contribution of this model is the derived e-learner experience model and its constituent constructs, the weights assigned to these constructs based on measurement and structural analysis and finally the proposed scale to assess each of these constructs. This work leaves the door open for extending this e-learner experience model to cover other institutional-oriented enhancements caused by e-learning technologies and investigating the interrelationships between these learner-oriented and institutional-oriented constructs.

4.6 The e-Learning Capability Maturity Model

The Capability Maturity Model (CMM), first developed by the Software Engineering Institute (SEI), is a framework that describes the key elements of an effective software process. As explained in Figure 4.27, it is composed of the following five maturity levels: (i) initial, (ii) repeatable, (iii) defined, (iv) managed and (v) optimising. Each maturity level represents a well-defined evolutionary plateau towards achieving a mature software process (Paulk

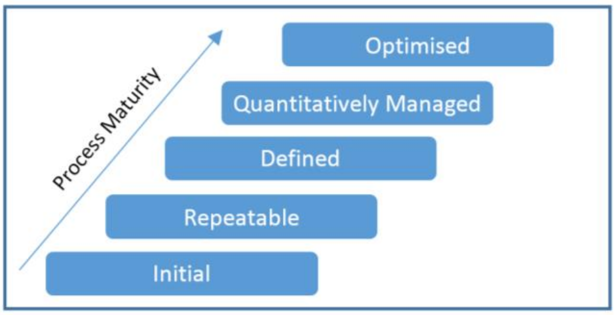


Figure 4.27: CMM Five-Level Representation (Paulk et al., 1995)

et al., 1995). Hence, it represents a path of improvements from initial or ad-hoc level (i.e. maturity level one) to the continuously improving level (i.e., maturity level 5). The successful application of CMM in software development processes motivates researchers to adopt a similar approach in different domains. This has led to the development of domain-specific CMMs such as the Capability Maturity Model for digital investigator (Kerrigan, 2013) and the CMM for digital forensics organisations (Hanaei, Hamad and Rashid, 2014).

4.6.1 Background

One of the most mature attempts to adopt CMM outside the domain of software processes is the e-Learning Maturity Model (eMM) developed by Victoria University of Wellington (Marshall, 2006). The eMM is the result of ongoing research that is initiated on 2002. Although eMM has been built based on combination of CMM and SPICE (Software Process Improvement and Capability dEtermination) (Marshall and Mitchell, 2004), it can be utilised to develop an e-Learning Capability Maturity Model. The main aim behind eMM is to assess the organisational capabilities to sustainably develop, deploy and maintain/support e-learning so that organisations can be involved in quality e-learning processes. Unlike CMM, eMM replaces levels with dimensions, it defines five process categories according to SPICE, or key process areas according to CMM, as listed in Table 4.6. Each of these *process categories* is composed of a number of *processes* (e.g., learning category is composed of 10 processes) and each of these *processes* are linked with a list of *practices* as shown in Figure 4.28.

From e-learning perspective, eMM is more mature than other research artefacts that are developed for evaluation purposes. For instance, e-learning readiness model has been proposed to define factors affecting e-learning and categorising them (Wibowo and Laksitowening, 2015), however, these factors are static and quite limited to certain types of learning. Also, Ozkan (Ozkan and Koseler, 2009) considerd multi dimentions to evaluate e-learning systems, but these dimensions are student-centric, which cannot reflect other roles involved in applying e-learning in complex academic institutions. Despite the comprehnisive nature of the eMM, its categories are static, complex to apply, and institution-centric (Hammad *et al.*, 2017a; Ruggeri, Farrington and Brayne, 2013). Also, the static categorisation of e-learning processes needs to be apdated, as e-learning technologies significantly evolved over the past decade (Rafique *et al.*, 2012).

Table 4.6: e-Learning Process Categories

Process category	Description
Learning	Processes that directly impact on pedagogical aspects of e-learning
Development	Processes surrounding the creation and maintenance of e-learning resources
Support	Processes surrounding the oversight and management of e-learning
Evaluation	Processes surrounding the evaluation and quality control of e-learning through its entire lifecycle
Organisation	Processes associated with institutional planning and management

Nevertheless, eMM development approach is slightly deviated from the CMM structure, it is a comprehensive ongoing work that has been applied in many universities around the world and it is worth to investigate the potential of extending it. As described previously, eMM works at the institutional level, however this research aims at measuring the impact of e-learning on enhancing the e-learner experience which results in adding two inner layers to the eMM. These layers are: (i) e-learner concerns and (ii) technology concerns. Hence, Separation of Concerns approach has been utilised and the proposed eLCMM will be composed of the following three layers/concerns: (i) e-learner, (ii) technology and (iii) institutions, whereas each layer represents a separate concern.

Process L1: Learning objectives are apparent in the design and implementation of courses (Dimension 1)		
	Assessment	Practices
1	□ □ □ ✗ ■	**Learning objectives are provided explicitly in the formal descriptions of the course provided to students, including the summary versions provided prior to enrolment as well as within detailed course prospectuses or syllabi.**
	□ □ ✗ □ ■	Learning objectives are linked explicitly throughout learning and assessment activities using consistent language.
	□ ✗ □ □ ■	Learning objectives for individual courses or modules are explicitly linked to wider programme or degree objectives and institutional graduate attributes.
	□ □ □ ✗ ■	Learning objectives are aimed at supporting student cognitive outcomes that go beyond recall and acquisition of knowledge.
	□ □ □ ✗ ■	Course workload expectations and assessment tasks are consistent with the learning objectives.

Figure 4.28: eMM Sample Process and its Practices

4.6.2 e-Learning Capability Maturity Model Structure and Concerns

As introduced earlier, the application of e-learning artefacts in any institution can be investigated according to different concerns. These concerns are depicted in Figure 4.29 and described as follows:

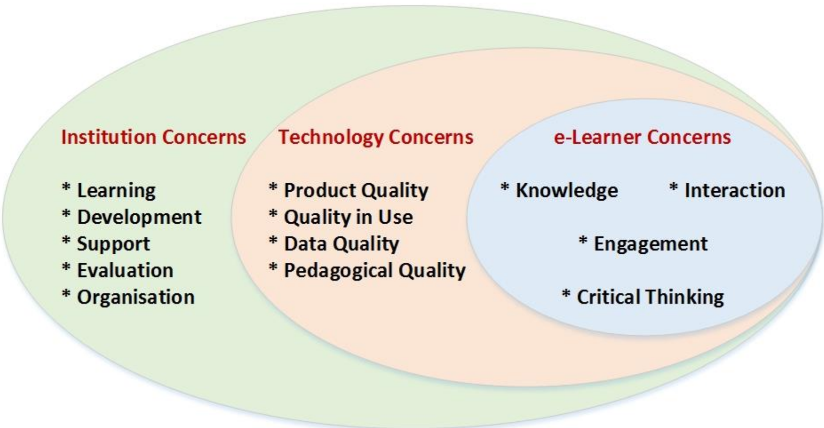


Figure 4.29: Concern-based e-Learning Capability Maturity Model

- e-Learner-oriented concerns which refers to the e-Learner Experience Model, as described earlier, that handles issues related to the e-learner and his/her interaction with the e-learning environment.
- Technology-oriented concerns which will respond to technological issues related to the e-learning software system utilised in a certain organisation.
- Institution-oriented concerns which is outside the scope of this research, yet the eMM can be re-used for satisfying institutional concerns.

The eLCMM responds to the technology-oriented concerns, and is organised, as appear in Figure 4.30, as five levels of maturity where each level has key process areas that are composed into processes and key practices.

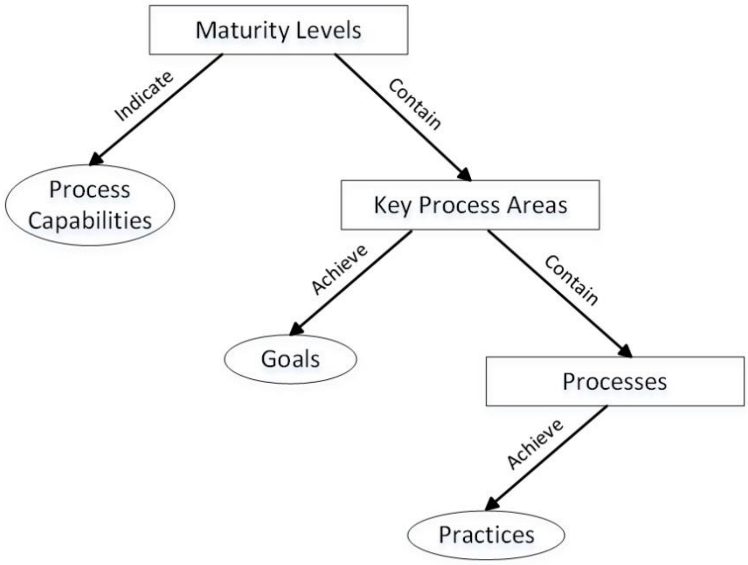


Figure 4.30: The Structure of the eLearning Capability Maturity Model

4.6.3 e-Learning Capability Maturity Model Key Process Areas

Furthermore, four Key Process Areas (KPA) have been derived from the literature based on the application of ISO Systems and software Quality Requirements and Evaluation (SQuaRE) standards on various e-learning models and frameworks. These KPA respond to the technological layer and they are: (i) product quality, (ii) quality in use, (iii) data quality and (iv) pedagogical quality. Each KPA is divided into a list of processes (i.e. 26 processes in total) that are supported by a list of key practices and five-level maturity scale as shown in Table 4.7 and Figure 4.31. Further scaling strategy will be devised. Measures and benchmarking is commonly used in different domains. It is useful because it allows to measure and compare results between groups of stakeholders/counterparts. It can be used for self-assessment purposes or take decisions based on benchmarking. However, benchmarking in e-learning is challenging because most e-learning benchmarks have been developed in specific projects with specific contexts and have not been generalised or formalised to be sustainably available for everyone. In other words, there is a lack of overall framework that can help in applying them in a specific case (Ossiannilsson, 2012). Examples on these benchmarks are ACODE, Excellence, Quality Matters and others. But, similar to eMM, these benchmarks are focused on institutional level (Beeck, Camilleri and Bijnens, 2012). So, this research will define its own e-learning Capability Maturity Model to achieve the goal of this research, while related literature will be considered.

Table 4.7: eLCMM Key Process Areas

Key Process Area	Description
Product Quality (PQ)	Qualities that focus on the static software properties and the system dynamic properties
Quality in Use (QiU)	Qualities related to the system use by a specific stakeholder in a certain context
Data Quality (DQ)	Qualities for data retained in a structured format within a computer system through its life cycle processes
Pedagogy Quality(PPQ)	Qualities that focus on learning related goals, learning and teaching processes and their assessment.

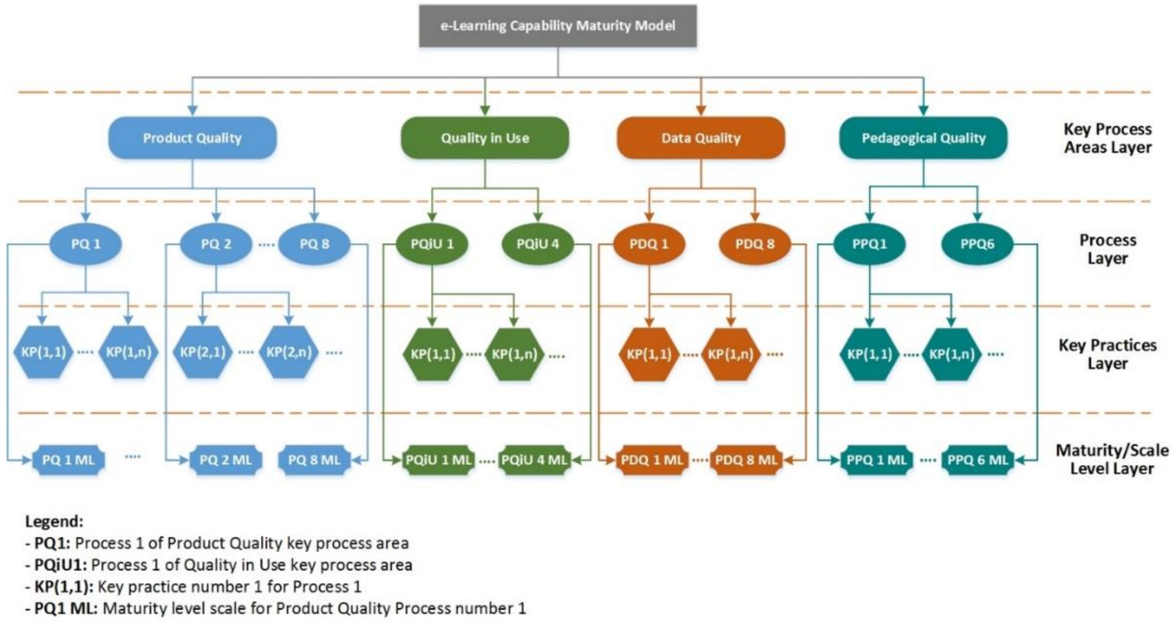


Figure 4.31: e-Learning Capability Maturity Model Detailed Structure

4.6.4 e-Learning Capability Maturity Model Detailed Description

Below is a description for each key process area, its processes along with its recommended key practices and scaling levels. This description is listed in the following four Tables 4.8, 4.9, 4.10, and 4.11.

Table 4.8: Processes of Product Quality Key Process Area

Key process area: Product Quality	
Processes	
Process Code	Description
PQ1	*e-learning system and its components can exchange information and use the information that has been exchanged in addition to the system capability to share resources with other artefacts [Compatibility, Interoperability and Co-existence]*
Key practice	Standard-based approaches are adopted to allow: (i) data exchange and use and (ii) sharing resources with other artefacts.
Levels	To what extent data can be exchanged and used (scale from 1 to 5) 1: e-learning system's components show limited capabilities in exchanging information and using the information that has been exchanged on the system level. 2: e-learning system's components effectively exchange information and use the information that has been exchanged on the system level. 3: e-learning system's components effectively exchange information and use the information that has been exchanged on the system level, in addition to the system's capabilities to perform its required functions while sharing resources with other artefacts. 4: In addition to the system's capability of exchanging information and using the exchanged information, and performing the required functions while sharing resources with other artefacts, the system provides mechanisms for sharing some of its data/resources (e.g. login to the system through Facebook credentials) 5: e-learning system offers the highest level of interoperability with standard artefacts in addition to its ability to perform its functionalities efficiently while sharing common environment and resources with other artefacts.

PQ2	*e-learning system can be used by a wide range of people with different capabilities in specific contexts to achieve user goals [Accessibility]*
Key practice	In addition to adopting standard-based approaches to make the e-learning system accessible to users, additional approaches should be followed to make the system accessible to users with special needs. For instance, adopting technical assistive technology for users with disabilities.
Levels	1: The system is accessible for the (N)ormal users; 2: The system is accessible for the N + (V)ision disability users; 3: The system is accessible for the N + V + (H)earing disability users; 4: The system is accessible for the N + V + H + Cognitive disability users; 5: The system is capable of dealing with combination of disabilities where advanced techniques to discover different disabilities and deal with them is adopted (e.g., psychological disorders such as affective state: disorders of mood or feeling states or personality disorders: deeply inadequate patterns of behaviour and thought of sufficient severity to cause significant impairment to day-to-day activities[7]).
PQ3	*e-learning system is composed of discrete components or modular architecture such that a change/modification for one component does not cause: (i) defects, (ii) degrade product quality and (iii) impact other components to the minimum level [Modularity and Modifiability]*
Key practice	Avoid black box design choices. Instead adopt software design principles such as loose coupling and high cohesion which can be realised in object oriented approaches, components, layers/tiers, distributed computing such as web services
Levels	The more modular system is higher modularity degree 1: e-learning system is offered as a black box. 2: e-learning system is composed of functions and components 3: *Separation of Concerns* approach is clearly reflected in the e-learning system and its constituent components. 4: e-learning system adopts logical and physical discretisation of its components such as layers/tiers, where distributed computing artefacts such as web services can be utilised. 5: e-learning system's abilities to effectively integrate with different distributed third party system/software/services are shown, well documented and supported with evidences.
PQ4	*e-learning system is operational and accessible when required for use [Availability, Functional Correctness, Security and Confidentiality]*
Key practice	The e-learning system, its components and functions are all secured and accessible all the time, based on 24 hour/7 days. *Practices are related to availability, security, functional correctness and hosting environment* System components and subcomponents are tested to the extent that they provide correct results/behaviours using the required resources. System components are secured to the extent that they cannot be attacked and stopped from working System is hosted in a way that ensure continuous service provision.
Levels	1: Availability and functional correctness are tested at the level of units and components. 2: Availability and functional correctness are tested at the level of components, subsystems, system. 3: Availability and functional correctness and security are tested at the level of components, subsystems, system. 4: Availability and functional correctness and security are tested at the level of components, subsystems, systems and hosting environment. 5: Optimising defect detection and prevention techniques are adopted to proactively respond to any interruption.
PQ 5	*e-learning system can effectively and efficiently be adapted for different or evolving hardware, software or other operational or usage requirements. [adaptability and adaptivity]*
Key practice	Adopt effective techniques to trace and build effective user model. Adopt proper design choices to separate concerns (e.g., Model-View-Controller) Adopt AI or evolutionary computational techniques to offer adaptive functionalities.
Levels	1: One-size-fits-all;

[7] http://www.disabled-world.com/disability/types/

	2: Adaptation is initiated by user (e.g., interface colouring scheme); 3: Adaptiveness is initiated by the system but for a limited number of functions compared to offered functions by the system; 4: Adaptiveness is initiated by the system for the majority of the system functions; 5: Adaptiveness is initiated by the system where the adaptiveness rules are created dynamically and evolving through advanced techniques such as machine learning and genetic algorithms.
PQ 6	*e-learning system can be used by specified users in specified context of use to achieve specified goals with effectiveness, efficiency and satisfaction. [Usability, Appropriate recognisability, Learnability]*
Key practice	Adopt standard HCI principles to design the e-learning system and it interfaces such as user interface aesthetics best practices. Adopt effective techniques to protect user from performing errors in the system (e.g., warn the user before deletion or clearly explain the required text boxes in a form). Add help and directions on how to use the system.
Levels	1: User can hardly use the system or its components to achieve specified goals. 2: User can (i) use the system and its components and (ii) learn how to use the system or its function with effectiveness, efficiency, freedom from risk and satisfaction in a specified context of use. 3: The system and its functionalities are well-organised and presented so that users can (i) recognise whether a system function/component is appropriate for their needs, (ii) use the required functionalities and (iii) learn how to use unknown functionalities. 4: In addition to point 3, the system is capable of protecting users against making errors through clear directions and interface design choices. 5: Users: (i) can use the system to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use, (ii) can learn how to use the system or its function, (iii) can recognise the appropriateness of a given components for their needs and (iv) are protected against making errors.
PQ 7	*The amounts and types of resources used by the e-learning system in order to perform its functions ant meet requirements. [Performance utilisation, resources utilisation, capacity]*
Key practice	Adopt effective algorithms to process data and get the results. Adopt techniques that allow to minimise the waste in resources, e.g. reduce the number of accessing the service in order to update a specific record.
Levels	1: The e-learning system can perform its function using extra resources (e.g., extra time) 2: The e-learning system can perform its functions with the minimum hardware and software resources but at the expense of response time. 3: The e-learning system can perform its functions with an acceptable level of resources (i.e., hardware, software and time) but cannot keep this level of performance when dealing with a large number of record (e.g., capacity issue). 4: The e-learning system can perform its functions with a good level of resources (i.e., hardware, software and time) and use effective techniques to minimise the waste of resources (e.g., minimise the number of accessing the server to update a record or to fetch simple data). 5: The e-learning system can perform its functions with dynamic and optimised level of resources (i.e., hardware, software and time) management (e.g., dynamic allocation of data on cloud or responding to elasticity (i.e., scale out) and scalability (i.e., scale up)
PQ 8	*The e-learning system provides functions that meet stated and implied needs when used under specified conditions where the provided functions cover all the specified tasks and user objectives. [Functional suitability and Functional completeness]*
Key practice	Adopt effective requirement elicitation and specification techniques Adopt effective testing techniques to ensure that all stated and implied user requirements can be fulfilled by the provided system.
Levels	1: The e-learning system provides 20% of the functions that meet stated and implied needs under specified conditions. 2: The e-learning system provides 40% of the functions that meet stated and implied needs under specified conditions. 3: The e-learning system provides 60% of the functions that meet stated and implied needs under specified conditions.

	4: The e-learning system provides 80% of the functions that meet stated and implied needs under specified conditions. 5: The e-learning system provides 100% of the functions that meet stated and implied needs under specified conditions.

Table 4.9: Processes of Quality in Use Key Process Area

The Second Key Process Area: Quality in Use	
Processes	
Process Code	Description
PQiU1	*e-learning system are satisfying the user needs when they use the system in a specified context [Satisfaction, Usefulness, Trust, Pleasure and Comfort]*
Key practice	Adopting effective traceability techniques to ensure that captured requirements are specified and developed properly. Adopting detailed evaluation (i.e. validation and verification) techniques to discover unexpected behaviour.
Levels	1: The e-learning system shows limited capabilities in satisfying its users' needs. 2: The e-learning system shows appropriate capabilities to make the user satisfied with their achievements and the results they got out of the system use. 3: The e-learning system gains the users trust to the extent that users have confidence that the system will behave as intended. 4: The e-learning system provides pleasure to user when they fulfilling their goals or tasks, e.g. rewarding advanced learners by giving them the ability to manage their learning or help other learners, showing pleasant memories to learners, etc. 5: The e-learning system provides appropriate degree for physical comfort when users use the system in specified context. ***This applies only in conditions where physical implications exist, e.g. using 3D glasses or Augmented Reality environments where users might be eyes might be exhausted or not.***
PQiU2	*e-learning system is effective so it allows users to achieve their specified goals with accuracy and completeness [Effectiveness]*
Key practice	Analyse potential user goals and define mechanisms to respond to them. Develop measurements for accuracy and completeness for goals achievement.
Levels	1: Users can achieve their goals with 20% of accuracy and completeness when they use the e-learning system. 2: Users can achieve their goals with 40% of accuracy and completeness when they use the e-learning system. 3: Users can achieve their goals with 60% of accuracy and completeness when they use the e-learning system. 4: Users can achieve their goals with 80% of accuracy and completeness when they use the e-learning system. 5: Users can achieve their goals with 100% of accuracy and completeness when they use the e-learning system.
PQiU3	*e-learning system is efficient to the extent that resources expended in relation to the accuracy and completeness with users achieve goals are appropriate. [Efficiency]*
Key practice	Define the resources that are used by the system, e.g. hardware, software, time, etc. Adopt effective management strategies in different contexts of use.
Levels	1: The waste in resources expended by the system to allow users to achieve their goals accurately and completely is 70% or more. 2: The waste in resources expended by the system to allow users to achieve their goals accurately and completely is in the range 50% to 70%. 3: The waste in resources expended by the system to allow users to achieve their goals accurately and completely is in the range 30% to 50%.

	4: The waste in resources expended by the system to allow users to achieve their goals accurately and completely is in the range 30% to 10%. 5: The waste in resources expended by the system to allow users to achieve their goals accurately and completely is less than 10%.
PQiU4	*The e-learning system can be used with effectiveness, efficiency, freedom of risk and satisfaction in contexts beyond those initially specified in the requirements. Adopting the system for e-training purposes not academic learning institutions or for not highly technical skilled users. [Flexibility]*
Key practice	Adopt flexible development approaches where system and its components can be customised easily. Adopt alternative ways to perform functions so users should be able to perform function in different ways without ambiguity.
Levels	1: The e-learning system offers limited capabilities in adopting it to different contexts. 2: The e-learning system offers appropriate capabilities to customise the system functions so that the system can be adopted in different contexts, but with low level of effectiveness, efficiency, freedom of risk and satisfaction. 3: The e-learning system offers appropriate capabilities to customise the system functions so that the system can be adopted in different contexts, but with medium level of effectiveness, efficiency, freedom of risk and satisfaction. 4: The e-learning system offers appropriate capabilities to customise the system functions so that the system can be adopted in different contexts, but with an appropriate level of effectiveness, efficiency, freedom of risk and satisfaction. 5: The e-learning system shows high capabilities in adopting it to different contexts.

Table 4.10: Processes of Data Quality Key Process Area

Third Key Process Area: Data Quality: This key process area handles only structured data. The term "*Unstructured Data*" will be used whenever this is intended.	
Processes	
Process Code	Description
PDQ1	*To what extent data in the e-learning system has attributes that correctly represent that true value of the intended attribute of a concept or event in a specific context of use. [Accuracy]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Data accuracy is 20% or less. 2: Data accuracy is in the range of 21% - 40%. 3: Data accuracy is in the range of 41% - 60%. 4: Data accuracy is in the range of 61% - 80%. 5: Data accuracy is 81% or more.
PDQ2	*To what extent data in e-learning system has attributes that are free from contradiction and are coherent with other data in a specific context of use.[consistency]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Data consistency is 20% or less. 2: Data consistency is in the range of 21% - 40%. 3: Data consistency is in the range of 41% - 60%. 4: Data consistency is in the range of 61% - 80%. 5: Data consistency is 81% or more.
PDQ3	*To what extent data in e-learning system has attributes that are regarded as true and believable by users in a specific context of use. [Credibility]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Data credibility is 20% or less.

	2: Data credibility is in the range of 21% - 40%. 3: Data credibility is in the range of 41% - 60%. 4: Data credibility is in the range of 61% - 80%. 5: Data credibility is 81% or more.
PDQ4	*To what extent data in e-learning system has attributes that are of the right age in a specific context of use.[Currentness]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Data currentness is 20% or less. 2: Data currentness is in the range of 21% - 40%. 3: Data currentness is in the range of 41% - 60%. 4: Data currentness is in the range of 61% - 80%. 5: Data currentness is 81% or more.
PDQ5	*To what extent data in e-learning system has attributes that are exact or that provide discrimination in a specific context of use [Preciseness]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Data Preciseness is 20% or less. 2: Data Preciseness is in the range of 21% - 40%. 3: Data Preciseness is in the range of 41% - 60%. 4: Data Preciseness is in the range of 61% - 80%. 5: Data Preciseness is 81% or more.
PDQ6	*To what extent data in e-learning system has attributes that provide an audit trail of access to the data and of any changes made to the data in a specific context of use. [Traceability]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Data traceability is 20% or less. 2: Data traceability is in the range of 21% - 40%. 3: Data traceability is in the range of 41% - 60%. 4: Data traceability is in the range of 61% - 80%. 5: Data traceability is 81% or more.
PDQ7	*To what extent data in e-learning system has attributes that enable them to be installed, replaced or moved from one system to another while preserving the existing quality in a specific context of use. [Portability]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Data portability is 20% or less. 2: Data portability is in the range of 21% - 40%. 3: Data portability is in the range of 41% - 60%. 4: Data portability is in the range of 61% - 80%. 5: Data portability is 81% or more.
PDQ8	*To what extent data in e-learning system has attributes that enable them to maintain and preserve a specified level of operations and quality, even in the event of failure, in a specific context of use. [Recoverability]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Data recoverability is 20% or less. 2: Data recoverability is in the range of 21% - 40%. 3: Data recoverability is in the range of 41% - 60%. 4: Data recoverability is in the range of 61% - 80%. 5: Data recoverability is 81% or more.

Table 4.11: Processes of Pedagogical Quality Key Process Area

Fourth Key Process Area: Pedagogical Quality Model: This key process area handles pedagogy related concerns and other extended qualities.
Processes

Process Code	Description
PPQ1	*The e-learning system offers a high level of automatic discovery and reuse for e-learning assets. [Discoverability and Reusability]*
Key practice	Adopt standard-based approach in designing the system and the form of publishing knowledge in distributed environments
Levels	1: The e-learning system is linked to a set of specified e-learning assets during module design process. 2: The e-learning system provides limited permission to instructors to discover specific types of e-learning assets and makes them available to learners. 3: The e-learning system utilises simple search techniques to find e-learning assets such as learning objects that are stored in a specific repository. 4: The e-learning system is capable of automatically discover contents in standard formats such as web services based on certain set of factors, e.g. keywords and provides their links to the learners. 5: The e-learning system is capable of automatically discover and manage web services based on certain set of factors, e.g. keywords in an integrated approach so the system can modify the e-learner profile based on the communications with those web services.
PPQ2	*The e-learning system can be adopted or applied by an institution without complex changes required from the institution.[Adoption Flexibility]*
Key practice	Adopt standard-based approach in designing the system, representing, storing, specifying and retrieving data.
Levels	1: Adopting the e-learning system requires complex changes at the level of institutions, e.g. managerial changes. 2: Adopting the e-learning system requires less complex changes at the level of faculties. 3: Adopting the e-learning system requires less complex changes at the level of departments. 4 Adopting the e-learning system requires less complex changes at the level of instructor and his way of teaching. 5: Adopting the e-learning system requires no or minimum changes.
PPQ3	*The e-learning system can capture its usage contexts by specific user and act upon captured information so system functionalities become more meaningful to the user. [Semanticability]*
Key practice	Adopt knowledge representation techniques that can capture domain knowledge and provide reasoning capabilities on the top of it.
Levels	1: No context information captured by the system. 2: The minimum information about e-learner is captured by the system. 3: The system captured extended information about the e-learner and domain knowledge. 4: The system captured extended information about the e-learner, domain knowledge, context, contents, etc. 5: The system is capable of acting upon the extended captured semantic knowledge.
PPQ4	*The e-learning system utilises formal business process management techniques at different levels such as design, management, enactment, and so on. [Processability]*
Key practice	Adopt formal business process approaches to specify e-learning processes. These formal specification can be used at different levels based on the goal of adopting process-based approaches
Levels	1: No adoption for process-based approach, process is cemented into the code or it is in the form of adhoc. 2: Processes are repeatable and not clearly stated and specified. 3: Processes are defined but need further enhancements such as being automatically generated for the e-learner. 4: Processes are managed and can update the e-learner profiles after the enactment phase. 5: Processes are dynamically generated from hybrid process models that represent different learning approaches
PPQ5	*e-Learning system has the capability of representing different pedagogical principles, models and frameworks to the sufficient level. [Pedagogical Neutrality and Pedagogical Expressiveness]*
Key practice	Separate the representation of the pedagogical principles, models and frameworks from the logic of the e-learning system.

Levels	1: The e-learning system can represent only one pedagogical approach, e.g. serial representation of contents. 2: The e-learning system can represent more than one pedagogical approach based on a selection from a template for pedagogical models. 3: The e-learning system can represent only many pedagogical approaches different level of expressivity. 4: The e-learning system can represent different models and can acquire new models based on customisable choices. 5: The e-learning system can represent different pedagogical approaches to the sufficient level of expressivity so that these models can be automatically enacted and executed.
PPQ6	*e-Learning system can bring satisfaction to the e-learner based on their perceived achievements of learning objectives, material fitness and learning outcomes as a result of interaction with the system, learning contents and peers.[Pedagogical Usefulness]*
Key practice	Effective pedagogical strategies should be adopted in cooperation with instructor and other technical roles who can facilitate this process.
Levels	1: Adopted pedagogical strategies are superficial and not sufficient to grasp knowledge. 2: Adopted pedagogical strategies are general and not customised based on e-learner's requirements. 3: Adopted pedagogical strategies are well-designed based on the customised e-learner's requirements. 4: Adopted pedagogical strategies are adaptive and responsive the e-learner's requirements. 5: Adopted pedagogical strategies are adaptive and brings back feedback to the e-learner to update his model.

4.6.5 Discussion

The proposed e-Learning Capability Maturity Model is both pedagogically and technologically-based, and is intended to respond to the early-identified research gap in the context of e-learning evaluation methods. The separation of concerns software engineering principle is utilised in this proposed model since each of the three identified concerns are handled by different artefacts (i.e. e-learning experience model, eLCMM and eMM). It is composed of (26) processes in total that can be used to critically assess the effectiveness of the current e-learning system, and at the same time provides a set of practices to improve the current Technology Enhanced Learning (TEL) practices. This is an additional advantage for applying CMM in an e-learning context because other models such as the ISO 25010 do not suggest a path for improvement. Furthermore, the proposed eLCMM is platform-independent and can be used to assess different e-learning systems/artefacts. Also, it uses generic terms that can suite a wide range of systems, and it is aligned with: (i) ISO 25010 product quality and quality in use, (ii) ISO 25012 data quality, and (iii) the extended pedagogical e-learning qualities addressed in (Hammad *et al.*, 2015). Yet, the proposed eLCMM needs to be applied in different institutions with different e-learning settings (i.e., using e-learning to support traditional teaching or using it as the only way for learning and teaching) in order to test its strengths and limitations.

4.6.6 Summary

This part of the thesis introduced a novel e-learning capability maturity model to inform the effectiveness of enacting e-learning systems. This model utilises the ISO 25010 and 25012 standards in relation to specifying and adopting different modelling components in order to evaluate key aspects regarding the organisation, the technology and the e-learner experience. The application of ISO standards in this model has led to identifying well-established key e-learning quality process areas. In addition, the proposed eLCMM embraces the separation of concerns principle and adds another layer on top of our early developed e-Learner Experience Model, and hence it provides further advanced research on assessing the maturity of adopting e-learning systems. However, applying the proposed eLCMM in a certain institution requires an e-learning process to instantiate in particular learning context. And hence, to implement the eLCMM, a set of assumptions/rules needs to be developed regarding e-learning overall goals, boundaries, application method, etc. along with a common or well-structured e-reporting mechanism adopted so that feedback can be conveyed to the concerned stakeholders engaged in both the institution's e-learning process and its enacting e-learning systems. Accordingly, this model adds a building block towards improving the e-learner's experience through the continuous feedback provided by the eLCMM implementation. Its main added value, in addition to the assessment, will be providing key practices to progress through its successive maturing levels which is missing in other standards such as ISO (Kaur, 2014).

4.7 The Data Layer

The final layer in HeLPS e-Learning Framework is the Data Layer. It is used to store and provide access to the data hosted by the software system, and also data that could be shared with other external applications, if any. Such data includes, but are not limited to, database servers, OWL files, WSDL files, etc. Data sources in this layer should be accessible to other layers and their constituent components in the proper mechanisms (i.e., only permitted users will be able to access these resources).

4.8 Critical Reflection and Conclusion

This chapter discussed the design and the development of the HeLPS e-Learning Framework through detailing the HeLPS framework instantiation process in certain settings. This process alludes to the complexity of the proposed framework and its internal artefacts (i.e., layers and modules). One central artefact of this framework is the e-Learning Meta-Model. It encapsulates a huge amount of information about the e-learners, learning pedagogy, contents and other broader contextual information, which can help in specifying the proper e-learning services. A Semantic Web Rule Language has been utilised, as explained in Appendix III, to support the transformation of the generic e-learning process to a specific e-learning process. Another essential part of this chapter discussed the application of Business Process in the e-learning domain, where various detailed e-learning processes have been identified from the literature. This has led to the development of a generalisation approach, which can be used to generalise a business process model from a set of detailed business processes that have the same goals and objectives. Although the proposed approach has been used in the e-learning domain, it is domain independent and may be applied in other domains, such as industrial processes, smart cities, provienance, etc.

Combining both artefacts (i.e., Business Process and Semantics) helps in the progressive answering of the following research questions: RQ 1: whether a generic e-learning process can be derived from the existing e-learning models, RQ 2: to what extent BPMN can be sufficient in modelling various e-learning processes, and RQ 3: to what extent semantic-based approaches can enrich e-learning processes. Service Derivation algorithms, from e-learning business processes, is the third essential artefact of the proposed framework. It allows the dynamic enactment of the semantically-enriched e-learning processes in service-oriented environment. This part of the work discussed the limited utilisation of service-orientation in the e-learning domain due to various e-learning particularities. It criticised the current approaches of identifying web services from business process models, generally and from e-learning business process models in specific. This has led to developing a novel approach to derive (i.e., identify and discover) web services from e-learning business process model. The third essential artefact helps as well in answering the fourth research question (RQ 4), which is related to the dynamic enactment of e-learning processes in SOA-enabled environment.

Instantiating HeLPS e-Learning Framework allows to discover various aspects related to the e-learning domain. *First*, the added value of combining the *business process* technology to specify e-learning processes with *semantics* to enrich the early-specified e-learning processes with the captured context, and *service-orientation* to execute these e-learning processes in a flexible environment. *Second*, the necessity of investigating the recently emerging e-learning models and their impacts on the e-learner experience. In this respect, we tend to cover, whenever it is possible, the newly emerged e-learning models (e.g., virtual reality and second life e-learning models) and theories (e.g., connectivism learning theory). Some of these models and theories (e.g., connectivism) are not fully tested, therefore the HeLPS framework investigated a hybrid approach to learning including the above-mentioned models and theories. *Third*, various Model Driven Engineering concepts and techniques have been applied in developing the HeLPS Framework in order to increase flexibility and ensure stable system behaviour over various implementation scenarios. Such techniques include meta-modelling (i.e., the e-Learning Meta-Model) and specialising the generalised e-learning process using SWRL rules and based on the contextual information captured in the eLMM. In addition, the adoption of service-oriented architecture promotes the flexibility, agility and effectiveness of e-learning artefacts. This research highlighted the limited use of service-oriented architecture in the e-learning domain due to various reasons (e.g., the limited web services capability of representing large amount of data). This research aims to open the doors for innovative application of SOA in the e-learning domain. One simple example of this could be wrapping the existing e-learning contents in the form of web services and semantic web services.

Fourth, this research also highlighted to what extent e-learning artefacts are context-dependent. This has been reflected in the comprehensive nature of the eLMM as it captures information about institution, processes and activities, pedagogy, content, actors and in particular e-learner, tools, presentation format, and context. The eLMM also captures relation and rules to make useful recommendations to the e-learner in order to enhance his/her experience. The early-developed eLMM, detailed in Appendix II, allows transforming the generic e-learning process into specific e-learning process for a particular e-learner. *Fifth*, developing a process-oriented e-learning artefacts help to abstract from various e-learning technical details. This could help in reactivating the research in modelling the e-learning processes/scenarios within a larger scope. This area has moved out of the focus since the standardisation of the IMS Learning Design and the various limitations appeared. *Sixth*, the development of the e-Learner Experience Model as well as the e-Learning Capability Maturity Model allows to gain further understanding on how e-learning can be evaluated in several contexts (i.e., organisational, technological, and personal). These six concerns, in addition to the early-identified research questions, are the key aspects that will be evaluated in the next chapter, Chapter 5.

This research has been informed and influenced by many Technology-Enhanced Learning and other related research papers and publications. The key influence stem from the area of modelling and enacting e-learning processes. In the early stages of performing this research, various limitations in modelling and enacting e-learning processes have been identified (Section 2.9). IMS LD, the most advanced process-based e-learning artefact, is limited in terms of its agility (Caeiro-Rodríguez *et al.*, 2010), flexibility, and adaptiveness. This has led to develop a new process-based approach using industrial standard BPMN to model e-learning processes and BPEL enact them effectively. In addition, the cuurent representation of pedagogy in TEL artefacts is limited. This presentation is either missing (e.g., MOOCs (Daradoumis *et al.*, 2013)) or biased to certain learning theories/pedagogical approaches (e.g., Responsive Open Learning Enviornment (Nussbaumer, 2013)). This has led to develop a pedagogical-neutral e-learning processes via identifying detailed e-learning approaches, driven from pedagogy, and then develop a generic e-learning approach that can represent all of the early-identified e-learning pedagogical approaches. In other words, a pedagogical-neutral e-learning process has been developed and used in an automated way. Such level of automation helps to manage e-learning processes in a better way, because instructor will be distracted with unnecessary tasks (e.g., recommending learning contents for e-learners) and will be able to use their time more effectively to interact with e-learners and help them to achieve their learning goals.

Furthermore, the continuously evolving requirements of educational intitutions increase the complexity of TEL software systems. Such evolving requirements (e.g., LMS capabilities, video streaming, plagiarism checker, etc.) cannot be met by one TEL solution. Therefore, a combination of various TEL software systems/tools in a flexible environment is needed. This has led to develop a SOA-enabled e-Learning Framework, that can enact e-learners' requirement via web services. Moreover, the developed framework tackled one of the key challenges in relation to SOA-enabled TEL artefact, which is deriving services from e-learning business process models. This has been done via identifying web services from e-learning prcesses and then discover the proper service(s) that meat the demand of the e-learner. This piece of work has been informed by others' research, especially (Jamshidi *et al.*, 2012; Azevedo *et al.*, 2009), and will be further developed so it can be used in contexts beyond e-learning. Also, the current utilisation of semantic technologies (e.g., (Mikroyannidis, 2012; Rodriguez Mier *et al.*, 2015; Nye, 2014)) informed the contextualisation of the HeLPS e-Learning Framewok and led to: (i) expand the range of captured constructs about e-learners and (ii) adopt semantic rule language to better respond to e-learner's requirements. Finally, the extended effort done towards evaluating e-learning artefacts including the e-learning maturity model (Marshall, 2006) informed the development of the e-learning evaluation framework and its constituent components eLEM and eLCMM.

Chapter 5:

Evaluating the HeLPS e-Learning Framework

After instantiating the HeLPS e-Learning Framework in Chapter 4, this chapter presents the overall evaluation with the objective to answer the research questions in order to prove or disprove the research hypothesis. This chapter is structured as follows: **First**, the overall evaluation framework for HeLPS, its components and its instantiation process, is briefly introduced. **Second**, the Validation and Verification Model, which is the core of the evaluation framework is presented. This model is designed to test the HeLPS e-Learning Framework using a hypothetical case study based on sufficiency analysis that is presented and discussed using a bottom up approach. This evaluation framework utilises the early-developed: (i) e-Learner Experience Model, which aims to clarify the concept of e-learner experience enhancement as it is missing in the literature (Kirkwood and Price, 2014), and (ii) the e-Learning Capability Maturity Model is defined that aims to: (a) assess to what extent e-learning processes are mature and (b) to provide a recommended key practices on how to improve e-learning processes. Both models (i.e., eLearner Experience Model and e-learning Capability Maturity Model) have been developed at the theoretical/conceptual level and they are at their fundamental stages because they are outside the scope of this research. Therefore, they remain for future work to be further developed and evaluated. Third, the results of the dynamic enactment of the HeLPS e-Learning Framework are presented and discussed in the context of both validation and verification aspects. **Finally**, reflections on error testing cases and conclusions are presented.

5.1 Research Evaluation Design

Evaluating the HeLPS e-Learning Framework shares the challenges of evaluating adaptive systems especially, *monolithic evaluation*. Monolithic evaluation refers to treating the system/artefact as a black box, which cannot provide granular results that can be useful in discovering system deficiencies (Manouselis *et al.*, 2011). Applying monolithic evaluation approaches in this research does not allow to discover if the problem is in modelling user capabilities or the adaptation algorithm or other system components. Hence, Separation of Concerns (SoC) principle is utilised to evaluate the HeLPS Framework effectiveness, and to provide fine-grained results that are useful at the level of the framework, its components and subcomponents (Hammad, Odeh and Khan, 2015).

Furthermore, SoC helps in explaining/integrating the evaluation results according to/with out-of-scope parameters (e.g., institutional e-learning processes). More specifically, it is not only the HeLPS e-Learning Framework quality and design choices that impact e-learning effectiveness, but also other institutional factors (e.g., supportive administrative processes and e-learning content quality) can indirectly impact the e-learner experience and the e-learning effectiveness as pointed in (Ozkan and Koseler, 2009). Since e-learning solutions and processes are context-dependent (Ruggeri *et al.*, 2013), careful considerations of various e-learning concerns need to be considered through evaluation methodology.

For the context of this research, e-learning has been divided into the following three main concerns: (i) *e-learner-oriented* concerns, which include e-learner knowledge, capabilities to interact and develop his/her skills, etc., (ii) *technological-oriented* concerns, which include technologies (i.e., e-learning solutions) used and their various qualities (e.g., performance, security, etc.) and (iii) *institutional-oriented* concerns, which include institution's components (e.g., e-learning contents, policies, processes, instructors, etc.). This research is concerned with evaluating the first two concerns. In other word, it is concerned with evaluating the impact of the early-developed HeLPS e-Learning Framework on the e-Learner Experience (i.e., e-learner oriented). Evaluating the institutional-oriented concerns is outside the scope of this research. Hence, the proposed evaluation framework, explained in Figure 5.1, is mainly based on the Validation and Verification Model (VM), and combines dynamic validation and static verification for various research components.

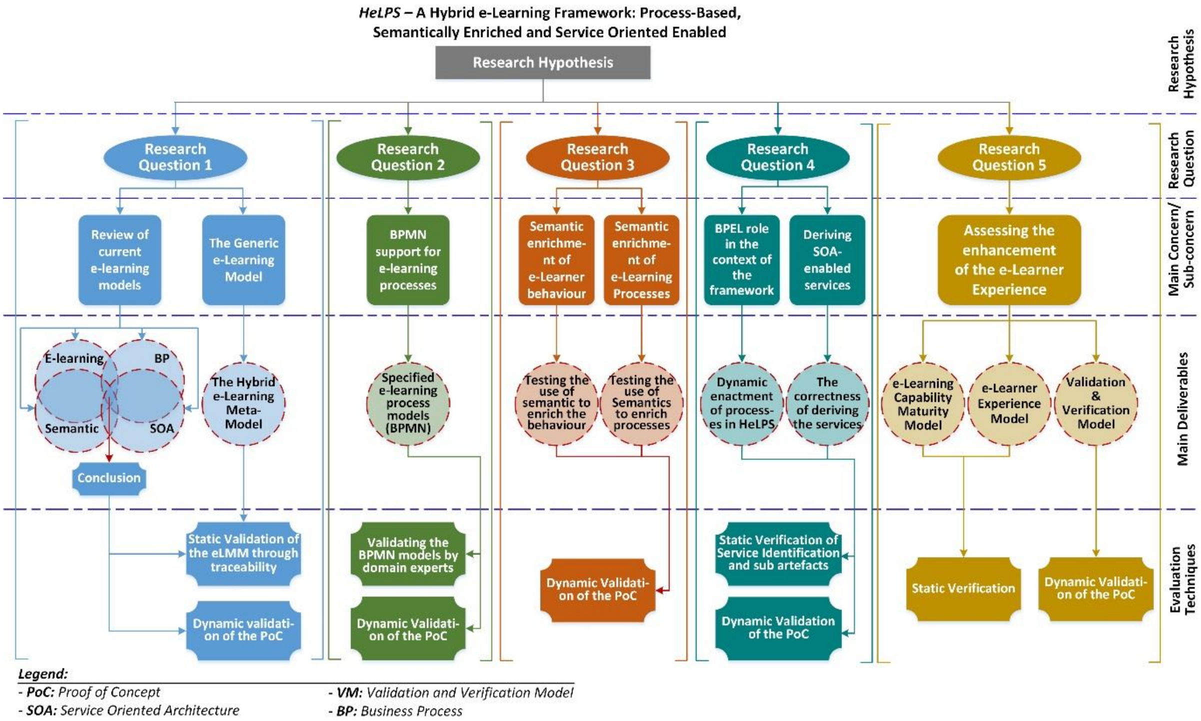


Figure 5.1: A Concern-based Evaluation Approach

Figure 5.1 shows that the research hypothesis is answered through research questions, concerns sub-concerns with their associated deliverables and evaluation technique(s). The proposed evaluation framework aims at evaluating the HeLPS e-learning framework correctness, consistency and completeness. Although completeness cannot be proven in such artefacts, but it can be shown via the sufficiency analysis. Hence, the focus should go to prove the framework correctness and consistency. So, a mixture of static and dynamic verification and validation techniques will be utilised. Static techniques are concerned with the analysis and checking of system representations such as the requirements document, design diagrams and the designed artefacts while dynamic techniques involve some experiments with the data set through the Validation and Verification Model (VM). The *VM* is a significant part of the proposed Evaluation Framework. It lists the testing cases/scenarios with their expected outputs, and aims at: (i) showing the expected and actual system behaviour in hypothetical-case instances, (ii) explains the consistency of the results in case of having similar scenarios, (iii) reveals the system deficiencies or errors in given scenarios and (iv) provides useful evidence to answer specific research questions. Table 5.1 reveals the developed research artefacts over the course of this PhD research along with their relationship to the research questions and the evaluation mechanisms.

Table 5.1: Coverage Matrix of Research Questions

Components / RQ	e-Learning Meta-model	e-Learning Processes BPMN Models	Enrichment of e-Learner Behaviour & Processes	Enacting e-Learning Processes	Deriving SOA Services (i.e., Algorithms)	e-Learner Experience Model	e-Learning Capability Maturity Model	Verification Model
RQ1	X							
RQ2		X						
RQ3			X					
RQ4				X	X			
RQ5						X	X	X
Evaluation Mechanism	Static & dynamic Validation	Static Validation	Static & dynamic Validation	Static Validation	Dynamic Validation	Static Validation	Static Validation	Dynamic Validation

5.1.1 Spiral Evaluation Process

To responds to the three early-identified concerns (i.e., e-learner, technological and institutional-oriented), the following spiral instantiation evaluation process, depicted in Figure 5.2, has been proposed. It is composed of four iterative phases, one phase for each concern and a final phase for synthesising the overall results. These phases are listed as follows: (i) handling e-learner experience concerns, (ii) handling technological concerns, (iii) handling the institutional concerns and (iv) synthesis of cross concern analysis and reflections. The innermost iteration starts with the e-learner and his/her e-learning community, the second covers the applied e-learning technologies, while the third targets the institution-oriented concerns. Despite the fact that the institutional concerns are outside the scope of this research, an iterative phase has been added to this process to reveal how the two innermost iterations evaluation results can be explained in the context of applying e-learning technologies in a particular institution. The process is represented as a spiral, where each iteration handles one concern. Each phase/loop, except the final/fourth phase, splits into the following four activities: (a) *plan*, to prepare for the setting of the evaluation phase, (b) *apply*, to put actual implementation in place, (c) *assess*, to what extent the planned and applied steps have been performed and whether there should be a link for this phase with the next phases and (d) *reflect*, to explain the results, answer why questions, extract lessons learnt or recommended practices. Having the third loop completed, one final step which is the cross-concerns analysis and reflections should be undertaken.

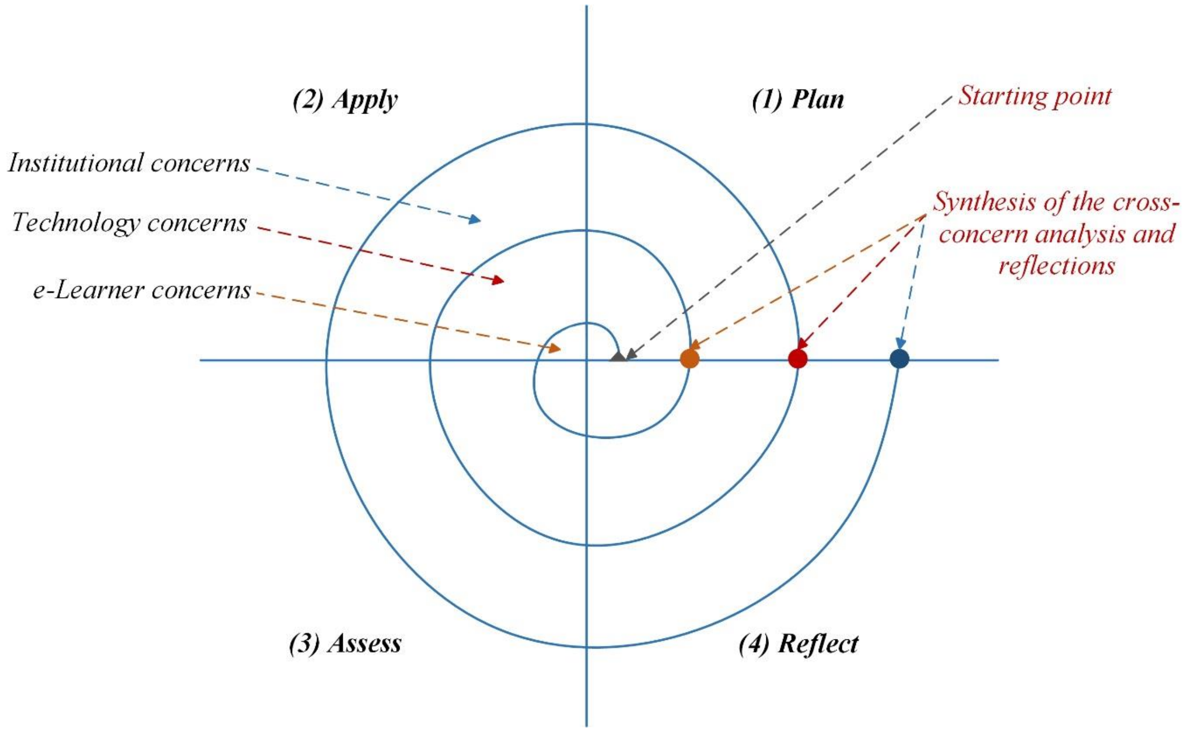


Figure 5.2: The Research Evaluation Spiral Instantiation Process

Figure 5.3 shows the final expected outcome of applying the proposed evaluation framework and its associated metrics. For instance, it shows that the ***e-learner* (*X*)** will be assigned a certain level (i.e., from level 1, the lowest to level 5, the optimised) for each construct in his/her e-Learner Experience Model. The constituent constructs of

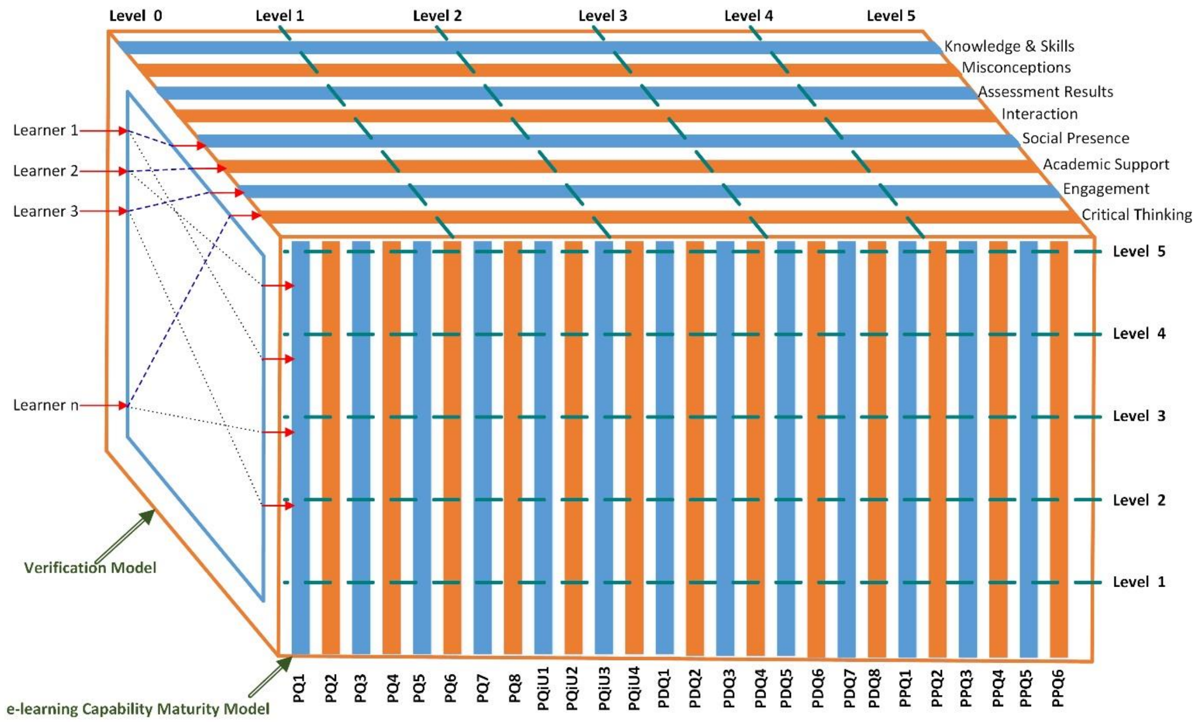


Figure 5.3: The Research Evaluation Framework Constituent Model Interaction

his/her experience, are listed on the right edge of the top rectangle and include: *knowledge and skills* up to *critical thinking*. Similarly, the same ***e-learner*** will be assigned a certain quality level (i.e., from level 1 to level 5) for the processes he/she utilised during his/her e-learning processes using the HeLPS e-learning framework. Those processes have been given various acronyms (e.g., PQ, PQiU, and PDQ as explained in e-LCMM (Section 4.6). Both models collectively provide insight inputs about how the enactment of different e-learning processes can impact the e-learner's learning experience. In summary, when the proposed e-learning framework is used by a certain e-learner, this evaluation framework will be able to tell to what extent this e-learner experience has been enhanced and the maturity level of the e-learning processes provided by the HeLPS e-Learning Framework.

5.2 The Validation and Verification Model

The Validation and Verification Model (VM) is a data-driven evaluation approach that lists sufficient number of testing cases/scenarios and their expected outputs. The VM cannot cover all the potential use scenarios due to the comprehensiveness of the e-Learning Meta-Model and consequently the large number of unique potential scenarios. As shown in the e-Learning Meta-Model description (Section 4.4.1), different constructs/parameters such as e-learner knowledge, learning styles and misconceptions contribute to adapting/customising his/her e-learning process. Hence, a multi-criteria decision making (MCDM) approach has been utilised to make the adaptation decision. Figure 5.4 depicts different e-learning processes that are generated by the HeLPS e-Learning Framework for e-learners based on their behavioural model. For readability purposes only, a subset of e-learner behavioural model constructs has been shown in figure 5.4. The total number of the unique e-learning paths is large due to: (i) the number of constructs modelled in the e-learning meta-model and (ii) the undecidable values of some of the constructs, such as: (a) learner background which could be a subject or a combination of subjects/topics and (b)

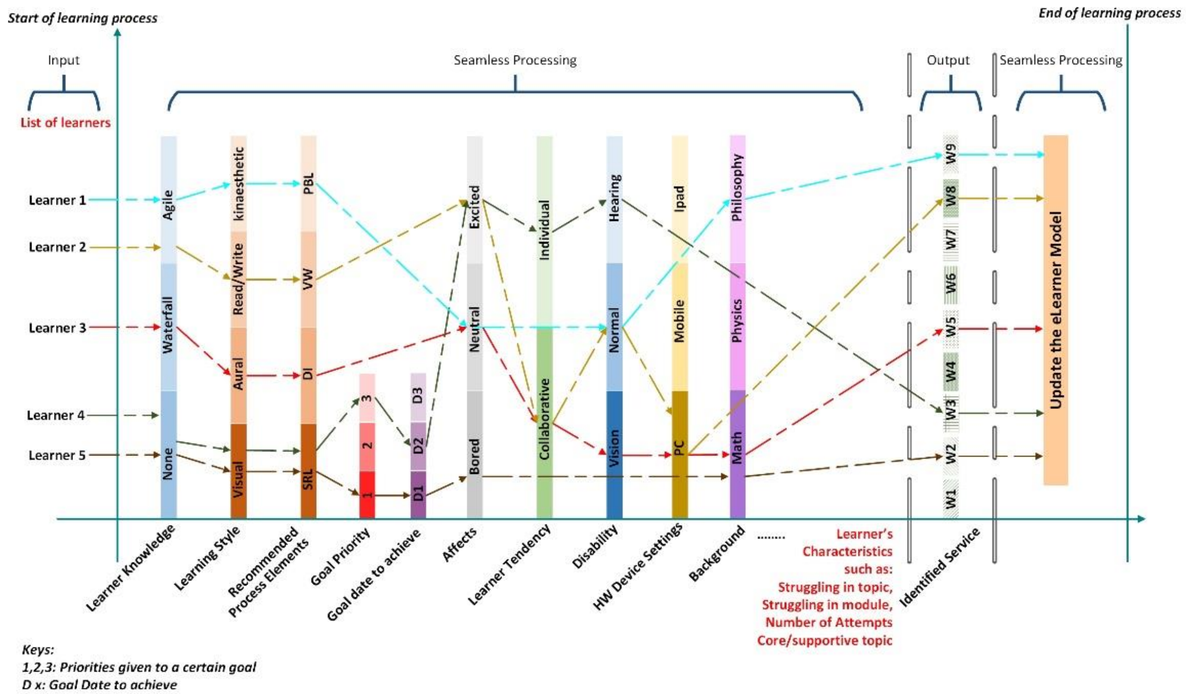


Figure 5.4: The Diversity of e-Learning Processes/Paths

a number of learning topics in a module and their pre-requisites. Therefore, a comprehensive list of variant scenarios will be carefully selected by performing a sufficiency analysis to evaluate the HeLPS e-Learning Framework. Appendix X details the experimental setup of the Valiation and Verification evaluation approach.

5.2.1 Rationale for Data-Driven Evaluation Approach

Various evaluation methodologies have been used to evaluate adaptive e-learning artefacts such as: dataset-driven evaluation (Verbert *et al.*, 2011), user studies (Knijnenburg, 2012) and real life testing or case studies (Shani and Gunawardana, 2011). Dataset-driven evaluation approaches (also called offline experiment or simulation-based) are widely used in evaluating e-learning artefacts (Baluja *et al.*, 2008; Verbert *et al.*, 2011). Datasets used in such experiments can be: (I) extracted from a real system interaction history which is challenging in this research because current e-learning systems do not have such a comprehensive set of data or (ii) artificially constructed datasets to test the performance of the algorithm, unit or system. In the second case, certain criteria such as data distribution should be followed in order to ensure the completeness and consistency of the experiments and correctness of its results (Erdt, Fernandez and Rensing, 2015; McNee, Riedl and Konstan, 2006).

Since HeLPS uses a wide range of constructs/parameters, such as pedagogy, learning style, e-learner knowledge, etc., for each e-learner. The comprehensiveness and complexity of wide range of parameters impose further restrictions on utilising real case study in given time. In case studies, e-learners use the system for a long period of time under normal conditions so their interaction as well as the system behaviour can be observed (Manouselis *et al.*, 2013). Adopting case studies is challenging as it needs the following: *First*, exposing e-learners to a mature system not a prototype for a long time so that e-learners can interact with the system and perform their tasks in real conditions. For instance, some data such as learning styles, skills (i.e., cognitive and metacognitive) and social interaction require extended system use to be captured by the system either implicitly or explicitly (Manouselis *et al.*, 2013). Furthermore, other parameters, such as the completion rate (i.e., the percentage of learners who pass a module to the whole number of learners at the time of module start) require longer time because it cannot be calculated in less than an academic term. Similarly, other indicators for an enhanced e-learner experience such as critical thinking may need more than one term to be formed and consolidated. In user studies, users are required to perform tasks in a short period of time and under a controlled environment (Erdt *et al.*, 2015), which is not suitable to capture all e-learner behavioural model constructs as mentioned above.

Second, a case study requires extended time, resources and effort for system/prototype deployment and maintenance (Erdt *et al.*, 2015). *Third*, both case study and user study need several variations of the experiment. If these variations have been evaluated by the same e-learners then user bias is expected because e-learners will notice any changes (McNee *et al.*, 2006; Shani and Gunawardana, 2011). However, if these variations have been evaluated by different groups, then the number of e-learners in each variation is expected to be less which is neither large enough nor representative to the extent that leads to significant results (Erdt *et al.*, 2015; Knijnenburg, 2012). The previous discussion has led to considering user studies as being very subjective as documented in a number of resources (e.g., (Erdt *et al.*, 2015)). *Fourth*, users' involvement might lead to the need of extended instructions, supervision, follow-up, support or training to avoid frustration and user drop which is challenging to be covered in detail during a PhD research. Although data-driven experiment cannot evaluate some aspects such as user's trust in the system (Erdt *et al.*, 2015), it is more appropriate for evaluating the proposed e-learning framework due to its ability to provide insights into the early-proposed HeLPS e-learning framework, which can be used to answer research questions. Therefore, VM adopts a data-driven approach to experiment with the system behaviour based on a *hypothetical case study and associated test cases/scenarios*.

It is also important to explain that this research is not after evaluating the data collection mechanisms (i.e., how to capture e-learners' data). Instead, this research focuses on modelling and interpreting the data and decision-making process (i.e., adaptation). In the following sections, a sufficiency analysis is conducted to ensure the construction of a comprehensive and valid data set that is sufficient for the evaluation purposes. Based on this analysis, a test input dataset will be generated along with certain acceptance criteria and coverage matrix. In this context, *Coverage Matrix* is used to explain to what extent the proposed testing cases cover the possibilities of the potential behaviour, while *Acceptance Criteria* is used to identify the measurable success indicators of the proposed e-learning framework and the possible way of measuring the success (Z. Khan, Ludlow and Loibl, 2013).

5.2.2 Sufficiency Analysis

The HeLPS e-Learning Meta-Model has (20) main/essential constructs that can affect the potential e-learning process. These constructs range from the most important, such as e-learner knowledge, learning style and recommended process element to the less important, such as interests and social-based features as shown below. Table 5.2 shows these constructs, number of potential values and their types; which could lead to a very large number of unique learning paths/processes that cannot be fully tested in this research. Types of values can be fixed (i.e., a known number) or based on assumptions (i.e., assumed number). So, a bottom up evaluation approach based on certain criteria and assumptions is devised to justify a reasonably sufficient set of testing cases/scenarios as explained below.

Table 5.2: HeLPS Main Constructs

#	Construct	No of potential values	Type of values
1.	e-Learner knowledge	3	Fixed
2.	e-Learning Process prerequisite	4	Assumption
3.	Learning style	4	Fixed
4.	Affects	3	Fixed
5.	Background	Multi (5)	Assumption
6.	Skill type	4	Fixed
7.	Learning tendency	2	Fixed
8.	Disability	3	Fixed
9.	Goal	Multi (3)	Assumption
10.	Goal priority	5	Fixed
11.	Goal date to achieve	Multi	Assumption
12.	Number of attempts	3	Fixed
13.	Feedback score	2	Fixed
14.	Learning Unit type	2	Fixed
15.	Misconception	Multi (7) using power set formula i.e. 2^7=128.	Assumption

16.	Interests	Multi (4)	Assumption
17.	Social interaction	Multi (10)	Assumption
18.	No. of topics with advancement	2	Fixed
19.	Recommended Process Elements	9	Fixed
20.	Learning Unit	Multi (3)	Assumption

Also, this section explains the criteria behind choosing the identified testing data set and why. Testing data refers to the data that has been specifically identified to be utilised in testing a given software system. The main purpose is to check whether the HeLPS e-Learning Framework, especially the e-Learning Meta-Model, can provide a customised and adaptive e-learning process for each e-learner based on a combination of the different e-learning processes in order to enhance his/her e-learning experience. Therefore, this testing utilises two approaches: (i) a *black box* that is driven by the requirement specifications and (ii) a *white box* that is driven by the programme structure and the rules/expressions (Linnenkugel and Mullerburg, 1990). To avoid the deficiency of adopting boundary testing such as its validity and inapplicability in certain cases (e.g., Boolean variables) (Murnane, Reed and Hall, 2007), the proposed data selection method is a mixture of both boundary value and equivalence partitioning testing techniques. Also, it combines functional testing through experiments and structural testing through cognitive walkthrough. This is due to the fact that structural testing cannot detect absence of functionality, while the functional one does not consider the implementation details.

Bottom-up Evaluation Approach

Since the proposed e-learning framework starts from a generalised e-learning process and customises it (i.e., further specifies it using the semantic/context) to enhance the e-learner experience, a sufficient evaluation approach would be to test the ability of the proposed framework to combine different combinations of the specified e-learning processes. As explained earlier in Chapter 4 – Figure 4.7, the nine detailed e-learning processes ($LP_1, LP_2, \ldots, LP_9$) have been derived and specified based on the thorough e-learning pedagogy analysis as well as the state-of-the-art e-learning models/artefacts. These nine e-learning processes have been abstracted in one of the following three categories: associative (ULP_1), cognitive/constructive (ULP_2), situated e-learning processes (ULP_3). Further abstraction of these three upper-level e-learning processes has led to the generic e-learning process (GLP). To fully test all possible combinations that could be generated for a given learner, there is a need to decide all possible combinations of the early specified nine e-learning processes.

All possible combinations (i.e., powersets) of the detailed nine processes can be computed throughout the following formula: $x = 2^n - 1, where\ n = 9 \qquad (formula_1)$, which equals 512 potential combinations. This combination includes:$\{(LP_1), (LP_4, LP_9), (LP_3, LP_5, LP_7, LP_8), \ldots\}$). However, calculating all possible combinations using this formula is not necessarly valid in this research, because from an e-learning perspective, a given e-learner follows an e-learning process that can be a combination of more than one e-learning process. Yet, lessons learnt from the learning domain show that this combination can be made at the level of perspectives (i.e., behavioural, cognitive/constructive and situated), which we named as Upper Level Processes, not at the detailed level of the nine e-learning processes (i.e., LP1 to LP9) (de Freitas and Jameson, 2012; Bransford *et al.*, 2006). Hence, this combination can be formed based on the upper-level of abstraction (i.e., $ULP_1, ULP_2\ and\ ULP_3$) not the detailed level. This means that any formed combination cannot contain two detailed processes from the same upper-level process category (i.e., these will be mutually exclusive). For instance, combining LP1 and LP5 is valid, while combining LP1 and LP2 or LP4 and LP6 is not valid. Consequently, the specialised/customised e-learning process for a given e-learner can be formed of: (i) single-based e-learning process, where one detailed e-learning process is used (e.g., LP3), (ii) Bi-based e-learning process, where two detailed processes (e.g., LP5 and LP9) are combined together, or (iii) tri-based e-learning process, where three detailed processes (e.g., LP2, LP4 and LP8) are combined together. Accordingly, all potential combinations will be calculated as follows:

For a ***single-based e-learning process*** the total number of possibilities is 9 which can be one of the following possibilities: $LP_1, LP_2, LP_3, LP_4, LP_5, LP_6, LP_7, LP_8\ or\ LP_9$. For ***Bi-based e-learning process*** (i.e., combinations made up of two detailed processes) the total number of unique and valid processes is 26 as explained in Table 5.3. This is supported by the fact that any combination can embrace only one detailed process from the same upper-level category. This is represented by the following formula:

$$\forall(LP_x \wedge LP_y) is\ True \equiv LP_x \in ULP_n \wedge LP_y \in ULP_m\ , where\ n \neq m \qquad (formula_{\ 2})$$

Table 5.3: Possible Combinations of Pairs of e-Learning Processes Bi-based

LP_{ID} / LP_{ID}	LP_1	LP_2	LP_3	LP_4	LP_5	LP_6	LP_7	LP_8	LP_9
LP_1	×	×	×	√	√	√	√	√	√
LP_2	×	×	×	√	√	√	√	√	√
LP_3	×	×	×	√	√	√	√	√	√
LP_4	√	√	√	×	×	×	×	√	√
LP_5	√	√	√	×	×	×	×	√	√
LP_6	√	√	√	×	×	×	×	√	√
LP_7	√	√	√	×	×	×	×	√	√
LP_8	√	√	√	√	√	√	√	×	×
LP_9	√	√	√	√	√	√	√	×	×

The above Table, Table 5.3, shows that out of the 81 combinations, there are: (i) 26 repeated combinations (i.e., marked as blue true mark √ in the above Table). For instance, $LP_4 \wedge LP_8 = LP_8 \wedge LP_4$), (ii) 29 invalid combination as a result of applying formula #2 and, (iii) 26 valid combinations – marked as black true mark (√). Therefore, only those 26 combinations will be considered. Finally, applying the second formula (i.e., formula #2) and omitting redundant combinations (i.e., LP1, LP5, and LP9 is equivalent to LP5, LP1, and LP9) has led to identify all possible ***tri-based e-learning processes*** (i.e., combinations made up of three detailed e-learning processes), as shown in Table 5.4. The total number of unique and valid tri-based e-learning processes is 24. Consequently, the overall number of unique possible combinations is: 9 + 26 + 24 = 59. Therefore, instantiating the early specified 59 testing cases allows sufficient testing for the HeLPS e-Learning Framework.

Table 5.4: Possible Combinations of Three e-Learning Processes

LP_1 Combinations			LP_2 Combinations			LP_3 Combinations		
LP_1	LP_4	LP_8	LP_2	LP_4	LP_8	LP_3	LP_4	LP_8
LP_1	LP_4	LP_9	LP_2	LP_4	LP_9	LP_3	LP_4	LP_9
LP_1	LP_5	LP_8	LP_2	LP_5	LP_8	LP_3	LP_5	LP_8
LP_1	LP_5	LP_9	LP_2	LP_5	LP_9	LP_3	LP_5	LP_9
LP_1	LP_6	LP_8	LP_2	LP_6	LP_8	LP_3	LP_6	LP_8
LP_1	LP_6	LP_9	LP_2	LP_6	LP_9	LP_3	LP_6	LP_9
LP_1	LP_7	LP_8	LP_2	LP_7	LP_8	LP_3	LP_7	LP_8
LP_1	LP_7	LP_9	LP_2	LP_7	LP_9	LP_3	LP_7	LP_9

5.2.3 Assumptions/Criteria for the Selected Testing Data/Scenarios

The following assumptions and competency questions are devised in order to identify representative enough testing cases/scenarios sufficient to answer the early-identified research questions/hypothesis. As explained earlier, the competency question approach, depicted in Figure 5.5, defines a list of questions that should be answered by the designed artefact (i.e., the HeLPS Framework) based on the early-performed research gap analysis and framework design (Gruninger and Fox, 1995). For further consistency, all assumptions, competency questions, and testing cases/scenarios are aligned with the early-identified research questions (RQs) and research artefacts as shown in Table 5.5.

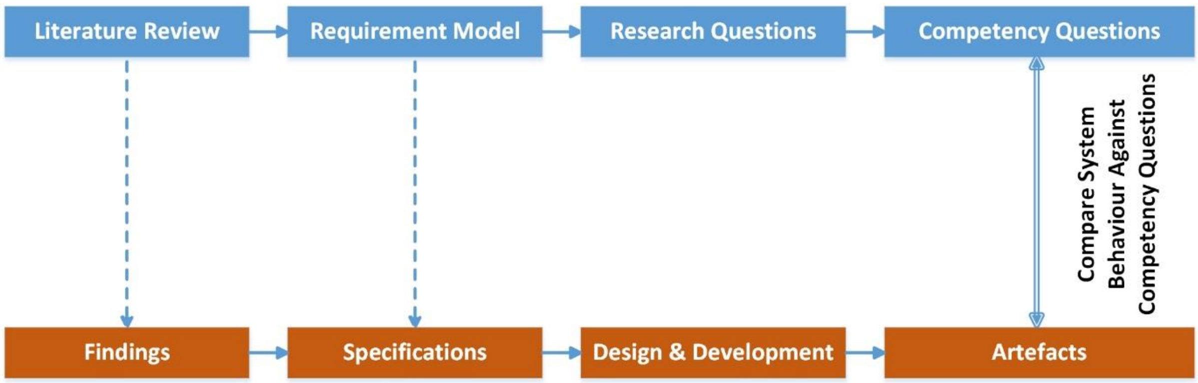


Figure 5.5: Competency Questions Utilisation in the Context of HeLPS

Table 5.5: Assumptions/Criteria for Testing Scenarios

#	RQ#	Artefact	Assumptions, Competency Questions, and Scenarios
1	Generic Assumptions		**Assumptions:** 1. Testing cases/scenarios should cover/represent different e-learning processes/paths through various values. An appropriate approach to achieve this goal is to utilise the Competency Question-based (CQ) approach (Gruninger and Fox, 1995), described and depicted below in figure 5.5, which shows how CQs are derived from the research gap analysis, requirement model, research hypothesis and questions. 2. Testing cases/scenarios should cover a various number of the e-Learning Meta-Model constructs especially the e-learner behavioural model. This is explained in the coverage matrix depicted in Table 5.7.

			3. Testing cases/scenarios should be sufficient to answer the identified research questions. 4. Testing cases/scenarios should be operational and reproducible. 5. Testing cases/scenarios should test the correctness of the rules specified in the framework (i.e., e-Learning Meta-Model, SWRL rules and the SI/D algorithms). 6. Testing cases/scenarios should generate conformance test data as well as error test data (i.e., self-induced testing). 7. Testing cases/scenarios should have multiple value in the e-learner behavioural model not a single value, so Multi-Criteria Decision-Making approach can be applied and tested.
2	RQ1	The generic e-learning process and its different level of abstractions.	**Assumption:** The specified generic e-learning process should have the capability of producing different combinations of e-learning processes from the second level of abstraction (i.e. associative, cognitive/constructive and situated) and their detailed level of processes/activities (Figure 4.7). **CQ1.1**: Is it possible to generate all possible combinations of the early-identified e-learning processes from the generic e-learning process? **Some Related Scenarios**: 1, 7, 12, 13.
3	RQ2	BPMN business process models for e-learning processes	**Assumption:** All e-learning processes along with their constituent activities that are identified from literature and classified into different categories/abstractions should be modelled in BPMN. **CQ2.1**: Is it possible to model all e-learning processes via BPMN process? **Related Scenarios**: All scenarios
4	RQ3	The hybrid e-Learning Meta-Model.	**Assumptions:** The hybrid e-Learning Meta-Model should enrich the e-learner behaviour and e-learning processes through covering a combination of the most essential meta-model constructs which include: (i) learner knowledge/Topic requested, (ii) topic prerequisite, (iii) learning style, (iv) affects (v) background (vi) learning tendency, (vii) recommended process elements, (viii) misconception, (ix) number of attempts, (x) learning unit type, (xi) feedback score, (xii) disability, (xiii) learner skill type, (xiv) learner goal, (xv) goal priority, (xvi) goal date to achieve, (xvii) social interaction, (xviii) interest, (xix) learner advancement in terms of topics and (xx) HW display setting. The selection of the above constructs is supported by the research gap analysis and various resources that they are the most important factors that affect learning processes. **CQ3.1**: Is the e-Learning Meta-Model capable of enriching the e-learning process to identify knowledge level for a certain e-learner? *If yes, then identifying the suitable web service that conform to the e-learner's knowledge is possible.* **Some Related Scenarios:** 2 and 6. **CQ3.2**: Is the e-Learning Meta-Model capable of enriching the e-learning process to identify learning style for a certain e-learner? **Some Related Scenarios:** 1, 2, 3, 8. **CQ 3.3**: Is the e-Learning Meta-Model capable of enriching the e-learning process to identify the emotional state for a certain e-learner? **Some Related Scenarios:** 1, 8, 10. **CQ3.4**: Is the e-Learning Meta-Model capable of enriching the e-learning process to identify the background for a certain e-learner? **Some Related Scenarios:** 5. **CQ3.5**: Is the e-Learning Meta-Model capable of enriching the e-learning process to identify the recommended pedagogical approach (i.e. recommended process element) for a certain e-learner? **Some Related Scenarios:** 1, 3, 5, 7, 13. **CQ3.6**: Is the e-Learning Meta-Model capable of enriching the e-learning process to identify capabilities (e.g., disability) for a certain e-learner? **Some Related Scenarios:** 6, 11.

			CQ3.7: Is the e-Learning Meta-Model capable of enriching the e-learning process to identify goals, their priorities and date to achieve for a certain e-learner? **Some Related Scenarios:** 13, 14, 15. **CQ3.7**: Is the e-Learning Meta-Model capable of enriching the e-learning process to identify the misconceptions of a certain e-learner? **Some Related Scenarios:** 4, 5. **CQ3.8**: Is the e-Learning Meta-Model capable of enriching the e-learning process via encoding/encapsulating domain-specific knowledge? **Some Related Scenarios:** 12.
5	RQ4	Enactment of e-learning process models	**Assumption:** Modelled e-learning processes should be dynamically enacted to fulfil the demands of e-learners. **CQ4.1**: Is it possible to dynamically enact all e-learning processes and derive the appropriate e-learning services from BPMNs? **Related Scenarios:** All scenarios **CQ4.2**: Are the derived services for a certain learner fully represent the corresponding e-learning BPMN process model? **Some Related Scenarios:** All scenarios
6	RQ5	The e-Learner Experience Model	**Assumption:** Modelled e-learning processes should be dynamically enacted to enhance the e-learners experience based on the hypothetical case study. **CQ5.1:** Is it possible to increase learner's knowledge/skills through the identified scenarios? **CQ5.2:** Is it possible to increase learner's assessment results through the identified scenarios? **CQ5.3:** Is it possible to resolve learner's misconceptions through the identified scenarios? **CQ5.4:** Is it possible to increase learner's interactions through the identified scenarios? **CQ5.5:** Is it possible to increase learner's social presence through the identified scenarios? **CQ5.6:** Is it possible to increase the number of positive-based academic support provided to e-learners through the identified scenarios? **CQ5.7:** Is it possible to decrease the number of negative-based academic support provided to e-learners through the identified scenarios? **CQ5.8:** Is it possible to increase learner's engagement through the identified scenarios? **CQ5.9:** Is it possible to increase learner's critical thinking abilities through the identified scenarios? **Related Scenarios for CQ5.1 - 5.9:** All scenarios.
		The e-Learning Capability Maturity Model	**Assumption:** Enacted e-learning processes for a certain e-learner must be assessed/measured against certain e-learning model. **CQ5.10:** Is it possible to critically assess the technological enhancements brought to the e-learning context through applying the identified scenarios? **CQ5.11:** Is it possible to critically assess the pedagogical enhancements brought to the e-learning context through applying the identified scenarios? **Related Scenarios for QC5.10 and 5.11:** all scenario, hypothetical
7	Generic artefacts: The HeLPS e-Learning Framework		Dynamic execution of the HeLPS e-Learning Framework Proof of Concept.
8	Service Identification and Discovery Algorithms		Dynamic execution of the HeLPS e-Learning Framework Proof of Concept.

Through the above-introduced sufficiency analysis, various assumptions and competency questions have been devised to prove that the HeLPS e-Learning Framework is capable of producing all possible combinations from the early-identified detailed e-learning processes; which have been developed through the proposed bottom up evaluation approach. In the next section, the above-mentioned scenarios will be presented and explained along with their details to evaluate the HeLPS e-Learning Framework.

5.2.4 The Testing Scenarios of the Validation and Verification Model

The Validation and Verification Model is composed of 65 testing cases and their expected outputs. Those 65 cases represent the basic 59 cases and additional 6 cases to prove the consistency (i.e., in case of repeated testing cases) and error testing cases (i.e., in case of error results). Table 5.6 details the specifications of a subset (i.e., only the first 10 cases) of those potential testing cases, whereas the complete list of cases can be found at Appendix XII. Each testing case represents one e-learner (e.g., eLearner1), his/her information and the acceptance criteria. This will be followed by the coverage matrix, for a subset of the presented testing cases to prove their conformance to the early-identified assumptions and competency questions and to show their coverage for the e-Learning Meta-Model.

Table 5.6: The Detailed Specifications of the Subset of the Validation and Verification Model Testing Cases

Constructs / Testing case ID	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	Struggling learner	Acceptance Criteria Or Expected System Behaviour
eLearner1	Waterfall Process Model	Fulfilled	Read Write	Neutral	Undefined	Cognitive	Individual	Undefined	Undefined	0	Undefined	No Disability	Undefined	Instructional Design	Reading	0	Undefined	Core	No	No	Reveal the contents of LT 1 in a behavioural-based process (i.e., behavioural text-based format).
eLearner2	Validation & Verification	Not fulfilled	Visual	Neutral	Mathematics	Undefined	Undefined	Undefined	Undefined	0	Undefined	No Disability	Undefined	Undefined	Cycling	0	Undefined	Core	No	No	Reveal remedial contents (i.e. prerequisite) to the e-learner in video-based style (i.e., intelligent tutoring process)
eLearner3	Waterfall Process Model	Fulfilled	Aural	Neutral	Physics	Cognitive	Individual	Undefined	Undefined	0	Undefined	No	Undefined	Direct Instrcution	Undefined	1	30	Core	No	Yes	The learner fails to learn this topic in the first attempts. Hence, the system should provide more support (i.e., Direct Instruction process)
eLearner4	Validation & Verification	Fulfilled	Aural	Neutral	IT	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No	Undefined	Undefined	Undefined	4	40	Core	No	Yes	The learner is struggling in the module, hence the system should join the learner to support groups that are led by advanced learners (i.e., combine LP 3 & LP 8)

eLearner5	Agile Process Model	Fulfilled	Read Write	Neutral	Mathematics	Undefined	Collaborative	Undefined	Undefined	Undefined	Undefined	No	elearner 24	Recommender System	Undefined	0	Undefined	Supportive	B	No	Reveal additional learning contents to resolve learner's misconception (i.e., Misconception B) and recommend peers to work collaboratively; combine LP2 & LP8
eLearner6	Validation & Verification	Fulfilled	Read Write	Neutral	Software Engineering	Undefined	Collaborative	Undefined	Undefined	2	Undefined	No Disability	Undefined	Undefined	Swimming	0	0	Core	No	No	This is an advance learner, the system will show a list of advanced options, such as leading support groups to help struggling learners or help others to adopt advanced learning strategies; combines LP1&8.
eLearner7	Agile Process Model	Fulfilled	Read Write	Neutral	History	Metacognitive	Undefined	Agile	Undefined	0	Undefined	No Disability	Goal-related (i.e. Agile) group	Undefined	Swimming	0	Undefined	Supportive	No	No	The system will (i) recommend SRL process and (ii) group peers based on their commonalities, i.e. learner x and learner y should have something common between them either background, goals, interests or annotations; combines LP6&8.
eLearner8	Waterfall Process Model	Fulfilled	Visual	Bored	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	No disability	Undefined	Undefined	Undefined	Undefined	Undefined	Core	Undefined	No	The system should motivate learner through recommending game-based learning processes (i.e., LP 9).

eLearner9	Validation & Verification	Fulfilled	Aural	Bored	Mathematics	Cognitive	Individual	Requirement Management	3	0	05/05/2015	No Disability	Undefined	Adaptive process	Undefined	0	Undefined	Core	No	No	The system should motivate learner through recommending contents that are relevant to his background (i.e. outside the subject being taught). For instance, Formal V&V; LP4
eLearner10	Waterfall Process Model	Fulfilled	Kinesthetic	Excited	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Undefined	Swimming	0	Undefined	Core	No	No	Provide enrichment contents to the e-learner who is eager to learn more. It should conform his/her background, interest and learning style; LP5.

Validation and Verification Model Coverage Matrix

To further support the above-mentioned sufficiency analysis, Table 5.7 shows how a subset of the testing cases (i.e., the first 15 testing cases) cover a wide range of the e-Learning Meta-Model constructs and classes. Each testing case (TC) has a list of constructs which will be used by the Proof of Concept (PoC) to make decisions related to customise the generic e-learning process for each e-learner.

Table 5.7: Validation and Verification Model Coverage Matrix

Constructs / TC #	Topic requested	Prerequisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	Goal date to achieve	Disability	Social interaction	Previous process element	Interest	No. of attempts	Feedback score	Learning Unit type	Misconceptions	No. of topics with advancement	Struggling learner	Learning unit	Module	Module component	Module specification	eContent	Context	Learning Process
TC 1	✓	✓	✓	✓			✓				✓		✓	✓	✓		✓			✓	✓	✓	✓	✓	✓	✓	✓
TC 2	✓	✓	✓	✓							✓						✓			✓	✓	✓	✓	✓	✓	✓	✓
TC 3	✓	✓	✓	✓	✓	✓							✓		✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓
TC 4	✓	✓	✓	✓							✓				✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓

TC 5	✓	✓	✓	✓	✓		✓					✓					✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
TC 6	✓	✓	✓	✓			✓				✓					✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
TC 7	✓	✓	✓	✓	✓	✓		✓			✓	✓			✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓
TC 9	✓	✓	✓	✓	✓		✓						✓		✓		✓			✓	✓	✓	✓	✓	✓	✓	✓
TC 10	✓	✓	✓	✓							✓						✓			✓	✓	✓	✓	✓	✓	✓	✓
TC 11	✓	✓	✓	✓							✓	✓			✓		✓			✓	✓	✓	✓	✓	✓	✓	✓
TC 12	✓	✓	✓	✓			✓						✓	✓			✓		✓		✓	✓	✓	✓	✓	✓	✓
TC 13	✓	✓	✓	✓		✓	✓				✓				✓		✓			✓	✓	✓	✓	✓	✓	✓	✓
TC 14	✓	✓	✓	✓		✓		✓	✓				✓	✓			✓			✓	✓	✓	✓	✓	✓	✓	✓
TC 15	✓	✓	✓	✓	✓			✓	✓	✓				✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Total	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

The Detailed Combinations of Scenarios' Attribute Values Matrix

Table 5.8 depicts the combinations of the first testing case in order to prove the wide variety of the coverage of the early-identified testing cases/scenarios. The following keys are essential to read the Table. ***First***, construct values are bold, italic and underlined. ***Second***, while cell background refers to constructs that have a definite list of values (e.g., affects). ***Third***, green background colour refers to the undecidable constructs (e.g., background). This testing scenario mainly tests behavioural/associative e-learning process based on instructional design setting, to teach waterfall software development process model topic through text-based (i.e., ReadWrite) learning style, whereas the e-learner tends to learn individually, has neutral emotional status and fulfil topic pre-requisite conditions. So, it tests multiple constructs to respond to the e-learner requirements. The rest of the combinations of other testing cases/scenarios are listed in Appendix XIII.

Table 5.8: The Combinations of the First Testing Case

Testing Case/Scenario ID: Testing Case/Scenario #1

Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	***Waterfall Process Model***	***Fulfilled***	Aural	Undefined	***Undefined***	***Undefined***	Undefined	***Undefined***	***Undefined***	***Undefined***
	Agile Process Model	Not fulfilled	Visual	***Neutral***	Physics	Cognitive	***Individual***	Waterfall	1	0
	Validation & Verification		***ReadWrite***	Excited	Mathematics	Metacognitive	Collaborativ e	Agile	2	1
			Kinaesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	***Instructional Design***	Swimming	Undefined	***Undefined***	***Core***	Undefined	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	***Reading***	***0***	< 50%	Supportive	***No***	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System		3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Communication-based		6			F	
				Virtual/Game based		7			G	

5.3 Evaluation Results

Table 5.9 shows the actual results of the dynamic evaluation of the HeLPS e-Learning Framework Proof of Concept (PoC). It lists the early-identified (65) testing cases one by one and explains the actual behaviour of the HeLPS PoC. Moreover, it shows the internal behaviour (i.e., white box verification approach) of the HeLPS key components, which allows further critical reflections for the conformance/successful testing cases as well as the error testing cases. If the actual PoC behaviour is successful based on the early-identified acceptance criteria, then the testing case will be considered as a successful one, otherwise the component behind the failure will be marked with Error. Error cases will be further analysed afterwards to find out the reasons behind the failure.

Table 5.9: Actual Behaviour of the HeLPS e-Learning Framework Proof of Concept

Testing Case ID	Actual Behaviour of the HeLPS PoC	SWRL Rules	Service Identification /Discovery	Process Representation	Successful Behaviour
eLearner1	HeLPS revealed the contents of waterfall software development process model topic in instructional design-based process setting. Content is in text-based format (i.e., ReadWrite learning style) whereas the e-learner tends to learn individually, has neutral emotional status and fulfil the pre-requisite conditions. So it tests multiple constructs.	Correct	Correct	Accurate	Yes
eLearner2	HeLPS revealed the contents of Validation and Verification topic through video-based contents (i.e., video learning style) whereas the e-learner does not fulfil the requirements of the learning process (i.e., prerequisite), therefore remedial contents (i.e., waterfall software development process model topic) has been selected and shown.	Correct	Correct	Accurate	Yes
eLearner3	HeLPS revealed the contents of Waterfall software development process model topic based on direct instruction approach because he has one failed attempt in the past to learn this topic. Learning web service is aural-based contents (i.e., aural learning style) whereas the e-learner fulfil the requirements of the learning process (i.e., prerequisite), has a physics background, neutral emotional situation. This is more-supportive approach to help the e-learner.	Correct	Correct	Accurate	Yes
eLearner4	HeLPS revealed the contents of Validation and Verification topic through aural-based contents (i.e., aural learning style). This learner is struggling in the module because he did not pass a core topic four times, therefore HeLPS recommended a more supportive approach, which includes recommending a direct instruction based e-learning process and adding this learner as a "struggling learner" to support-based group to get help and feedback from tutor and advanced e-learners, as well. Support groups are led by advanced learners to help instructors.	Correct	Correct	Accurate	Yes
eLearner5	HeLPS revealed the contents of Agile software development process model topic through text-based approach (i.e., readwrite learning style) whereas the e-learner fulfil the requirements of the learning process (i.e., prerequisite), tends to learn collaboratively and has misconception B based on his/her previous record. Also, remedial contents to resolve this misconception have been shown and collaborative-based learning process has been recommended as he tends to learn collaboratively as shown in the social interest construct.	Correct	Correct	Accurate	Yes

eLearner6	HeLPS revealed the contents of Validation and Verification topic through text-based contents (i.e., readwrite learning style) whereas the e-learner is an advanced learner due to his advancement in two learning topics and tends to learn collaboratively, therefore an option of leading support-based group to help struggling e-learners has been revealed to him as well.	Correct	Correct	Accurate	Yes
eLearner7	HeLPS revealed the contents of Agile software process model topic through text-based contents (i.e., readwrite learning style) based on SRL learning process settings. Also, the learning process suggested relevant peers based on their commonalities, goals, interests or annotations (i.e., elearner13). In this context, peers are grouped in social-based group (not support-based group) to allow further interaction to increase their engagement within the system	Correct	Correct	Accurate	Yes
eLearner8	HeLPS revealed the contents of Waterfall software development process model topic through game-based learning approach whereas the e-learner fulfils the requirements of the learning process (i.e., prerequisite) and has bored emotional status.	Correct	Correct	Accurate	Yes
eLearner9	HeLPS revealed the contents of Validation and Verification topic through audio-based contents (i.e., aural learning style) whereas the e-learner fulfils the requirements of the learning process (i.e., prerequisite) and has bored as an emotional status. To motivate the e-learner, HeLPS recommended contents that are relevant to his/her background (i.e., outside the subject being taught), in this case the topic was the formal verification approaches.	Correct	Correct	Accurate	Yes
eLearner10	HeLPS revealed the contents of Validation and Verification topic through learning by doing approach (i.e., kinaesthetic learning style) whereas the e-learner fulfils the requirements of the learning process (i.e., prerequisite) and his emotional status is excited, therefore an enrichment contents will be shown to the e-learner because he/she is expected to be eager to learn more.	Correct	Correct	Accurate	Yes
eLearner11	HeLPS revealed the contents of Agile software development process model topic through audio-based contents (i.e., aural learning style) whereas the e-learner fulfils the requirements of the learning process (i.e., prerequisite), has a vision disability. Therefore audio-based contents supported by assistive technologies, such as ALT for images or Braille capable text is shown. Game-based learning services do not exist, was not possible to match all preferences.	Correct	Error, required game-based learning service is not available	Accurate	Error
eLearner12	HeLPS revealed the contents of Validation and Verification topic through learning by doing approach (i.e., kinaesthetic learning style) whereas the e-learner fulfils the requirements of the learning process (i.e., prerequisite) and tends to learn individually, therefore a constructive-based approach such as learning by doing has been shown to the e-learner.	Correct	Correct	Accurate	Yes
eLearner13	HeLPS revealed the content of Agile software development process model topic in self-regulated learning process through video-based contents (i.e., visual learning style) whereas the e-learner fulfils the requirements of the learning process (i.e., prerequisite). The metacognitive skills is the reason for having SRL process. Also, communication-based process element has been recommended so the e-learner can talk to peers and invite them to his/her space.	Correct	Correct	Accurate	Yes
eLearner14	HeLPS revealed the content of Waterfall software development process model topic through SRL-based process supported by learning by doing (i.e., kinaesthetic learning style) whereas the e-learner fulfils the requirements of the learning process and has metacognitive skills. Therefore, the first goal, which has higher priority, has been recommended first to the e-learner.	Correct	Correct	Accurate	Yes

eLearner15	HeLPS revealed the content of Agile software development process model topic through SRL-based process in text-based contents (i.e., ReadWrite learning style) whereas the e-learner fulfils the requirements of the learning process (i.e., prerequisite), has metacognitive skills, set of goals with priorities and date to achieve. Therefore, goals have been listed based on their date to achieve construct.	Correct	Correct	Accurate	Yes
eLearner16	Reveal the contents of LT 3 SRL settings with helps from instructor (i.e., combines LP3 & LP6).	Correct	Correct	Accurate	Yes
eLearner17	Reveal the contents of LT 2 in a problem-based learning process (i.e., combines LP1 & LP7).	Correct	Correct	Accurate	Yes
eLearner18	Reveal the contents of LT 1 in a problem-based learning process supported by intelligent tutoring system and communication-based processes (i.e., combines LP2, LP7 & LP8).	Correct	Correct	Accurate	Yes
eLearner19	Reveal the contents of LT 2 SRL settings in video-based behavioural format (i.e., combines LP1 & LP6).	Correct	Correct	Accurate	Yes
eLearner20	Reveal the contents of LT 2 in a behavioural and problem-based learning process supported by game-based process (i.e., combines LP1, LP7 & LP9).	Correct	Correct	Accurate	Yes
eLearner21	Provide situated–based learning process based on communication elements, contents for LT1 will be available but the learner can find his/her topics; LP8.	Correct	Correct	Accurate	Yes
eLearner22	Provide content for LT3 and recommend contents relevant to the learner background; combine LP1 &LP4	Correct	Correct	Accurate	Yes
eLearner23	Reveal the contents of LT 1 in a problem-based learning process supported by direct supervision (i.e., combines LP3 & LP7).	Correct	Correct	Accurate	Yes
eLearner24	Reveal the contents of LT 2 through recommending the proper contents and peers and support this with intelligent tutoring-based process element to resolve the learner's misconceptions (i.e., combines LP2 & LP4).	Correct	Correct	Accurate	Yes
eLearner25	Reveal the contents of LT 2 through recommending the proper contents supported by direct instruction-based process element to closely supervise the learner behaviour & game-based process to attract him (i.e., combines LP3, LP4 & LP9).	Correct	Correct	Accurate	Yes
eLearner26	Reveal the contents of LT 2 in a behavioural, problem-based learning process supported by communication-based process (i.e., combines LP1, LP7 & LP8).	Correct	Correct	Accurate	Yes
eLearner27	HeLPS revealed the pre-requisite (i.e., the waterfall process model lesson before showing the required Agile process model learning topic but failed to show the proper format to resolve the learner misconception, because it was mainly based on text only.	Correct	Error	Error	Error
eLearner28	Reveal remedial contents for LT 2 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception and communication-based process (i.e., combines LP2, LP5 & LP8).	Correct	Correct	Accurate	Yes
eLearner29	Reveal the contents of LT 2 in a problem-based learning process supported by intelligent tutoring system and game-based processes (i.e., combines LP2, LP7 & LP9).	Correct	Correct	Accurate	Yes
eLearner30	Reveal contents for LT 2 in a direct instruction process supported by adaptive process elements to resolve the learner misconception and situated communication process to help him (i.e., combines LP3, LP5 & LP8).	Correct	Correct	Accurate	Yes
eLearner31	Reveal remedial contents for LT 2 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception and game-based process (i.e., combines LP2, LP5 & LP9).	Correct	Correct	Accurate	Yes
eLearner32	Reveal the contents of LT 2 in problem-based learning process supported by direct instruction and game-based process elements (i.e., combines LP3, LP7 & LP9).	Correct	Correct	Accurate	Yes

eLearner33	Reveal contents for LT 2 in a direct instruction process supported by adaptive process elements to resolve the learner misconception and situated game-based process to motivate him (i.e., combines LP3, LP5 & LP9).	Correct	Correct	Accurate	Yes
eLearner34	Reveal the contents of LT 2 in problem-based learning process supported by direct instruction and communication-based process elements (i.e., combines LP3, LP7 & LP9).	Correct	Correct	Accurate	Yes
eLearner35	Provide game-based learning process to motivate the learner, contents for LT1 and relevant peers (i.e., combine LP4 & LP9).	Correct	Correct	Accurate	Yes
eLearner36	Provide SRL process and game-based learning process to motivate the learner (i.e., combines LP6 & LP9).	Correct	Correct	Accurate	Yes
eLearner37	Provide situated communication-based learning process to connect the learner with his peers, contents for LT3 (i.e., combine LP4 & LP8).	Correct	Correct	Accurate	Yes
eLearner38	Reveal contents for LT 3 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception and communication-based process (i.e., combines LP1, LP5 & LP8).	Correct	Correct	Accurate	Yes
eLearner39	Reveal contents for LT 2 in a direct instruction process supported by adaptive process elements to resolve the learner misconception (i.e., combines LP3 & LP5).	Correct	Correct	Accurate	Yes
eLearner40	Provide SRL process and game-based learning process under direct supervision from instructor -i.e., direct instruction process element - (i.e., combine LP3, LP6 & LP9).	Correct	Correct	Accurate	Yes
eLearner41	Reveal the contents of LT 1 in a problem-based learning process supported by intelligent tutoring system process (i.e., combines LP2 & LP7).	Correct	Correct	Accurate	Yes
eLearner42	Reveal contents for LT 3 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception and game-based process (i.e., combines LP1, LP5 & LP9).	Correct	Correct	Accurate	Yes
eLearner43	Provide aural-based adaptive learning process for LT1 supported by communication process elements (i.e., combine LP4 & LP8).	Correct	Correct	Accurate	Yes
eLearner44	Provide SRL process to the learner which allows him to create & manage his learning space/ talk to peers. This should be supported by intelligent tutoring element to show remedial contents in game-based learning process (i.e., combine LP2, LP6 & LP9.	Correct	Correct	Accurate	Yes
eLearner45	Reveal the contents of LT 2 through recommending the proper contents and peers and support this with (i) intelligent tutoring-based process element to resolve the learner's misconceptions and (ii) game-based process element (i.e., combines LP2, LP4 & LP9).	Correct	Correct	Accurate	Yes
eLearner46	Provide a behavioural-based learning process supported by game-based learning process elements (i.e., combines LP1 & LP9).	Correct	Correct	Accurate	Yes
eLearner47	Reveal the contents of LT 2 through recommending the proper contents supported by direct instruction-based process element to closely supervise the learner behaviour & communication with peers to help him in his learning (i.e., combines LP3, LP4 & LP8).	Correct	Correct	Accurate	Yes
eLearner48	Provide problem-based learning process for LT1 supported by communication process elements (i.e., combine LP7 & LP8).	Correct	Correct	Accurate	Yes
eLearner49	Provide SRL-based process to allow the learner to regulate his learning. This process should be supported by behavioural-based content in the form of game-based process (i.e., combine LP1, LP6 & LP9.	Correct	Correct	Accurate	Yes

eLearner50	Reveal the contents of LT 2 through recommending the proper contents and peers and support this with (i) intelligent tutoring-based process element to resolve the learner's misconceptions and (ii) communication-based process element (i.e., combines LP2, LP4 & LP8).	Correct	Correct	Accurate	Yes
eLearner51	Provide remedial learning contents and additional contents to resolve the learner's misconception. This should be supported by game-based learning process element (i.e., combine LP2 & LP9).	Correct	Correct	Accurate	Yes
eLearner52	Reveal the contents of LT 2 through recommending the proper contents supported by direct instruction-based process element to closely supervise the learner behaviour (i.e., combines LP3 & LP4).	Correct	Correct	Accurate	Yes
eLearner53	Provide SRL-based process to allow the learner to regulate his learning. This process should be supported by behavioural-based content and communication based elements (i.e., combine LP1, LP6 & LP8).	Correct	Correct	Accurate	Yes
eLearner54	Provide instructional-based process to show LT2 contents in the appropriate video format supported by adaptive process elements to resolve the learner misconception (i.e., combine LP1 & LP5).	Correct	Correct	Accurate	Yes
eLearner55	Provide direct instruction learning supported by game-based learning process element (i.e., combine LP3 & LP9).	Correct	Correct	Accurate	Yes
eLearner56	Reveal the contents of LT 1 through learning by doing and communication-based process element (i.e., combines LP7 & LP8).	Correct	Correct	Accurate	Yes
eLearner57	Provide content for LT3, recommend contents/peers relevant to the learner record supported by game-based process element (i.e., combine LP1, LP4 & LP9)	Correct	Correct	Accurate	Yes
eLearner58	Provide SRL and communication-based learning process under direct supervision from instructor -i.e., direct instruction process element - (i.e., combine LP3, LP6 & LP8).	Correct	Correct	Accurate	Yes
eLearner59	Provide problem-based learning process for LT1 supported by game-based process elements (i.e., combine LP7 & LP9).	Correct	Correct	Accurate	Yes
eLearner60	HeLPS revealed content for Validation and Verification topic, in the form of recommender system learning process. This e-learner has no peers in his/her record and therefore, the communication-based element did not work effectively.	Error	Error	Error	Error
eLearner61	HeLPS revealed SRL supported by game-based learning process element - (i.e., combine LP6 & LP9).	Correct	Correct	Accurate	Yes
eLearner62	Return an error message because the requested learning services cannot be provided.	Error	Error	Error	Error
eLearner63	HeLPS revealed problem-based learning process for Waterfall software development process in text-based format	Correct	Correct	Accurate	Yes
eLearner64	HeLPS revealed instructional-based learning services for Agile process supported by communication-based process elements to engage the learner and reveal contents to resolve his/her misconceptions	Correct	Correct	Accurate	Yes
eLearner65	HeLPS revealed the contents of Validation and Verification in a problem-based learning process supported by direct instruction.	Correct	Correct	Accurate	Yes

As shown in Table 5.9, the HeLPS e-Learning Framework PoC behaviour is successful in 61 testing cases out of 65 testing cases. According to the results of the above-listed testing cases/scenarios, the HeLPS e-Learning Framework is capable of specialising the generic e-learning process according to the e-learner behavioural model as well as the context of the e-learning process. Specialising the generic e-learning process is not limited to combining different e-learning processes, but also includes showing: (i) the proper e-learning contents for the e-learner based on his/her knowledge level (e.g., testing case 2), learning style (e.g., testing case 1), etc. It also includes showing different functionalities in certain settings (e.g., Self-regulated e-learning processes) such as allowing the e-learner to plan his/her learning goals and reflect on them. Moreover, it includes recommending peers and joining the e-learner to different groups based on his/her interest, background, and achievements or progress. In the next two sub-sections, further reflections on the Validation and Verification will be shown.

5.3.1 Verification in the Context of the HeLPS Proof of Concept

In light of the results shown in Table 5.9, this section illuminates the verification aspects of the HeLPS Proof of Concept in order to assure that the HeLPS framework has been developed right. As explained in the HeLPS e-Learning Framework Architecture (Chapter 3), and the Design and Development (Chapter 4), different components underpin HeLPS behaviour. This includes the e-learning process models – which will be validated in the next Section–, the eLMM, the SWRL rules, and the service derivation (i.e., identification and discovery) approach. *Firstly*, the eLMM is an essential artefact of the HeLPS Framework as it supports all the 65 testing cases. As explained earlier in Section 4.4.1, specialising the generic e-learning process for a particular e-learner is carried out based on the eLMM contextual inputs such as the e-learner knowledge level, his/her skills and so on. For instance, in the *e-learner 9* testing case, the recommended e-learning process is the Validation and Verification topic which is part of the Software Engineering Module, because this e-learner is enrolled in the software engineering module as shown in the eLMM.

Secondly, the SWRL rules specified in the eLMM play essential roles in responding to the e-learner's demands. For instance, the Validation and Verification is recommended because this e-learner (i.e., e-learner 9) fulfils the Validation and Verification topic pre-requisites. This is decided by SWRL rule ID 20 specified at Appendix III. Similarly, in the *e-learner 4 testing case*, the third SWRL rule – Appendix III – defines this e-learner as a struggling e-learner in the module because: (i) he/she was not able to pass the formative assessment element of this topic in his two previous attempts and (ii) this topic (i.e., V&V) is a core topic. In the eLMM, all topics are classified either as core or supportive topics. Those e-learners who are struggling in two core topics in a particular module are considered as *struggling e-learners in the module*. The eLMM and the SWRL rules support the HeLPS e-Learning Framework to respond to this category of e-learners by providing further supportive learning approaches. For example, in the e-learner 4th case, a direct instruction-based e-learning process has been recommended to the e-learner so he/she can remain under the instructor observation during his/her e-learning process. Additionally, this e-learner will be joined to the support-based group, where advanced e-learners can help and guide other e-learners with lower level of progress.

Another example on how the eLMM and SWRL rules perform to specialise the generic e-learning process is the *e-learner 13th testing case*, where different SWRL rules have been automatically fired to recommend a self-regulated e-learning process (through SWRL Rule ID #1) supported by video-based e-learning contents (through SWRL Rule ID 10). *Thirdly*, the service derivation approach from the e-learning business process model has led to derive a list of web services that are sufficient and representative enough to the corresponding e-learning business process model. The first step in this approach is to identify the services and then to discover them from the service registry.

Some of these services are *utility services* that are very common such as login service, *application services* that are very specific to the HeLPS application such as check e-learner goals, or core services that are designed to present the e-learning contents and their assessment elements. In all of the above (65) testing cases, the service derivation approach provided satisfactory results, except the error cases that will be explained in Section 5.4. To conclude, the above discussion proves that these sub artefacts perform the roles that have been specified to them early, and therefore this affirms that the HeLPS e-Learning Framework has been developed right. The next section will illuminate the validation aspect of the HeLPS e-Learning Framework to ensure that it is the right artefact that can respond to the early-performed research gap analysis.

5.3.2 Validation in the Context of the HeLPS Proof of Concept

This section affirms that the early-developed HeLPS e-Learning Framework Proof of Concept is the right product that is capable of responding to the research gap analysis (Section 2.9). This involves checking whether the implemented Proof of Concept meets the expectations and the requirements of the e-learners. These requirements have been described earlier as acceptance criteria. *First*, most of the testing cases that have been listed in Table 5.9 prove the HeLPS e-Learning Framework capability to provide a hybrid e-learning approach through combining different e-learning models, theories and pedagogical approaches in order to respond the e-learner requirements (Section 2.9 – conclusion point #1). This can be seen, as examples, in testing case number 13, 18, 26 and others as stated in Table 5.9. *Second*, the above-listed testing cases show that the use of process-based approaches in the e-learning domain guide e-learners and allow them to achieve their goals (e.g., master the intended learning outcomes/topics, resolving their misconceptions and so on). This can be seen as all e-learning activities are specified in business process modelling notations using BPMN 2.0. This responds to the research gap analysis (Section 2.9 – conclusion point #2). Selected examples include testing cases number 1, 4, 12 and others. However, this use of process-based approaches remains in need for contextualisation as will be discussed in the next point.

Third, the successful behaviour of the HeLPS Proof of Concept is basically supported by its ability to use semantic technologies to capture the context of the e-learning process and the e-learner behaviour and specialise the e-learning process for a particular e-learner based on the conceptualisation of the e-learning domain (i.e., the e-Learning Meta-Model). This includes an extended list of e-learning concepts, relationships, and rules that are specified in SWRL. *Fourth,* and according to the results of experimenting the previously-mentioned testing cases, the HeLPS Proof of Concept dynamically enacts all of the e-learning processes, with marginal errors to be discussed later, in a SOA-enabled environment. This responds to the fourth point in the early-performed research gap analysis (Section 2.9) to increase the agility and avoid the legacy of the e-learning artefacts, because a wide range of services will be available to respond to the e-learner requirements. However, this opens the door for future research to establish a policy to control the quality of the available web services, and consequently approve or disapprove services that do not conform to the policy.

Fifth, the HeLPS Proof of Concept proves that the use of MDE principles, as recommended in the research gap analysis (Section 2.9 – conclusion point #5), is useful in two folds. On the one hand, it allows to conceptualise the e-learning domain including concepts, relationships, restrictions, and domain-specific concerns (e.g., when to provide a direct instruction or self-regulated learning for a particular e-learner) in the eLMM. On the other hand, MDE allows generating a specialised e-learning process for a particular e-learner from the generic e-learning process that has been presented earlier. All of the 65 testing cases can be considered as examples on using semantic technologies (i.e., the third point in the above discussion), using business process techniques to model and enact e-learning processes in SOA-enabled environment to adopt flexible design (i.e., the fourth point in the above discussion), and adopting various MDE principles to abstract from technical complexity and allows developing more generic solutions that can respond to a wide range of e-leaners (i.e., the fifth point in the above discussion). Reflecting on the above-mentioned conclusions of the research gap analysis assures that we have developed the right product that can respond to the e-learner's requirements and enhance his/her experience. Further insights on validating sub components/artefacts of the HeLPS Framework is also useful as follows.

The first artefact is *the process-based approach*, which has been used specify the most common e-learning processes from the literature, model them, and generalise them in one generic e-learning process model that can be dynamically enacted. In this respect, two domain experts[8] from two different domains, faculties (Education and Computing), universities, and geographically places reviewed and validated the early-developed e-learning business process models. Their main recommendations were related to using common domain-specific terms/ language to specify e-learning processes and their activities. For instance, using the term *learning outcomes* instead of *learning objectives* or *learning goals*; e-learning contents instead of topics, etc. Also, being consistent in describing all activities in order to bring further coherence to the specified e-learning processes. For instance, using *instructor* instead of *subject matter expert*. Moreover, improving the description/annotations of all e-learning processes to make them clear. Additionally, using the same level of abstraction in describing all e-learning activities. Finally, dividing some of the activities into a list of constituent activities to precisely specify them. For example, it is recommended to divide the following activity "design and publish e-learning contents", into two different activities (i.e., design and publish). Also, further explanation of the design activity, whenever is possible, is preferred, as this will make these activities clear and understandable by various stakeholders.

The second artefact is the *generalised e-learning business process model*. In order to respond to the research gap analysis, a generalisation process has been proposed by the researcher to develop a generalised e-learning process model from the early-identified detailed e-learning processes. This generalisation approach has been validated as well by the two domain experts to check whether it adapts to all other e-learning processes and their activities or not. The third artefact to be discussed in this section is *the eLMM*. To ensure the validity of this artefact, traceability matrices have been provided in Appendix IV, as mentioned earlier. These matrices reveal the traceability of the eLMM on three different levels of detail: (i) *level A*, at the core elements level, (ii) *level B*, at the core and supportive elements level, and (iii) *level C*, at the rule level.

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The fourth artefact is the *e-Learner Experience Model*. As stated earlier, the 65 testing cases combine elements (e.g., activities, rules, etc.) from different e-learning processes, and therefore, these e-learning processes target more than one construct of the e-Learner Experience Model. For example, the focus of the first e-learning process (i.e., e-Learner 1, Figure 5.4) is to increase the e-learner' knowledge as well as resolving his/her misconceptions. However, the focus of the fifth e-learning process (i.e., e-Learner 5, Figure 5.4) goes to increase the e-learner's critical thinking abilities and his/her interaction. Overall, all of the above-mentioned testing cases aim to increase the e-learner knowledge and skills and this must be reflected on the e-learner's assessment results. As stated above, the eLEM successfully models the e-learner experience in all of the previously-discussed testing cases as follows. 20% of the testing cases target the academic support construct of the eLEM, 18% of the testing cases target the engagement construct of the eLEM, 16% target the critical thinking construct and engagement construct of the eLEM, 14% of the testing cases target the interaction construct of the eLEM, 11% of the testing cases target the misconception construct of the eLEM, and 8% of the testing cases target the social presence construct of the eLEM. This proves eLEM capability to successfully model the e-learner experience in various contexts (e.g., behavioural, pedagogical, etc.)

The fifth and the final artefact is the e-Learning Capability Maturity Model (eLCMM). The eLCMM, as explained in Section 4.6, is composed of the following four Key Process Areas (KPA): (i) Product Quality, (ii) Quality in Use, (iii) Data Quality, and (iv) Pedagogical Quality. Within the current evaluation design settings only selected set of the Product Quality (PQ) processes (Table 4.8) can be evaluated because the remaining KPAs require applying the HeLPS e-Learning Framework in real institutions, which remains for future work. The HeLPS e-Learning Framework Proof of Concept (PoC) has been given the evaluated and assigned the following levels as follows. *First*, although HeLPS PoC and its components can exchange information and use the information that has been exchanged with ability to share resources, it will be assigned 3 out of 5. This is due to the fact that HeLPS PoC cannot share its services with other artefacts. *Second*, although HeLPS PoC can be used by a wide range of people with different capabilities in specific contexts to achieve user goals, it will be assigned level 3 out of 5. This is because HeLPS PoC cannot automatically detect cognitive disabilities (e.g., psychological disorders) and deal with them. *Third*, although HeLPS PoC is composed of discrete layers and components so that changes can be made without degrading product quality, it will be assigned level 4 out of 5. This is due to HeLPS PoC deficiency in integrating with third party software systems in a well-documented and supported way.

Fourth, although HeLPS PoC is operational and accessible when required for use, it will be assigned level 4 out of 5. This is because HeLPS PoC does not employ defect detection and prevention techniques that are continuously optimising to proactively respond to any interruptions. *Fifth*, HeLPS PoC can effectively and efficiently be adapted for different or evolving usage requirements, it will be assigned level 4 out of 5. This is because of HeLPS PoC deficiency in learning from its behaviour and dynamically forming rules in order to respond to the continuously evolving e-learner's needs and requirements. *Sixth*, HeLPS PoC can be used by specified users in specified context of use to achieve specified goals with effectiveness, efficiency and satisfaction, it will be assigned level 3 out of 5. This is because HeLPS PoC cannot protect users against making errors through clear direction and interface design choices. In the light of the above results, the overall assessment of the HeLPS PoC is satisfactory as not related to

HeLPS functionalities. They are either out of scope (i.e., do not impact the e-learner experience) or related to HCI concerns such as interface design. Applying the eLCMM on mature e-learning software systems that are tested in terms of their performance, scalability, etc. can lead to better results. To conclude, the above-mentioned discussion in this section proves that the HeLPS e-Learning Framework is the right product that can respond to the research gap analysis performed in Section 2.9.

5.4 Results Reflections in the Context of Research Questions

As shown in Table 5.9, only four testing cases are error cases, while the rest of the cases are conformance cases. Table 5.10 reflects on these error cases and reveals the reasons behind this failure in terms of the output of the internal components/structure of the HeLPS e-Learning Framework. In addition, this section illuminates on the results in the context of the early-identified research questions to show how these results contribute to answering them. Then, it reflects on some of the limitations of the developed PoC, and alludes to some future directions that will be further explained in Chapter 6.

Table 5.10: Reflections on Error Testing Cases

Testing Case ID	Reason behind expected and actual behaviour mismatch	Directions for future work
Testing Case 11	The required web service is not published in the UDDI. The preferred web service should be game-based, prepared for visually impaired learners and incorporate the aural learning style. Such web service does not exist in the UDDI at the time of execution.	This case is expected to happen again even in the case of less keywords. Therefore, further web services are needed to fulfil the e-learners' demand. Hence, an automatic wrapping mechanism for the available online e-learning contents might be used to expand the available learning services/resources. Including human in the loop to validate the wrapped contents and supervise the quality may be one of the solution.
Testing Case 27	Misconception resolving web services have been designed and published as a separated web services. In other word, they are not linked to the learning web services of the main learning units (i.e., waterfall, agile and validation and verification lessons). They have been designed in text format only and disability features have not been considered. Therefore, the PoC failed to meet the demand of the learner because the	Better analysis for the contents and the web services must be in place. Misconception resolving services might be designed as methods inside one service or more depending on the analysis of the contents and bearing in mind the two basic principles loose coupling and high cohesiveness. There should be some trade off during the design and development of such services. Adding too much

	identified web service is not designed for visually impaired learners.	contents/methods for the same service will nullify the SOA reusability features.
Testing Case 60	HeLPS failed to recommend the relevant learning peers as there is no one who shares the same interest with elearner60. Despite the fact that HeLPS added this learner to the support-based group as a "struggling learner" to get some knowledge from other advanced learners, but without any added value, because there is no advanced e-learner match to this e-learner's preferences.	Further SWRL rules need to be identified, developed and specified in order to help stakeholders (i.e., e-learners, instructors and organisations) to achieve their educational goals. For example, in this case the e-learner must be linked directly with the instructor. This needs to be done based on implementing this PoC in real settings instead of prototyping.
Testing Case 62	HeLPS recommended SRL process for this e-learner due to his/her capabilities, which allows him/her to plan his/her learning process and finding related resources to achieve the early-identified goals. Yet the required web service was not modelled in the system (i.e., outside the scope of the contents designed for this PoC).	The solution here could be establishing a stronger link between the advanced e-learner and their community (i.e., instructor and peers). This will allow the instructor, if he got proper notifications, to add further contents automatically or semi-automatically. Another solution could be devising additional SWRL rules to encourage such an advanced e-learner to fully adopt the social learning theory as an alternative approach to search, design, publish, rate and recommend contents with peers.

The above-mentioned four error testing cases show how the HeLPS e-Learning Framework may lead to unsatisfactory results. Such errors are mainly produced due to the deficient human involvement in the e-learning processes. For instance, it might be related to the way of designing the learning/assessment contents in the form of web services as they might be not properly structured, described or annotated. One of the potential solution for this case is to use semantic web services, not only web services, to capture the semantics of learning services in a better way. This needs to be done by adding another layer to the current e-Learning Meta-Model to produce a computational-specific model that can deal with semantic web services. Additional error cases could happen if the requested e-learning web services are not existed in the UDDI (i.e., service registry). Also, it could be related to the poor design of some of the contents or the insufficient number of e-learners who share the same model with the intended e-learner and must be available so that the e-learner can follow a social-based e-learning process.

Nonetheless, the above outcomes of applying the developed PoC need to be explained in the context of the early-identified research questions as follows. ***First***, as explained above, HeLPS e-Learning Framework is capable of producing various variations of hybrid e-learning processes for different e-learners based on their behavioural models and process contexts. Experimenting the 65 testing cases proves that combining elements from different e-learning processes is possible and leads to coherent processes. This aspect of the evaluation satisfies the first research question as follows as each technology (i.e., Business Process, Semantics and SOA), we may call them research components for this context only, contributes differently to generating this hybrid e-learning process. The pedagogical component provides the foundation to generate a hybrid process that is pedagogically useful (i.e., enhance the e-learner experience). It is backed by certain domain-specific rules that decide when and how to combine different elements from various e-learning processes in a meaningful way. So, all possible sufficient and representative enough combinations of the nine detailed e-learning processes have been produced by HeLPS and therefore the answer of the first research question is: yes, HeLPS can provide all possible combinations of detailed e-learning processes in the form of a hybrid e-learning process. ***Second***, the Business Process Modelling Notation supports specifying the e-learning processes and dynamically enacting them. One of the key particularities of the e-learning domain is related to its manual activities (e.g., the activity "The e-learner has to comprehend/understand the presented learning unit"). Such activities require introducing additional activities to check to what extent this activity has been realised or implemented (i.e., successful activity or failed activity). This adds further complexity to the e-learning processes because such activities significantly vary. One activity might be simple quiz, while the other might require massive human contributions (e.g., interactions with instructor) and consequently different judgments whether this activity has been successfully implemented or not may occur. However, it has been demonstrated throughout the Verification Model that BPMN supports the modelling and the enactment of the identified e-learning processes, with certain limitations related to semantics as will be discussed in the next section. This part of evaluation experiment answers the second research question and concludes that industrial-standard Business Process Modelling Notation supports the e-learning processes to the sufficient level of modelling the processes and their activities and enacting them, but with limitations in capturing the semantics of e-learning processes, which will be discussed in the next paragraph.

Third, the BPMN limited capability in capturing the semantics, has led to developing the third technological component, e-Learning Meta-Model and SWRL rules to semantically-enrich the HeLPS Framework. This contributes to capturing the overall context of e-learning processes and domain-specific knowledge and acting as customisation engine (i.e., making inference about a certain e-learner). All of the previous testing cases have benefited from this research component. This part of the evaluation experiment answers the third research question and consequently the semantic-based approaches can enrich e-learning processes and most particular e-learner's behaviour through capturing their characteristics to guide their future e-learning processes. This enrichment has been useful enough to dynamically generate a specific e-learning model from the e-Learning Meta-Model. ***Fourth***, HeLPS underpinning logic is service-oriented. So, the early-modelled e-learning processes need to be dynamically enacted in a SOA-enabled environment to derive the relevant software services that meet the e-learner's requirements. BPEL plays the intrinsic role of representing the e-learning processes of the 65 testing cases shown in Table 5.14 in an XML-based scripts to automatically execute them by Business Process Execution Server. So, the BPEL scripts of all of the 65 e-learning processes have been executed correctly. This correct execution only means that all BPEL scripts have been dynamically executed. It does not mean that the derived services are correct. This answers that fourth research questions and concludes that all BPMNs can be dynamically enacted in a SOA-enabled environment.

Fifth, the e-Learning Evaluation Framework along with the application of the Validation and Verification Model explains that combining the early-identified technologies (i.e., Business Processes, Semantics and Service-orientation) in one e-learning framework, as explained in the research design (i.e., Chapter 3), can enhance the e-learner experience, at least theoretically. Such research outcomes have led to answer all the research questions and conclude that the e-learner experience can be enhanced, as will be further explained in the Conclusion Chapter.

5.5 Conclusion

In this chapter, a new e-learning evaluation approach has been proposed. It is mainly based on the validation and verification model and it uses the early-developed e-Learner Experience Model and e-Learning Capability Maturity Model as metrics or measurement tools. The experiment (dynamic enactment of the HeLPS Proof of Concept) carried out in the previous sections, along with its results, shows that all research questions have been answered to the sufficient level. More specifically, *first* it shows how the generic e-learning process (i.e., derived from the literature) has been tested and proved its capabilities in covering a wide range of e-learners' demands. *Second*, the dynamic enactment of the modelled e-learning business process models reveals how the industrial standard business process modelling notation is capable, with some limitations as will be discussed in Chapter 6, to capture the e-learning processes. *Third*, also the dynamic enactment of these e-learning processes shows how semantics technologies have been used: (i) to capture the e-learner behaviour and the e-learning process context and (ii) to use the captured information in order to enrich the modelled e-learning processes during the dynamic enactment phase. *Fourth* in all of the previously-discussed 65 testing cases, a set of software services have been derived from the e-learning business process models in order to meet the e-learner's demands. *Fifth*, the above-developed evaluation design proved that the HeLPS e-Learning Framework can be critically assessed against the early-performed research gap analysis.

Further reflections on these results and the answers of the research questions will be explained in Chapter 6. Yet, this proposed evaluation framework should be applied in real organisations to discover its strengths and weaknesses. Although this evaluation framework is designed to respond to the following concerns: e-learner, technology, and institution, there are other e-learning aspects that require further detailed models/metrics to be evaluated but they are outside the scope of this research. Examples on such aspects include usability, which is very important for e-learning. Such concerns remain for future work on the so that the results of applying the proposed evaluation framework can be aligned/integrated with the results of evaluating other e-learning concerns. Evaluating such aspects can be simplified to the level of applying System Usability Scale (SUS) or complicated to the level of developing advanced evaluation tools (e.g., heuristic usability evaluation).

Furthermore, adopting Separation of Concerns for evaluating the HeLPS e-Learning Framework is challenging as the borders between the three identified e-learning concerns are not clear (e.g., UX and Usability). To some extent, UX evolved from usability, and consequently, different UX measure are driven from usability (Albert and Tullis, 2013). This does not deny that UX is more complex, composed of a mixture of social, physiological and psychological concepts. For instance, emotions are intrinsic in UX, where these emotions are the results of learner's cognitive interpretations of perceptual sensory responses (Hartmann, De Angeli and Sutcliffe, 2008). To conclude, real applications of the proposed evaluation framework in different settings (more than one educational institutions, higher and further education, various subjects, etc.) will significantly improve the framework, its settings, instantiation process and its applicability. Moreover, the real application will also give the chance of applying/testing the current e-learning models/theories and the capability of forming hybrid e-learning approaches, especially the social learning theory and how it can be combined with other e-learning models. One of the related potential enhancement for the current framework is the need for further SWRL rules to regulate the social-based learning models (e.g., Learner Support-based Group leading and participation tasks and when the human (i.e., instructor or facilitator) must intervene. Such tasks cannot be restricted for a certain type of e-learners (e.g., advanced learners) because this will nullify its goal. So, more flexible rules need to be developed to allow effective social-based e-learning models. Such development needs the involvement of human users and educational experts, which remains for future work.

Chapter 6:

Conclusion and Future Work

6.1 Introduction

This research investigated the feasibility to formally specify e-learning processes, generalise them in a generic e-learning process, enrich the generic e-learning process for a certain e-learner based on his/her behavioural model and the context of his/her e-learning process, dynamically enact the early-specified and enriched e-learning process and derive the services that can meet the e-learner' demand. It was demonstrated that the business process domain is not only useful in specifying and enacting e-learning processes, but also in comprehensively capturing the e-learning process and achieving a coherence between its activities. This research was carried out using a mixed research method that combines case study with experimental method, where the HeLPS e-Learning Framework has been developed and evaluated. This chapter is organised as follows. Section 6.2 summarises the key contributions to knowledge. Section 6.3 addresses the answering of the research hypothesis and associated research questions. Section 6.4 highlights future directions.

6.2 Key Contributions

The key contribution to the knowledge in this research is **to minimise the early-identified research gap** by developing a hybrid e-Learning framework that is process-based, semantically-enriched, service oriented-enabled in order to enhance the e-learner experience. The principal contributions of this research are summarised below ordered by their significance. First**, The HeLPS e-Learning Framework**, which is the main artefact in this research. It consisted of three main basic layers in addition to two supportive layers that work as metrics. Within the HeLPS Framework, the following main concerns are critically investigated: (i) e-learning business process, (ii) the semantic enrichment of the early-specified process, and (iii) the service orientation that is designed to meet the enactment of business process. Second**, Business Process Adoption in e-Learning** has been achieved, because e-learning processes have been derived from the literature, generalised, modelled and dynamically enacted in SOA-enabled environment. Third, using **Semantic technologies (Ontology and SWRL)** to capture the semantics of e-learning domain, and more specifically processes, and the e-learner behaviour so that a specific instance of the generic e-learning process can be transformed to a specific e-learning process. Fourth, developing a **Semantically-enriched**

Service Identification and Discovery algorithms to identify and discover web services from a certain instance of an e-learning business process model.

Fifth, an **e-Learner Experience Model (eLEM)** has been developed to identify what is meant by the e-learner experience and to quantify and measure it in certain context. Sixth, an **e-Learning Capability Maturity Model (eLCMM)** has been proposed inspired by the Software Engineering Capability Maturity Model to assess the quality of e-learning processes from technological perspective. Seventh, a concern-based **e-Learning Evaluation Framework**, has been developed based on the following three main artefacts: the eLEM, the eLCMM and the data-driven Verification Model to test and verify e-Learning Software Systems. Eighth, **a Generalisation Approach for a Business Process Model** from a set of related business processes sharing the same goals and associated objectives has been devised. Ninth, the comprehensive capture of the e-learning context through the use of e-learning process instead of e-learning activities and capturing the semantics of e-learning through the e-Learning Meta-Model and specialising the generic e-learning process for a particular e-learner, which is a part of applying **Model Driven Engineering (MDE)** techniques.

Since HeLPS e-Learning Framework is expected an automated solution, it is expected to help stakeholders, especially instructors, to user their time in a better way, and consequently improve the management of e-learning software systems. The above-mentioned contributions belong to both theory and practice. For instance, deriving e-learning business process models from learning literature, formalising them, and developing a generalisation approach to produce a generic e-learning process model is a proper example on theory. The HeLPS e-Learning Framework its self and its supportive models, more specifically the e-Learner Experience Model and the e-Learning Capability Maturity Model belong to practice.

6.3 Fulfilment of the Research Hypothesis and the Research Questions

The instantiation of the HeLPS e-Learning Framework using the early-identified hypothetical case study, followed by the evaluation framework has led to conclude that Business Process, Semantics and Service orientation technologies can be applied in e-learning as designed and demonstrated respectively in Chapter 3 and 4. However, the outcome of such application needs to be discussed in order to answer the research questions as follows:

Research Question 1: What e-learning models exist and whether these can lead to the development of a generic e-learning model?

There exist several e-learning models with different features and capabilities. Some of these models are *content-oriented* (e.g., Learning Object), some are *semi-process* where e-learning processes (i.e., sequence of activities) are: (i) hardcoded into systems' code and design and (ii) not formalised using formal business process approaches (e.g., Learning Management Systems). There exist a limited number of conceptualised process-based e-learning systems, with a limited number of functionalities. A wide range of e-learning models have been selected, classified into different categories, investigated by a semi-process approach to derive their main elements and the relations between their elements and have led to defining a generic e-learning model that combines elements from a wide range of e-learning models. The defined generic e-learning model works as a meta-model that represents the most essential elements of common e-learning models and consequently can satisfy the requirements of a large number of e-learning practitioners. Due to the richness of learning as a domain of this research, it is very challenging to prove that a given e-learning model is generic to the extent that can lead to every single model in e-learning. Instead, the proposed model can meet the demands of a wide range of e-learning practitioners. The proposed model combines eight main concepts and an extended list of supportive concepts along with their attributes and relations between elements. The main elements are: (i) learning process, (ii) learning activities, (iii) pedagogy, (iv) context, (v) content, (vi) facilitating tools, (vii) presentation format and (viii) actor.

The proposed model is hybrid in a way that (i) it adopts different pedagogical approaches (i.e., learning theories) in order to satisfy the demands of different learners and lead to a rich learning process and (ii) it utilises various technologies (i.e., process-based, semantic and SOA) to combine different inputs and to achieve the goal of enhancing the e-learner experience. In addition, this research has employed Model-Driven Engineering techniques to represent this hybrid model into a semantic e-Learning Meta-Model. The proposed meta-model is Computational and Platform independent (CIM and PIM respectively), where further platform specific models are generated in the subsequent layers of the proposed framework. Description Logic-based Web Ontology Language (OWL-DL) has been used to specify the proposed meta-model to capture its semantic. To conclude the answer, the existing e-learning models can lead to development of a generic e-learning model that exhibits a wide number of capabilities and consequently can respond to a wide range of practitioners.

Research Question 2: To what extent can industry-standard business process modelling and notation support e-learning processes? For instance, BPMN may not be fitting with e-learning activities, it could model the necessary activities but not enough to capture the whole process.

Industry-standard Business Process (BP) technology is utilised in this research in two folds: (i) modelling of e- learning processes and (ii) their dynamic enactments. Adopting BP techniques in e-learning domain has its roots in the Educational Modelling Languages (EML) research, such as the Open University Netherland (OU) EML and CDF Swiss Federal Institute of Technology (EPEL). The OU EML, among other EMLs, has been standardised in the form of IMS Learning Design (LD). Despite the heavy research in IMS LD, its adoption level is low due to its large number of limitations as mentioned in the literature review. This motivates the researcher to choose an Industry-standard BP modelling tool (i.e., BPMN) to specify e-learning processes, which includes activity flow, interaction and so on. Two different types of activities are distinguished in modelling e-learning processes and e-learning activities. First, activities that can be implemented technologically (e.g., extracting e-learner model and searching for e-learning contents). Second, activities carried out by human (e.g., understanding the presented learning topic or changing the e-learner's misconception). The BPMN 2.0 has the capability, among other capabilities, to model such activities under the title of "manual activities."

From BP perspective, especially automation-wise, manual learning activities are challenging because it is not straightforward to decide to what extent these activities have been implemented correctly. Processes in other domains (e.g., health-care) include manual activities, as well (e.g., perform an MRI scan for a given patient), yet such activities are easily judged whether they have been implemented or not. In e-learning domain, manual activities should be decomposed to simpler activities to the extent that this decomposition can help in deciding if this process/activity has been modelled and executed correctly or not. For instance, understanding a topic will be followed by an assessment activity to judge learner understanding. Judging to what extent BPMN has been useful in modelling e-learning processes requires recalling the goal of modelling these processes which is the automated execution/enactment of these processes in a distributed computational environment. To precisely and effectively specify e-learning processes, the researcher performed a detailed analysis of the current e-learning models and their underpinning pedagogical models in order to specify e-learning processes as clear as possible. A generalisation approach for these business process models has been proposed by the researcher (Hammad, Odeh and Khan, 2017c), its application has led to specify a generic e-learning business process model. The business process models were semantically enriched by instantiating the BPMN 2.0 ontology with these models, using the instaBPMN20 utility by Ahmed (Mahmoud Ahmed, 2015). Therefore, the generic e-learning process can be transformed to a more specific one by consulting the semantic representations, encoded in the proposed framework ontology. This will help also in resolving the ambiguity of e-learning processes.

Having these e-learning processes captured in BPMN models, the logical step is to execute them in a SOA-enabled e-learning services. BPEL is the de-facto standard for defining executable processes. Translating BPMN models to their BPEL counterparts has been thoroughly investigated as discussed in literature and as a result a list of tools/plug-ins have been produced. This research utilises the most recent translation approach which is BPMN2BPEL plugin. This allows enacting the early specified e-learning processes into SOA-enabled e-learning services through a given business process execution engine (i.e., WSO2), as identified earlier.

Research Question 3: What is the extent that semantic-based approaches can enrich e-learner's processes and the e-learner's behaviour?

Existing e-learning artefacts adopt semantic technologies to offer adaptive e-learning systems, but this adaptivity was limited to recommending contents or learning peers based on different characteristics (e.g., e-learner's learning styles) modelled in the e-learner profile/model. However, this research claims that learning is neither restricted to learning contents nor learning peers or community. Learning is a comprehensive process that involves a series of activities done by the learner, interacting with different actors, interacting with e-learning contents and resources that are presented in different formats (e.g., text or video) based on sound pedagogical foundations situated in certain contexts and finally facilitated by technological tools. Hence, semantics are applied in this research in two folds. **First**, the Web Ontology Language (OWL) is used to specify the hybrid e-learning meta-model that encode the following eight essential elements: actor, process, activity, context, content, pedagogy and learning theories, tools and presentation formats and their supportive elements. The essential elements are supported with a list of supportive elements along with their data properties (i.e., attribute) and object properties (i.e., relations between elements). This hybrid model reuses one of its components (i.e., Business Process Modelling and Notation Ontology) to capture the semantics of different learning processes adopted by e-learners.

Bringing semantic to business process modelling and execution is challenging as current industrial standards notations (e.g., BPMN) are useful at the business level but with minimum level of text description and semantic; therefore, reasoning over these processes is not achievable (Cabral *et al.*, 2009). Effective semantic coverage requires effective context-aware modelling and notation techniques which is not available to the enough extent. Hence, BPMN ontology has been adopted to work in cooperation with other ontological components (e.g., eActor Ontology) of the hybrid e-learning model in order to provide effective semantic base for rich e-learning processes. This BPMN ontology works as a process meta-model for different e-learning processes adopted by e-learners and helps in resolving the ambiguity of e-learning processes. These e-learning processes have driven from a thorough pedagogical analysis performed by the researcher (i.e., Chapter 2) and are organised into the following two levels. *The specialised level of e-learning processes* which includes nine different e-learning processes and *the abstract level of e-learning processes* which includes one generic e-learning process that embraces activities from those detailed nine e-learning processes. As stated earlier, the main aim of this hybrid model is to generate different e-learning paths for e-learner based on their behavioural model as well as other contextual inputs. In other words, the proposed e-learning framework will generate a specified learning process from the generic one based on certain domain-specific rules. Such rules, specified in SWRL, represent the **second** way of applying the semantics in this research. These SWRL rules represent a layer that works on the top of OWL to extend it and to increase its reasoning capabilities. The early-developed verification model demonstrates the ability of those components (i.e., the hybrid e-Learning Meta-Model specified in OWL and the SWRL Rules) to generate different e-learning paths based on different e-learners' characteristics.

Research Question 4: Could the semantically-enriched e-learning process model and e-learners' behaviour be enacted dynamically using service oriented enabled e-learning services so that the e-learner experience is enhanced?

The semantically-enriched e-learning process model as well as the e-learners' behavioural model is encoded in the hybrid e-Learning Meta-Model discussed the previous research question (i.e., RQ 3). As stated above, BPEL was selected in order to dynamically enact the identified e-learning processes. This enactment will result in deriving proper e-learning service from a list of candidate e-learning services that are available for that learner. Web services has been chosen to meet the demands of e-learners due to the well-known characteristics such as loose coupling, reusability and formal definition through WSDL. In addition, the e-learning framework adopts SOAP web services due to their flexibility. Furthermore, keyword-based technique has been adopted to discover web services that are described by WSDL. These keywords are the results of firing the SWRL rules for a specific learner based on his/her model. Each web service is composed of two methods: the first is *the learning method* that presents learning contents and the second is *the assessment method* that has the assessment elements. The use of web services has its disadvantages as well, such as difficulties in sending a large amount of data but there are some technical frameworks that can help in this issue.

The main goal of identifying the candidate web services is to enhance the e-learner experience. As one of the research contributions, an e-learner experience model has been proposed by the researcher to measure the outcome of using an e-learning system by a specific e-learner in a specific context. As identified earlier, 'a learner's knowledge' is only one element of e-learner experience model. Other elements such as learner engagement and interaction with the learning community are implicitly captured by the system and recorded in the learner behavioural model, so they can be used to measure the e-learner experience later.

Research Question 5: What Model/Framework can be developed/derived from existing e-learning literature to critically assess the enhancement of the e-learner experience when facilitated using service oriented enabled e-learning services?

The success of Capability Maturity Model (CMM) in Software Engineering domain has inspired the idea of developing CMM in different domains. The most mature attempts in developing a maturity model is the e-learning Maturity Model (eMM). However, the target of this Maturity Model is the institutional level. In other words, eMM is designed to assess the capabilities of a given institution to sustainably develop, deploy and support an e-learning programme in a way that could lead to high quality processes. Therefore, the proposed e-Learning Capability Maturity Model (eLCMM) extends eMM capabilities through being technologically-oriented. The eLCMM includes the e-learning system capabilities (e.g., interoperability and modularity) categorised in different Key Process Areas and described on a scale of maturity from one to five. The eLCMM is driven from the early-identified model-based e-learning effectiveness evaluation approach (Hammad *et al.*, 2015), which has been built based on: (i) ISO 25010 System and software Quality Requirements and Evaluation *Product in Use* Model and *Product Quality* Model and (ii) ISO 25012 *Data Quality* Model to identify a list of capabilities that should be offered by e-learning system. Both eLEM and eLCMM have been combined with the early-developed Verification Model to form the e-Learning Evaluation Framework that can assess the enhancement in the e-learner experience when applying the HeLPS e-Learning Framework in certain context.

As explained above, HeLPS e-Learning Framework: (i) starts with a specific instance of the generic e-learning process for a particular e-learner, and (ii) specialises this process based on the semantic information available for that particular e-learner, and finally (iii) enacts the specialised process to derive services that meet the e-learner's demand. The utilisation of semantic technologies played the key roles, with the support of other HeLPS components, in specialising the generic e-learning process for a particular e-learner; and consequently, increasing his/her experience by increasing his knowledge, social interactions, and so on. Test cases, listed in Table 5.9, explain that all possible combinations of the detailed e-learning processes can be generated from the generic e-learning process. All of these *processes* have been modelled via BPMN and then represented via BPEL scripts to be enacted in SOA-enabled environment. Moreover, *semantic* technologies have been used to enrich these processes, e.g., the goals of e-learners have been captured via semantic technologies and used later to derive the best e-learning contents for him/her, whether this content is learning web services or assessment web services. The derivation of web services, as explained in Table 5.9, proves that these processes can be *dynamically enacted* in SOA-enabled environment.

In addition, the white box testing approach used in Section 5.3 explains that e-learner experience can be *enhanced* as the recommended e-learning process for that particular e-learner helps him to acquire the suitable level of new knowledge, resolve any misconceptions, engage with his/her peers, and consequently increase his/her overall assessment results. Nonetheless, HeLPS e-Learning Framework is a *hybrid* artefact because it utilises: (i) the process-based industrial standards Business Process Modelling Notation and Business Process Execution Language to model various e-learning processes and dynamically enact them, respectively, (ii) semantic technologies to capture the context of e-learning processes and to enrich them during the enactment phase, and (iii) SOA enabled environment to execute the early-modelled and enriched e-learning processes. Aditionally, HeLPS e-Learning Framework is *hybrid* as it has been informed by the knowledge of the e-learning domain, its applications, theories, models, and underpinning pedagogical frameworks and models. The above discussion reveals that the early-identified research questions (i.e., RQ 1 - RQ 5) have been answered and consequently proved the following research hypothesis: "***A hybrid, semantically-enriched and process-based e-learning framework when enacted using service oriented enabled e-learning services enhances the e-learner experience.***" To fulfil the lifecycle of this research, a number of future research directions will be explained in the next section.

6.4 Research Limitations

This research is limited to fine-grained e-learning processes, which include flow of activities and interaction implemented by e-learners and other supportive stakeholders to achieve specific short-term goals (e.g., mastering a lesson). Even though these processes are essential in any e-learning systems, they need additional supportive processes, such as course-grained e-learning processes that might span over one more academic term/year, management processes, design processes, etc. Expanding the scope of this research to cover these processes entail further complexity as they significantly differ in terms of their roles (i.e., stakeholders), time frame, relationships and dependencies on each other's. Also, this requires a multi-disciplinary involvement from educational experts, higher education institution leaders, quality experts, legal specialists, etc. which is far beyond PhD scope. Additionally, the dynamic enactment of such processes will be challenging to large extent as this entangled environment will further complicate the service identification and discovery algorithms. Furthermore, including these processes will increase the human interventions (i.e., manual activities). These manual activities might be interpreted differently by different instructors; and therefore, will impact the learning processes differently. Potential solutions for this might be developing clear policies and guidelines to guide users on the best possible ways of using such tools.

Other limitations of this research include the fact that the HeLPS e-Learning Framework can only be effective if sufficient e-learning web services are well-designed, described, and published. The current utilisation of web services in e-learning domain is very low due to many reasons including web services limited capability in handling large data (e.g., video or second life contents). Additional limitation is the limited utilisation web services in the HeLPS e-Learning Framework. For instance, the use of semantic web services needs to be thoroughly investigated in the context of the big data and learning analytics. Moreover, the current research is focused around academic institution models, which is based on formal learning models. However, there is a need to expand the scope and context of HeLPS to include recent innovative contexts such as smart cities (Hammad and Ludlow, 2016) and Internet of Things.

6.5 Future Research Directions

Below is a list of the key future research directions emerged during the life cycle of this research:

6.5.1 Adopting Further Advanced Contextualisation Approaches

Since this research puts further emphasis on capturing the e-learning context (i.e., the eLMM) and use this context to enrich the e-learner learning processes, further development for the eLMM and other semantic-oriented artefacts such as SWRL rules in needed. Such development aims to respond to the richness of the e-learning domain by allowing instructors, or other authorised stakeholders, to customise/edit certain types of e-learning rules. For instance, instructors should be given the ability, if they want, to decide the number of failed attempts required to classify a particular e-learner as a struggling e-learner in a topic or module. The HeLPS e-Learning Framework utilises various generic thresholds in such cases, but these thresholds might differ from one context/subject to another, therefore there is a need for a dynamic rule development process so that such thresholds can be modified automatically or semi-automatically.

Also, there is a need to empower the eLMM so it can guide and test various e-learning models. For instance, Self-Regulated e-learning processes need additional tools to facilitate the implementation of SRL concepts. Such tools allow e-learner to set their goals, monitoring their progress, prioritising their actions, etc. These tools should be designed based on an extended version of the eLMM, so that better recommendations can be given to e-learners. Another example of empowering the eLMM to better guide/test certain e-learning models is to expand the current list of the eLMM constructs/attributes to test controversial e-learning models, such as connectivism and its underpinning social learning theories. This can be done by putting more focus on various cultural aspects of e-learners, e-learning communities in order to test their impact on the e-learner experience and behaviour. Additional constructs need to be analysed to provide better learning experience. These constructs might be: (i) individual, such as: gender (i.e., the difference between male and female in learning), religion, etc. or (ii) group based, such as the relationship between e-learners in a certain group and the kind of communication model used among certain group members.

6.5.2 Expanding the Scope of the HeLPS e-Learning Processes

Amongst the various categories of e-learning processes identified in the literature, this research, as explained earlier, targets the learning-oriented e-learning processes. Therefore, any other administrative, logistic, design and development processes are not investigated in this research. Covering these processes will significantly impact the e-learning processes and the e-learner experience because of the various dependencies and inter-relationships existed between different categories of e-learning processes. For instance, the process of designing and development of e-learning contents will provide further insights on learning outcomes and detailed e-learning concerns that can be handled differently by different instructors or content designers. Similarly covering other categories of e-learning processes (e.g., management processes) might impact the e-learner experience. For instance, they will provide more control on to what extent other stakeholders respond to the e-learner's demands and interact with the e-learning communities. Hence, an effective analysis for all categories of e-learning processes must be carried out to identify relationships, dependencies, time frame, intersections or contradictions, if any. This is expected to lead to a valuable knowledge that can be encoded at a higher level of abstraction. This abstraction might be encoded in various meta-models (e.g., e-learning management meta-model, e-learning design meta-model, etc.) which can be integrated with the early-developed e-Learning Meta-Model (eLMM). Another abstraction levels might be bringing the Business Process Architecture domain to abstract the details of all e-learning business processes used in e-learning.

6.5.3 Improving the Service Orientation Module of the HeLPS e-Learning Framework

The current utilisation of the service orientation in the HeLPS e-Learning Framework is mainly dedicated to deriving web services from business process models. This is carried out through the following two main phases: Service Identification from a business process model and Service Discovery. So, candidate services have been identified from a business process model, and then mapped to web services. The process of deriving services from e-learning business process is not complicated as the scope of this research is limited to learning-oriented e-learning processes. However, expanding the research scope and covering various management, logistics, design, and development processes will lead to a large list of intertwined processes/activities. Such kind of processes vary in terms of their time scale. For example, the current e-learning processes start when the e-learner wants to learn a topic and ends when he/she achieve the intended learning outcomes/objectives. However, management processes time scale might be longer, especially in case of planning or programme re-structuring and so on. This means there is a need for further complicated service identification and derivation process where more composite candidate services are expected to be used. Also, the proper process/service boundaries, as some of these services might be manual or sermi-automated, and quality criteria must be considered. Another area to invetigate as well is the move towards more distributed environments such as cloud-based environment, where various research challenges can be further examined.

6.5.4 Further Development and Testing for the HeLPS e-Learning Framework Supportive Models

To respond to the early-performed research gap analysis (i.e., the deficiency of quantifying and measuring the e-learner experience as well as the maturity of technological e-learning artefacts), the following two models have been developed: the e-Learner Experience Model (eLEM) and the e-Learning Capability Maturity Model (eLCMM). Both models need to be applied in a real scenario, where various institutions – two to three – with significant differences in their education systems, locations, and cultures are selected to test to what extent these models are generic and applicable. One of the potential eLEM (Hammad, Odeh and Khan, 2017b) testing scenarios is to assess its capability in modelling and quantifying the e-learner experience for those e-learners who follow different e-learning models (e.g., behavioural e-learning model, social e-learning model, or hybrid e-learning model). Also, the eLEM needs to be assessed in relation to different taught subjects (e.g., theoretical, applied, etc.), where different learning and teaching mechanism are utilised. Similarly, the eLCMM needs to be tested in different hardware and software settings. This includes legacy e-learning systems, SOA-enabled, Cloud-based, or other distributed e-learning systems arrangement. The human involvement of this testing process is essential specially to test the pedagogical qualities of the HeLPS e-Learning Framework.

6.5.5 Enhancing the Process of Capturing the e-Learner Behaviour

An essential part of the e-Learning Meta-Model (eLMM) is the e-Learner Behavioural Model, which plays an inevitable role in specialising the generic e-learning process for a particular e-learner. However, a successful e-learner behavioural model must employ effective behavioural capturing processes and mechanisms. In order to avoid the e-learner disappointment, such processes are recommended to work behind the scene according to the lessons learnt from the research gap analysis. This means opting for implicit techniques to decide the e-learner's learning styles, his/her affects, etc. this also is related to the scale, model, or the baseline used to model the e-learner behavioural characteristics. For instance, for *learning styles* construct only more than 120 models exist in the literature. Hence, further investigation is needed to decide which one of them is more suitable for a particular subject, so it can be used to model the e-learner learning style. Moreover, investigations need to be carried out to decide whether it is appropriate to allow the privileged stakeholders such as the instructor or the system administrator to choose the best model for a particular module, subject, or programme. More challenges are expected to be faced in the near future when capturing the e-learner behaviour as we are heading towards more distributed environments, where various devices (e.g., mobile, laptops, etc.) with different settings, learning models, and configurations (e.g., virtual reality) are used by e-learners. This necessitates experiment-based investigations for e-learner modelling techniques.

6.5.6 Incorporating the HeLPS e-Learning Framework with Existing e-Learning Systems

As the HeLPS e-Learning Framework aims to provide a flexible e-learning environment, there is a need to examine to what extent it can co-exist and interoperate with other existing legacy e-learning systems such as Moodle and Blackboard. This will be beneficial for both HeLPS and legacy e-learning systems as more services, architectural components, and architecture amendments are going to be added so both types of systems (i.e., the HeLPS e-Learning Framework and other legacy e-learning systems) co-exist with each other. This will lead to further flexibility because most educational institutes have evolving requirements that involve various communciations, ineteractions, migration, data extractions – import and export – between e-learning systems and tools. Therefore, opting for SOA-enabled e-learning environment makes this task much easier. This will allow moving from *monolithic systems*, where every capability is secured inside one or more black box to *open or semi-open architecture*. As a result of that, e-learners, and other stakeholders, might use login services, as an example, provided by certain e-learning system (e.g., Moodle) in order to access their HeLPS learning space or other HeLPS functionalities.

Similarly, e-learners will be able to export/import some information, statistics, and figures from/to external tools, which is extremely beneficial especially in the case of social-based e-learning models. Technically, HeLPS e-Learning Framework is capable to co-exist with other systems via web services, however web services are not widely adopted in e-learning domain. One possible step could be to encourage publishers and academic institutes to design and publish their online contents in the form of web services. Currently, many universities seek the advantages of open education initiative and widening participation, and hence they are investing in MOOCs either by publishing their own MOOCs or participate in centeral MOOCs platforms. Another step needed here is to develop processes, procedures and policies to effectively implement the HeLPS e-Learning Framework in any institution. Such processes and policies are not technical only, they go beyond that to include teaching and learning models, evaluation approaches, management procedures and the way of running programmes, etc. Such processes and procedures will make the implementation of the early-developed framework achievable and beneficial.

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Appendices

Appendix I: Applying the Process of Developing the e-Learning Meta-Model on the Learning Object Model

This appendix shows the application of the process-based approach, proposed in Section 3.3.2, to develop an e-Learning Meta-Model on the Learning Object Model.

e-Learning Model Name: Learning Object.

Resources used in this application: [18], [21], [22], [23], [24], [133], [134], [135], [136], [137], [138], [139], [140], [141], [142], [143], [144] and [145].

Detailed Log: shown in Table I.1.

Table 0.1: Applying The Process-based Approach on Learning Object Model to Develop eLMM

Description of Step 1 : Determine the boundary of the model under review, that only relevant aspects that are related to research scope are covered.
Output of Step1: The boundary includes: (i) learning object itself, (ii) learner, (iii) the only part of LO hosting environment that directly affect LO and (iv) other roles such as instructor, technical designer and administrator if and only if they are directly affecting the main actor (e.g., interacting with learner); otherwise, those actors are beyond the boundary of this model.
Description of Step 2: Discover model elements which are the building blocks of the model. For instance, learning objectives is one of building blocks for learning object model. *Please consider the difference between model elements and features. Content is an elements while reusability is a feature.*
Output of Step 2: Material/Resources [22][23][137][142], Content[18][135][23], Learning Context [22], Instructional Context[22][18], Instructional Model[22], Pedagogy [18][22][136], Tutor/Teacher[22][136], Unit[22], Instructional Component [23][134]/LO/Knowledge Object [23]/Lesson [23][24][134]. LO Metadata [18][23][133][134][135][136], Dublin Core Metadata Initiative (DCMI), IEEE LOM[134], IMS Learning Recourse Metadata IMS LRM version 1.3[21][133], Resource Description[21][133], DCMI elements: title, creator/author, subject, description, publisher, contributor, date, type, format, identifier (URI), source, language, relation, coverage, and rights [143][144][145], LO title [142][143], author/creator [142], location of the resource [142], uniform resource identifier (URI) [143], subject [143], keyword [143], IEEE LOM [134][143][145]. IEEE LOM elements are [139]: 1. General: Identifier.Catalog, Identifier.Entry, Title, Language, Description, Keyword, Coverage, Structure, Aggregation Level. 2. Life Cycle: Version, Status, Contribute, Contribute.Role, Contribute.Entity, Contribute.Date. 3. Meta-Metadata: Identifier, Identifier.Catalog, Identifier.Entry, Contribute, Contribute.Role, Contribute.Entity, Contribute.Date, Metadata Schema, Language. 4. Technical: Format,Size, Location, Requirement, Requirement.OrComposite, Requirement.OrComposite.Type, Requirement.OrComposite.Name, Requirement.OrComposite.Minimum Version, Requirement.OrComposite.Maximum Version, Installation Remarks, Other Platform Requirements, Duration 5. Educational: Interactivity Type, Learning Resource Type, Interactivity Level, Semantic Density, Intended End User Role, Context, Typical Age Range, Difficulty, Typical Learning Time, Description, Language. 6. Rights: Cost, Copyright and Other Restrictions, Description. 7. Relation: Kind, Resource, Resource.Identifier, Resource.Identifier.Cataloge, Resouce.Identifier.Entry, Resource.Description 8. Annotation: Entity, Date, Description 9. Classification: Purpose, Taxon Path, Taxon Path.Source, Taxon Path.Taxon, Taxon Path.Taxon.Id, Taxon Path.Taxon.Entry, Description, Keyword.

Learner [22][135][136], target audience[22], Learner needs [22][136], learner characteristics [18], SCORM [22][136], Learning objective [18][134][137], Instructional goal [18][23], learning activity [18][134], practice activity [18][134], assessment activity[18][134] , content format (multimedia, Audio, visual, text, graphics, link) [18], LO structure [18][134][137], asset[18][134], concept/idea [18], learning task [18], learning activity [18], flexibility[18], interfaces [18], Interaction[18], Packaging or Content Packaging [18][134], Learning/education/training [21][133], Resource textual description[21][133], learning resources[23], small chunk (size and time scale) [22] Granularity [23] [134][135] Aggregation [23], Learning Object component [24], Learning Object Content Model (LOCM) [24][137], Learnativity content model: Raw data [24][135]/media elements[24], Information Objects [134], Application Specific Objects, Aggregate Assemblies, Lessons or chapters, SCORM Content Aggregation Model: Asset [24][134], Sharable Content Object (SCO) [24][134], Content Aggregation [24][134], CISCO RLO/RIO Model: Reusable Learning Object (RLO) is a collection of 7 ± 2 Reusable Information Objects (RIOs): Overview, RIO content item, RIO practice item, RIO assessment item, Summary and Assessment [24][134], NETg LOCM: topic, lesson, unit and course [24][134][135][136], Currier, S., & Campbell aggregation model [134][135]: Information object, Information resource, Learning object, Unit of study, Module, Course, Collection. Virtual learning environments (VLEs) [135], learning content management systems [135], Modules [135], LO Repository [136][137], Content fragments/raw data/material[137], Content objects[137], learning components [134][137], Learning environment[134], Reusability[18][22][23][24][134][135], sharing [24], specification and standards [18][22][134][136][137], Compatibility [22][136], Accessibility[18][22], Navigation[18], sequencing [22][23], interoperability [18][22][134][135].
Description of Step 2.1: Group the discovered model elements and identify synonyms. This will be useful to enable semantic heterogeneity in the e-learning ontology. *Bold titles are written to make the classifications of this large number of elements possible, they are not elements, they are written only to ease classifying elements.*
Output of Step 2.1: **Content** Learning Resources[23]/small learning unit (size and time scale) [22] / Material[22][23][137] [142]/resources [22][23][137][142] /content[18][135][23], Unit[22], Instructional component [23][134]/LO/Knowledge Object [23]/Lesson [23][24][134], Content fragments[137]/raw data[137]/material[137], Content objects[137], learning components [134][137], Modules [135] **Pedagogy** Learning context [22]/ Instructional context[22][18] instructional model[22], pedagogy [18][22][136] **Roles** Tutor/Teacher[22][136] Learner [22][135][136]/Target audience[22] Learner needs [22][136]/Learner characteristics [18] **Standards** LO Metadata [18][23][133][134][135][136]/Dublin Core Metadata Initiative (DCMI)/ IEEE LOM[134][143][145]/IMS Learning Recourse Metadata IMS LRM version 1.3[21][133]/Resource description[21][133]/ Keyword [143], Resource Description[21][133], SCORM [22][136]. **LO Components** Learning objective [18][134][137]/Instructional goal [18][23], learning activity [18]/learning task [18]/practice activity [18][134], assessment activity[18][134] , content format (multimedia, Audio, visual, text, graphics, link) [18], asset[18][134], concept/idea [18] interfaces [18] **Purpose of LOs** Learning/education/training [21][133], **Hosting Environment**

Virtual Learning Environments (VLEs) [135]/Learning Management Systems [135]/Learning Content Management Systems [135], LO Repository [136][137], Learning Environment [134].

Features
Reusability[18][22][23][24][134][135], Sharing [24], Interoperability [18][22][134][135], Flexibility[18], Compatibility [22][136], Accessibility[18][22], Specification and Standards [18][22][134][136][137], Interaction[18][139], Navigation[18], Sequencing [22][23], Packaging/Content Packaging [18][134],

Content Fragmentation
Granularity/Aggregation level/degree of granularity [23][134][135], Learning Object component [24]

Learning Object Content model (LOCM) [24][137]:
Learnativity content model: Raw data [24][135]/media elements[24], Information Objects [134], Application Specific Objects, Aggregate Assemblies, Lessons or chapters.
SCORM Content Aggregation Model: Asset [24][134], Sharable Content Object (SCO) [24][134], Content Aggregation [24][134].
CISCO RLO/RIO Model: Reusable Learning Object (RLO) is a collection of 7 ± 2 Reusable Information Objects (RIOs): Overview, RIO content item, RIO practice item, RIO assessment item, Summary and Assessment [24][134].
NETg LOCM: topic, lesson, unit and course [24][134][135][136].
Currier, S., & Campbell aggregation model:
Information object, Information resource, Learning object, Unit of study, Module, Course, Collection [134][135]

Metadata Standard
IEEE LOM:
LOM.General.Identifier.Catalog[139]
LOM.General.Identifier.Entry[139]
LOM.General.Title[139]/ DCMI.LO Title [142][143][144][145]
LOM.General.Language[139]/ DCMI.Language [143][144][145]
LOM.General.Description[139]/ DCMI.Description [143][144][145]
LOM.General.Keyword[139]/ DCMI.Subject [143][144][145]
LOM.General.Coverage[139] / DCMI.Coverage [143][144][145]
LOM.General.Structure[139]
LOM.General.Aggregation Level [139] / DCMI.Type [143][144][145]

LOM.Life Cycle.Version [139]
LOM.Life Cycle.Status[139]
LOM.Life Cycle.Contribute.Role[139] / DCMI.LO Creator/Author [142] [143][144][145]
LOM.Life Cycle.Contribute.Entity[139]/ DCMI.Publisher [143][144][145] / DCMI.Contributor [143][144][145]
LOM.Life Cycle.Contribute.Date[139] / DCMI.Date [143][144][145].

LOM.Meta-Metadata.Identifier.Catalog[139]
LOM.Meta-Metadata.Identifier.Schema[139]
LOM.Meta-Metadata.Contribute.Role[139]
LOM.Meta-Metadata.Contribute.Entity[139]
LOM.Meta-Metadata.Contribute.Date[139]
LOM.Meta-Metadata.Metadata Schema[139]
LOM.Meta-Metadata.Language[139]

LOM.Technical.Format[139]/ DCMI.Format [143][144][145]
LOM.Technical.Size[139]
LOM.Technical.Location[139]/ DCMI.Identifier /Uniform Resource Identifier (URI) [143][144][145]/location of the resource [142]
LOM.Technical.Requirement[139]
LOM.Technical.Requirement.OrComposite [139]
LOM.Technical.Requirement.OrComposite.Type[139]

LOM.Technical.Requirement.OrComposite.Name[139] LOM.Technical.Requirement.OrComposite.Minimum Version [139] LOM.Technical.Requirement.OrComposite.Maximum Version[139] LOM.Technical.Installation Remarks[139] LOM.Technical.Other Platform Requirements[139] LOM.Technical.Duration[139] LOM.Educational.Interactivity Type[139] LOM.Educational.Learning Resource Type[139] LOM.Educational.Interactivity Level[139] LOM.Educational.Semantic Density[139] LOM.Educational.Intended End User Role[139] LOM.Educational.Context[139] LOM.Educational.Typical Age Range[139] LOM.Educational.Difficulty[139] / DCMI.Relation [143][144][145] LOM.Educational.Typical Learning Time[139] LOM.Educational.Description[139] / DCMI.Source [143][144][145] LOM.Educational.Language[139] LOM.Rights.Cost[139] LOM.Rights.Copyright and Other Restrictions[139] LOM.Rights.Description[139] LOM.Relation.Kind[139] LOM.Relation.Resource.Identifier.Cataloge[139] LOM.Relation.Resouce.Identifier.Entry[139] LOM.Relation.Resource.Description[139] LOM.Annotation.Entity[139] LOM.Annotation.Date[139] LOM.Annotation.Description[139] LOM.Classification.Purpose [139] LOM.Classification .Taxon Path.Source [139] LOM.Classification.Taxon Path.Taxon.Taxon.Id [139] LOM.Classification .Taxon Path.Taxon.Taxon.Entry [139] LOM.Classification.Description [139] LOM.Classification.Keyword [139]
Description of Step 3: Elaborate the selected model using different perspectives (e.g. model behaviour, interaction, flow, interaction, etc.) or refer to the existing literature and apply verb-noun analysis technique in order to: i) Identify model attributes, such as eLearner ID, background, etc. These attributes are labelled as tags. ii) Identify relationships between elements (e.g., learning objectives describe learning object). This would result in a list of basic relationships between model elements. These relationships are meta-association. *Elements are written in italic format.*
Output of Step 3.i and 3.ii: 1. LO is made of *material/content/resources/assets/raw data/information objects or smaller LOs* [22][23][137][18][135]. 2. LO must be context independent, to some extent, to be reusable [22][18]. 3. Each LO has its own *instructional model* that makes the value of LO, instructional model is based on *pedagogy* [18][22][136]. 4. Following *standards* (SCORM, IMS, etc.) gives the LO: wide accessibility, compatibility, reusability and interoperability [18][22][23][134][136][137]. 5. LO is combined through one of the *aggregation levels* of *LOCMs* [24][137]. 6. *Learning contents* are built based on learner needs [18][22][136]. 7. *Learning contents* must be designed in a way that can attract large number of *learner* [22]. 8. LO or its granular contents (asset, raw data, information object, etc.) are artefacts produced in standard formats (i.e. pdf, docs, ppt, images, web pages, xml, multimedia files, etc.) [23][139]

9. Learning artefact is created by authoring tools to present contents in a standard technology-based format.
10. Tutors develop their own *pedagogic approaches* to the *material* [22].
11. *Metadata* describes learning objects [18][22][23][134][136].
12. *Learning objective* describes goals to be achieved by *leaner* at the end of this particular *learning unit* [22][23][24].
13. *Learning objectives* are designed to satisfy that particular set of *learners' needs* [22].
14. A *unit of learning* consists of smaller units that are governed by a given sequence/structure [24][23].
   a. Learner should be able to navigate the learning object [18][23].
   b. Smaller units of learning should be linked to each other to produce some kind of continuity.
15. *A unit of assessment* is built based on *contents* and *learning objectives* to measure learner progress [18][22][23].
   a. Assessment may be *online test*, *essay* or *writing skills*, *problem/project-based*, *case-based analysis, etc.*
   b. Assessment might be composed of one or more *assessment question* (e.g. MCQ, T/F, etc.).
   c. *Results* must be shown to learner either at the end of questions or assessment items.
   d. *Feedback* must be given to learner to inform him/her about his overall progress (it might be automatic feedback which offers the minimum level of feedback or it might be written by human actor). This feedback might show future directions for learner e.g. go to the next unit or repeat the current one [24][136].
16. LO *hosting environment* (e.g., VLE, LMS, LCMS, MLE, LO Repositories, adaptive systems, etc.) provides [135][137]:
(i) Cataloguing service to learning objects.
(ii) interaction tools (email, chat, web conference),
(iii) Help information necessary to guide users.
17. Learning object should be organised/structured in a specific way e.g. linear, sequential, collaborative, etc. [22][18][139].
18. Learning Object must be self-identified, which means it has [139]:
   a. Title: shortly describes the learning object.
   b. Author(s) name.
   c. Date of production
   d. Version/release
   e. Purpose
   f. Type of LO (e.g. designed for self-paced, DL, etc.)
19. LO must be built based on educational standards taken out from pedagogy (good practices, instructional design concepts, learning theories, etc.) [136]
20. LO navigation must be clear and systematic [18].
21. Raw data/asset is the basic level of any learning contents [24][134].

Findings:
All elements discovered above are mentioned in IEEE LOM standards [139] except the following:
   a) Learner: his needs, motivation, characteristics, etc.
   b) Hosting environment: capabilities provided such as: interacting with tutor and peers, getting technical support and help.
   c) Advanced educational context: pedagogy, assessment and consequently feedback, learning theories, etc.

Conclusion:
To adapt IEEE LOM and extend it further to cover LO model from this research point of view (e.g. using LOCM instead of aggregation level to include other aggregation schemas. The elements of IEEE LOM which has been listed in the output of step 3 are based on IEEE standard mentioned in [139]. These elements are grouped in the following nine categories:
   (i) General to store general information that describes the learning object.
   (ii) Lifecycle where the features related to the history and current state of this learning object maintained.
   (iii) Meta-metadata which group information about the metadata instance itself
   (iv) Technical where technical requirements and technical characteristics of the learning object is grouped
   (v) Educational where educational and pedagogic characteristics of the learning object are found.
   (vi) Rights where intellectual property rights and use conditions are declared
   (vii) Relation features that define the relationship between the learning object and other related learning objects are stated

(viii) Annotation where comments on the educational use of the learning object, comments date, and comments creator are provided.

(ix) Classification where learning object is classified in relation to a particular classification system.

Figure I.1 shows a hierarchical representation of LOM model. Each element has its own description, data type and further explanation in [139].

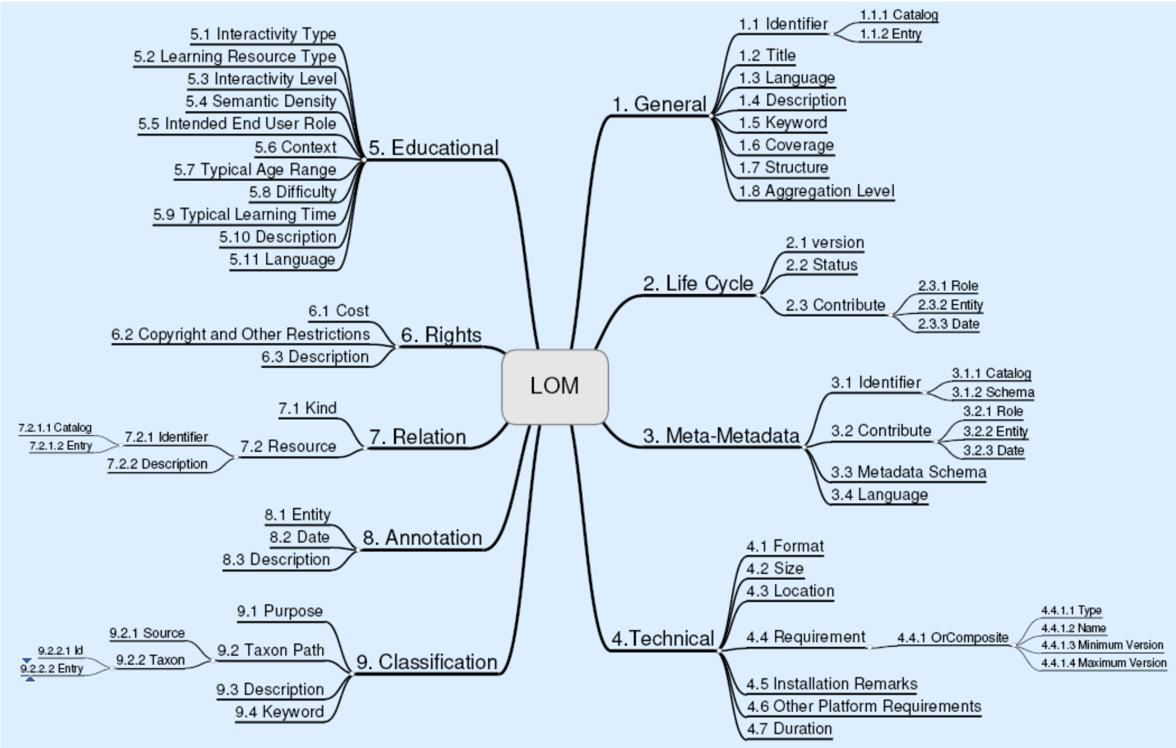


Figure A.0.1: IEEE LOM Elements and their Hierarchy

The model shown above includes wide range of information about LO to the extent that LOs could be discovered automatically. Despite the necessity of discovering different LOs by a given web service or based on user query, organising those LOs in a proper educational context still problematic. Proper educational context means that those LOs should be organised in a proper sequence according to the learner. This also brings the issue of personalised learning where matching learner preferences and needs with LO instructional or pedagogical model is possible. What is shown in the current LOM model especially in educational category lacks such pedagogical information, therefore this model should be extended to accommodate those required information.

Additionally, LO is designed to respond to specific learner needs. This is a complex design process as it includes: identifying and analysing learners, collecting their needs, planning how to respond to learners' needs and finally designing contents according to the outputs of the previous activities. This process has been left to instructors and technical teams without much explanation which added further ambiguity to LO model. E.g. for this purpose, CISCO adopted ADDIE model developed by Gagne in their own LO model [140]. ADDIE stands for Analyse, Design, Develop, Implement, Evaluate. This very tricky, for instance, analysis means to identify the problem/ need and its reasons, propose a solution (e.g. tutoring, motivation, etc.), define performance goals to be addressed by the solution and finally ensure that the proposed solution can solve the predefined problem/need. Excluding all these details from IEEE LOM makes it insufficient for pedagogical reasons. At least, the minimum level of information about learners, their characteristics, preferences, etc. should be included. Hence, leaner should be modelled in the extended version of this IEEE LOM.

Finally, learning as a process is an inherent dimension of everyday life [94]. It is a social process requires interactions with: tutor to get academic support, peers to engage in collaborative learning activities and technical teams to get support or solve problems. Therefore, collaborative and interaction aspects should be considered as well. Figure I.2 shows the class diagram designed to represent IEEE LOM model. It represents model elements categorised in the previously-mentioned nine categories and shows the required cardinalities.

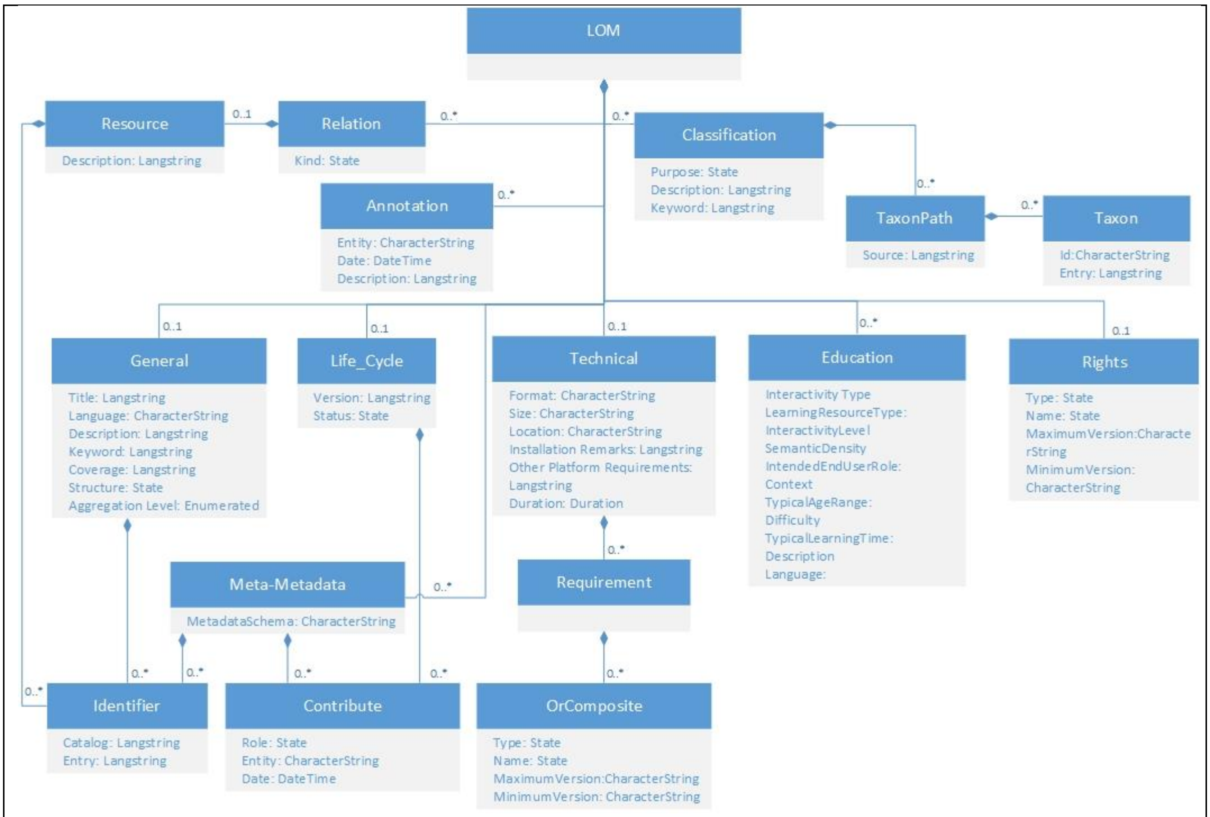


Figure A.0.2: IEEE LOM Class Model

Extending this model is possible to overcome some of the current drawbacks mentioned earlier. For instance, figure I.3 shows an extendable version of IEEE LOM class diagram to include different LOCMs (CISCO LOCM as an example). However, this extension does not make significant differences from researcher point of view because LOM inability to cover other LOCMs (e.g. CISCO) is not a major drawback. The major criticism for LOM model is its deficiency of pedagogical information. Existence of such pedagogical information in LOM model will improve the ability of allocating and organising different LOs for specific user on the fly.

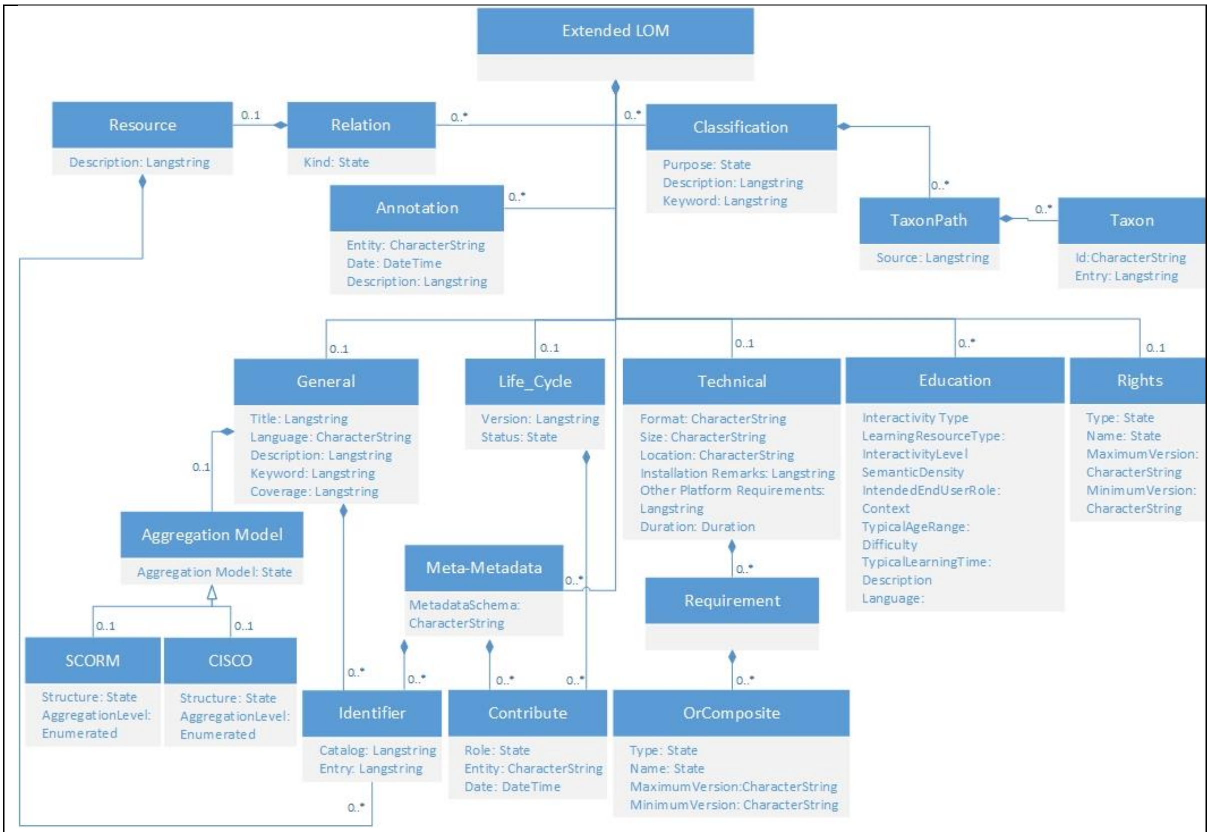


Figure A.0.3: Extended IEEE LOM Class Diagram

Description of Step 3.iii:
Identify constraints between elements and their associations (i.e., cardinality, conditions, attributes and formats if any). These rules and constraints constitute the semantics of the e-learning domain/models.

Output of Step 3.iii:
According to [139], LO model elements are described as: element title, element description, element category, element data type, constraints (i.e. whether the order of element value makes difference or not e.g. 1,2,3 is not equivalent to 3,2,1) and relationships or dependencies with other elements. Table 1 pp 8-22 shows this information while other sections of the standards in [139] provide further details such as special data type definitions. This level of element description in [139] is sufficient to derive the intended e-learning ontology and will be used in the later steps.

Description of Step 4 and 5:
Repeat steps from 2 to 5 to enhance model analysis whenever you think it is needed.

Output of Step 4 and 5:
No output as this analysis shows the final trial. Proper notations are listed above to make the description more coherent and avoid repetition and extra text.

Appendix II: HeLPS e-Learning Meta-Model Description

#	Concepts	Definition/Sub concepts	Data properties	Datatype	Constraints	How to capture
Actor Ontology *(ActorOnt)*						
1	eActor (A1)	Represents human or software agent performing some action in the e-learning system to achieve a given purpose.				
		1.1 MachineActor (A2): Non-human actor e.g. service				
		1.2 HumanActor (A3)				
			Identifier	String	Obligatory	Implicit
			User ID	String	obligatory	Explicit via learner sign up
			Password	String	obligatory	Explicit via learner sign up
			First name	String	obligatory	Explicit via learner sign up
			Last name	String	obligatory	Explicit via learner sign up
			Email address	String	Obligatory	Explicit via learner sign up
			Address	String	Obligatory	Explicit via learner sign up
			Phone number	Integer (14) digits	Optional	Explicit via learner sign up
		1.2.1 Staff (A4)				
			Staff qualification	String	Obligatory	Explicit based on user data
			Contract type	Enumerated, Controlled list: FT fixed, FT Temp, PT	Obligatory	Explicit
			Employment date	Date	Obligatory	Explicit
		1.2.1.1 Non-academic staff (A5)				
		1.2.1.1.1 Technical staff (A6)				
		1.2.1.1.2 Admin staff (A7)				
		1.2.1.2 Instructor (A8)				
		1.2.2 e-Learner (A9): The main actor in the system, the student.				
2	eLearner Behavioural Model (A10)	is a representation of information about an individual user that is essential for an adaptive system to provide the adaptation effect in order to behave differently for different users (Brusilovsky and Millán, 2007).				
		2.1 Extended general properties (A11)	Programme = Major	String	Obligatory	Explicit via learner sign up
			Profession=occupation = career = vocation	String	Optional	Explicit via learner sign up, e.g. web developer

			Qualification	String	Obligatory	Explicit via learner sign up, e.g. web developer
			Affiliation: *to certain group or community*	String	Optional	Explicit via learner sign up, e.g. University College London (UCL) or Food Production LTD
			Interface preferences	By default one colour scheme is assigned to user.	A predefined list of colour scheme	Assigned to user by default but learner can change it later, e.g. scheme 1 has colours: white, Gainesboro and Gray. Scheme 2 has light blue, DarkSlateBlue and white. Scheme 3 has GreenYellow, LimeGreen and white.
			Language preferences	String	Optional	Explicit via learner sign up, e.g. English
		2.2 Physical property (A12)	Date of birth	Date	obligatory	Explicit via learner sign up
			Gender	Controlled vocabulary (Male, Female)	obligatory	Explicit via learner sign up
			Disability	Enumeration: No, Visual, Hearing, Cognitive	If yes, provide more explanation (text)	Explicit via learner sign up
		2.3 Demographic properties (A13)	Ethnic origin	String	can be null	Explicit via learner sign up
			Native language	String	obligatory	Explicit via learner sign up
			Spoken languages	List of up to 5 languages	Controlled variables of languages	Explicit via learner sign up
		2.4 Skills(A14)	skillTitle	String	Optional	Captured by the system based on assessment scores and other achievements.
			skillLevel	Controlled variable	Good, fair, poor	
			skillType	Controlled variable	Cognitive, metacognitive, intellectual skills and motor skills	
		2.5 eLearnerGoal (A15)	goalTitle	String	Optional	Implicit, e.g. keywords used to explain goal title.

			goalDescription	Text	Optional	Extracted from learning outcomes defined by instructor
			goalPriority	Number (1 is the least and 5 is the highest)	1-5	Assigned by learner *This allows more flexibility in planning for learning.*
			goalDateToAchieve	Date	Optional	
		2.6 Advanced Properties (A16)	Learning style	Controlled vocabulary: visual, aural, read/write and kinaesthetic.	Optional	VRAK learning style model is used here as discussed above.
			Affects = emotions	Controlled vocabulary	Optional	Explicit, 3-state Russell's model for emotions is adopted to capture learner's affect state. It consists of positive (i.e. excited), neutral and negative state (i.e. bored) (Shen *et al.*, 2009)
			Interests	String	Optional	Explicit such as reading, swimming
			Background, refer to knowledge outside the domain of teaching.	String	Optional	Explicit via user input e.g. Math.
			Social interaction	String	Optional	Explicit and implicit. It includes communities membership, groups created by lecturers, preferred contacts/friends (learner defines this list), peers, project mates.
		2.7 LearningHistory(A17)	learningTendency	Controlled variable	Individual, collaborative.	Implicit by monitoring the types of activities carried out by the learner. This can be done at the level of learning or assessment activities. For instance, assessment can be done by collective projects or exam.

			previousProcesses activities	Controlled variable of the most used types of processes	Behavioural, cognitive, etc.	Implicit by monitoring learner history, provide types of process e.g. behavioural.
			Number of additional support given to learner	Integer number	Optional	It shows learner need for further explanation such as example, resources given to him.
			Misconceptions: *common mistakes e.g. in ability to write in passive*	List of misconception, e.g. non-functional requirement validation	Optional	Implicit, errors associated with topics. These misconceptions are modelled in the system as a list contains the followings: A, B, C, D, E, F and G.
			Rate of failure to success	Percentage in integer	Optional	Implicit, rate of failed to successful attempts of passing a quiz on a specific topic.
			messagesProvidedToLearner	Based on his interaction with academic staff	Optional	Explicit by instructor when he replies learner requests, it includes a controlled list: advanced, neutral, failure
			knowledgeLevel	Ontology based representation	[topic, level]	Implicit based on assessment results, e.g. agile,7;waterfall,2; 1 out of 10 where 1 is the least and 10 is the highest
			engagement	decimal	Optional	Implicit, minutes taken to use collaborative tools divided by total time for learning process.
			learnerAnnotation	String	Optional	Implicitly by the systems. It includes shares, tags, rate, likes in learner learning process
			learningHistoryMark	Integer: The percentage of the total learner marks i.e. GPA	Optional	Captured by the system, the percentage of the learner in all his modules, e.g. 76%.
			isLearnerStruggling			
			isLearnerAdvacned			

3	LearnerGroup	Groups that connect learners with each other based on their needs or similarities				
		SupportBasedLG	For those learners who need further support from advanced learners			
		SocialBasedLG	For those learners who have commonalities between themselves.			
	Further elements of Actor ontology: 17 classes as listed above in addition to their data properties					
	Object properties	Learner gains support from staff				
		Learner interacts with actor				
		Learner has an e-learner behavioural model				
		e-learner behavioural model is composed of (i) extended general properties, (ii) physical properties, (iii) demographic properties, (iv) goals, (v) skills, (vi) learning history and (vii) advanced properties. For instance relations are stated in this format *haseLearnerModelAdvancedProperties*				
	Object properties for LearnerGroup					
	Restrictions	Each learner has only one e-learner behavioural model, as mentioned below: *hasAneLearnerBehaviouralModel exactly 1 eLearnerBehaviouralModel*				
Pedagogy Ontology *(PedagogyOnt)*						
2	Learning Theory (P1)	Provides empirically-based investigations of the variables which influence the learning process, and provide explanations of the ways in which that influence occurs				
		Data properties	Learning Theory ID	Integer	Obligatory	
			Learning Theory Title	String	Obligatory	
		Behavioural (P2)				
		Subtypes: instructional design , direct instruction, intelligent tutoring	Stimuli	String	Optional	
			Response	String	Optional	
		Cognitive Constructive (P3)				
		Subtypes: problem-based, self-regulated, recommender systems, adaptive-based.	Information processing	String	Optional	
		Situated based(P4)				
		Subtypes: participation/communication-based and virtual word/game-enhanced	Context	String	Optional	
			Social participation	String	Optional	
	Further elements of pedagogy ontology: 13 classes in addition to the data properties					

	Object properties	-				
	Relations with other ontologies	Process, pedagogy				
Activity Process Ontology *(ActivityProcessOntology)*						
3	LearningProcess (AP1)		learningProcessID	String	Obligatory	Implicitly assigned
			Process Title	String	Obligatory	Implicitly assigned
			recommendedProcessElement	String	Optional	Implicitly assigned
			Learning Process Description	String	Optional	Implicitly assigned based on the keyword of the process goal/objective
			learningProcessDuration	Integer	Optional	Implicitly, the duration of using the learning process.
			recommendedProcessTendency	Controlled list: Individual or Collaborative		
			Process Time	Time	Optional	Implicit
			Process Location	String	Optional	Implicit
			HW Device Type	String	Optional	Implicit
			HW Display Setting	String	Optional	Implicit
			HW Operating System	String	Optional	Implicit
			Physical Context	Controlled list: heat, light, noise.	Optional	Explicit by learner
4	LearningProcessPrerequisites (AP2)	Skills, knowledge or technical details required to be mastered by learner before strarting a certain learning process.				
			technicalPrerequisites	text	Optional	Stated by developer
			nontechnicalPrerequisites	text	Optional	Stated by instructor
5	eActivity (AP3)	series of actions done by learner either individually or in cooperation with others to achieve specific learning objectives				
			Activity ID	Integer	Obligatory	Implicit via the system
			Activity title	String	Obligatory	Generated by the system
			Activity metadata	String	Optional	Keywords
			Description	String	Optional	Description
			Objective	String	Optional	Stated by instructor
			Prerequisite	String	Optional	Stated by instructor

		Learning activity (AP4)	Activities done with purpose of learning			
			Completion condition	String	Optional	Conditions to complete the activity
			On completion	String	Optional	What to do next
			Learning activity type	Controlled value: interactive, individual-based, collaborative-based		
		Sub of learning activity: IndividualBasedLA (AP5)				
			Interaction level	1-5 based on IEEE LOM levels	Optional	Level of the interaction with the system
		Sub of Learning activity: CollaborativeBasedLA (AP6)				
			durationOfUse	Integer, duration by minutes	Optional	Implicitly.
			Peer roles	Controlled list	Optional	Exchange messages, review others work, proofread, etc.
		Assessment activity (AP7)	Activity used to assess learner pera topic/goal. It can be done in different ways (i.e. quiz, coursework, project, etc.) and different tools can facilitate it. For general topic knoweldge assessment, results are produced in pair (topic, level) e.g. (solving equations, good).			
			Assessment type	Controlled list	Formative or summative	
			Completion condition	String	Optional	Conditions to complete the activity
			On completion	String	Optional	What to do next
		Sub of Assessment activity: Exam (AP8)	Regulations	String	Must	How to proceed in exams e.g. answer all the questions, or select 5 questions out of 6
			Question	String	Obligatory	Explicit, Stated by instructor
			Answer	String	Obligatory	Explicit, Stated by instructor
			Duration time	Integer (minutes)	Obligatory	Explicit, Stated by instructor

			Mark	Integer	Obligatory	Explicit, Stated by instructor
		Sub of assessment activity: Essay (AP9)	Essay question	String	Obligatory	Explicit, Stated by instructor
			Deadline	Date time	Obligatory	Explicit, Stated by instructor
			Assessment criteria	String	Optional	Explicit, Stated by instructor
			Essay	Text	Obligatory	Explicit, Stated by instructor
		Sub of assessment activity: Project (AP10)	Project specification	String	Obligatory	Explicit, Stated by instructor
			Project deadline	Date time	Obligatory	Explicit, Stated by instructor
			Project marking criteria	String	Optional	Explicit, Stated by instructor
			Team member roles	String	Optional	Explicit, Stated by instructor
			Project	Text	Obligatory	Explicit, Stated by instructor
		Support activity (AP11)				
			Support initiator	Controlled list	Optional	Learner, instructor, technician, facilitator
		Sub of support activity: Academic support (AP12)	Support status	Status of the support provided to learner. Controlled list: positive, neutral, negative	Optional	Stated by instructor
		Sub of support activity: Non-academic support (AP13)	Stage	Controlled variable	Optional	Closed support case or needs further follow up
6	Feedback (AP14)	Information shown to learner as a result of reaching the end of activity/process.				
			feedbackID	Integer		
			feedbackDescription	String		
			feedbackScore	Percentage %100		
			feedbackMessage	Controlled variable		Failure, neutral, advance
			remedialActions	String		Describe must to do actions
			Topic related to	String	Optional	The name of the topic this feedback relates to
Further elements of Activity process ontology:						
	Object properties	Learning process has process prerequisites				
		Learning process is composed of activities				
		Assessment activity leads to feedback leadToAssessmentActivityFeedback				

		Learning process has assessment activity hasLPAssessmentActivity				
	Related classes/artefacts	This ontology will be supported by reusing BPMN ontology (BPMNO). BPMNO works as a metamodel for different e-learning processes.				
ContentContext Ontology *(ContentContextOnt)*						
7	eContext (CC1)	Refers to settings in which a learning process occures, it is an aggregation of attributes related to e-learner, e-learning process scuh as time and location, pedagogy of learning and the organisational context.				
		e-LearnerContext (CC2)	Such as his characteristics, goals, and skills.			
		e-LearningProcessContext (CC3)	scuh as time and location			
		Pedagogy of e-learning (CC4)	refers to the processes, experiences, contexts, outcomes and relationships of teaching and learning in higher education.			
			Pedagogical approach adopted	Controlled list: learning theory, conditions of learning, good pedagogical design)	Optional	Explicitly captured by the system
		OrganisationalContext (CC5)	The context of organisation in which learning occurs.			
			Organisation title	String	Obligatory	Explicit from organisation profile
			Organisation address	String	Obligatory	
			Organisation description	Text	Obligatory	
			Organisation type	Controlled list (higher education, education)	Obligatory	
		Sub of OrganisationalContext: NonFormal learning (CC6)				
			ID	Integer	Obligatory	Explicit from organisation profile
			Title	String	Obligatory	
			Description	Text	Obligatory	
		Sub of Organisational context: FormalLearning (CC7)				
			ID	Integer	Obligatory	Explicit from organisation profile
		Sub from Formal learning: ResearchDegree (CC8)				
			Code	String	Obligatory	Explicit from organisation profile
			Title	String	Obligatory	

			Description	String	Obligatory	
			Major	String	Obligatory	
			Requirement	String	Obligatory	
			Type	Controlled list: PhD, DPhil, MPhil, Professional doc.	Obligatory	
8		Sub from Formal learning: Programme (CC9)				
			Programme Code	String	Obligatory	
			Programme Title	String	Obligatory	
			Programme Description	String	Obligatory	
			Programme Entry year	Integer	Obligatory	
			Programme Campus	Controlled list of university campuses	Obligatory	
			Programme Level	Controlled list (PG, UG)	Obligatory	
			Programme Department	Controlled list of university departments	Obligatory	
			Programme Duration	Integer (months)	Obligatory	
			Programme Delivery	Controlled list FT, PT, both	Obligatory	
			Programme leader	String	Obligatory	
9	Rules and Policy (CC10)	Rules that govern a running programme, degree or other formal learning processes.				
			RuleCode	String	Obligatory	Explicit from organisation profile
			RuleTitle	String	Obligatory	
			RuleBody	String	Obligatory	
			RulePenalty	String	Obligatory	
		Sub of rules and policy: AssessmentRules (CC11)				
			Target	String Controlled list (exam, essay, etc.)	Obligatory	
			Directions for application	String	Obligatory	
			Extenuating circumstances	String	Obligatory	

10	ProgrammeStructure (CC12)	Explains the structure of the programme				
			Module code	String	Obligatory	*reused from module specification*
			Module title	String	Obligatory	
			Module summarised description	Text (50 words maximum)	Obligatory	
			Module credit	integer	Obligatory	
			In programme module type	Controlled list: core or optional	Obligatory	
			ProgStructure learning and teaching	Text	Obligatory	Explicit from organisation profile
			ProgStructure assessment	Text	Obligatory	
11	ProgrammeFeature (CC13)	Collection of detailed description of the programme				
			Accreditation and partnership	Text	Obligatory	Explicit from organisation profile
			Facilities	Text	Obligatory	
			Career	Text	Obligatory	
			Fees	Integer	Obligatory	
			Entry requirement	Text	Obligatory	
			Placement	Text	Obligatory	
			Fieldwork	Text	Obligatory	
			Contact	Text	Obligatory	
12	Award (CC14)	A certificate of successful completion of a programme for a given learner				
			Award title	String	Obligatory	Explicit from organisation profile
			Award subject	String controlled list of university subjects	Obligatory	
			Award level	Controlled list (PG, UG)	Obligatory	
			Award degree	Controlled list (Distinction, merit, pass)	Obligatory	
13	Module (CC15)	The basic unit of the university programmes				
			Module code	String	Obligatory	Explicit from organisation profile

14	ModuleSpecification (CC16)	Detailed specification of the module				
			Module code	String	Obligatory	Explicit from organisation profile
			Module title	String	Obligatory	
			Module credit	Integer	Obligatory	
			Syllabus outline	String	Obligatory	
			numberOfModuleComponents	Integer	Obligatory	
			Module contact hours	Integer	Obligatory	
			Module summarised description	Text, Summarised description to be used in programme structure tab.	Obligatory	
			Module reading strategies	Text	Obligatory	
			Module teaching methods	Text	Obligatory	
			Module indicative reading list	Text	Obligatory	
			Module assessment strategy	Text	Obligatory	
			Module pass mark	Integer	Obligatory	
			Module leader	String	Obligatory	
			Module prerequisites	String: list of modules	Obligatory	
			Module learning outcomes	Text	Obligatory	
			Component ID	Integer	Optional	
15	ModuleComponent (CC17)	Part of a module				
			Component ID	Integer	Obligatory	Explicit from organisation profile
			Module code	String	Obligatory	
			Module component pass mark	Integer	Obligatory	
			Component description	Text	Obligatory	
16	Environment (CC18)	Environment hosting the content.				

			Environment reference	String	Obligatory	Links to the hosted environment
			Environment descriptive metadata	String: LMS, social network, CMS, etc.	Optional	Implicitly captured by the system to get some indications regarding the time spent by learner
			Environment adopted standards	Controlled list of related standards e.g. IEEE LOM, IMS Content Packaging (CP),	Optional	Captured by the system
			Environment services	List of available services	Optional	Captured by the system
17	SuperDomain* (CC19)	The domain of the module being taught. It is equivalent to discipline or subject. ** Because domain is a reserved word, it has been replaced by SuperDomain.*				
			Domain title	String	Obligatory	Explicit
			Domain description	Text	Obligatory	Explicit
18	LearningUnit (CC20)	The basic unit of topics taught in a module. It could be on the level of lecture, week or other scale.				
			learningUnitIdentifier	Integer	Obligatory	Explicit
			learningUnitTitle	String	Obligatory	Explicit
			learningUnitTopic	String	Obligatory	Explicit
			learningUnitPrerequisite	String	Obligatory	Explicit
			learningUnitType	Controlled variable: core, supportive	Optional	Explicit
			learningUnitObjective	Text	Obligatory	Explicit
			learningUnitDescription	Text	Optional	Explicit
			learningUnitOutline	Text	Optional	Explicit
			learningUnitResources	Text, could be a reference to other forms of	Obligatory	Explicit
			learningUnitIntendedLearnerRole	Text	Optional	Explicit
			learningUnitTypicalLearningTime	Time	Optional	Explicit

			learningUnitAgeRange	Integer	Optional	Explicit
			learningUnitLanguage	String	Optional	Explicit
			learningUnitMisconception	String	Optional	Explicit
19	eContent (CC21)	The content of lesson, learning units or module that is designed for the purpose of learning and teaching. It could be organised in a linear way or discursive i.e. small fragmented learning objects.				
			Content ID	integer	Obligatory	Captured by the system
			Content description	Text	Optional	Stated by content developer/publisher
			Content reference	URI	Obligatory	
20	EvaluationProcess (CC22)	Refers to judging how effective the design of the learning environment is for supporting learning, it could target a programme, a module or an overall organisational context (see evaluation chapter about this).				
			Evaluation goal	String	Obligatory	Explicit, stated by examiner or evaluation team
			Evaluation process target	Controlled list (module, programme, organisational context)	Obligatory	
			Evaluation process criteria	Text	Obligatory	
			Evaluation process activity	Text	Obligatory	
			Evaluation process decision	Text	Obligatory	
			Evaluation process recommendation	Text	Optional	
21	PresentationFormat (CC23)	refers to how to present content for an e-learner				
			Identifier	Integer	Obligatory	Explicit, stated by content publisher
			Title	String	Obligatory	
			Author	String	Optional	
			Copyright	String	Optional	
			Publication date	Date	Optional	
		TextBased (CC24)	Description	Text	Optional	
		Sub of TextBased: Book (CC25)	Editor	String	Optional	
			ISBN	String	Optional	
			Publisher	String	Optional	
		Sub of TextBased: Article (CC26)	ISBN	String	Optional	

			Publisher	String	Optional	
			Journal	String	Optional	
			Volume	Integer	Optional	
			Issue	Integer	Optional	
			Page number from	Integer	Optional	
			Page number to	Integer	Optional	
		Sub of Text-based: Online Source (CC27)	URL	URI	Obligatory	
		MultimediaBased (CC28)	Format	Controlled list: image, audio, video, hybrid	Optional	
			ALT (Alternative Text)	Text, Useful in the case of learners with disability	Optional	
			Technical detail	Text	Optional	
		ImmersiveBased (CC29)	Hardware requirement	Text	Optional	
			Software requirement	Text	Optional	
22	FacilitatingTool (CC30)	refers to the wide range of software tools (e.g. wiki) that can be used in e-learning context to facilitate learning and support e-learners				
			Tool ID	Integer	Obligatory	Explicit or implicit
			Tool description	Text, keyword or metadata	Optional	
			Tool accessibility	Text	Optional	
		ContentBased (CC31)	Content	Text	Optional	
		ContentFree (CC32)	Purpose	Controlled list: communication, search, etc.	Optional	
		Sub of ContentBased: e-LearningArtefact (CC33)				
23	DescriptionLanguageConcept (CC34)	To describe an e-learning artefact e.g. web service				
			Title	String	Optional	
33	MisconceptionRepository	Modelling of common misconceptions				
			MisconceptionID	String	Obligatory	Explicit
			MisconceptionTitle	String	Obligatory	Explicit
			MisconceptionResolvingContent	String	Obligatory	Explicit

	Description of the ContentContext ontology	
	Rules	Formal learning degree is controlled by rules and policy hasControlledByFormalLearningRules
		Programme is composed of Modules isComposedOfProgrammeModule
		Programme is structured according to programme structure isStructuredAccordingToProgrammeProgrammeStructure
		A programme has a programme features hasProgrammeProgrammeFeature
		A programme leads to an award hasLeadToProgrammeAward
		A module has a module specification hasModuleModuleSpecification
		One module has only one module specification
		Module has one or more module components hasModuleSpecificationModuleComponent
		Module component is composed of learning units isComposedOfModuleComponentLearningUnit
		Content contains learning unit (aggregation) hasContentLearningUnit
		Content is hosted by environment isHostedByContentEnvironment
		Module is a part of a given domain/subject/discipline. isPartOfModuleSuperDomain
		Module is evaluated by evaluation process, inverse of ** isEvaluatedByModuleEvaluationProcess
		Programme is evaluated by evaluation process, inverse of *** isEvaluatedByProgrammeEvaluationProcess
		Organisational Context is evaluated by evaluation process, inverse of **** isEvaluatedByOrganisationalContextEvaluationProcess
		** Evaluation process affects module, transitive hasAffectEvaluationProcessModule
		*** Evaluation process affects programme, transitive hasAffectEvaluationProcessProgramme
		**** Evaluation process affects organisation context, transitive hasAffectEvaluationProcessOrganisationalContext

		Assessment rule is a kind of rules and policy (taxonomic relationship, inheritance)
		Context is composed of organisational context hasContextOrganisationalContext
		Context is composed of pedagogy context hasContextPedagogyContext
		Context is composed of e-learning process and environment context hasContexteLearningProcessContext
		Context is composed of e-learner context hasContexteLearnerContext
		Content is presented in a presentation format isPresentedInContentPresentationFormat
		Content based facilitating tool contains content hasContainContentBasedContent
		Learning unit is related to misconception hasRelatedLearningUnitMisconception
	e-Learning Ontology *(e-learningOnt)*	This ontology imports: (i) actor ontology, (ii) activity process ontology, (iii) pedagogy ontology, (iv) content context ontology and (v) BPMN ontology.
	Rules/ Object properties	Assessment activity is based on assessment rules isBasedOnAssessmentActivityAssessmentRules
		Instructor teaches module hasTeachInstructorModule
		Instructor leads module hasLeadInstructorModule
		Instructor leads programme hasLeadInstructorProgramme
		Learner has enrolled in a module hasEnrolledLearnerModule
		eLearner behavioural model is captured from elearner context isCapturedFromeLearnerBehaviouralModeleLearnerContext
		Pedagogy is explained in terms of learning theories isExplainedInTermsOfPedagogyLearningTheory
		Feedback updates e-learner behavioural model hasupdateFeedbackeLearnerBehaviouralModel
		Support Activity updates e-learner behavioural model hasupdateSupportActivityeLearnerBehaviouralModel

		Activity is facilitated by facilitating tool isFacilitatedByActivityFacilitatingTool
		Learner follows a learning process hasFollowLearnerLearningProcess
		Learning process is owned by a learner hasLearningProcessLearner
		Every learning process is connected to elearner behavioural model hasLPBehaviouralModel
		Learning process generates process model i.e. BPMN diagram hasGeneratedLearningProcess
		Learning process adopts learning theory hasAdoptedLearningProcessLearningTheory
		An e-learner has attempted a topic for the first time firstAttempt (e-learner, learning unit)
		An e-learner has attempted a topic for the second time secondAttempt (e-learner, learning unit)
		An e-learner is struggling a module strugglingInModule
		An e-learner is struggling a learning topic strugglingInUnit
		An e-learning is an advanced in a module advancedInModule (learning history, module)
		A support-based group is linked to a particular module linkingGroupModule
		An e-learner joins support-based group joinedLearnerGroup
		An e-learner lead support-based group ledSupportBasedLG

Appendix III: SWRL Rules Specifications

This appendix shows the specifications of SWRL rules.

Rule ID	SWRL ID	Rule
1.	1	Learning process combines SRL elements for those learners who have SRL skills. **IF THEN Translation:** If a learner has SRL skills then suggests SRL elements for his/her learning process. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), Skills(?s), LearningProcess(?lp), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelSkill(?lbm, ?s), hasFollowLearnerLearningProcess(?x,?lp),skillType(?s, ?str), matchesLax(?str, "Metacognitive") -> recommendedProcessElement(?lp,"SRL")
2.	2	Module pass mark is the sum of module component pass marks. **IF THEN Translation:** If module has one components or more (always correct) then module pass mark is the summation of its component pass marks. **SWRL Format:** Module(?m), ModuleSpecification(?mspec), ModuleComponent(?mc1), ModuleComponent(?mc2), numberOfModuleComponents(?mspec,?v3), hasModuleModuleSpecification(?m,?mspec), hasModuleSpecificationModuleComponent(?mspec,?mc1), hasModuleSpecificationModuleComponent(?mspec,?mc2), componentPassMark(?mc1,?v1), componentPassMark(?mc2,?v2) -> modulePassMark(?m,divide(add(?v1,?v2), ?v3))
3.	3 4	***Struggling learner in a topic*** is a learner who did not pass two assessment unit for that particular concept. This rule will be specified in the *following two SWRL rules*. **IF THEN Translation:** If a learner did not pass two assessment elements for the same topic (his mark<50) then he should be recognised as ***struggling learner in a topic*** to give further support later. **SWRL Format:** eLearner(?x), LearningProcess(?lp), Feedback(?f),AssessmentActivity(?aa), LearningHistory(?lh), eLearnerBehaviouralModel(?lbm), Module(?m), ModuleSpecification(?mspec), ModuleComponent(?mc), LearningUnit(?lu), hasModuleModuleSpecification(?m,?mspec), hasModuleSpecificationModuleComponent(?mspec,?mc), hasModuleComponentLearningUnit(?mc,?lu), hasEnrolledLearnerModule(?x,?m), hasAneLearnerBehaviouralModel(?x, ?lbm), hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh), hasLPAssessmentActivity(?lp,?aa), leadToAssessmentActivityFeedback(?aa,?f), learningUnitTopic(?lu,?t), feedbackScore(?f,?v), lessThan(?v,50) -> remedialAction(?f,"retry"), firstAttempt(?lh,?lu) **2nd SWRL rule:** eLearner(?x), LearningProcess(?lp), Feedback(?f),AssessmentActivity(?aa), LearningHistory(?lh), eLearnerBehaviouralModel(?lbm), Module(?m),

		ModuleSpecification(?mspec), ModuleComponent(?mc), LearningUnit(?lu), hasModuleModuleSpecification(?m,?mspec), hasModuleSpecificationModuleComponent(?mspec,?mc), hasModuleComponentLearningUnit(?mc,?lu), hasEnrolledLearnerModule(?x,?m), hasAneLearnerBehaviouralModel(?x, ?lbm), hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh), hasLPAssessmentActivity(?lp,?aa), leadToAssessmentActivityFeedback(?aa,?f), learningUnitTopic(?lu,?t), feedbackScore(?f,?v), lessThan(?v,50), firstAttempt(?lh,?lu), learningUnitTopic(?lu,?lut),matchesLax(?t,?lut) -> secondAttempt(?lh,?lu), strugglingInUnit(?lh,?lu)
4.	5	***Struggling learner in a topic*** should be given extra support e.g. instructor-centred approaches. **IF THEN Translation:** If a learner is ***struggling in a topic*** then provides less-controlled approaches such as direct instruction. **SWRL Format:** eLearner(?x), LearningProcess(?lp), LearningHistory(?lh), eLearnerBehaviouralModel(?lbm), Module(?m), ModuleSpecification(?mspec), ModuleComponent(?mc), LearningUnit(?lu), hasModuleModuleSpecification(?m,?mspec), hasModuleSpecificationModuleComponent(?mspec,?mc), hasModuleComponentLearningUnit(?mc,?lu), hasEnrolledLearnerModule(?x,?m), hasAneLearnerBehaviouralModel(?x, ?lbm), hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh), learningUnitTopic(?lu,?t), strugglingInUnit(?lh,?lu) -> recommendedProcessElement(?lp, "DirectInstruction")
5.	6	***Struggling learner in a module*** is a learner who is struggling in two or more core learning topics of the module and should be given extra support e.g. instructor-centred approaches and join group to get help from talent/advanced learners. **IF THEN Translation:** If a learner is *struggling in a module* then provides direct instruction and join him to groups of advanced learners. **SWRL Format (To define a struggling learner in a module and assign learner to support-based group):** eLearner(?x), LearningProcess(?lp), LearningHistory(?lh), eLearnerBehaviouralModel(?lbm), Module(?m), ModuleSpecification(?mspec), ModuleComponent(?mc), LearningUnit(?lu), hasModuleModuleSpecification(?m,?mspec), hasModuleSpecificationModuleComponent(?mspec,?mc), hasModuleComponentLearningUnit(?mc,?lu1), learningUnitTopic(?lu1,?t1), learningUnitType(?lu1,?type1), hasModuleComponentLearningUnit(?mc,?lu2), learningUnitTopic(?lu2,?t2), learningUnitType(?lu1,?type2), hasEnrolledLearnerModule(?x,?m), hasAneLearnerBehaviouralModel(?x, ?lbm), hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh), matchesLax(?type1, "Core"), matchesLax(?type2, "Core"), strugglingInUnit(?lh,?lu1), strugglingInUnit(?lh,?lu2), not(matchesLax(?t1,?t2)) -> strugglingInModule (?lh,?m), isLearnerStruggling(?lh,true), recommendedProcessElement(?lp, "DirectInstruction")
	7	**2nd SWRL Format (To join a group as a struggling learner):** eLearner(?x), LearningHistory(?lh), eLearnerBehaviouralModel(?lbm), Module(?m), SupportBasedLG(?sb), linkingGroupModule(?sb,?m),hasEnrolledLearnerModule(?x,?m),

		hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelLearningHistory(?lbm,?lh), isLearnerStruggling(?lh,true), strugglingInModule (?lh,?m) -> joinedLearnerGroup(?x,?sb)
6.	8	*Advanced learner* is a learner that already finished two or more learning topic and achieved 85% or more in their assessment units and their grade point average (i.e. overall mark average) is above 70%. **IF THEN Translation:** If a learner achieved 85% or more in two learning topics of a module and his grade point average is greater than 70% then he is an advanced learner. **SWRL Format:** eLearner(?x), LearningProcess(?lp), Module(?m), ModuleSpecification(?mspec), ModuleComponent(?mc), LearningUnit(?lu1), LearningUnit(?lu2), eLearnerBehaviouralModel(?lbm), LearningHistory(?lh), Feedback(?f1), Feedback(?f2), AssessmentActivity(?aa1), AssessmentActivity(?aa2), hasModuleModuleSpecification(?m,?mspec), hasModuleSpecificationModuleComponent(?mspec,?mc), hasModuleComponentLearningUnit(?mc,?lu1), learningUnitTopic(?lu1,?t1), hasModuleComponentLearningUnit(?mc,?lu2), learningUnitTopic(?lu2,?t2), hasEnrolledLearnerModule(?x,?m), hasAneLearnerBehaviouralModel(?x, ?lbm), hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh), not(matchesLax(?t1,?t2)), hasLPAssessmentActivity(?lp,?aa1), leadToAssessmentActivityFeedback(?aa1,?f1), feedbackScore(?f1,?v1), greaterThan(?v1,85), hasLPAssessmentActivity(?lp,?aa2), leadToAssessmentActivityFeedback(?aa2,?f2), feedbackScore(?f2,?v2), greaterThan(?v2,85), learningHistoryMark(?lh,?v3), greaterThan(?v3,70) -> isLearnerAdvanced(?lh,true), advancedInModule(?lh,?m)
7.	9	*Advanced learners* are encouraged to help struggling learners e.g. publish supporting contents, interact with them **IF THEN Translation:** If a learner (a) is struggling in a module and another learner (b) is an advanced learner in that module then learner (b) leads the support based group and learner (a) join the support based group to learn from advanced learner. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm1), LearningHistory(?lh1), eLearner(?y), eLearnerBehaviouralModel(?lbm2), LearningHistory(?lh2), Module(?m), hasAneLearnerBehaviouralModel(?x, ?lbm1), haseLearnerModelLearningHistory(?lbm1,?lh1), isLearnerAdvanced(?lh1,true), advancedInModule(?lh1,?m), hasAneLearnerBehaviouralModel(?y, ?lbm2), haseLearnerModelLearningHistory(?lbm2,?lh2), isLearnerStruggling(?lh2,true), strugglingInModule (?lh2,?m) -> ledSupportBased(?x,?m), joinedLearnerGroup (?y,?m) ***Linked to rule number 5: struggling learners are already added to the group.***
8.	10	Presentation format of a learning content should be suitable for learner's learning style. The system should provide video-supported material for those learners who would like to learn by video-based contents. **IF THEN Translation:** If a learner's learning style is video then show him/her video-based learning processes **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), AdvancedProperties(?ap), hasAneLearnerBehaviouralModel(?x, ?lbm),

		haseLearnerModelAdvancedProperties (?lbm, ?ap), hasFollowLearnerLearningProcess(?x,?lp), learningStyle(?ap, ?str), matchesLax(?str, "Visual") -> recommendedContentStyle(?lp, "Visual")
9.	11	Presentation format of a learning content should be suitable for learner's learning style. The system should provide audio-supported material for those learners who would like to learn by audio-based contents. **IF THEN Translation:** If a learner's learning style is audio then show him/her audio-based learning processes **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), AdvancedProperties(?ap), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelAdvancedProperties (?lbm, ?ap), hasFollowLearnerLearningProcess(?x,?lp), learningStyle(?ap, ?str), matchesLax(?str,"Audio") -> recommendedContentStyle(?lp, "Audio")
10.	12	Presentation format of a learning content should be suitable for learner's learning style. The system should provide read/write-supported material for those learners who would like to learn by read/write-based contents. **IF THEN Translation:** If a learner's learning style is read/write then show him/her read/write-based learning processes **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), AdvancedProperties(?ap), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelAdvancedProperties (?lbm, ?ap), hasFollowLearnerLearningProcess(?x,?lp), learningStyle(?ap, ?str), matchesLax(?str,"ReadWrite") -> recommendedContentStyle(?lp, "ReadWrite")
11.	13	Presentation format of a learning content should be suitable for learner's learning style. The system should provide Kinesthetic-supported material for those learners who would like to learn by Kinesthetic-based contents. **IF THEN Translation:** If a learner's learning style is Kinesthetic then show him/her Kinesthetic-based learning processes **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), AdvancedProperties(?ap), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelAdvancedProperties (?lbm, ?ap), hasFollowLearnerLearningProcess(?x,?lp), learningStyle(?ap, ?str), matchesLax(?str,"Kinesthetic") -> recommendedContentStyle(?lp,"Kinesthetic")
12.	14	Bored learners want to see interesting and motivating learning processes such as game-enhanced approaches. **IF THEN Translation:** If a *learner's affect state* is bored then recommend interesting learning approaches such as game-enhanced learning approaches. **SWRL Format:**

		eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), AdvancedProperties(?ap), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelAdvancedProperties (?lbm, ?ap), hasFollowLearnerLearningProcess(?x,?lp), affects(?ap, ?str), matchesLax(?str, "Negative") -> recommendedProcessElement(?lp,"GameBased")
13.	15	Bored learners with related background should see learning processes related to their background (*). (*) *Background refer to e-learner's knowledge outside the module being taught. For instance, if a learner's background is good in Math then he/she might be taught the "Validation & Verification" topic with more focus on formal verification.* **IF THEN Translation:** If a *learner's affect state* is bored and he/she has related background then recommend background-oriented learning process **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), AdvancedProperties(?ap), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelAdvancedProperties (?lbm, ?ap), hasFollowLearnerLearningProcess(?x,?lp), affects(?ap, ?str), matchesLax(?str, "Negative"), Background(?b,?bgstr), matchesLax(?bgstr, "Math") -> recommendedProcessBackground(?lp, "Math"), recommendedProcessElement(?lp,"GameBased")
14.	16	Excited learners are eager to learn more so recommend enrichment learning contents. **IF THEN Translation:** If a *learner's affect state* is excited (i.e. positive) then recommend enrichment learning contents. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), AdvancedProperties(?ap), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelAdvancedProperties (?lbm, ?ap), hasFollowLearnerLearningProcess(?x,?lp), affects(?ap, ?str), matchesLax(?str, "Positive") -> recommendedProcessContent(?lp,"Enrichment")
15.	17	Learners with visual disability should be treated in a way that is suitable for their visual conditions. **IF THEN Translation:** If an e-learner has a visual disability then recommend alternative learning contents. For instance, contents supported by alternative text-based (ALT). **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), PhysicalProperties(?pp), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelPhysicalProperties (?lbm, ?pp), hasFollowLearnerLearningProcess(?x,?lp), disability(?pp, ?str), matchesLax(?str, "Visual") -> recommendedAssistiveElement(?lp,"Visual")
16.		Learners with hearing disability should be treated in a way that is suitable for their hearing conditions. **IF THEN Translation:** If an e-learner has hearing disability then text-based learning contents. For instance, contents without sound material (e.g. podcasting), video material should be supported by scripts.

	18	**SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), PhysicalProperties(?pp), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelPhysicalProperties (?lbm, ?pp), hasFollowLearnerLearningProcess(?x,?lp), disability(?pp, ?str), matchesLax(?str, "Hearing") -> recommendedAssistiveElement(?lp, "Hearing")
17.	19	An e-learner masters a learning topic when he/she gets 50% or more in the assessment part of that learning topic. **IF THEN Translation:** If a learner gets 50% or more in a given learning topic, then he/she mastered that topic. **SWRL Format:** eLearner(?x), LearningProcess(?lp), AssessmentActivity(?aa), Feedback(?f), eLearnerBehaviouralModel(?lbm), LearningHistory(?lh), hasAneLearnerBehaviouralModel(?x, ?lbm), hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh), hasLPAssessmentActivity(?lp,?aa), leadToAssessmentActivityFeedback(?aa,?f), learningProcessTopic(?lp,?topicstring), feedbackScore(?f,?v), greaterThan(?v,50) -> knowledgeLevel(?lh,concat(?topicstring,?v))
18.	20	A learner cannot access a learning topic unless he/she fulfils its prerequisites. **IF THEN Translation:** If a learner masters a prerequisite for a learning topic then he/she can access the required learning topic. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningHistory(?lh), LearningProcess(?lp), Module(?m), ModuleSpecification(?mspec), ModuleComponent(?mc), LearningUnit(?lu), hasAneLearnerBehaviouralModel(?x, ?lbm),hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh),hasEnrolledLearnerModule(?x,?m), hasModuleModuleSpecification(?m,?mspec), hasModuleSpecificationModuleComponent(?mspec,?mc), hasModuleComponentLearningUnit(?mc,?lu), learningUnitPrerequisites(?lu,prerequisitestr), knowledgeLevel(?lh,?knowntopicstr), contains(?knowntopicstr,?prerequisitestr) -> learningProcessTopic(?lp,learningUnitTopic(?lu))
19.	21	Learning process should be directed towards the pre-requisite of a learning topic instead of the learning topic itself if the prerequisite is not fulfilled by the e-learner. **IF THEN Translation:** If an e-learner does not master the prerequisite of a given learning topic then show the content for that prerequisite. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningHistory(?lh), LearningProcess(?lp), Module(?m), ModuleSpecification(?mspec), ModuleComponent(?mc), LearningUnit(?lu), hasAneLearnerBehaviouralModel(?x, ?lbm),hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh),hasEnrolledLearnerModule(?x,?m), hasModuleModuleSpecification(?m,?mspec),

		hasModuleSpecificationModuleComponent(?mspec,?mc), hasModuleComponentLearningUnit(?mc,?lu), learningUnitPrerequisites(?lu,prerequisitestr), knowledgeLevel(?lh,?knowntopicstr), not(contains(?knowntopicstr,?prerequisitestr)) -> learningProcessTopic(?lp,?prerequisitestr)
20.	22	Learners with misconception should be exposed to a learning process that resolve the identified misconception. **IF THEN Translation:** If an e-learner has a specific misconception, then provides a learning process that can resolve the specified misconception. **SWRL Format:** eLearner(?x),eLearnerBehaviouralModel(?lbm), LearningHistory(?lh),Module(?m), ModuleSpecification(?mspec), ModuleComponent(?mc),LearningProcess(?lp), LearningUnit(?lu),MisconceptionRepository(?mr), hasAneLearnerBehaviouralModel(?x, ?lbm), hasFollowLearnerLearningProcess(?x,?lp), haseLearnerModelLearningHistory(?lbm,?lh), hasEnrolledLearnerModule(?x,?m), hasModuleModuleSpecification(?m,?mspec), hasModuleSpecificationModuleComponent(?mspec,?mc), hasModuleComponentLearningUnit(?mc,?lu), hasRelatedLearningUnitMisconception(?lu,?mr), misconceptions(?lh,?learnerstr), misconceptionID(?mr,?misconstr), containsIgnoreCase(?learnerstr,?misconstr) -> recommendedProcessContent(?lp,misconceptionResolvingContent(?misconstr))
21.	23	Collaborative-oriented learning approaches should be recommended for learners who are highly engaged with collaborative and social activities (*). For instance, their learning processes involve obvious recommendations for peers and collaborative tools that allow more interactions such as commenting on the work of others, tagging, sharing and so on. (*) *Engagement,* as defined in the meta-model specification, refers to the time spent on social tools and interactions with actors. **IF THEN Translation:** If a learner is highly engaged with in social interaction (i.e. 30% of the learning process time is spent on social activities) then recommend collaborative learning approaches. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), LearningHistory(?lh), CollaborativeBasedLA(?cbla), hasAneLearnerBehaviouralModel(?x, ?lbm), hasLearningModelLearningHistory(?lbm,?lh), hasFollowLearnerLearningProcess(?x,?lp), hasCollaborativeBasedLALearningProcess(?cbla,?lp), collldurationOfUse(?cbla,?subDuration), learningProcessDuration(?lp,?totalDuration), greaterThan(?divide(?subDuration,?totalDuration),0.3) -> recommendedProcessTendency(?lp,"Collaborative"), engagement(?lh,?divide(?subDuration,?totalDuration)), learningTendency(?lh,"Collaborative") *Is it necessary to have learning tendency in the behavioural model? We might delete it*
22.		Individual-oriented learning approaches should be recommended for learners who spend minor time in social tools interacting with peers and instructor (*). (*)Such learners will be able to interact with others and use the social tools but those tools (e.g. peers recommendations) are not highlighted to them as per collaborative approaches. **IF THEN Translation:** If a learner is not highly engaged with social interaction (i.e. less than 30% of the learning process time is spent on social activities) then recommend individual learning approaches.

	24	**SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningProcess(?lp), LearningHistory(?lh),IndividualBasedLA(?ibla), hasAneLearnerBehaviouralModel(?x, ?lbm), hasLearningModelLearningHistory(?lbm,?lh), hasFollowLearnerLearningProcess(?x,?lp), hasIndividualBasedLALearningProcess(?ibla,?lp), inDurationOfUse(?ibla,?subDuration), learningProcessDuration(?lp,?totalDuration), lessThan(?divide(?subDuration,?totalDuration),0.3) -> recommendedProcessTendency(?lp,“Individual”), engagement(?lh,?divide(?subDuration,?totalDuration)), learningTendency(?lh,“Individual”) *Is it necessary to have learning tendency in the behavioural model? We might delete it*
23.	 25	Learners with 30% or more *academic support failure messages* (e.g. 3 out of 7 messages) are recommended to take direct instruction learning process i.e. under observation and support. **IF THEN Translation:** If a learner has 30% or more failure messages in his behavioural model then recommend direct instruction-based learning process. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningHistory(?lh), LearningProcess(?lp),hasFollowLearnerLearningProcess(?x,?lp), hasAneLearnerBehaviouralModel(?x,?lbm), hasLearningModelLearningHistory(?lbm,?lh), greaterThan(?divide(?numberOfFailureMessages(?lh), ?numberOfMessagesProvidedToLearner(?lh),0.3) -> recommendedProcessElement(“DirectInstruction”) We need to create a rule to set/modify number of messages and number of failure messages in learner history.
24.	 26	Learners who are skilled in SRL and have their own goals should be offered more flexible environment where they can find the appropriate content. **IF THEN Translation:** If a learner has SRL skills and has specific goals then suggests processes that meet his/her goals(*). **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), Skills(?s), LearningProcess(?lp), eLearnerGoals(?lg), hasAneLearnerBehaviouralModel(?x, ?lbm), haseLearnerModelSkill(?lbm, ?s), haseLearnerModelGoals(?lbm, ?lg), hasFollowLearnerLearningProcess(?x,?lp),skillType(?s, ?str), matchesLax(?str, "Metacognitive"), goalTitle (?lg,?goalstr) -> learningProcessTopic(?lp, “goalstr”) (*) goalTitle data property is represented by keyword (i.e. topic title).
25.	 27	Learners are grouped in peers based on their commonalities in goals, interests, social interaction or annotations so they become more motivated to interact with each other. **IF THEN Translation:** If a group of learners have common factors (i.e. goals, interests, social interaction or annotations), then group them together. **1st SWRL Format (based on common goals):** eLearner(?x), eLearnerBehaviouralModel(?lbm1), eLearnerGoals(?lg1), Module(?m), eLearner(?y), eLearnerBehaviouralModel(?lbm2), eLearnerGoals(?lg2), hasAneLearnerBehaviouralModel(?x, ?lbm1),

		haseLearnerModeleLearnerGoals(?lbm1,?lg1), hasEnrolledLearnerModule(?x,?m) hasAneLearnerBehaviouralModel(?y, ?lbm2), haseLearnerModeleLearnerGoals(?lbm2,?lg2), hasEnrolledLearnerModule(?y,?m), goalTitle (?lg1,?gt1), goalTitle (?lg2,?gt2), containsIgnoreCase (?gt1,?gt2) -> hasParticipateLearnerSocialBasedLG(?x,?m), hasParticipateLearnerSocialBasedLG(?y,?m), Is there any need to include the module code in this rule?
	28	**2nd SWRL Format (based on e-learner interests):** eLearner(?x), eLearnerBehaviouralModel(?lbm1), AdvancedProperties(?ap1), Module(?m), eLearner(?y), eLearnerBehaviouralModel(?lbm2), AdvancedProperties(?ap2), hasAneLearnerBehaviouralModel(?x, ?lbm1), haseLearnerModelAdvancedProperties(?lbm1,?ap1), hasEnrolledLearnerModule(?x,?m) hasAneLearnerBehaviouralModel(?y, ?lbm2), haseLearnerModelAdvancedProperties(?lbm2,?ap2), hasEnrolledLearnerModule(?y,?m), interests(?ap1,?intereststr1), interests(?ap2,?intereststr2), containsIgnoreCase (?intereststr1,? intereststr2) -> hasParticipateLearnerSocialBasedLG(?x,?m), hasParticipateLearnerSocialBasedLG(?y,?m), Is there any need to include the module code in this rule?
	29	**3rd SWRL Format (based on e-learner annotations):** eLearner(?x), eLearnerBehaviouralModel(?lbm1), LearningHistory(?lh1), Module(?m), eLearner(?y), eLearnerBehaviouralModel(?lbm2), LearningHistory(?lh2), hasAneLearnerBehaviouralModel(?x, ?lbm1), haseLearnerModelLearningHistory(?lbm1,?lh1), hasEnrolledLearnerModule(?x,?m) hasAneLearnerBehaviouralModel(?y, ?lbm2), haseLearnerModelLearningHistory(?lbm2,?lh2), hasEnrolledLearnerModule(?y,?m), learnerAnnotations(?lh1,?annstr1), learnerAnnotations(?lh2,?annstr2), containsIgnoreCase (?annstr1,? annstr2) -> hasParticipateLearnerSocialBasedLG(?x,?m), hasParticipateLearnerSocialBasedLG(?y,?m), Is there any need to include the module code in this rule?
	30	**4th SWRL Format (based on e-learner social interaction):** eLearner(?x), eLearnerBehaviouralModel(?lbm1), AdvancedProperties(?ap1), Module(?m), eLearner(?y), eLearnerBehaviouralModel(?lbm2), AdvancedProperties(?ap2), hasAneLearnerBehaviouralModel(?x, ?lbm1), haseLearnerModelAdvancedProperties(?lbm1,?ap1), hasEnrolledLearnerModule(?x,?m) hasAneLearnerBehaviouralModel(?y, ?lbm2), haseLearnerModelAdvancedProperties(?lbm2,?ap2), hasEnrolledLearnerModule(?y,?m), socialInteraction(?ap1,?socinterstr1), socialInteraction(?ap2,?socinterstr2), containsIgnoreCase (?socinterstr1,? socinterstr2) -> hasParticipateLearnerSocialBasedLG(?x,?m), hasParticipateLearnerSocialBasedLG(?y,?m), Is there any need to include the module code in this rule?
26.		For those learners who preferred situated learning approaches (i.e. collaborations with instructor and others learners is an indicator) recommend situated learning approaches **IF THEN Translation:** If a leaner is highly interacting with the community (i.e. instructor and others learners), then recommend situated approaches.
	31	**SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningHistory(?lh),

		hasAneLearnerBehaviouralModel(?x, ?lbm), hasLearningModelLearningHistory(?lbm,?lh), learningTendency(?lh,?learnstr), matchesLax(?learnstr, "Collaborative") -> recommendedProcessElement(?lp, "Situated")
27.	32	For those learners who preferred situated learning approaches and their learning style is kinaesthetic, recommend virtual world-oriented learning approaches. **IF THEN Translation:** If an e-leaner prefers situated learning approaches and his/her learning style is kinaesthetic then recommend virtual world-oriented situated learning approaches. **SWRL Format:** eLearner(?x), eLearnerBehaviouralModel(?lbm), LearningHistory(?lh), AdvancedProperties(?ap),hasAneLearnerBehaviouralModel(?x, ?lbm), hasLearningModelLearningHistory(?lbm,?lh), learningTendency(?lh,?learnstr), matchesLax(?learnstr,"Collaborative"),learningStyle(?ap,?lnstylestr), matchesLax(?lnstylestr,"Kinaesthetic") -> recommendedProcessElement(?lp, "Virtual World")

Appendix IV: Traceability of the e-Learning Meta-Model

This section shows the traceability of the e-Learning Meta-Model on three different levels of detail: (i) level A: at the core elements level, (ii) level B: at the core and supportive elements level, and (iii) level C: at the rule level. Each one is shown in a separate table as explained below.

2.5.5.1 Traceability: Level A

Model ID	Elements / Model	eActor	e-Learning Facilitating Tool	Pedagogy	Learning Process	eActivity	eContext	eContent	Presentation
1.	C1	N	N	I	N	Y	N	Y	Y
2.	C2	P	Y	I	I	Y	P	Y	Y
3.	C3	Y	Y	I	I	Y	N	Y	Y
4.	C4	Y	Y	P	N	Y	N	Y	Y
5.	PS1	Y	Y	Y	Y	Y	N	Y	Y
6.	PS2	Y	Y	N	Y	Y	N	Y	Y
7.	PS3	Y	Y	I	I	Y	N	Y	Y
8.	PS4	Y	Y	I	I	Y	N	Y	Y
9.	PS5	Y	Y	I	I	Y	N	Y	Y
10.	S1	Y	Y	P	I	Y	Y	Y	Y
11.	S2	Y	Y	P	I	Y	Y	Y	Y
12.	S3	Y	Y	P	I	Y	Y	Y	Y
13.	A1	Y	Y	P	I	Y	I	Y	Y
14.	A2	Y	Y	P	I	Y	I	Y	Y
15.	A3	Y	Y	P	I	Y	Y	Y	Y
16.	T1	I	N	P	N	P	N	Y	Y
17.	T2	Y	N	P	I	N	N	Y	Y
18.	T3	Y	Y	P	N	Y	N	Y	Y
19.	T4	I	P	P	N	N	N	Y	Y
20.	P1	Y	N	Y	N	P	N	Y	Y
21.	P2	I	N	Y	N	Y	N	Y	Y

Table 0.2: e-Learning Meta-Model Core Element Traceability

Keys:

Y: Yes, N: No, P: Partial refer to partial coverage of the concept, I: Implicit refers to the implicit inclusion of the concept within a particular model.

2.5.5.2 Traceability: Level B

Table 0.2 shows the traceability of the e-Learning Meta-Model at the level 2 (i.e., core and supportive elements).

#	Model / Elements	C1	C2	C3	C4	PS1	PS2	PS3	PS4	PS5	S1	S2	S3	A1	A2	A3	T1	T2	T3	T4	P1	P2
1.	A1	N	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	I	Y	I
2.	A2	N	P	Y	I	N	N	Y	Y	Y	N	Y	N	Y	P	N	N	N	N	N	N	N
3.	A3	N	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	I	Y	Y
4.	A4	N	P	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	N	N	N
5.	A5	N	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	Y	Y	Y
6.	A6	N	P	Y	N	N	N	Y	N	N	N	N	N	N	N	N	I	Y	N	N	N	N
7.	A7	N	P	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	N	N	N
8.	A8	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
9.	A9	N	Y	Y	Y	N	N	P	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	N	N	N
10.	A10	N	Y	Y	Y	Y	N	P	P	Y	Y	Y	Y	P	P	Y	Y	Y	P	P	N	N
11.	A11	N	Y	Y	Y	P	N	P	N	Y	Y	Y	Y	P	P	Y	P	Y	P	P	N	N
12.	A12	N	N	P	N	N	N	N	N	P	P	P	P	P	P	P	I	N	N	I	I	N
13.	A13	N	N	N	N	N	N	N	N	N	Y	Y	P	P	P	Y	I	N	N	P	I	N
14.	A14	N	N	N	N	N	N	N	N	N	P	Y	P	Y	Y	P	P	N	N	I	N	N
15.	A15	N	N	N	N	N	N	N	N	N	N	Y	N	P	Y	N	N	N	N	N	N	N
16.	A16	N	N	N	N	N	N	N	N	P	P	P	P	N	N	P	N	N	N	P	N	N

Table 0.3: e-Learning Meta-Model core element traceability

2.5.5.3 Traceability: Level C Rules

#	Model / Rules	C1	C2	C3	C4	PS1	PS2	PS3	PS4	PS5	S1	S2	S3	A1	A2	A3	T1	T2	T3	T4	P1	P2
1.	R1	N	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	I	Y	I
2.	R2	N	P	Y	I	N	N	Y	Y	Y	N	Y	N	Y	P	N	N	N	N	N	N	N
3.	R3	N	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	I	Y	Y

4.	R4	N	P	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	N	N	N
5.	R5	N	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	Y	Y	Y
6.	R6	N	P	Y	N	N	N	Y	N	N	N	N	N	N	N	N	I	Y	N	N	N	N
7.	R7	N	P	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	N	N	N
8.	R8	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
9.	R9	N	Y	Y	Y	N	N	P	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	N	N	N
10.	R10	N	Y	Y	Y	Y	N	P	P	Y	Y	Y	Y	P	P	Y	Y	Y	P	P	N	N
11.	R11	N	Y	Y	Y	P	N	P	N	Y	Y	Y	Y	P	P	Y	P	Y	P	P	N	N
12.	R12	N	N	P	N	N	N	N	N	P	P	P	P	P	P	P	I	N	N	I	I	N
13.	R13	N	N	N	N	N	N	N	N	N	Y	Y	P	P	P	Y	I	N	N	P	I	N
14.	R14	N	N	N	N	N	N	N	N	N	P	Y	P	Y	Y	P	P	N	N	I	N	N
15.	R15	N	N	N	N	N	N	N	N	N	N	Y	N	P	Y	N	N	N	N	N	N	N
16.	R16	N	N	N	N	N	N	N	N	P	P	P	P	N	N	P	N	N	N	P	N	N
17.	R17	N	P	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	N	N	N
18.	R18	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
19.	R19	N	Y	Y	Y	N	N	P	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	N	N	N
20.	R20	N	Y	Y	Y	Y	N	P	P	Y	Y	Y	Y	P	P	Y	Y	Y	P	P	N	N
21.	R21	N	Y	Y	Y	P	N	P	N	Y	Y	Y	Y	P	P	Y	P	Y	P	P	N	N
22.	R22	N	P	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	N	N	N
23.	R23	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
24.	R24	N	Y	Y	Y	N	N	P	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	N	N	N
25.	R25	N	Y	Y	Y	Y	N	P	P	Y	Y	Y	Y	P	P	Y	Y	Y	P	P	N	N
26.	R26	N	Y	Y	Y	P	N	P	N	Y	Y	Y	Y	P	P	Y	P	Y	P	P	N	N
27.	R27	N	N	P	N	N	N	N	N	P	P	P	P	P	P	P	I	N	N	I	I	N
28.	R28	N	N	N	N	N	N	N	N	N	Y	Y	P	P	P	Y	I	N	N	P	I	N
29.	R29	N	N	N	N	N	N	N	N	N	P	Y	P	Y	Y	P	P	N	N	I	N	N
30.	R30	N	N	N	N	N	N	N	N	N	N	Y	N	P	Y	N	N	N	N	N	N	N
31.	R31	N	N	N	N	N	N	N	N	P	P	P	P	N	N	P	N	N	N	P	N	N
32.	R32	N	N	P	N	N	N	N	N	P	P	P	P	P	P	P	I	N	N	I	I	N

Appendix V: Example-Based Operationalisation Scenario of HeLPS e-Learning Framework

Conceptually, there exist a generic process model and a hybrid e-learning meta-model where both models need to interact with each other to produce the desired HeLPS behaviour. This section shows how both components can work together in a simplified scenario. The generalised e-learning process explains the generalised behaviour of the e-learning system, while the ontology encodes a significant amount of knowledge about learner behaviour, history, context and processes, which will be used to enrich the overall HeLPS behaviour. To explain the HeLPS behaviour, let's assume that two learners X and Y would like to learn a new topic in the Web Development module. This module combines simple and advanced topics. X is not an advanced learner, he has a modest behavioural model, while Y has a better behavioural model. The step by step description below depicts HeLPS behaviour, while the process model is shown in the figure below:

1- *Learner X* will start by login to the e-learning system.

2- Once the credentials are correct, the system will extract the basic information about learner such as his name, level (undergraduate, graduate learner, etc.) time, device hardware, etc.

3- The system will instantiate a monitoring service that will run in the background in order to record every action done by *Learner X*.

4- *Learner X* will choose the web development module among the list of the modules shown to him by the system

5- The system will retrieve a preliminary version of *Learner X's* learning space.

6- The system will reason the ontology especially learner's behavioural model (e.g. knowledge level) to extract further information about the learner.

7- The system will instantiate a learning process for the learner.

8- The system will consult the domain ontology to know the sequence of the topics e.g. *Learner X* cannot learn Java Script Object Notation (JSON) unless he has some background about HTML. Also, domain ontology suggests the use of specific learning approaches. For instance, direct instruction (i.e. step by step) might be useful in teaching how to develop a dynamic web site but not for proving a mathematic theory.

9- The system will reason the ontological model to extract any misconceptions or missing conceptions in learner's behavioural model. In a technical language, there is a concept called *struggling learner* in the ontology, and *Learner X* belongs to this category of learners based on the following SWRL rule: *Every leaner who did not pass two assessment units for the same learning topic is a struggling learner in this particular topic*.

10- Based on the information extracted from the ontological model, the system will decide: (i) the topic to be taught and (ii) the best way to teach this topic. For instance, the next topic *Learner X* should start with is "Designing a dynamic website by php based on a database and formatting the results in proper way according to user preferences". Unfortunately, *Learner X* is struggling in CSS (i.e. according to the result of the last assessment activity). Therefore, the system will provide additional remedial contents about CSS to *Learner X* before proceeding to the dynamic website construction learning unit.

11- Also, *Learner X* record shows that he is performing better in a collaborative learning. Therefore, the system reason the ontology to extract the peers who share the same goals and interests with *Learner X*. The system will order the peers from higher achievement learners to lower achievement learners to encourage him contacting the ones scored highly.

12- The system will finalise the specification of the *Learner X's* e-learning process.

13- The system will derive the candidate e-learning services that are suitable for *Learner X*.

14- The system will translate the semantically-enriched BPMN process model to BEPL which is an XML-based language that is used to describe the process model as a series of activities implemented and executed by a web services.

15- The system will execute the BPEL script by a potential process execution engine.

16- The system will manage learner learning process, e.g. allow learner to interact with instructor, request technical help, etc.

17- Once the *Learner X* finish his learning, the system will instantiate an assessment activity to assess the understanding of the *Learner X* in that particular topic.

18- The system will provide the automatic feedback if it is applicable or request the instructor feedback.

19- The system will update *Learner X* model by the monitoring service.

20- Move to the next learning topic.

On the other hand, the system will behave differently when *Learner Y* use the system. Below are some steps to highlight part of the different system behaviour.

1- *Learner Y* will login to the system and choose the web development module.

2- The system will retrieve a preliminary version of *Learner Y's* learning space.

3- The system will instantiate a learning process for the *Learner Y*.

4- Because *Learner Y* is an advanced learner, his behavioural model points out to advanced topics (e.g. configuring large-scale web-based system) in the same module despite the fact that *Learner X* and *Learner Y* started the course at the same time.

5- Again, because *Learner Y* has proper self-regulating skills in his behavioural model, the system will allow him to plan his learning by choosing types of learning approaches (e.g. problem-based or project-based approach). Also, learning style attribute in *Learner Y* model shows that he tends to learn by watching videos.

6- The system will decide to combine a learning process where behavioural-based approaches (i.e. video lectures) are combined with cognitive and constructive-based approaches (self-regulating and problem-based) to teach *Learner Y.*

7- Once *Learner Y* submit his projects, the monitoring service will record his actions, update his model and wait the instructor final feedback to close this specific learning session with a final update.

In this way, the proposed framework provides a hybrid e-learning process based on selective parts from different processes according to the hybrid meta-model which contains learner's behavioural data. SWRL rules govern the interaction between the generic e-learning process and the rest of ontological components in order to derive a specialised e-learning process for a given learner.

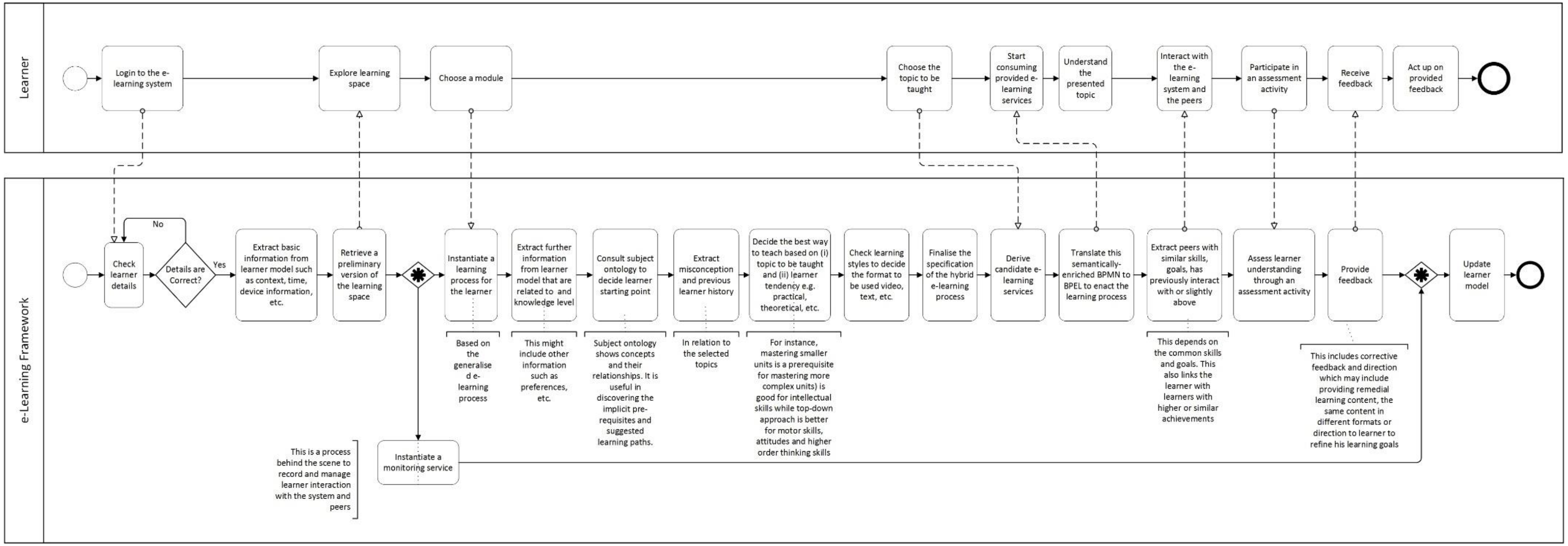


Figure A.0.4: Ontological and Process Models interaction

Appendix VI: Proof of Concept Design Choices and Deployment

This appendix discusses the various options and design choices available for the proof of concept design, development, and deployment. Some of these options were not feasible in the case of the HeLPS e-Learning Framework due to different reasons (e.g., some options are not compabtible with others).

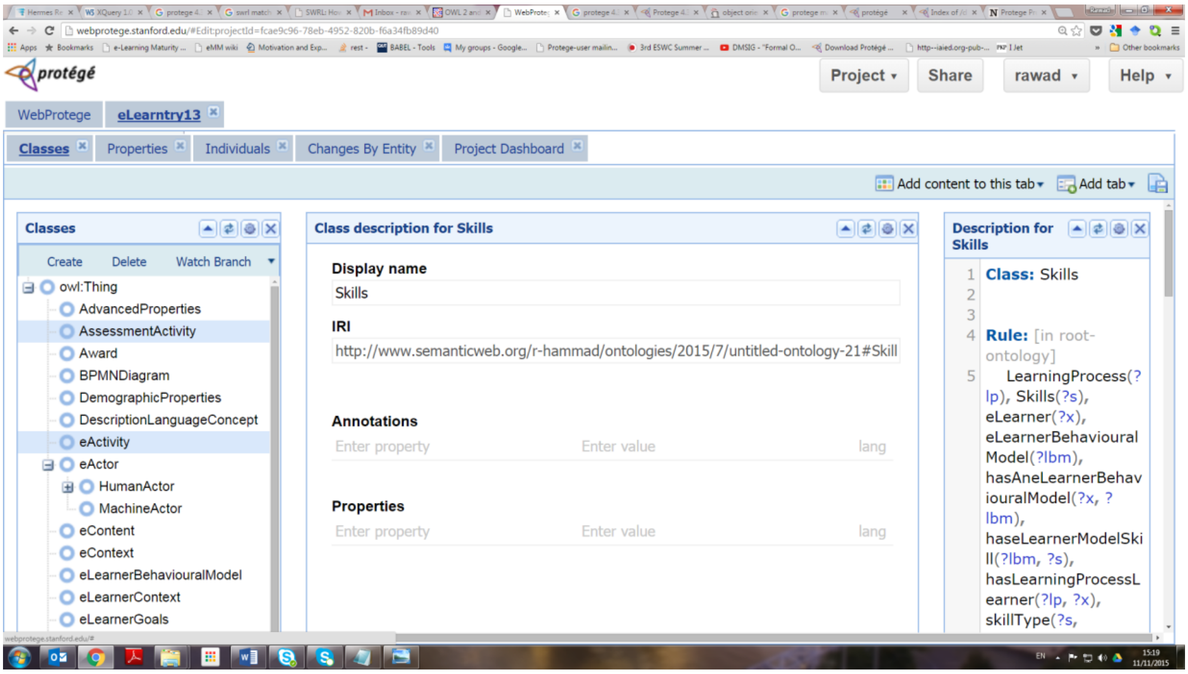
Options for Implementations:

1. **OWL API vs Jena API**: Jena is not a choice since it does not support OWL 2 and it is RDF centric. Protégé API can be used but OWL API is more abstract and adequate.
2. **Moodle vs our own prototype:** Moodle needs extensive interruptions
3. **PHP vs Java**: Java will be used to instantiate the ontology and some other tasks, and will be used due to the available support and library.
4. Pellet Reasoner is not supported as a plugin in the new protégé, so download it from and put it the plugin folder in the protégé. It can be downloaded from: https://github.com/Complexible/pellet/tree/master/protege/plugin or from here: https://groups.google.com/forum/?fromgroups#!topic/pellet-users/-wWWP-L_RbM
5. Change the plugin registry location in the Protégé to: https://raw.githubusercontent.com/Complexible/pellet/master/protege/plugin/update.properties

Challenges in Implementing the Proof of Concept

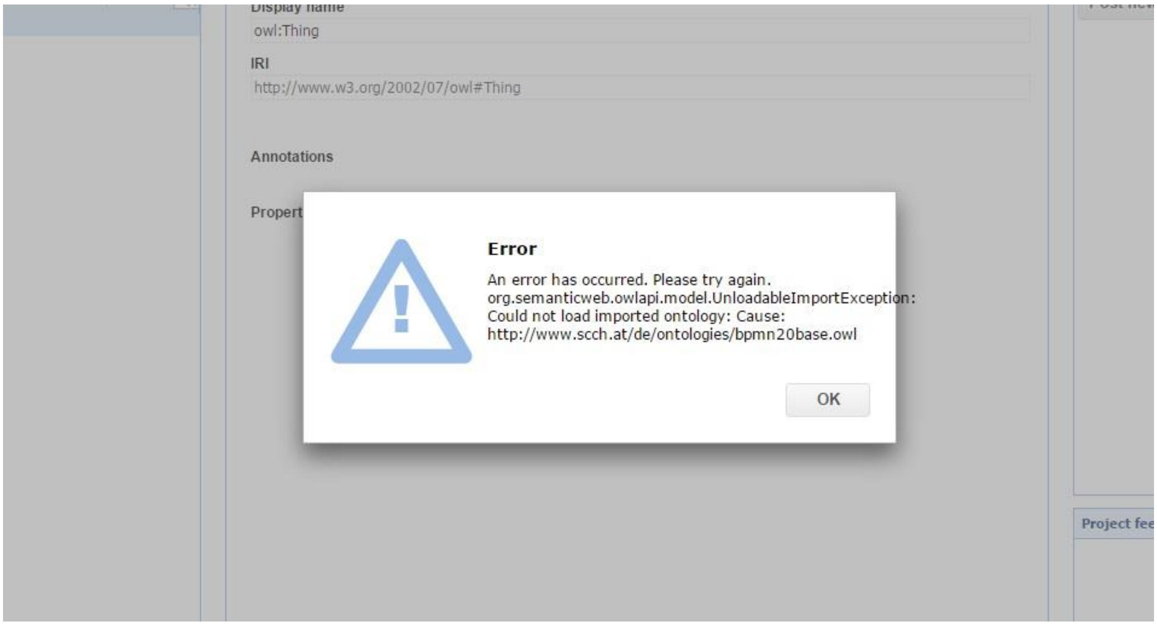
First , Specifying complicated SWRL rules for instance, setting a data property.

Trying Web Protégé 5 and the classess hirarchy was not shown in the right way, refer to Protégé Development Team (Tania’s email). Similarly, it did not show the sub-classes of assessment as shown in the figure below.



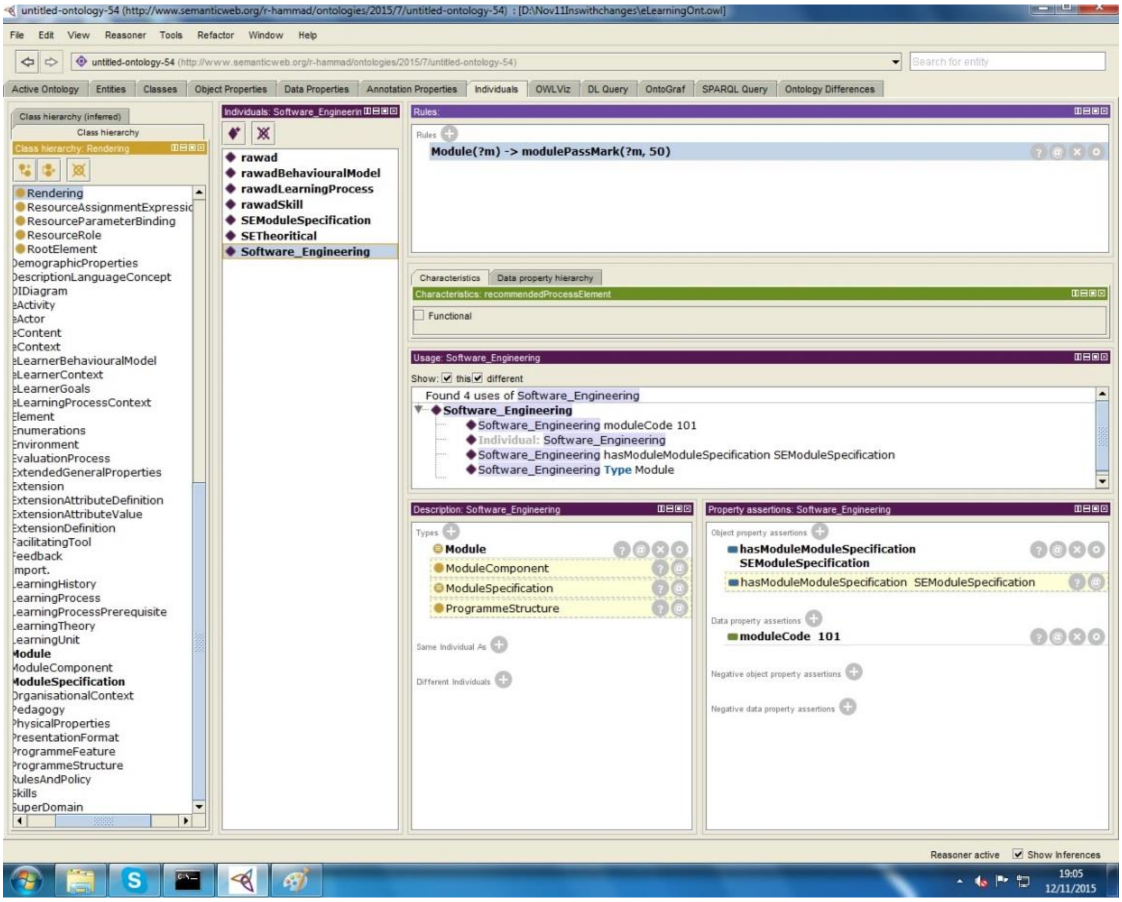
A.0.5: Web Protégé Deficiencies

Such deficinciesss are true when we upload BPMN Ontology, developed by a FP7 European Research Project mentioned earlier, to the webprotégé, the message in the figure below appears:



A.0.6: Errors seen when trying to reuse the BPMN2.0 Ontology

Second, Data property assertion failure by SWRL rule as shown in the figure below:



A.0.7: Protégé 4.3 Failure to Reserve the Data Generated by SWRL Rules

These are some of the examples that shows the limitations of the SWRL in the current standards.

The requirements for instantiating the e-learning ontology and framework are:

1. Specify it using OWL.
2. Validating the ontology by Protégé tool.
3. Move to the next step e.g., scenarios, process and services perspectives.
4. Create individuals/data (manually via protégé).
5. Select proper reasoning techniques: Pellet Reasoner.
6. Instead of using Moodle as an e-learning environment, developing a simplified prototype.
7. Semantic representation: e-learning ontology is specified in OWL and there is a need to use OWL API to read/extract the ontology.
8. Camunda Modeller has been used to model the early-designed e-Learning Business Processes Models.
9. Business Process Modelling and Enactment is necessary for executing the semantically-enriched modelled processes, therefore, the WSO2 Business Process Server has been used for this purpose.
10. As a UDDI for service registry, WSO2 Service Registry (GREG) is used.

11. BABEL is a tool for translating BPMN to BPEL, but it exists now as a plugin in eclipse at https://code.google.com/p/bpmn2bpel/ and http://www.bpm.scitech.qut.edu.au/research/projects/oldprojects/babel/tools/
12. In relation to BPMN and BPEL, DiaGen and DiaMeta exist but not effective http://modeling-languages.com/diagen-and-diameta-tools-generation-diagram-editors/
13. Tomcat server is used to host the application via its path x:\SW Nov 7\apache-tomcat-8.0.28\bin
14. Below are some related links that might be useful for such deployment:
    1- Hermit owl reasoner http://www.hermit-reasoner.com/java.html
    2- Owl api http://owlapi.sourceforge.net/documentation.html
    3- Apache ode http://ode.apache.org/
    4- Active vos http://www.activevos.com/products/activevos/overview
    5- End point configuration http://ode.apache.org/endpoint-configuration.html
    6- BPEL test http://ode.apache.org/writing-bpel-test-cases.html
    7- Ode http://ode.apache.org/userguide/
    8- Ode creating a process https://ode.apache.org/creating-a-process.html

Appendix VII: e-Learning Models Commonalities and Specific Features

Element **Model**	Learner model/ profile	Learning objectives	Learning activity	Assessment activity	Feedback	Granularity	Description/ Technology used	Pedagogy	Process orientation	Support from staff	Automatic discovery / reuse	Adaptivity/ adaptability	Working with peers
Learning Object (LO)	No	Yes	Yes	Yes	Could be available	Vague to the extent that LO range from a single image to large amount of combined elements	Described via meta data but not efficient as meta-data has nothing about the instructional approach used in this LO	No clear link with pedagogy. LO is more instructional rather than constructivist	No process-based aspects found in literature	Not an intrinsic part of LOM	Not effective due to the lack of proper description	Depends on the design of LO but difficult to prove	Collaborative work approach is rarely supported by LO
Intelligent Tutoring Systems Model	Yes	Yes	Wide and adaptive range of learning activities	Yes	Yes and it leads to changes in teaching strategies i.e model tracing is used in LISP Tutor to provide detailed feedback [22].	Complex as it depends on authoring tools as well as domain model.	It can be described as a system or subsystem, but this description cannot be used to automatically/ on the fly combine ITS with other external teaching approaches.	Mostly instructional and individual however, some collaborative works reported. Pedagogy is not sufficient	There are some process-based aspects within ITS but they are hidden inside this black box and cannot be reused or executed	Has the ability to provide very good support from tutor due to its one-to-one instructional approach.	Can be discovered through manual online searching rather than agent based approach.	Highly adaptive as it has learning models attached to different piece of knowledge and	Mostly one-to-one teaching with rare collaborative or peer to peer working.

									over a collaborative environment e.g. orchestrating process in cloud.			teaching strategies.	
E-training Model	No, instead it depends on general list learning needs for the target audience	Should have clear learning outcomes which are similar to learning objectives.	Yes	Yes. yet it may not the same as academic approaches and could be based on achievements or reflections on real e-trainer's experience	Not clearly stated but could be applied through different approaches to guide e-trainers	Similar to learning objects granularity	Can be described by text or meta data similar to web pages.	Based on Instructional System Design (ISD)/ Instructional Design (ID) which is based on bottom up approach where simple units constitute complex unit	There is no clear process-based approach but implicit process is there.	Could be available, but it depends on the company and the used learning model. Material can be live e-training with direct support and can be simple online material produced by other publisher without direct support	e-training model is not designed to be discovered and assembled automatically, so manual online searching can be used to find e-training material	Similar to traditional e-learning systems capabilities. e-trainer can chose the material but system do not offer high adaptivity such as modifying learning approach.	Similar to traditional e-learning systems capabilities. Peers are available but collaborative learning approach is rarely used

MOOCs and other open-based model	No	Yes	Yes, in different format based on its pedagogical model	Yes	Due to the unlimited number of learners, it is difficult to provide on time effective feedback from staff. Automated feedback is one of the used approaches	Large amount of information packaged as a course	Described as a system by text, metadata and other techniques used for traditional online web sites.	Mainly, two types of pedagogy are there. cMOOCs based on connectivism and xMOOCs based on behavioural learning theories. Hybrid model has not been found. Further enhancement is needed for cMOOCs as it is more self-directed learning	Mostly, information listed in linear approach with limited directions or restrictions (i.e. doing a quiz after the end of given learning topic. No mention to process-based approach in literature, but it could be implicitly applied	Due to the unlimited number of learners, it is difficult to provide either technical or subject matter support from staff. Again automated support (i.e. FAQ) is used.	Can be discovered through online searching.	Limited adaptivity found in literature with limitations to specific learning material	cMOOCs showed effective grouping techniques and connections with peers.
OUELO	No	Yes	Yes, rich learning activities compared to LOM	Yes ideally pool of assessment activities are available for	More active feedback compared to LOM	Complete course built out of LOs and narrative LOs. LOs can be reused while	Described by text, metadata and other techniques used for traditional online web sites.	Enhanced the pedagogy of LOM in terms of learner participation, group-based work,	No clear evident on process-based approach, however, it	Better support form staff compared to LOM	Can be detected automatically as a course but means nothing as some	Limited features of adaptability (i.e. choosing assess	Provides a chance for group-based activities with no bases for choosing peers

				learner to choose and it could be supported with an e-portfolio		narrative LOs cannot be reused		discussion, etc. but still instructionally dominant	provides guidance to learner to go through the whole course		of its components cannot be reused.	ment activity from a list and get feedback based on it)	
OpenLearn	No, yet learning analytics tools and techniques are used	Yes	High quality learning activity	Yes, in the form of automated assessment	Feedbacks are available from tutor and peers	Varies from single documents or unit of study to complete courses	Described by text, metadata and other techniques used for traditional online web sites.	Combination of teacher-centred and learner-centred approach along with analysis framework (activity theory) but needs further pedagogical base (i.e. learning theory)	Similar to other OER linear approach is used. No mention to process-based approach in literature , but it is implicitly applied	Automated support (i.e. FAQ) is usually used. Human–based support are available but delay is expected according to learner/staff percentage	Can be discovered through online search at the level of course, yet no evidence found in literature that this can be done on the level of unit of study	Limited adaptivity and adaptability features due to the limitations of user modelling techniques	Provides good potential for collaborative work especially LabSpace part.
IMS Learning Design	No	Yes	Yes in the form of unit of study	Yes	No explicit mention for feedback	Unit of study is the smallest unit providing learning for learners to , satisfy one or more interrelated	Described by text, metadata and other techniques used for traditional online web sites. Additionall, it uses XML	Pedagogy is considered in this model however being abstract to this extent does not add much	Implicitly applied without providing the ability of this process to be broken	Support can be provided but no clear explanation of how it could be done.	The formalism concept can work for automatic discovery yet unit	Depends on the design and delivery of unit of study but difficult	Provides potential for collaborative and group based activities

						learning objectives.	namespaces for integration issues	value, so Koper's model developed.	into smaller activities.		of study cannot be broken down to its components without losing its semantic and effectiveness towards the attainment of learning objectives.	to make a generic conclusion.	
Laurillard Conversational Framework	No	Not clearly stated while focus on learning needs	Yes, almost through conversation-based approach with tutor	Could be formative assessment to provide feedback to learner	Intrinsic part, but difficult to prove with multiple number of learners	Not applicable	Not applicable. LFC is a theoretical base for tools and approaches used in e-learning	Instructional-based approach based on constructivist approach with more focus on interaction	Implicit	Support is available in individualised approach but difficult to prove its effectiveness in real online environment	Not applicable	Adaptive as it uses individualised approach	Could be used for cooperation with peers in a limited way
Britain and Liber Framework	No, group-based learners	Yes	Yes	Yes	Should be provided	A whole virtual learning	Not applicable. LFC is a theoretical	Limited pedagogical base in terms of	Implicit	Similar to traditional online systems	Not applicable	Adaptive for group-	Could be used for cooperation

	needs is mentioned					environment	base for tools and approaches used in e-learning	learning theories used by practitioners				based needs	with peers in a limited way
e-Learning Process Life Cycle Model	Learner profile is available	Yes	Yes	Yes	Cyclic feedback from one stage to another is not represented.	Offers a complete theoretical e-learning process from planning to assessment	Theoretical framework influenced by standardisation concerns	Does not support a solid base for the pedagogy of e-learning	Yes, process is there but no evident for real application of this process in distributed environment such as cloud or SOA	Provides a framework for getting support without details	Not applicable	Depends on strategies used in implementation of the whole process	Yes can be used for collaborative learning
Process-Oriented Model for TEL	Learner profile is used	Yes	Yes	Yes	Yes	Holistic theoretical framework for learning	Theoretical framework with no connection with technical aspects	Provides abstract guidance for learning stages from novice learner to expert	It has been claimed to be process-oriented yet this process is not well presented (roles, resources, etc.)	Yes	Not applicable	Not applicable	Yes

Badrul Khan	Learner profile is considered as a part of pedagogical dimension	Yes	Yes	Yes	Feedback is provided here in different directions for learners, tutors, institution	Describes a holistic picture of e-learning without t	Purely theoretical framework to provide a comprehensive picture for e-learning	Pedagogical dimension cover learning goals, design approach, methodology, medium, etc. with no mention to learning theories or similar concepts	Process is implicitly applied	Yes	Not applicable	Contents should be adapted based on feedback but no automatic adaptivity/adaptability.	Yes
Khan's e-Learning P3 Model	Learner competences/skills are mentioned as a base for learning design	Yes	Mostly this model is content-based model	Evaluating learning content is the main activity however; assessment activities can be included in this model.	No	Describes a comprehensive mechanism for approaching e-learning project from planning to evaluation	Theoretical framework divides e-learning into content development, and content delivery and maintenance	Used pedagogical model lacks flexibility and participatory learning approach	Process is there without clear mention learning process itself.	Kept to the minimum level	Not applicable	Feedback from project evaluation is used to modify and update content	No
eLSM	Minimal consideration for learning goals	Not applicable	Yes	Yes	Yes	Not applicable	Describes a broad evaluation mechanism for e-learning	Considers learners' feedback as bases for e-learning	Adhoc approach is used	Not applicable	Not applicable	Feedback from a stage to another	Not mentioned

							course from different perspectives.	design and delivery				can be used to update other phases	
Semantic framework for CLE	Yes, learner layer stores information about learner and his behaviour	Yes	Yes, they are named as learning services	Yes	Yes, mostly through direct communications with peers	Learning services are the smallest chunk of knowledge and can be used independently	Integrate framework that uses semantic representation to describe learning services, form learner groups and recommend resources to learners. Cloud has been used as a deployment environment	Based on responsive learning approach or self-regulated learning which is learner-centric. learners choose and assemble resources that meet their goals and regulate their learning in their own ways	Process is implicitly there. Yet, it cannot be automatically mapped to collaborative environment such as cloud.	Yes, however most support is supposed to be gained through cooperation with peers.	Learning services can should be searched manually based on semantic represenation and can be re-used later on	Yes, it is adaptive according to learner behaviour, progress and achievement	Yes provided to large extent
Cloud-based framework for HEI in Ethiopia	No	Yes	Yes	Yes	Facilitates feedback	Offers a complete framework for all Ethiopian universities	Pure technical framework that is focused around the use of cloud technology to fulfil HE needs with no coverage for learning issues	Not covered in this framework	Not applicable	Should facilities getting support	Not applicable	Not applicable	Should facilitates working with peers

Cloud-based cost effective e-learning framework	No	Not applicable	Yes	Yes	Facilitates feedback	Offers a framework for using federation of cloud environment	Pure technical framework based on cloud technology with the main aim of minimising the cost of e-learning	Not covered in this framework	Not applicable	Should facilities getting support	Not applicable	Not applicable	Should facilitates working with peers

Table 0.4: Summary

Appendix VIII: HeLPS e-Learning Framework Proof of Concept

This section briefly explains the design of the Proof of Concept of HeLPS e-Learning Framework in terms of its front and back end.

1 HeLPS Front End Explained

This section explains HeLPS front end design which includes the use cases, sequence diagrams, class diagram and selected screen shots from HeLPS prototype. Figure A.8 illustrates HeLPS structure in terms of its three modules: (i) AdaptiveLearn, (ii) LearnServices and (iii) EndPointLookUp and their constituent packages, such as com.learnmatters.services. Figure A.9 explains HeLPS class diagram where different annotations and colours have been used to represent different classes, interfaces and packages. As mentioned earlier, Figure 4.1 illustrates HeLPS Use Case diagram that have been specified. Finally, Figure A.10 illustrates HeLPS Sequence Diagram.

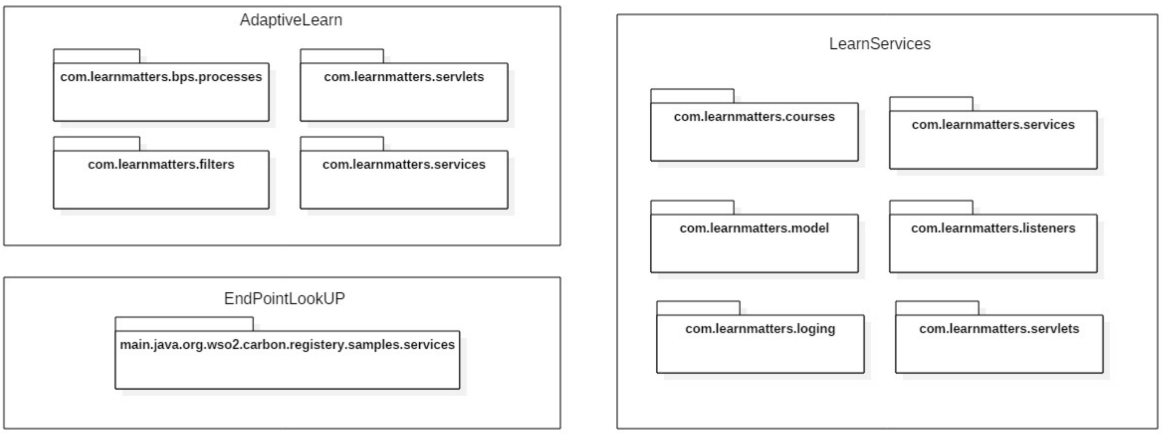


Figure A.0.8: HeLPS Framework Modules and Packages

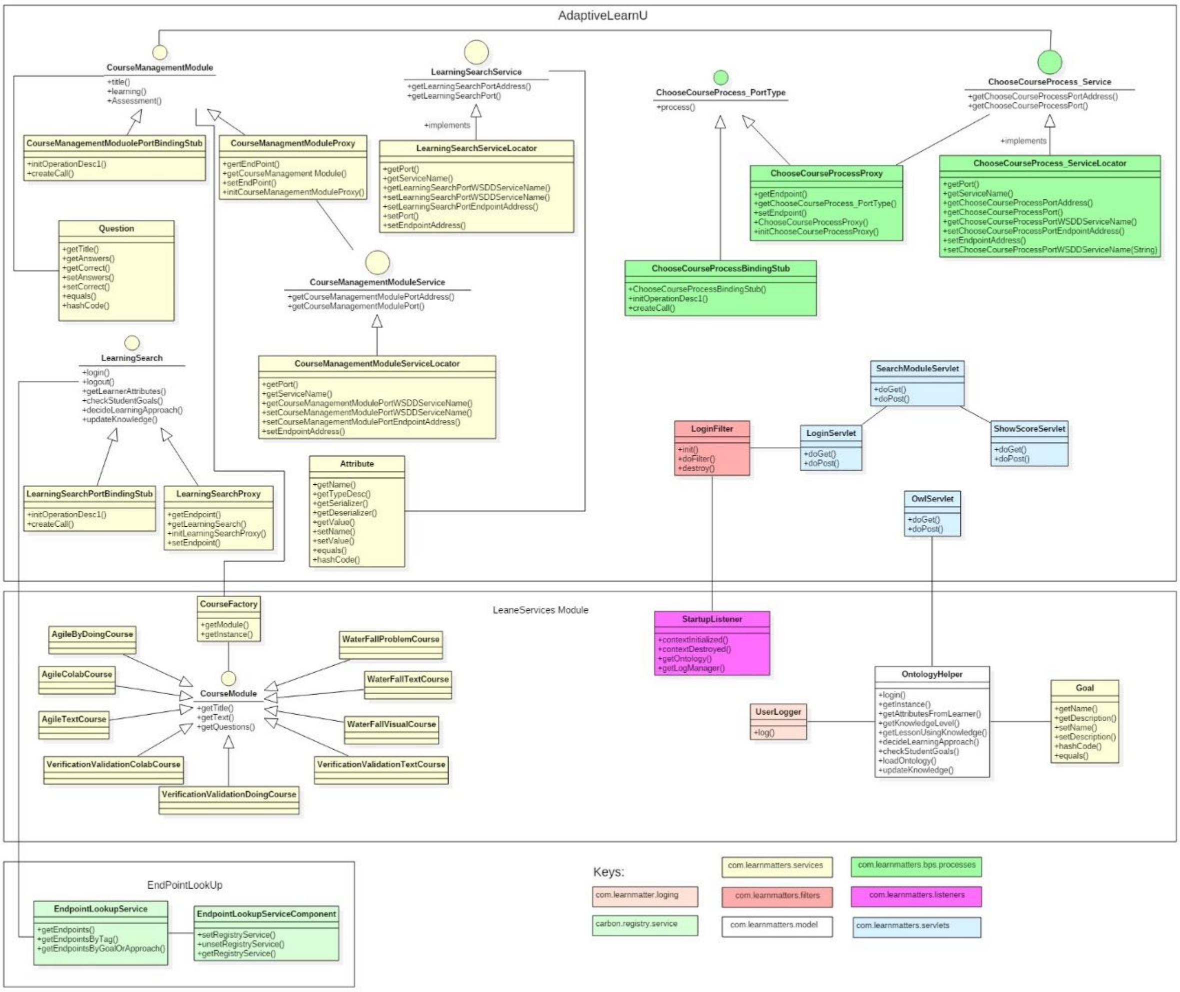


Figure A.0.9: HeLPS e-Learning Framework Class Diagram

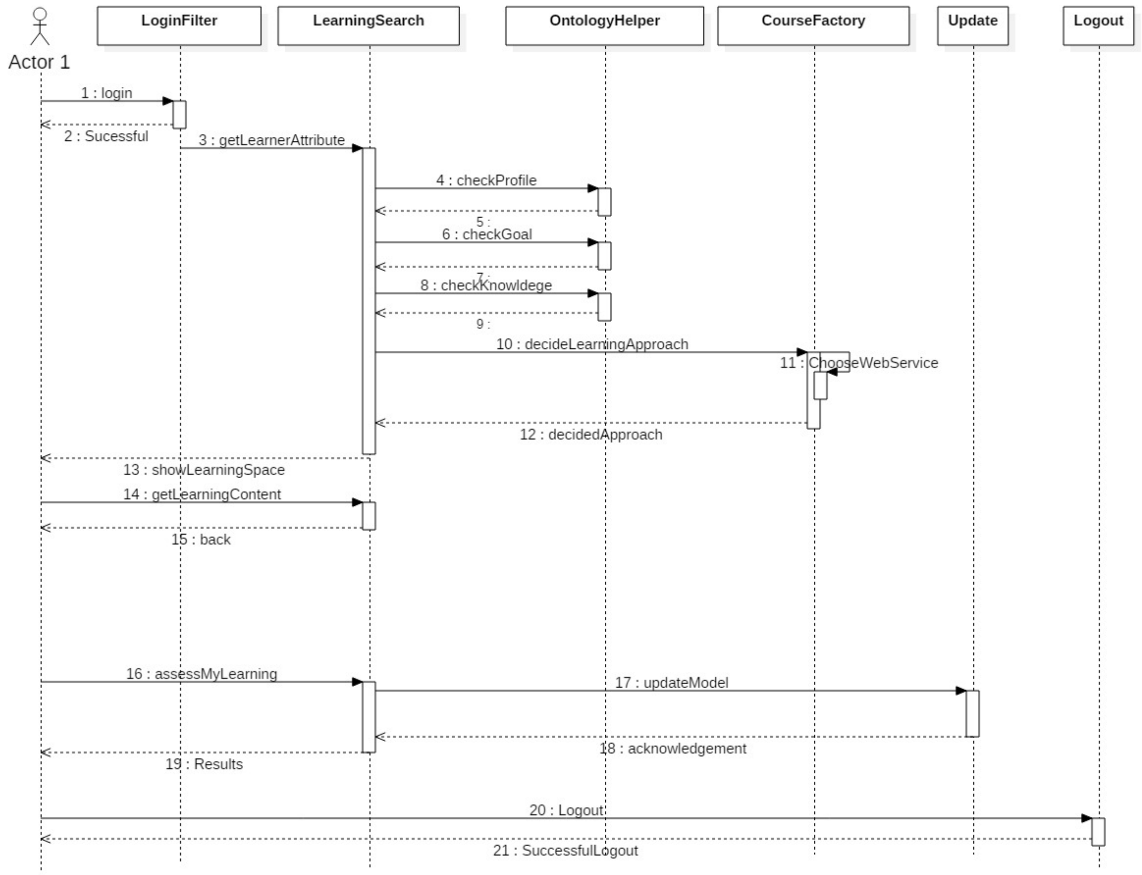


Figure A.0.10: HeLPS e-Learning Framework Sequence Diagram

Figures A.11, A.12, A.13, and A.14 represent the following screens: Login screen, Waterfall Software Development Process Model Lesson (i.e., web service), the assessment element (i.e., web services) of Waterfall Lesson and Assessment results, respectively.

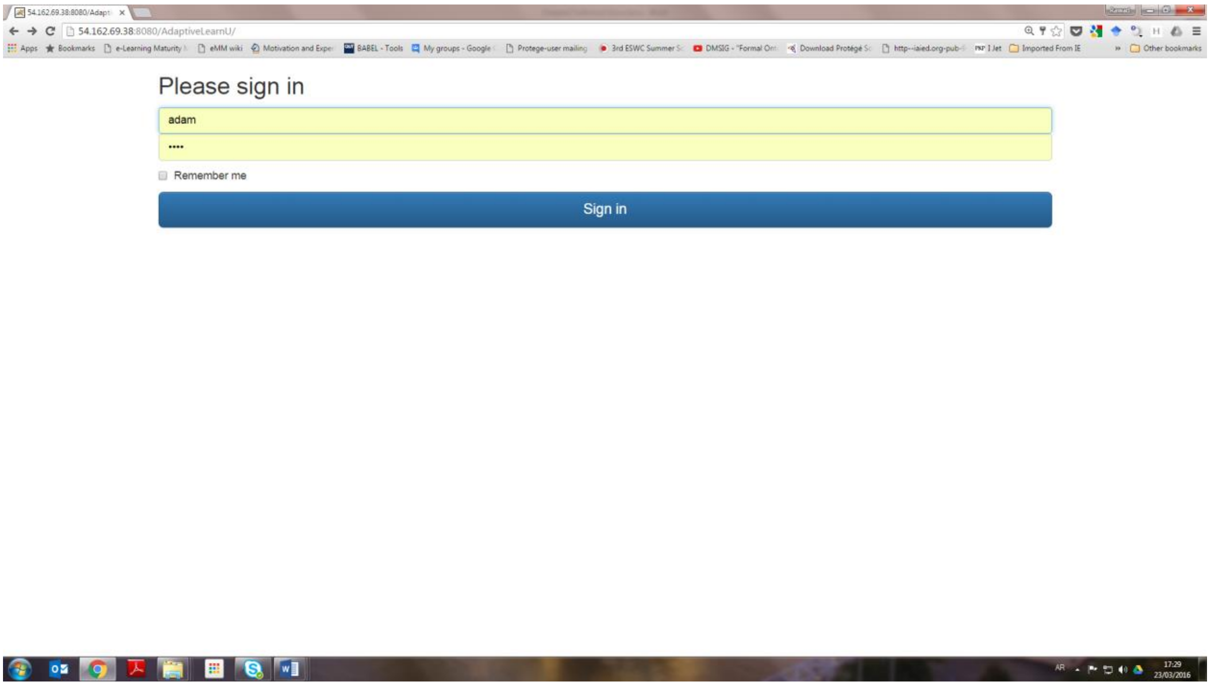


Figure A.0.11: HeLPS Login Screen

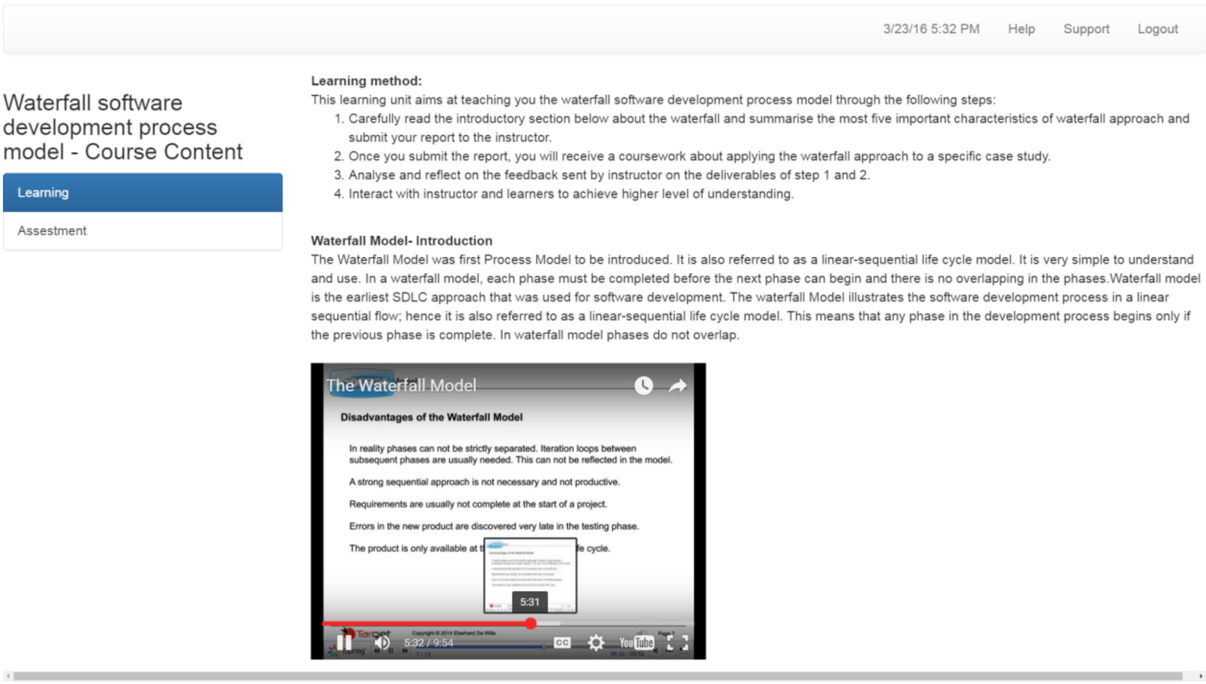


Figure A.0.12: Waterfall Process Lesson (i.e., Web Service)

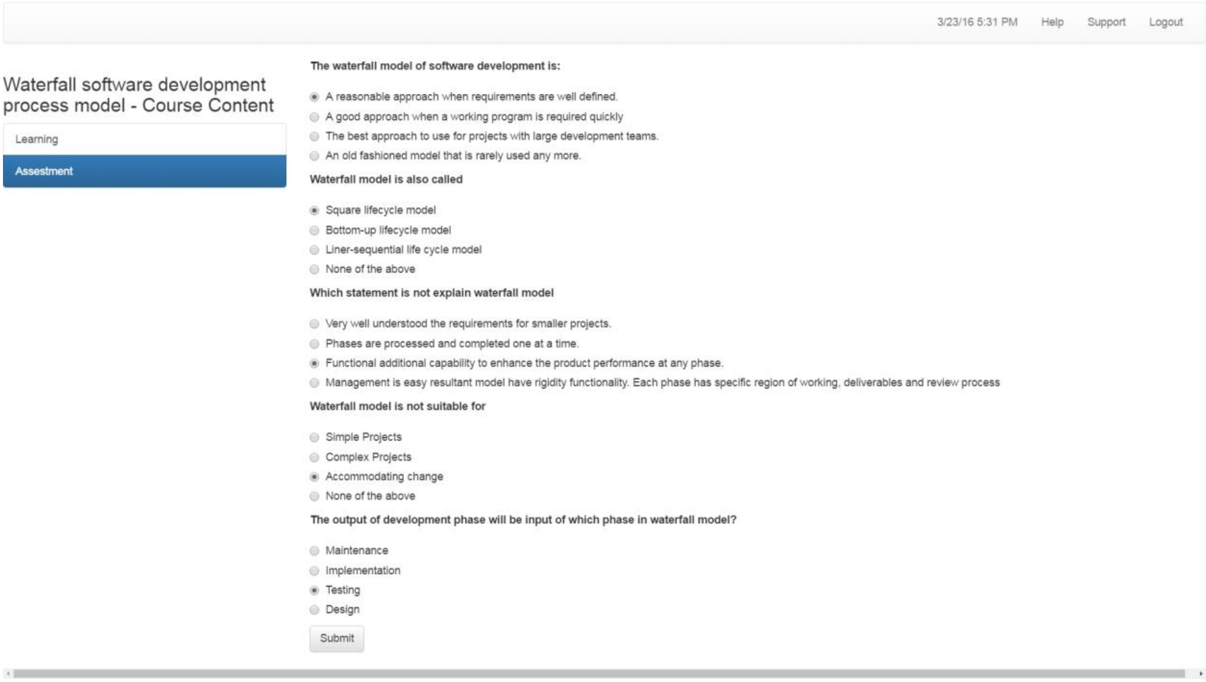


Figure A.0.13: Assessment Web Services

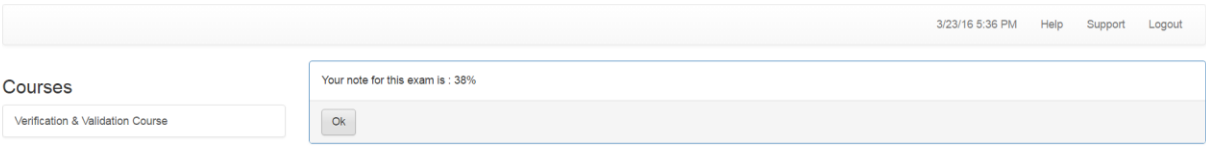


Figure A.0.14: Assessment Results

2 HeLPS Back End Explained

This section briefly illuminates HeLPS framework backend design, which includes the Business Process Models BPMN and their correspondent BPEL code, ontology model and web services. More specifically, Figure A.15 illustrates the list of Business Process instances created so far in the system. They reside in the WSO2 Business Process Server and respond to the instantiation of a new e-learning process for a certain e-learner. Figure A.16 represents one Business Process instance by showing its BPEL script as well as limited visual representation of its activities and flow, shown by the WSO Business Process Server. Figure A.17 and A.18 deal with the service orientation component as the first Figure shows how to register or add a web service to WSO Governance Registry (GREG) (i.e., the chosen UDDI tool), while the second Figure represents a selected list of web services, their end point, addresses, WSDL files location and where they have been implemented. Finally, Figure A.19 shows a simplified version of the Ontology that is used to enrich the HeLPS e-Learning Framework.

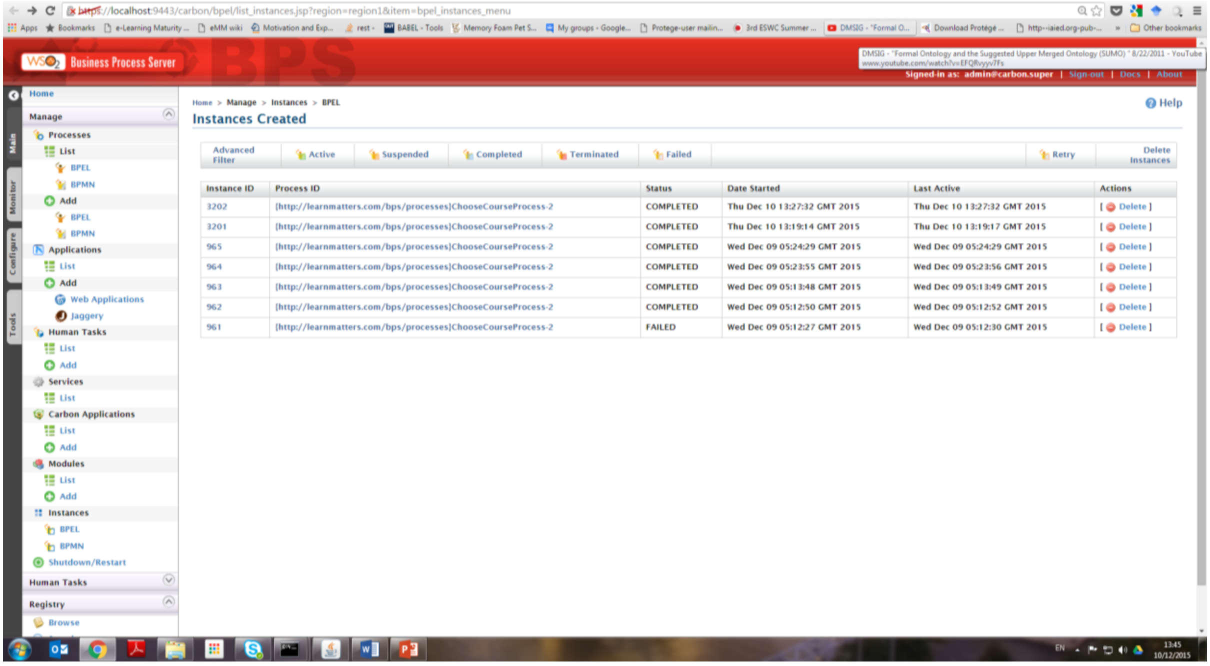


Figure A.0.15: Business Process Instances

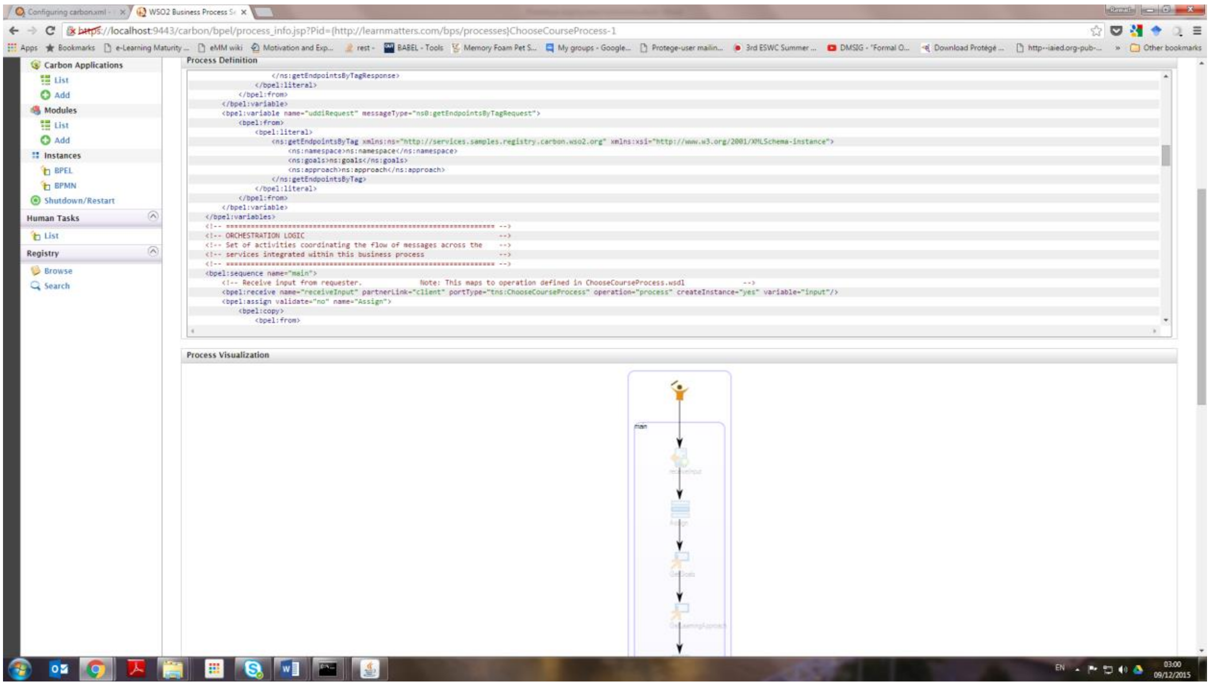


Figure A.0.16: Business Process Representation in BPEL and its Visualisation

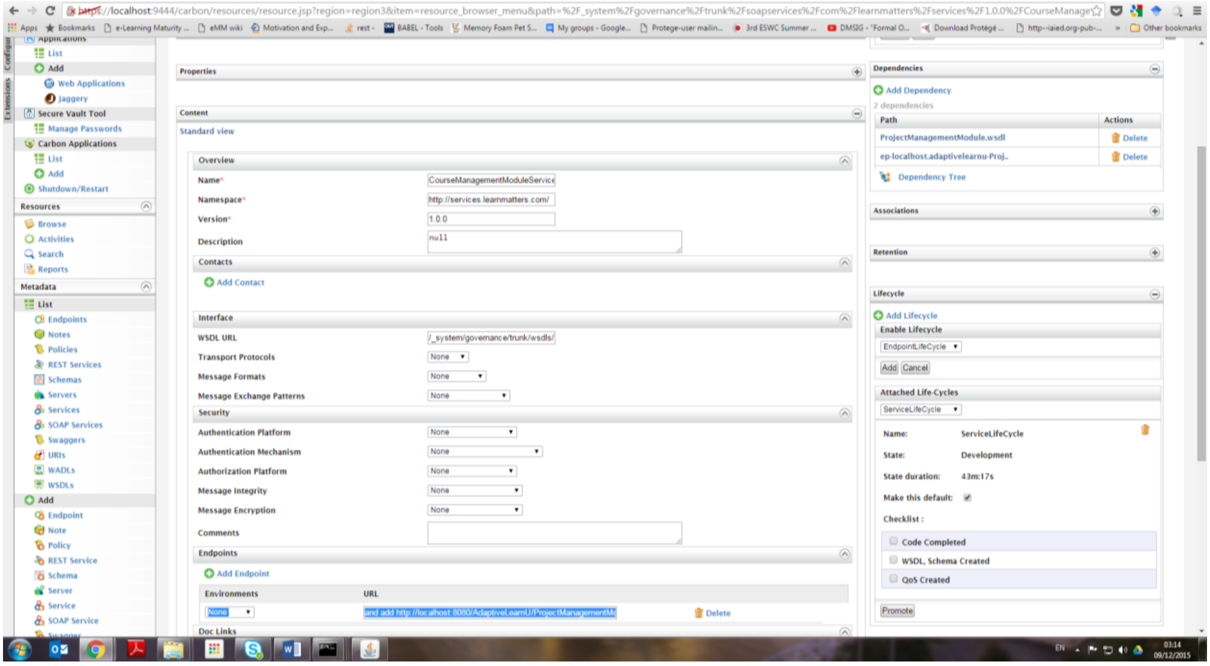


Figure A.0.17: Adding Web Services to the UDDI

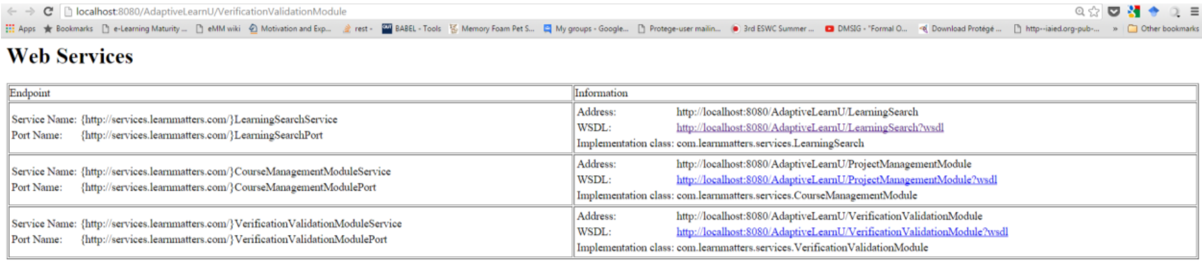


Figure A.0.18: Selected List of Web Services

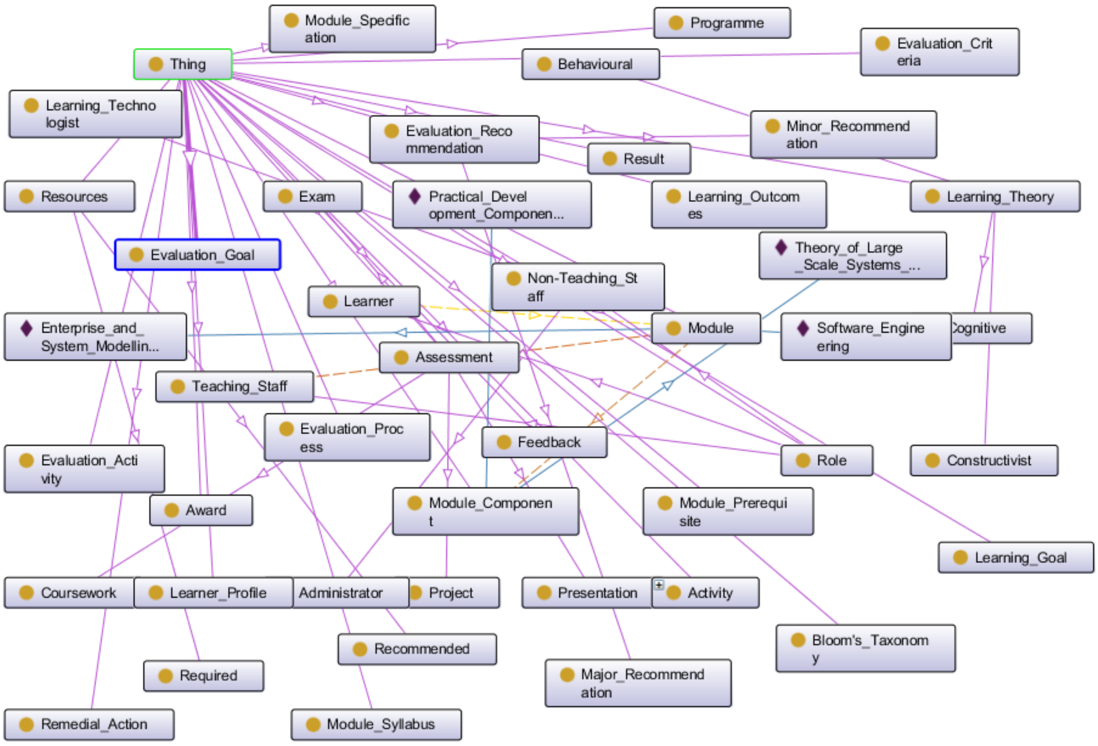


Figure A.0.19: A Simplified Visualisation of the HeLPS e-Learning Ontology

Appendix IX: The Log File of Applying the Generalisation Methodological Approach

This appendix shows the log files of applying the early-developed process generalisation approach (Section 4.4.3) used to generate a generic e-learning process model from a set of goal-related business process models.

#	Steps	Implementation
1	Analyse all available business processes, their goals, activities, underpinning pedagogic models/theories and determine the boundary of these processes. This allows getting insights about the different e-learning processes, their scopes and whether they can be formally modelled using BPMN visual notations and the corresponding machine-readable formats.	The most noticeable examples in this perspective are: (i) instructional-design e-learning process, (ii) intelligent tutoring e-learning process and (iii) direct instruction. The above-listed processes depend on the e-learner's responses in order to decide whether he/she achieved the intended learning outcomes/objectives. More specific, e-learners will be given various activities and their responses (e.g., quiz) will help the system to decide to what extent they have achieved the goals.
2	If necessary, classify the early-identified business processes based on domain-specific concerns to bring further coherence to the proposed processes/activities.	They are classified according to underpinning pedagogy to the behavioural or associative e-learning processes.
3	Identify all processes elements which include: (i) flow objects (events, activities and gateways), (ii) data (data objects, inputs, outputs and data stores), (iii) connecting objects (sequence flows, message flows, associations and data associations), (iv) swimlanes (pools and lanes) and (v) artefacts (group and text annotation). Some of these elements (e.g., text annotations) help to capture semantics of specific activities, which can be useful later on for business process enactment and execution in a Service-Oriented Architecture (SOA) environment.	e-learner, e-learning system, instructor, login to the e-learning system, check the credentials, request an account, explore learning space, choose topic, read goals, satisfied and want to proceed, Read goals, instructions and pre-requisites if any, Participate in e-learning activities specified by instructor, Understand and comprehend the presented topic, Initiate communication with peers e.g. chat, email, wiki, etc., Seek academic support from instructor or technical support from technician for technical issues, Participate in the specified assessment activity, View feedback, Learning outcomes achieved?, Access remedial contents or processes, Check the provided credentials, Send verification results, e.g., quiz to assess learner's understanding, usually this assessment element is simple because it is automatically corrected, Define

		lesson learning outcomes/ objectives based on course learning outcomes, Break the learning outcomes into e-learning activities, Develop and publish learning activities, Develop and publish assessment activities along with perceived feedback; Discover e-learner misconception and topics to learn, Choose topic based on learner model and rules used in ITS including the sequence of contents designed by tutor, Choose proper instruction technique based on domain model and e-learner model, Choose proper presentation format, Reveal the learning space and the chosen topics, Present an assessment activity, Automatically assess e-learner's response, Send e-learner response to the instructor, Provide feedback, Update e-learner's model; Break the learning outcomes into e-learning activities, Develop and publish learning activities, Develop and publish assessment activities along with perceived provisional feedback, Assess e-learner response and provide feedback; Observe e-learner responses and behaviour, Provide feedback based on the results of e-learner behaviour and the analysis of e-learner responses, Consider comments to refine the future practice spaces
4	Identify the common process elements and the special/unique ones from the early-identified process elements (i.e., the outcome of step 3). For instance, "user login" and "set profile" are common activities, while for example "plan your e-learning" activity is not.	The listed below represent the special/unique ones: Intelligent Tutoring Systems: Choose topic based on learner model and rules used in ITS including the sequence of contents designed by tutor, Choose proper instruction technique based on domain model and e-learner model, Choose proper presentation format, Reveal the learning space and the chosen topics, Present an assessment activity, Automatically assess e-learner's response, Send e-learner response to the instructor, Provide feedback, Update e-learner's model; Break the learning outcomes into e-learning activities, Develop and publish learning activities, Develop and publish assessment activities along with perceived provisional

		feedback, Assess e-learner response and provide feedback. Direct Instruction: Observe e-learner responses and behaviour, provide feedback based on the results of e-learner behaviour and the analysis of e-learner responses, consider comments to refine the future practice spaces.
5	Generalise the special/unique process elements (e.g., the following two activities: (i) "study a particular learning lesson" and (ii) "perform the following instructions" can be generalised to the following activity: "participate in the specified learning activity"). Careful considerations for the terms used is needed as they reflect different underpinning learning approaches (e.g., "perform" usually entails participatory learning while "study" does not).	Choose proper presentation format, Reveal the learning space and the chosen topics: Present the e-learning content in the proper format. Present an assessment activity, automatically assess e-learner's response: manage the assessment element Send e-learner response to the instructor, Provide feedback: Update e-learner's model;
6	Define, from the literature appropriate sources, and specify the rules and the conditions that are essential to customise the generic e-learning process for a certain e-learner (i.e., generate a specialised business process from the generic one).	The only contradiction among these processes that the direct instruction e-learning process is almost equivalent to other behavioural e-learning process models. However, it provides more emphasis on the practice, and consequently acting upon this practice via feedback. Therefore, e-learner behaviour is observed by the instructor in order to provide the relevant feedback that is suitable to the e-learner and his/her progress towards the attainment of the learning outcomes/objectives. Also, ITS updates the e-learner model. The outcomes of the early attempts is essential to specialise the e-learning process for the e-learner.
7	Make the information required to execute the early-specified rules available. For example, to execute the above-mentioned rule, the type of e-learner skills (i.e., metacognitive) should be modelled in the e-learner behavioural model.	The outcomes of the early attempts is essential to specialise the e-learning process for the e-learner.

8	Identify, if any, potential contradiction between process elements (e.g., SRL e-learning processes contradict with Direct Instruction especially in selecting learning goals). This has essential consequences on the process's roles and their actions.	The Instructional Design Process is instructor-led e-learning process, where the e-learner is mostly recipient of information. His feedback is quite generic and automated. Yet, the direct instruction e-learning process depends on the observation concept, where the e-learner is receiving very customised and close feedback from the instructor. In the case of the ITS, the feedback is encoded in the system in many cases and the intervention of the instructor is requested on demand. It can be misconception tailoring-oriented or based on comparing both models (e-learner and the domain).
9	Resolve the discovered contradictions through introducing intermediate process elements, further rules or making assumptions necessary to accurately specify the business process. For instance, to resolve the above-mentioned contradiction between activities in step 8, "Decide Learning Approach" activity has been added to the generic e-learning process model, where this activity is supported by certain rules to check the e-learner's skills and context and decide the best learning approach for this particular e-learner.	**Rule 1**: e-Learners with 30% or more academic support failure messages (e.g. 3 out of 7 messages) are recommended to take direct instruction e-learning process i.e. under observation and support. *If the e-learner has 30% or more failure messages in his/her behavioural model, then recommend direct instruction-based e-learning process.* **Rule 2**: e-Learners with misconception should be exposed to a learning process that resolve the identified misconception. *If the e-learner has a specific misconception, then provides a learning process that can resolve the specified misconception.*
10	If the early-identified business processes have been classified, then make one level of generalisation for each category.	Yes, the result of applying this step has led to identifying the ULP1: The Generalised Behavioural e-Learning Process
11	Perform another level of generalisation for the outcome of the previous step (i.e., the early-generalised processes) using steps 4 to 10.	The outcomes of applying this step has led to identifying the GLP: The Generalised e-Learning Process

Appendix X: The Experimental Setup of the V&V Evaluation Approach

To perform data-driven evaluation approach , the following experimental setup is used: one machine with 2.4 GHz, MS Windows 7, service pack 1, 64 bit OS, 4.00 GB RAM, Eclipse Java EE IDE for web developer version: MARS.1, release 4.5.1, Protégé 4.3, Web Ontology Language (OWL 2.0), Web Service Description Language (WSDL). Data attributes are in text format and are passed to the e-Learning Meta-Model (eLMM) encoded in OWL Ontology.

Appendix XI: Potential Publications

A Systematic Review of Learning Theories Used in e-Learning, Journal of Educational Computing Research, [In Submission].

Hammad, R., Odeh, M. and Khan, Z. (2017). A Hybrid e-Learning Framework that is Process-based, Semantically-enriched and Service oriented-enabled, ELSEVIER Information and Software Technology Journal, [In Submission].

Hammad, R., Odeh, M. and Khan, Z. (2017). Service Identification and Discovery for Process and Service-Oriented e-Learning Systems, Service Science and Engineering for New Global Challenges (SOST), [In Submission].

Hammad, R., Odeh, M. and Khan, Z. (2017). e-Learning Evaluation Framework: HeLPS e-Learning Framework as a Case Study, Journal of Educational Technology & Society, [Draft].

Hammad, R., Odeh, M. and Khan, Z. (2017). e-Learning Models Survey, Journal of Educational and Behavioural Statistics, [Draft].

Hammad, R., Odeh, M. and Khan, Z. (2017). Hybrid e-Learning Meta-Model, IEEE Transactions on Learning Technologies, [Draft].

Hammad, R., Odeh, M. and Khan, Z. (2017). Turning e-Learning Pedagogy to e-Leaning Business Process Models, Emerald BPM Journal, [Draft].

Hammad, R., Odeh, M. and Khan, Z. (2017). Using Semantic Web Rule Language to Develop a Process-based Adaptive e-Learning Framework, [Draft].

Appendix XII: Verification Model Scenarios/Testing Cases

The Verification Model is composed of the (65) testing case/scenario and their expected outputs. They represent the basic testing cases and additional cases to test the error testing cases and the consistency. Each testing case has been given a learner ID (e.g., eLearner17).

Constructs / Testing case ID	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	Struggling learner	Acceptance Criteria Or Expected System Behaviour
eLearner1	Waterfall Process Model	Fulfilled	Read Write	Neutral	Undefined	Cognitive	Individual	Undefined	Undefined	0	Undefined	No Disability	Undefined	Instructional Design	Reading	0	Undefined	Core	No	No	Reveal the contents of LT 1 in a behavioural-based process (i.e., behavioural text-based format).
eLearner2	Validation & Verification	Not fulfilled	Visual	Neutral	Mathematics	Undefined	Undefined	Undefined	Undefined	0	Undefined	No Disability	Undefined	Undefined	Cycling	0	Undefined	Core	No	No	Reveal remedial contents (i.e. prerequisite) to the e-learner in video-based style (i.e., intelligent tutoring process)
eLearner3	Waterfall Process Model	Fulfilled	Aural	Neutral	Physics	Cognitive	Individual	Undefined	Undefined	0	Undefined	No	Undefined	Direct Instrcution	Undefined	1	30	Core	No	Yes	The learner fails to learn this topic in the first attempts. Hence, the system should provide more support (i.e., Direct Instruction process)

eLearner4	Validation & Verification	Fulfilled	Aural	Neutral	IT	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No	Undefined	Undefined	Undefined	4	40	Core	No	Yes	The learner is struggling in the module, hence the system should join the learner to support groups that are led by advanced learners (i.e., combine LP 3 & LP 8)
eLearner5	Agile Process Model	Fulfilled	Read Write	Neutral	Mathematics	Undefined	Collaborative	Undefined	Undefined	Undefined	Undefined	No	elearner24	Recommender System	Undefined	0	Undefined	Supportive	B	No	Reveal additional learning contents to resolve learner's misconception (i.e., Misconception B) and recommend peers to work collaboratively; combine LP2 & LP8
eLearner6	Validation & Verification	Fulfilled	Read Write	Neutral	Software Engineering	Undefined	Collaborative	Undefined	Undefined	2	Undefined	No Disability	Undefined	Undefined	Swimming	0	0	Core	No	No	This is an advance learner, the system will show a list of advanced options, such as leading support groups to help struggling learners or help others to adopt advanced learning strategies; combines LP1&8.
eLearner7	Agile Process Model	Fulfilled	Read Write	Neutral	History	Metacognitive	Undefined	Agile	Undefined	0	Undefined	No Disability	Goal-related (i.e. Agile) group	Undefined	Swimming	0	Undefined	Supportive	No	No	The system will (i) recommend SRL process and (ii) group peers based on their commonalities, i.e. learner x and learner y should have something common between them either background, goals, interests or annotations; combines LP6&8.

eLearner8	Waterfall Process Model	Fulfilled	Visual	Bored	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	No disability	Undefined	Undefined	Undefined	Undefined	Undefined	Core	Undefined	No	The system should motivate learner through recommending game-based learning processes (i.e., LP 9).
eLearner9	Validation & Verification	Fulfilled	Aural	Bored	Mathematics	Cognitive	Individual	Requirement Management	3	0	05/05/2015	No Disability	Undefined	Adaptive process	Undefined	0	Undefined	Core	No	No	The system should motivate learner through recommending contents that are relevant to his background (i.e. outside the subject being taught). For instance, Formal V&V; LP4
eLearner10	Waterfall Process Model	Fulfilled	Kinesthetic	Excited	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Undefined	Swimming	0	Undefined	Core	No	No	Provide enrichment contents to the e-learner who is eager to learn more. It should conform his/her background, interest and learning style; LP5.
eLearner11	Agile Process Model	Fulfilled	Aural	Bored	Physics	Undefined	Undefined	Undefined	Undefined	0	Undefined	No Disability	List of peers	Undefined	Undefined	Undefined	Undefined	Supportive	Undefined	No	Provide audio-based learning services for LT2 supported by game-based process elements to involve engage the learner (e.g., combine LP5 & LP9).
eLearner12	Validation & Verification	Fulfilled	Kinesthetic	Neutral	Undefined	Undefined	Collaborative	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Problem-based	Cycling	0	Undefined	Core	Undefined	No	Provide constructive learning approach such as learning by doing or problem-based learning approaches; LP 7.

eLearner13	Agile Process Model	Fulfilled	Visual	Neutral	Undefined	Metacognitive	Collaborative	Undefined	Undefined	0	Undefined	No Disability	Undefined	Undefined	Management	0	Undefined	Supportive	Undefined	No	Provide SRL process to the learner which allows him to create his learning space and manage his learning by inviting other peers to his space, e.g., blog. Learning service related to his interest LP2, LP6 & LP8.
eLearner14	Waterfall Process Model	Fulfilled	Kinesthetic	Neutral	Undefined	Metacognitive	Undefined	Waterfall	1	Undefined	Undefined	No Disability	Undefined	Self-regulated	Reading	0	Undefined	Core	Undefined	No	Provide contents related to the goals first based on their priority, second based on the date to achieve goals; LP6.
eLearner15	Agile Process Model	Fulfilled	Read Write	Neutral	Drama	Metacognitive	Individual	Agile	2	1	3/1/2016	No Disability	List of peers	Undefined	Swimming	0	Undefined	Supportive	No	No	Provides adaptive SRL capabilities, such as consider the goal date to be achieved, its date, etc. combines LP2& LP6.
eLearner16	Validation & Verification	Fulfilled	Read Write	Neutral	Undefined	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Direct Instruction	Reading	0	Undefined	Core	No	Yes	Reveal the contents of LT 3 SRL settings with helps from instructor (i.e., combines LP3 & LP6).
eLearner17	Agile Process Model	Fulfilled	Kinesthetic	Neutral	Undefined	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving	0	Undefined	Supportive	No	No	Reveal the contents of LT 2 in a problem-based learning process (i.e., combines LP1 & LP7).
eLearner18	Agile Process Model	Not fulfilled	Kinesthetic	Neutral	Undefined	Undefined	Collaborative	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving, agile	0	Undefined	Supportive	No	No	Reveal the contents of LT 1 in a problem-based learning process supported by intilegent tutoring system and communication-based processes (i.e., combines LP2, LP7 & LP8).

eLearner19	Agile Process Model	Fulfilled	Visual	Neutral	Undefined	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Instructional Design	Reading	0	Undefined	Supportive	No	Yes	Reveal the contents of LT 2 SRL settings in video-based behavioural format (i.e., combines LP1 & LP6).
eLearner20	Agile Process Model	Fulfilled	Kinesthetic	Bored	Undefined	Undefined	Indivisual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving, software development, cloud	1	52	Supportive	No	No	Reveal the contents of LT 2 in a behavioural and problem-based learning process supported by game-based process (i.e., combines LP1, LP7 & LP9).
eLearner21	Waterfall Process Model	Fulfilled	Kinesthetic	Neutral	Math, Physics	Cognitive	Collaborative	Water fall	1	0	Undefined	No Disability	elearner21,elearner37	situated-based	Reading	0	85	Core	No	No	Provide situated–based learning process based on communication elements, contents for LT1 will be available but the learner can find his/her topics; LP8.
eLearner22	Validation & Verification	Fulfilled	Read write	Excited	Philosophy	Undefined	Individual	Undefined	Undefined	2	Undefined	No Disability	Undefined	Instructionl design	Undefined	0	Undefined	Core	No	No	Provide content for LT3 and recommend contents relevant to the learner background; combine LP1 &LP4
eLearner23	Waterfall Process Model	Fulfilled	Kinesthetic	Neutral	Undefined	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving	0	Undefined	Core	No	Yes	Reveal the contents of LT 1 in a problem-based learning process supported by direct supervison (i.e., combines LP3 & LP7).

eLearner24	Agile Process Model	Fulfilled	Visual	Neutral	Geology	Cognitive	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Undefined	web-based application, security	0	Undefined	Supportive	B and E	No	Reveal the contents of LT 2 through recommending the proper contents and peers and support this with intelligent tutoring-based process element to resolve the learner's misconceptions (i.e., combines LP2 & LP4).
eLearner25	Agile Process Model	Fulfilled	Read write	Bored	Drama	Cognitive	Collaborative	Undefined	Undefined	0	Undefined	No Disability	elearner 2, elearner 14	Undefined	web-based application, security	3	49	Supportive	No	Yes	Reveal the contents of LT 2 through recommending the proper contents supported by direct instruction-based process element to closely supervise the learner behaviour & game-based process to attract him (i.e., combines LP3, LP4 & LP9).
eLearner26	Agile Process Model	Fulfilled	Kinesthetic	Neutral	Undefined	Undefined	Collaborative	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving, software development, cloud	1	50	Supportive	No	No	Reveal the contents of LT 2 in a behavioural, problem-based learning process supported by communication-based process (i.e., combines LP1, LP7 & LP8).

eLearner27	Agile Process Model	Not fulfilled	Aural	Neutral	Biology, Chain management	Cognitive	Individual	project management	1	1	20/09/2015	Visual	software configuration	instructional design	Cryptography, cloud	1	50	Supportive	C	No	Reveal remidical contents for LT 2 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception (i.e., combines LP2 & LP5).
eLearner28	Agile Process Model	Not fulfilled	Read write	Neutral	Management, Psychology	Cognitive	Collaborative	project management	2	0	05/01/2015	No Disability	project management	instructional design	Security, cloud	1	78	Supportive	D	No	Reveal remidical contents for LT 2 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception and communication-based process (i.e., combines LP2, LP5 & LP8).
eLearner29	Agile Process Model	Fulfilled	Kinesthetic	Bored	Undefined	Undefined	Collaborative	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving, agile	0	Undefined	Supportive	No	No	Reveal the contents of LT 2 in a problem-based learning process supported by intilegent tutoring system and game-based processes (i.e., combines LP2, LP7 & LP9).
eLearner30	Agile Process Model	Fulfilled	Read write	Neutral	Psychology	Cognitive	Collaborative	project management	2	2	03/05/2015	No Disability	project management	adaptive-based process	Software development, cloud computing	3	43	Supportive	B	Yes	Reveal contents for LT 2 in a direct instruction process supported by adaptive process elements to resolve the learner misconception and situated communication process to help him (i.e., combines LP3, LP5 & LP8).

eLearner31	Agile Process Model	Not fulfilled	Read write	Bored	Management, Psychology	Cognitive	Collaborative	project management	2	0	22/11/2015	No Disability	project management	adaptive-based process	Security, cloud	1	57	Supportive	B	No	Reveal remidical contents for LT 2 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception and game-based process (i.e., combines LP2, LP5 & LP9).
eLearner32	Agile Process Model	Fulfilled	Kinesthetic	Bored	Undefined	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving, software development, cloud	3	47	Supportive	No	Yes	Reveal the contents of LT 2 in problem-based learning process supported by direct instruction and game-based process elements (i.e., combines LP3, LP7 & LP9).
eLearner33	Agile Process Model	Fulfilled	Read write	Bored	Psychology	Cognitive	Collaborative	project management	7	0	29/04/2015	No Disability	project management	adaptive-based process	validation, cloud computing	3	50	Supportive	B	Yes	Reveal contents for LT 2 in a direct instruction process supported by adaptive process elements to resolve the learner misconception and situated game-based process to motivate him (i.e., combines LP3, LP5 & LP9).
eLearner34	Agile Process Model	Fulfilled	Kinesthetic	Neutral	Undefined	Undefined	Collaborative	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving, software architecture	2	22	Supportive	No	Yes	Reveal the contents of LT 2 in problem-based learning process supported by direct instruction and communication-based process elements (i.e., combines LP3, LP7 & LP9).

eLearner35	Waterfall Process Model	Fulfilled	Aural	Bored	Undefined	Cognitive	Collaborative	Verification	3	0	19/08/2015	No Disability	Undefined	Adaptive process	Undefined	0	0	Core	No	No	Provide game-based learning process to motivate the learner, contents for LT1 and relavent peers (i.e., combine LP4 & LP9).
eLearner36	Waterfall Process Model	Fulfilled	Read Write	Bored	Linguistics	Metacognitive	Individual	Waterfall process model	1	0	22/01/2015	No Disability	elerner12,elearner29	Undefined	System integration	0	0	Core	No	No	Provide SRL process and game-based learning process to motivate the learner (i.e., combines LP6 & LP9).
eLearner37	Validation & Verification	Fulfilled	Aural	Neutral	Undefined	Cognitive	Collaborative	Requirement Management	4	0	15/06/2015	No Disability	Undefined	Adaptive process	Undefined	0	Undefined	Core	No	No	Provide situated commmunication-based learning process to connect the learner with his peers, contents for LT3 (i.e., combine LP4 & LP8).
eLearner38	Validation & Verification	Fulfilled	Read write	Neutral	Chemistry, Medicine	Cognitive	Individual	project management	Undefined	0	09/02/2015	No Disability	project management	instructional design	Security, serive oriented computing	1	78	Core	F	No	Reveal contents for LT 3 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception and communication-based process (i.e., combines LP1, LP5 & LP8).
eLearner39	Agile Process Model	Fulfilled	Read write	Neutral	Psychology	Cognitive	Individual	project management	2	0	08/07/2015	No Disability	project management	adaptive-based process	Security, cloud computing	3	43	Supportive	B	Yes	Reveal contents for LT 2 in a direct instruction process supported by adaptive process elements to resolve the learner misconception (i.e., combines LP3 & LP5).

eLearner40	Validation and Verification	Fulfilled	Read Write	Bored	Linguistics	Metacognitive	Individual	software verification	1	1	25/01/2015	No Disability	elerner36,elearner7	Self-regulated	System integration	2	24	Core	No	Yes	Provide SRL process and game-based learning process under direct supervision from instructor -i.e., direct instruction process element - (i.e., combine LP3, LP6 & LP9).
eLearner41	Agile Process Model	Not fulfilled	Kinesthetic	Neutral	Undefined	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving	0	Undefined	Supportive	No	No	Reveal the contents of LT 1 in a problem-based learning process supported by intilegent tutoring system process (i.e., combines LP2 & LP7).
eLearner42	Validation & Verification	Fulfilled	Read write	Bored	Chemistry, Medicine	Cognitive	Collaborative	project management	Undefined	0	19/03/2015	No Disability	Visual	instructional design	Security, serive oriented computing	1	68	Core	F	No	Reveal contents for LT 3 in a behavioural-based learning process supported by adaptive process elements to resolve the learner misconception and game-based process (i.e., combines LP1, LP5 & LP9).
eLearner43	Waterfall Process Model	Fulfilled	Aural	Neutral	History	Cognitive	Collaborative	Requirement Management	4	0	23/05/2015	No Disability	elearner37, elearner48	Adaptive process	software maintenance	0	0	Core	No	No	Provide aural-based adaptive learning process for LT1 supported by communication process elements (i.e., combine LP4 & LP8).

eLearner44	Validation & Verfication	Not fulfilled	Visual	Neutral	Psychology	Metacognitive	Individual	Software Validation	2	0	18/03/2015	No Disability	elearner37,elearner12	adaptive process	Management	0	0	Core	No	No	Provide SRL process to the learner which allows him to create & manage his learning space/ talk to peers. This should be supported by intelligent tutoring element to show remidial contents in game-based learning process (i.e., combine LP2, LP6 & LP9.
eLearner45	Agile Process Model	Fulfilled	Visual	Bored	Geology	Cognitive	Indivisual	Agile	2	0	10/10/2015	No Disability	elearner24	Undefined	web-based application, security	0	Undefined	Supportive	B and E	No	Reveal the contents of LT 2 through recommending the proper contents and peers and support this with (i) intelligent tutoring-based process element to resolve the learner's misconceptions and (ii) game-based process element (i.e., combines LP2, LP4 & LP9).
eLearner46	Validation & Verification	Fulfilled	Read Write	Bored	Mathematics	Cognitive	Individual	Software testing	3	2	07/07/2015	No Disability	elearner6,elearner8	instructional desing	Swiming	1	87	Core	No	No	Provide a behavioural-based learning process supported by game-based learning proess elements (i.e., combines LP1 & LP9).

eLearner47	Agile Process Model	Fulfilled	Visual	Neutral	Drama	Cognitive	Collaborative	Undefined	Undefined	1	Undefined	No Disability	elearner4, elerner52	Undefined	web-based application, security	3	49	Supportive	No	Yes	Reveal the contents of LT 2 through recommending the proper contents supported by direct instruction-based process element to closely supervise the learner behaviour & communication with peers to help him in his learning (i.e., combines LP3, LP4 & LP8).
eLearner48	Waterfall Process Model	Fulfilled	Read write	Neutral	History	Cognitive	individual	Requirement Management	4	0	03/11/2015	No Disability	Undefined	Learning by doing	software maintenance, problem-based	0	0	Core	No	No	Provide problem-based learning process for LT1 supported by communication process elements (i.e., combine LP7 & LP8).
eLearner49	Waterfall Process Model	Fulfilled	Read write	Bored	Management	Metacognitive	Individual	Water fall	3	1	16/10/2015	No Disability	elearner5,elearner41	instructional design	Management	0	0	Core	No	No	Provide SRL-based process to allow the learner to regulate his learning. This process should be supported by behavioural-based content in the form of game-based process (i.e., combine LP1, LP6 & LP9.

eLearner50	Agile Process Model	Fulfilled	Read write	Neutral	Mathematics	Cognitive	Collaborative	Agile	2	0	30/09/2015	No Disability	elearner 24	Undefined	web-based application, security	0	Undefined	Supportive	D	No	Reveal the contents of LT 2 through recommending the proper contents and peers and support this with (i) intelligent tutoring-based process element to resolve the learner's misconceptions and (ii) communication-based process element (i.e., combines LP2, LP4 & LP8).
eLearner51	Agile Process Model	Not fulfilled	Read Write	Bored	Mathematics	Cognitive	Collaborative	Agile Process Model	2	0	02/01/2015	No disability	elearner 5, elearner 41	Recommender System	Reading	0	0	Supportive	B	No	Provide remedial learning contents and additional contents to resolve the learner's misconception. This should be supported by game-based learning process element (i.e., combine LP2 & LP9).
eLearner52	Agile Process Model	Fulfilled	Visual	Neutral	Geology	Cognitive	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Undefined	web-based application, security	3	49	Supportive	No	Yes	Reveal the contents of LT 2 through recommending the proper contents supported by direct instruction-based process element to closely supervise the learner behaviour (i.e., combines LP3 & LP4).

eLearner53	Waterfall Process Model	Fulfilled	Read write	Neutral	Physics	Metacognitive	Collaborative	Waterfall	3	2	26/12/2015	No Disability	elearner16,elearner9	instructional design	Management	0	0	Core	No	No	Provide SRL-based process to allow the learner to regulate his learning. This process should be supported by behavioural-based content and communication based elements (i.e., combine LP1, LP6 & LP8).
eLearner54	Agile Process Model	Not fulfilled	Visual	Neutral	Biology, Chain management	Cognitive	Indivisual	project management	1	1	25/12/2015	No Disability	software configuration	instructional design	Cryptography, cloud	2	20	Supportive	C	Yes	Provide instructional-based process to show LT2 contents in the approapriate video format supported by adaptive process elements to resolve the learner misconception (i.e., combine LP1 & LP5).
eLearner55	Agile Process Model	Fulfilled	Read Write	Bored	Mathematics	Cognitive	Collaborative	Agile Process Model	2	0	22/05/2015	No disability	elearner16, elearner39, elearner52	Recommender System	Reading	3	34	Supportive	No	Yes	Provide direct instruction learning supported by game-based learning process element (i.e., combine LP3 & LP9).
eLearner56	Waterfall Process Model	Fulfilled	Kinesthetic	Neutral	Mathematics	Cognitive	Collaborative	System design	2	0	30/09/2015	No Disability	elearner24	Instructional design	web-based application, security	0	60	Core	No	No	Reveal the contents of LT 1 through learning by doing and communication-based process element (i.e., combines LP7 & LP8).
eLearner57	Validation & Verification	Fulfilled	Read write	Bored	Philosophy	Cognitive	Individual	Verification	1	1	12/02/2015	No Disability	elearner25, elearner47	Instructionl design	Requirement Engineering	0	0	Core	No	No	Provide content for LT3, recommend contents/peers relevant to the learner record supported by game-based process element (i.e., combine LP1, LP4 & LP9)

eLearner58	Validation and Verification	Fulfilled	Read Write	Neutral	Linguistics	Metacognitive	Collaborative	software verification	1	1	22/01/2015	No disability	elerner36,elearner7	Self-regulated	System integration	2	24	Core	No	Yes	Provide SRL and communication-based learning process under direct supervision from instructor -i.e., direct instruction process element - (i.e., combine LP3, LP6 & LP8).
eLearner59	Waterfall Process Model	Fulfilled	Read write	Bored	Physics	Cognitive	Individual	Requirement Management	4	0	04/10/2015	No Disability	elearner48	Learning by doing	software maintenance, problem-based	0	0	Core	No	No	Provide problem-based learning process for LT1 supported by game-based process elements (i.e., combine LP7 & LP9).
eLearner60	Validation & Verification	Fulfilled	Read write	Excited	Philosophy	Cognitive	Collaborative	Verification	Undefined	Undefined	Undefined	No Disability	Null	communication based	Situated learning	3	30	Core	No	Yes	Provide content for LT3, recommend contents/peers relevant to the learner record supported by communication-based process element (i.e., combine LP3, LP4 & LP8)
eLearner61	Validation and Verification	Fulfilled	Read Write	Bored	Linguistics	Metacognitive	Individual	software verification	1	1	25/01/2015	No Disability	elerner36,elearner7	Self-regulated	System integration	2	24	Core	No	No	Provide SRL supported by game-based learning process element - (i.e., combine LP6 & LP9).
eLearner62	Software Architecture	Fulfilled	Read Write	Neutral	Undefined	Metacognitive	Individual	Systems of systems	1	1	Undefined	No Disability	elerner42	Self-regulated	System integration	0	0	Undefined	No	No	Provide a Direct instruction based services for software architecture learning topic

eLearner63	Waterfall Process Model	Fulfilled	Read write	Neutral	History	Cognitive	individual	Requirement Management	4	0	03/11/2015	No Disability	Undefined	Learning by doing	SOA	0	0	Core	No	No	Provide problem-based learning process for LT1 in text-based format (i.e., LP7).
eLearner64	Agile Process Model	Fulfilled	Read write	Excited	Physics	Cognitive	Collaborative	Undefined	Undefined	0	Undefined	No Disability	Undefined	Undefined	Undefined	Undefined	Undefined	Supportive	B	No	Provide instructional-based learning services for LT2 supported by communication-based process elements to engage the learner and reveal contents to resolve his/her misconceptions (e.g., combine LP2,LP5& LP8).
eLearner65	Validation and Verification	Fulfilled	Read write	Neutral	Undefined	Undefined	Individual	Undefined	Undefined	Undefined	Undefined	No Disability	Undefined	Learning By Doing	Problem solving	2	39	Core	No	Yes	Reveal the contents of LT 3 in a problem-based learning process supported by direct instruction (i.e., combines LP3 & LP7).

Appendix XIII: Detailed Sufficiency Analysis of Testing Cases

This appendix shows the rest of the 15 sceanrios that have been designed to evaluate the e-learning framework.

The Second Scenario:

Scenario ID: Scenario #2										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	Fulfilled	Aural	Undefined	Undefined	***Undefined***	***Undefined***	***Undefined***	***Undefined***	Undefined
	Agile Process Model	***Not fulfilled***	***Visual***	***Neutral***	Physics	Cognitive	Individual	Waterfall	1	***0***
	Validation & Verification		ReadWrite	Excited	***Mathematics***	Metacognitive	Collaborative	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	Instructional Design	Swimming	Undefined	***Undefined***	***Core***	Undefined	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	Reading	***0***	< 50%	Supportive	***No***	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	***Cycling***	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	Undefined	3			C	
				Self-regulated		4			D	

				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Validation and Verification topic through video-based contents (i.e. video learning style) whereas the e-learner does not fulfil the requirements of the learning process (i.e. prerequisite), therefore a remedial contents will be shown before going to the required lesson. So it tests multiple constructs to respond to the e-learner demand.

The Third Scenario:

Scenario ID: Scenario #3										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	***Waterfall Process Model***	***Fulfilled***	***Aural***	Undefined	Undefined	Undefined	Undefined	***Undefined***	***Undefined***	Undefined
	Agile Process Model	Not fulfilled	Visual	***Neutral***	***Physics***	***Cognitive***	***Individual***	Waterfall	1	***0***
	Validation & Verification		ReadWrite	Excited	Mathematics	Metacognitive	Collaborative	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	Instructional Design	Swimming	Undefined	Undefined	***Core***	Undefined	***PC***
	30/6/2016	Hearing	List of peers	***Direct Instruction***	Reading	0	***30 (i.e. < 50%)***	Supportive	***No***	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	***1***	> 50%		A	Ipad

	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	***Undefined***	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Waterfall software development process model topic through aural-based contents (i.e. aural learning style) whereas the e-learner fulfil the requirements of the learning process (i.e. prerequisite), has a physics background, neutral emotional situation and one failure attempt, therefore a more-supportive approach is recommended (i.e. direct instruction) to him to allow him persuading learning.

The Fourth Scenario:

Scenario ID: Scenario #4										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	***Aural***	Undefined	***Undefined***	***Undefined***	***Undefined***	***Undefined***	***Undefined***	***Undefined***
	Agile Process Model	Not fulfilled	Visual	***Neutral***	Physics	Cognitive	Individual	Waterfall	1	0
	Validation & Verification		ReadWrite	Excited	Mathematics	Metacognitive	Collaborative	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting

Value	***Undefined***	Visual	***Undefined***	Instructional Design	Swimming	Undefined	Undefined	***Core***	Undefined	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	Reading	0	***40 (i.e.< 50%)***	Supportive	***No***	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	***Undefined***	3			C	
				Self-regulated		***4***			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Validation and Verification topic through aural-based contents (i.e. aural learning style) for a struggling learner because she did not pass a core learning topic for four times, therefore the system recommends to provide less-learner controlled learning process and to add this e-learner to support-based group to get help and feedback from tutor and advanced e-learners. So it tests multiple constructs to respond to the e-learner demand.

The Fifth Scenario:

Scenario ID: Scenario #5										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	Aural	Undefined	Undefined	***Undefined***	Undefined	***Undefined***	***Undefined***	***Undefined***
	Agile Process Model	Not fulfilled	Visual	***Neutral***	Physics	Cognitive	Individual	Waterfall	1	0

	Validation & Verification		***ReadWrite***	Excited	***Mathematics***	Metacognitive	***Collaborative***	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	Undefined	Instructional Design	Swimming	Undefined	***Undefined***	Core	Undefined	***PC***
	30/6/2016	Hearing	***List of peers***	Direct Instruction	Reading	***0***	< 50%	***Supportive***	No	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		Group titles	***Recommender System***	Astronomy	2			***B***	
				Adaptive System	***Undefined***	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Agile software development process model topic through text-based approach (i.e. readwrite learning style) whereas the e-learner fulfil the requirements of the learning process (i.e. prerequisite), tends to learn collaboratively and has a certain misconception (i.e. misconception B) based on her previous record, therefore a remedial contents will be shown to solve the misconception and collaborative-based learning process will be recommended.

The Sixth Scenario:

Scenario ID: Scenario #6										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	Aural	Undefined	***Undefined***	***Undefined***	Undefined	***Undefined***	***Undefined***	Undefined
	Agile Process Model	Not fulfilled	Visual	***Neutral***	Physics	Cognitive	Individual	Waterfall	1	0
	Validation & Verification		***ReadWrite***	Excited	Mathematics	Metacognitive	***Collaborative***	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	**2**
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	Instructional Design	***Swimming***	Undefined	Undefined	***Core***	Undefined	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	Reading	0	< 50%	Supportive	***No***	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	**1**	***87 (i.e. > 50%)***		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	Undefined	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Validation and Verification topic through text-based contents (i.e. readwrite learning style) whereas the e-learner is an advanced learner due to due to his previous record and tends to learn collaboratively, therefore this e-learner will be allowed to lead support-based group to help struggling e-learners in addition to being offered proper learning contents.

The Seventh Scenario:

Scenario ID: Scenario #7										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	Aural	Undefined	Undefined	Undefined	***Undefined***	Undefined	***Undefined***	Undefined
	Agile Process Model	Not fulfilled	Visual	***Neutral***	Physics	Cognitive	Individual	Waterfall	1	***0***
	Validation & Verification		***ReadWrite***	Excited	Mathematics	***Metacognitive***	Collaborative	***Agile***	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Histroy					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	Undefined	Instructional Design	***Swimming***	Undefined	***Undefined***	Core	Undefined	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	Reading	***0***	< 50%	***Supportive***	***No***	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		***Goal-related (i.e. Agile) group***	Recommender System	Astronomy	2			B	
				Adaptive System	Undefined	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	

				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Agile software process model topic through text-based contents (i.e. readwrite learning style) whereas the e-learner shares certain goals and interests with peers, therefore in addition to showing the proper contents peers should be recommended and joined together to a social-based group (not support-based group) to allow further interaction which will increase learner engagement within the system.

The Eighth Scenario:

Scenario ID: Scenario #8										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	***Waterfall Process Model***	***Fulfilled***	Aural	Undefined	***Undefined***	***Undefined***	***Undefined***	***Undefined***	***Undefined***	***Undefined***
	Agile Process Model	Not fulfilled	Visual	Neutral	Physics	Cognitive	Individual	Waterfall	1	0
	Validation & Verification		Read Write	Excited	Mathematics	Metacognitive	Collaborative	Agile	2	1
			Kinesthetic	***Bored***	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	Instructional Design	Swimming	***Undefined***	***Undefined***	***Core***	***Undefined***	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	Reading	***0***	< 50%	Supportive	No	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad

	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	***Undefined***	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Waterfall software development process model topic through learning by doing approach (i.e. kinaesthetic learning style) whereas the e-learner fulfils the requirements of the learning process (i.e. prerequisite) and has bored emotional status, therefore game-based approach will be recommended to respond to the e-learner demand.

The Ninth Scenario:

Scenario ID: Scenario #9										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	***Aural***	Undefined	Undefined	***Undefined***	***Undefined***	***Undefined***	***Undefined***	***Undefined***
	Agile Process Model	Not fulfilled	Visual	Neutral	Physics	Cognitive	Individual	Waterfall	1	0
	Validation & Verification		ReadWrite	Excited	***Mathematics***	Metacognitive	Collaborative	Agile	2	1
			Kinesthetic	***Bored***	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting

Value	***Undefined***	Visual	***Undefined***	Instructional Design	Swimming	Undefined	***Undefined***	***Core***	Undefined	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	Reading	***0***	< 50%	Supportive	***No***	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	***Undefined***	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Validation and Verification topic through audio-based contents (i.e. aural learning style) whereas the e-learner fulfils the requirements of the learning process (i.e. prerequisite) and has bored as an emotional status, therefore the framework should motivate the e-learner by recommending contents that are relevant to his/her background (i.e. outside the subject being taught) which is Math, e.g. formal verification approach.

The Tenth Scenario:

Scenario ID: Scenario #10										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	***Waterfall Process Model***	***Fulfilled***	Aural	Undefined	***Undefined***	***Undefined***	***Undefined***	***Undefined***	***Undefined***	***Undefined***
	Agile Process Model	Not fulfilled	Visual	Neutral	Physics	Cognitive	Individual	Waterfall	1	0

	Validation & Verification		ReadWrite	***Excited***	Mathematics	Metacognitive	Collaborative	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	Instructional Design	***Swimming***	Undefined	***Undefined***	***Core***	Undefined	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	Reading	***0***	< 50%	Supportive	***No***	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	Undefined	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Validation and Verification topic through learning by doing approach (i.e. kinaesthetic learning style) whereas the e-learner fulfils the requirements of the learning process (i.e. prerequisite) and his emotional status is excited, therefore an enrichment contents will be shown to the e-learner because he/she is expected to be eager to learn more and more.

The Eleventh Scenario:

Scenario ID: Scenario #11										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	***Aural***	Undefined	Undefined	***Undefined***	***Undefined***	***Undefined***	***Undefined***	Undefined
	Agile Process Model	Not fulfilled	Visual	Neutral	***Physics***	Cognitive	Individual	Waterfall	1	***0***
	Validation & Verification		ReadWrite	Excited	Mathematics	Metacognitive	Collaborative	Agile	2	1
			Kinesthetic	***Bored***	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	***Visual***	Undefined	Instructional Design	Swimming	***Undefined***	***Undefined***	Core	***Undefined***	***PC***
	30/6/2016	Hearing	***List of peers***	Direct Instruction	Reading	0	< 50%	***Supportive***	No	Mobile
	10/4/2016	No Disability	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	***Undefined***	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Agile software development process model topic through audio-based contents (i.e. aural learning style) whereas the e-learner fulfils the requirements of the learning process (i.e. prerequisite), has a vision disability and shares social group with peers, therefore audio-based contents that is supported by assistive technologies such ALT for images or Braille to respond to the e-learner demand.

The Twelfth Scenario:

Scenario ID: Scenario #12

Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	Aural	Undefined	***Undefined***	***Undefined***	Undefined	***Undefined***	***Undefined***	***Undefined***
	Agile Process Model	Not fulfilled	Visual	***Neutral***	Physics	Cognitive	Individual	Waterfall	1	0
	Validation & Verification		ReadWrite	Excited	Mathematics	Metacognitive	***Collaborative***	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business					3

Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	Instructional Design	Swimming	Undefined	***Undefined***	***Core***	***Undefined***	***PC***
	30/6/2016	Hearing	List of peers	Direct Instruction	Reading	***0***	< 50%	Supportive	No	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	***Cycling***	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	Undefined	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	

				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Validation and Verification topic through learning by doing approach (i.e. kinaesthetic learning style) whereas the e-learner fulfils the requirements of the learning process (i.e. prerequisite) and tends to learn collaboratively, therefore a constructive-based approach such as learning by doing or problem based will be shown to the required lesson.

The Thirteen Scenario:

Scenario ID: Scenario #13										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	Aural	Undefined	***Undefined***	Undefined	Undefined	***Undefined***	***Undefined***	Undefined
	Agile Process Model	Not fulfilled	***Visual***	***Neutral***	Physics	Cognitive	Individual	Waterfall	1	***0***
	Validation & Verification		ReadWrite	Excited	Mathematics	***Metacognitive***	***Collaborative***	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	Instructional Design	Swimming	Undefined	***Undefined***	Core	***Undefined***	***PC***
	30/6/2016	Hearing	List of peers	Direct Instrcution	Reading	***0***	< 50%	***Supportive***	No	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad

			Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	Undefined	3			C	
	3/1/2016			Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Agile software development process model topic through video-based contents (i.e. visual learning style) whereas the e-learner fulfils the requirements of the learning process (i.e. prerequisite), has metacognitive skills and neutral emotional status, therefore self-regulated learning process will be recommended so that learner is allowed to create his/her learning space and manage his/her learning by inviting other peers to his/her space such as blog while he is doing various learning tasks. This approach embraces situated-based learning approach since it allows further interactions and collaboration between peers.

The Fourteen Scenario:

Scenario ID: Scenario #14										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	***Waterfall Process Model***	***Fulfilled***	Aural	Undefined	***Undefined***	Undefined	***Undefined***	Undefined	Undefined	***Undefined***
	Agile Process Model	Not fulfilled	Visual	***Neutral***	Physics	Cognitive	Individual	***Waterfall***	***1***	0
	Validation & Verification		ReadWrite	Excited	Mathematics	***Metacognitive***	Collaborative	Agile	2	1
			Kinesthetic	Bored	Drama	Motor skills		Validation & Verification	3	2
					Business				4	3

Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	***Undefined***	Visual	***Undefined***	Instructional Design	Swimming	Undefined	***Undefined***	***Core***	***Undefined***	***PC***
	30/6/2016	Hearing	List of peers	Direct Instrcution	***Reading***	***0***	< 50%	Supportive	No	Mobile
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	Undefined	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Waterfall software development process model topic through constructive-based approach such as learning by doing or by problem (i.e. Kinesthetic learning style) whereas the e-learner fulfils the requirements of the learning process (i.e. prerequisite) has metacognitive skills, defined and prioritised goals and previous history of using self-regulated learning approach, therefore self-regulated learning process will be recommended and contents will be recommended based on the goals identified by the e-learner taking into account: (i) their priorities and then (ii) date to achieve goal.

The Fifteen Scenario:

Scenario ID: Scenario #15										
Construct	Topic requested	Pre-requisite	Learning style	Affects	Background	Skill type	Learning tendency	Goal	Goal priority	No. of topics with advancement
Value	Waterfall Process Model	***Fulfilled***	Aural	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined
	Agile Process Model	Not fulfilled	Visual	***Neutral***	Physics	Cognitive	***Individual***	Waterfall	1	0
	Validation & Verification		***ReadWrite***	Excited	Mathematics	***Metacognitive***	Collaborative	***Agile***	***2***	***1***
			Kinesthetic	Bored	***Drama***	Motor skills		Validation & Verification	3	2
					Business					3
Construct	Goal date to achieve	Disability	Social interaction	Previous process elements	Interest	No. of attempts	Feedback score	Learning Unit type	Misconception	HW display setting
Value	Undefined	Visual	Undefined	Instructional Design	***Swimming***	Undefined	***Undefined***	Core	Undefined	PC
	30/6/2016	Hearing	***List of peers***	Direct Instruction	Reading	***0***	< 50%	***Supportive***	***No***	***Mobile***
	10/4/2016	***No Disability***	Project mates	Intelligent Tutoring	Cycling	1	> 50%		A	Ipad
	3/1/2016		Group titles	Recommender System	Astronomy	2			B	
				Adaptive System	Undefined	3			C	
				Self-regulated		4			D	
				Problem-based		5			E	
				Situated-based		6			F	
				Virtual/Game based		7			G	
				Undefined						

This scenario mainly tests teaching Agile software development process model topic through text-based contents (i.e. read write learning style) whereas the e-learner fulfils the requirements of the learning process (i.e. prerequisite), has metacognitive skills, set of goals with priorities and date to achieve and mobile hardware display settings, therefore self-regulated learning process will be recommended to the e-learner in a way that matches his goal date to achieve and his hardware settings (i.e. with limited graphical capabilities).