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ORGANIZATIONAL LEARNING ASSESSMENT IN SOFTWARE DEVELOPMENT ORGANIZATIONS

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September 2012

TECHNICAL REPORT
METU/II-TR-2012-02

ABSTRACT

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September 2012, 257 pages

Knowledge is one of the most important assets of an organization that directly affects business success, and its importance increases for organizations that use knowledge-intensive processes such as the software development industry. In an industry in which technological developments are rapid, in order to keep up with the continuously increasing competition and to obtain competitive advantage the software organizations need to obtain the correct knowledge, use it efficiently and pass it to future projects evolving it accordingly. The major aim of this research is to propose a novel model, namely AiOLoS, for assessing the level of organizational learning and learning characteristics in software development organizations. The primary contributions of this two-legged AiOLoS model are the identification of the major process areas and the core processes that a learning software organization

follows during its organizational learning process and to provide the necessary measures and metrics and the corresponding definitions/interpretations for the assessment of the learning characteristics of the software development organization. The research is supported with a multiple case-study work conducted in software development teams in order to identify the mapping of the core processes and the applicability of the AiOLoS model to software development organizations, its utilization as a tool for assessing organizational learning and providing a basis for software process improvement.

Keywords: Organizational Learning, Knowledge Management, Learning Organizations, Learning Software Organizations, AiOLoS

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LIST OF ABBREVIATIONS AND ACRONYMS

AiOLoS	:	Assessing Organizational Learning of Software Development Organizations
BBS	:	METU Integrated Information System *(ODTÜ Bütünleşik Bilgi Sistemi)*
CMM	:	Capability Maturity Model for Software
CMMi	:	Capability Maturity Model Integration for Development
DLOQ	:	Dimensions of the Learning Organization Questionnaire
DIKW	:	Data, Information, Knowledge, Wisdom
GQM	:	Goal/Question/Metric
ICSM	:	Incremental Commitment Spiral Model
ICSM-EPG	:	Incremental Commitment Spiral Model – Electronic Process Guide
IT	:	Information Technology
JAS	:	Juridical Automation System
K3M	:	Knowledge Management Maturity Model
KM	:	Knowledge Management
LO	:	Learning Organization

LSO	:	Learning Software Organization
METU	:	Middle East Technical University
METU-CC	:	Middle East Technical University Computer Center
NA	:	non-applicable
OK	:	Organizational Knowledge
OL	:	Organizational Learning
OV	:	Organizational Value
PC	:	Phase Coefficient
QIP	:	Quality Improvement Paradigm
SPI	:	Software Process Improvement
SPICE	:	Software Process Improvement and Capability dEtermination
SQ4R	:	Survey, Question, Read, Recite, Review, and wRite
TC	:	Team Coefficient

CHAPTER 1

INTRODUCTION

"*Aeolus in a cavern vast*
With bolt and barrier fetters fast
Rebellious storm and howling blast.
They with the rock's reverberant roar
Chafe blustering round their prison door;
He, throned on high, the sceptre sways,
Controls their moods, their wrath allays."

(Virgil, *"Aeneid"*,
Conington's translation)

A brief overview of the background, scope and objectives of the study, together with the underlying motivations are presented in this chapter. Moreover, the general framework and characteristics of the proposed model are introduced with some essential concepts and definitions. Herein, the focus is concentrated on the relationship between organizational learning (OL) and software process improvement (SPI) and how assessing OL can advance SPI. The chapter also describes the research context, problem, and questions, the claimed contributions and the methodology employed during the research. The chapter concludes with an outline of the rest of this thesis study.

1.1. Background of the Study

Software pervades almost every piece of our modern lives: from business to entertainment, from communication to defense, from transportation to education, and many more. The increase in demand for more capable software to operate in wider areas of application with advanced functionality, results in software becoming more complex and voluminous, "*perhaps the most intricate and complex ... of the things humanity makes*" [1] as Brooks points out. In order to address these difficulties, *software engineering*, that is the application of a systematic, disciplined, and quantifiable approaches to the areas related to software, emerged, bringing with it many practices, proposals, and undergoing studies to improve software development processes. However, as stated by Brooks [1] and Gibbs [2], in their respective seminal works, despite all the efforts undertaken by the software engineering discipline, these problems[1] still exist today, resulting in delayed, over budget, poor quality software which fails to meet the necessary requirements or even having wrong functionality [3].

One of the major goals of software engineering is to develop high quality products; the term *quality* focusing not only on the final product but also on the artifacts of the software development processes. There are several models currently in use for evaluating the level of quality in software products and development processes, such as the Capability Maturity Model Integration for Development (CMMi) [4] and Software Process Improvement and Capability Determination (SPICE or ISO/IEC 15504) [5]. These models propose the idea that the quality of the software product that is being developed depends on and is largely governed by the quality of the development and maintenance processes applied [6]. However, none of these models focuses on the subject of OL, which is the process of learning by individuals and teams in a software organization through the software development process, or knowledge management (KM). On the other hand, a commonly used SPI model and Software Engineering Institute's recommended framework for SPI, IDEAL, makes a reference to "learning". In IDEAL model, as depicted by Gremba

[1] Named as "*software's chronic crisis"* by Gibbs, and as "*essential problems"* by Brooks.

and Myers [7], the last phase[2] is the Learning phase, consisting of the Analyze and Validate, and Propose Future Action sub-phases, where the learned lessons are documented and analyzed to improve the SPI program of the organization. Although this learning phase is related to the learning acquired from the implementation of a SPI program, still it emphasizes the importance of learning with respect to SPI.

The importance of learning with respect to quality comes from the fact that learning is the necessary prerequisite of knowledge as well as maturity, and the three terms are closely related. Knowledge is one of the most essential assets of an organization directly affecting the business success, and its importance increases for organizations that use knowledge-intensive processes such as the software development industry. Organizational knowledge (OK) should be stored in organization memory or mind, thus allowing sustainable quality practices and processes, at least with the reuse of the acquired knowledge. In an industry in which technological developments are rapid, in order to keep up with the continuously increasing competition and to obtain competitive advantage the software organizations need to *obtain the correct knowledge*, *use it efficiently* and *pass it to future projects* while evolving it accordingly. These three processes are the major process areas of KM. In [8] it is argued that a software development organization's practices are eventually based on the knowledge, experiences and capabilities of its personnel and managers, and that SPI efforts depend on the implicit, individual knowledge of experts in an organization. Therefore, in order to improve software practices, the organization should improve the existing knowledge of its employees and managers, and make available new knowledge regarding software practices but also should develop mechanisms and strategies for obtaining, using and passing that newly obtained knowledge. These, in other words are practices of OL and KM, which terms are further defined and described in Section 2.2 and 2.5 respectively.

A software organization that manages the processes of obtaining, using and passing knowledge, and learns within the domain of software development, evolution and application is referred as Learning Software Organization (LSO) [9]. Although

[2] Following the phases of Initiating, Diagnosing, Establishing, and Acting [7].

the terms learning organization (LO), LSO and KM are already coined, there is need for a model that will allow software organizations to assess their current OL capabilities and KM activities in all process areas, identify the areas that need improvement and monitor their continuous improvement.

The fundamental idea of this thesis and on developing the aforementioned model is that the major requirement for SPI is commitment to OL and KM, and that only by assessing and measuring its learning capabilities can a software development organization exploit its competency in process improvement. In [10], the motivations for performing measurements to assess the OL capabilities of a software development organization are summarized as being necessary for organizational survival, renewal and growth, for management briefing and for performance control. With these considerations, the requirement for developing such an assessment model becomes evident.

The term *assessing* in Oxford Advanced Learner's Dictionary[3] is defined as *"to make a judgment about the nature or quality of somebody or something"* and *"to calculate the amount or value of something"*, whereas the term assessment is defined as *"an opinion or a judgement about somebody or something that has been thought about very carefully"* and *"the act of judging or forming an opinion about somebody or something".* In this study we propose an assessment model in these aforementioned senses, as the aim of the model is not only to measure and calculate the extent of OL in a software development organization but also to form an opinion and judgement of that calculated OL, and we develop measures for that assessment after carefully examining the nature and attributes of software development organizations and characteristics of OL.

1.2. Problem Statement and Research Questions

This thesis addresses the problem of modeling, and assessing on this model, the OL capabilities of software development organizations. It also examines the applicability and the implications of the proposed model in real-world software

[3] http://oald8.oxfordlearnersdictionaries.com/

organizations and projects. Based on these, a concise statement of the problem that frames the area of this research is:

Research Problem: *How can we model and assess the OL capabilities of software development organizations?*

In this thesis, the adopted viewpoint is that the OL capability of a software development organization is a combination of OL, KM, and LO (or LSO) practices, both general and specific to the domain of software development. Thus, all these three approaches need to be taken into account while elaborating the research problem.

Furthermore, the following specific questions (sub-problems) have been formulated in order to support the addressing of the research problem, but also to narrow down the borders of this study:

Research Question 1: *What are the major process areas and core processes of OL in software development organizations?*

An extensive literature survey, regarding the KM models and OL and LO methodologies proposed and implemented, was conducted. The results were utilized in order to formulate the major process areas and core process areas of the proposed model.

Research Question 2: *How can the core processes of OL be measured?*

Following a literature survey of the proposed models, three qualitative case studies were undertaken in order to develop the appropriate measures with the use of the Goal/Question/Metric (GQM) approach.

Research Question 3: *How can the measurement results be used for SPI?*

Expert opinions within the conducted qualitative case studies were obtained in order to comprehend the utilization approaches of the measurement results in SPI, and to evaluate the possible contribution of the overall assessment for SPI.

Research Question 4: *Can an approach be proposed to enhance the OL capability of software development organizations and teams?*

As a result of surveying different learning methodologies and approaches proposed for team learning, an approach to increase the OL capabilities of software development organizations is proposed and its applicability is examined with the use of a case study.

1.3. Scope and Objective of the Study

The objective of this thesis is the development of a model for assessing the OL capabilities of a software development organization, in accordance to the research problem and research questions provided in Section 1.2. The theoretical scope of the study has been identified as all software development organizations in any maturity level, and the model was constructed with this scope taken into account. However, the undertaken case studies for the validation of the model were conducted in three organizations: a graduate/undergraduate software engineering course (Section 5.1), a public software development company that shows indicators of being a Capability Maturity Model for Software (CMM) 1 level organization with respect to its organizational and software development maturity (Section 5.2) and a private software development company with SPICE capability level 2 (Section 5.3). Moreover, the case studies have assessed not the software development organizations in their totality, but instead software development teams within the context of single projects. Therefore, these case studies have restricted the actual scope of the study to these three software development environments.

The acronym AiOLoS (Assessing OL of Software Development Organizations) has been coined for the developed model for assessing the OL of software development organizations, after the deity of storms and winds *Aiolos*[4] in Greek mythology (pronounced as ['e.olos] in Ancient Greek and written as Aeolus in Latin). AiOLoS is not only an acronym for the proposed model but also has a significance regarding the vitality of "true" and "good" knowledge for the software

[4] http://www.theoi.com/Titan/Aiolos.html

organization and the peril that incorrect, wrong and disproportionate knowledge poses to any organization[5,6]; parallel to the story of Odysseus in Homer's Odyssey[7].

Figure 1 Theodor van Thulden's (1606 - 1669) Depiction of Aiolos and Ulysses

[5] There are many sayings about the dangers of knowing too much and too little, the most famous being "*A little knowledge is a dangerous thing. So is a lot*" which is misattrubuted to Albert Einstein.

[6] "A little learning is a dangerous thing; / drink deep, or taste not the Pierian spring: / there shallow draughts intoxicate the brain, / and drinking largely sobers us again." by *Alexander Pope, An Essay on Criticism*

[7] "Odysseus went on to the island of Aiolia, of which Aiolos was king. Zeus had set him up as coordinator of the Anemoi (Winds), for both stopping them and stirring them up. After playing host to Odysseus, he gave him an ox-skin, in which he had tied up the Anemoi (Winds). He explained which Winds would be needed for sailing, and fastened the skin securely in the ship. So Odysseus, by using the correct Winds, had a good voyage, but as they drew near enough to Ithaka to see the smoke rising from the polis, he fell asleep. His comrades, in the belief that he carried gold in the skin, opened it and let the winds escape. Back again they went, captured by the Winds, but when Odysseus made his way to Aiolos to ask for a sailing breeze, Aiolos threw him off the island, saying he could not save him as long as the gods had other ideas." by *Pseudo-Apollodorus*, translated by *Aldrich*.

The AiOLoS model, its overall structure and the proposed measures were developed with the utilization of ideas, methodologies and practices from three major areas, namely these of OL, KM and LOs (and LSOs), as shown in Figure 2. Each of these major areas has been surveyed with respect to their theoretical approaches (Chapter 2) and with respect to the existing or proposed practices and methodologies (Chapter 3).

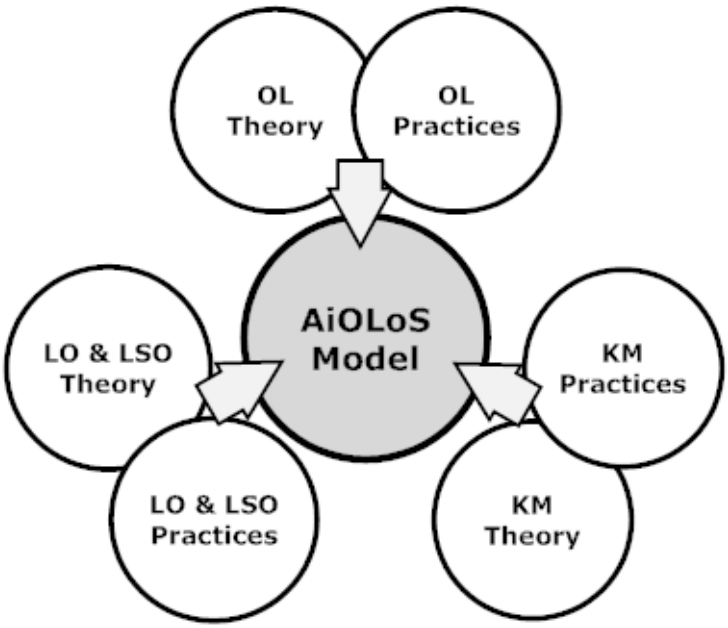

Figure 2 The Development of the AiOLoS Model

The details of the AiOLoS model are presented in Chapter 4; with the major process areas and the core processes identified and defined in Section 4.1, and the corresponding measurements thoroughly described in Section 4.4. The major process areas have been developed based on the theoretical background (Chapter 2) and the applied background (Chapter 3) of OL, KM, LOs and LSOs. The measurements have been developed based on the GQM approach (Section 4.4). The major process areas, core processes and proposed measures are depicted in Figure 3.

1.4. Research Design and Method

In order to test the applicability of the AiOLoS model and to validate whether it does measure and assess the OL capabilities of a software development organization, an empirical study was designed. According to Runeson and Höst [11], empirical studies in the field of software engineering are continuously increasing and they may be conducted either quantitatively, or qualitatively, or in combination of these two[8]. As the software engineering domain is a highly knowledge intensive development process, depending on human behavior, in order to understand *why* something has happened qualitative approaches need to be employed.

The research method that has been employed in this study is summarized in Figure 4. As a first step, an extensive literature survey in the subjects of OL, KM and LOs (and LSOs) was conducted, which was utilized to develop a preliminary model (Chapters 2 and 3). This model was tested using an exploratory case study in order to have insight about the strengths and weaknesses of the preliminary model, to seek new insights and to develop new hypotheses and ideas [11]. The case study was formulated and conducted by means of action research methodology, using a classroom environment consisting of both undergraduate and graduate students, modeled according to the CSCI577ab course [12]. The aim of the action research approach was to both influence and change the way students were developing software and learning from the development process, but also to influence and change the AiOLoS model processes and measures [11]. The details of the case study are given in Section 5.1.

[8] Runeson and Höst [11], citing Robson (2002), define the combination of qualitative and quantitative data methods as "mixed methods".

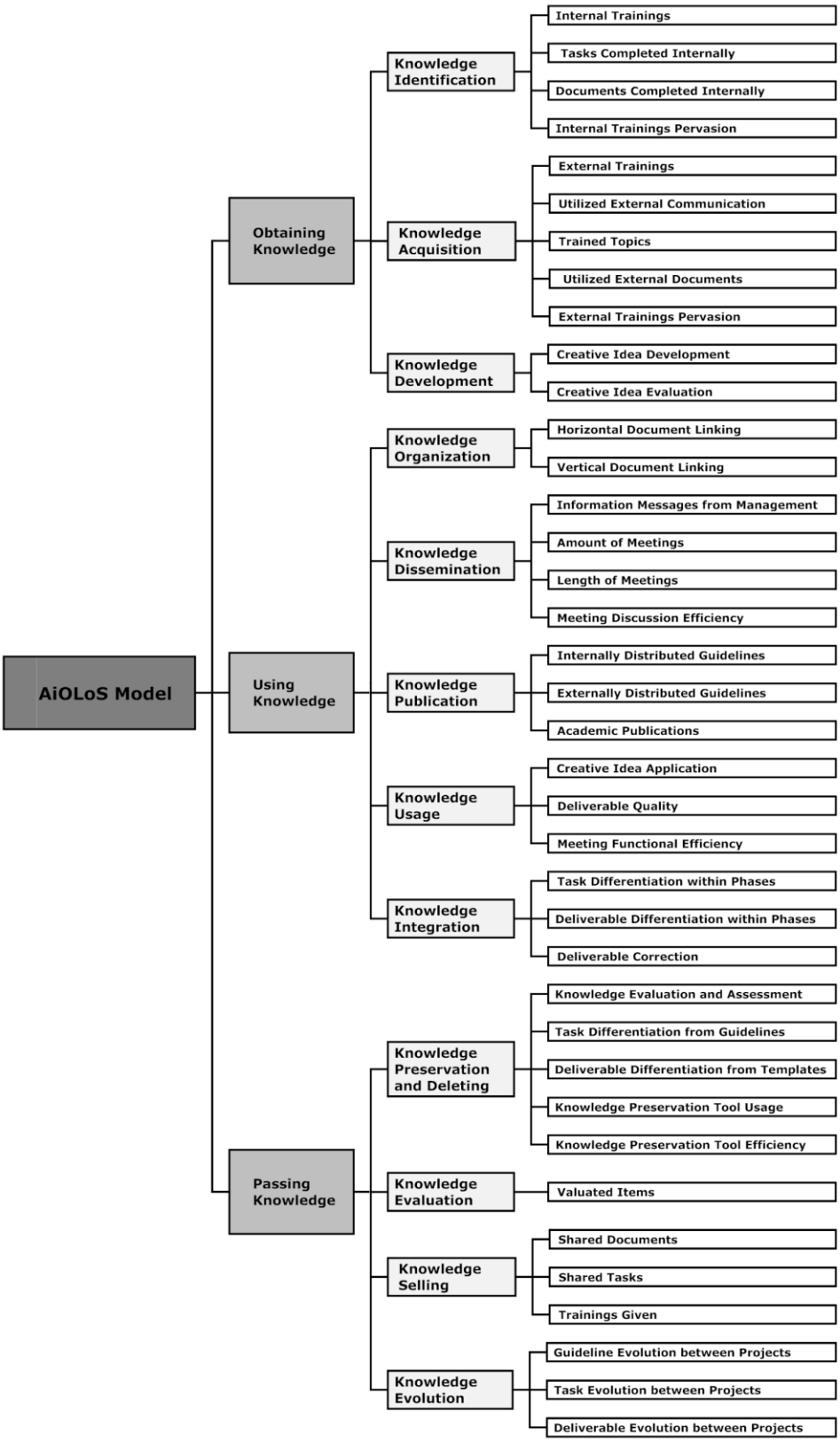

Figure 3 Major Process Areas, Core Processes and Proposed Measures of the AiOLoS Model

The results of the case study were correlated with a second round of a literature survey and the AiOLoS model was finalized. The measures of the finalized model were re-developed using the GQM approach, considering goals explicitly from and towards the professional software development environment. The AiOLoS model and the new measures were tested using two more qualitative case studies conducted in two different software development companies (one in the public sector with one project team and one in the private with three project teams). Both case studies basically formulated as *descriptive* case studies in order to portray the OL aspects of these four different project groups, but also in an *improving* mode in order to find the OL shortcomings and improvement areas [11]. The research methodology in both case studies was surveying, as information and data were collected from a specific population without manipulating any variables or changing the model or the way things are being conducted in the project groups [11]. The major aims of these two case studies were to: a) demonstrate that the AiOLoS model can be employed in professional software development organizations, and b) understand whether the findings of the AiOLoS model can be actually used for SPI. The details of these studies are given in detail in Sections 5.2 and 5.3.

Based on the results and the findings of all three conducted case studies, the AiOLoS model was further investigated with respect to its strong and weak points. All case study results were submitted as reports to the corresponding company management and project groups, and the results were discussed with both participators and management at the end of the case studies. The validity of the AiOLoS model and the measurements were investigated, and the weak and the strong aspects of the model were identified with use of exit interviews. Furthermore, all findings from both the literature survey and the case studies were used to support the theoretical structure of the maturity dimension of the AiOLoS model. However, that dimension was not tested with the use of further case studies.

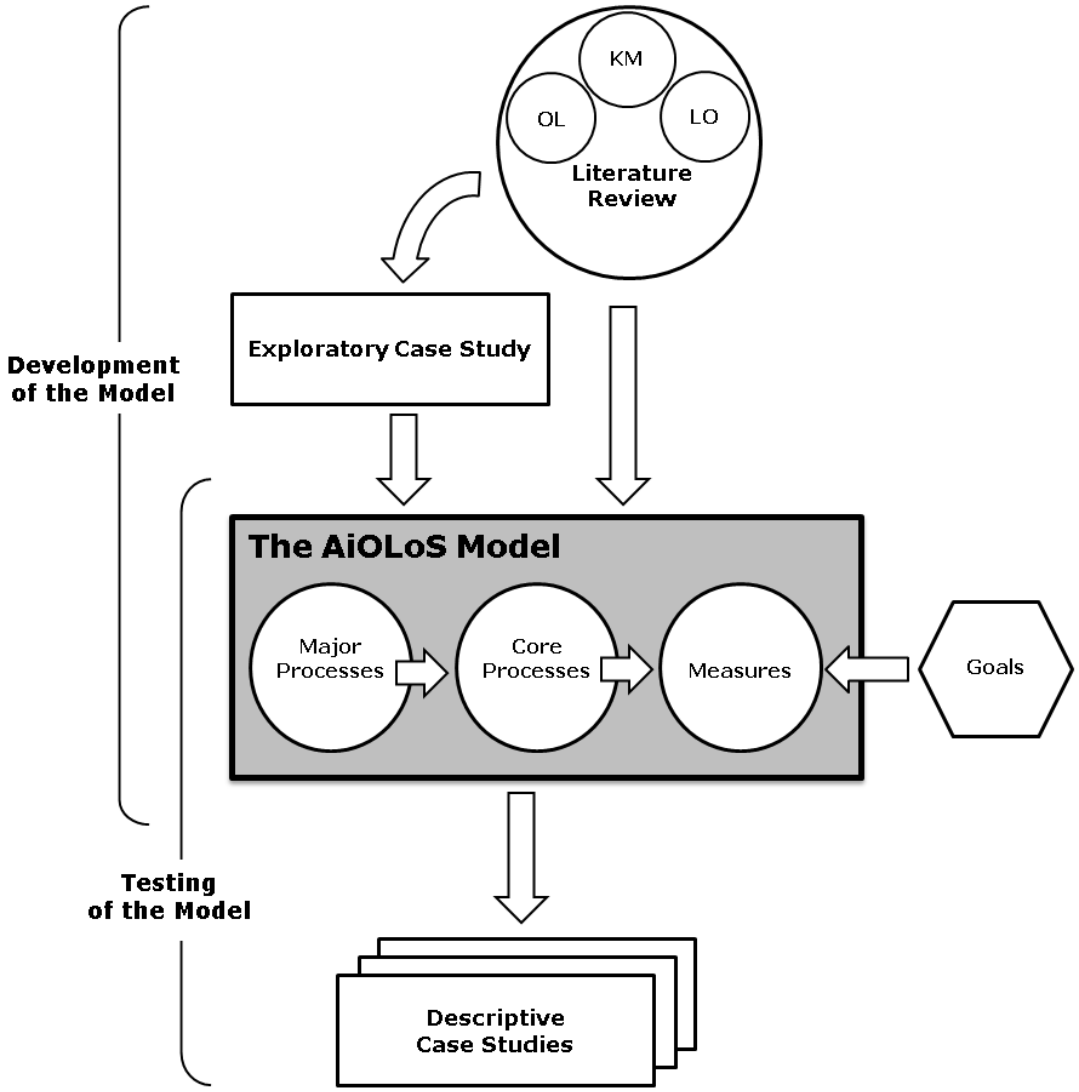

Figure 4 Research Design and Method

1.5. Major Contributions

The main contributions of this research can be summarized as:

- A unified model, AiOLoS, for assessing the OL capabilities of software development organizations, utilizing and addressing concepts from the areas of OL, KM, LOs in general and LSOs, in particular, is proposed. The model, the major process areas and the core process areas were developed based on a literature survey and an explorative case study, and they were tested using two case studies in two different software development organizations.
- An extensive list of measures related to the core process areas of the AiOLoS model, developed using the GQM approach with respect to the organizational and SPI goals of software development organizations, but also the data that software development organizations collect and store, is provided. The measures are also tested with respect to their applicability, and validated with the use of three different case studies, of software development organizations from three different environments, namely academic, public sector and private sector, to provide a basis regarding their ease of collectability.
- A starting point to enhance OL capabilities of software development organizations, which in turn will provide a basis to conduct SPI activities with respect to OL. The qualitative nature of the conducted case studies provides grounds to find answers for the *why* questions that the organization may ask regarding its OL capabilities. Some of these questions have been answered with the use of the findings and results of the case studies.
- The proposal of using a differentiated development approach based on critical thinking, namely SQ4R (Survey, Question, Read, Recite, Review, and wRite), to enhance the OL experience of individuals, teams or the organizations in whole. Utilized only in one of the three case studies conducted, the SQ4R has been shown that is applicable in software

development teams; however, further case studies are required to measure the benefits of it.

1.6. Outline

This study is organized in 6 chapters, which correspond to the phases of the research that were discussed in Section 1.4.

Chapter 2 provides an extensive literature survey of the theory and the theoretical studies related to the fields of OL, KM, LOs and LSOs. The effect and significance of each of the discussed and analyzed theory is linked to the AiOLoS model. Moreover, a brief introduction of the necessary background information is given, defining the cornerstone concepts of data, information and knowledge.

Chapter 3 consists of a literature survey of the methodologies and applications proposed or actually implemented in the areas of OL, KM, LOs and LSOs. The strengths and weaknesses of each surveyed model are discussed and the effects to the AiOLoS model are provided.

Chapter 4 gives a detailed description of the AiOLoS model, the major process areas, the core processes, the measure and the measurement details. Each core process and measurement is linked to the literature reviews conducted in Chapters 2 and 3.

Chapter 5 provides the details of all three conducted case studies, with respect to the formulation and design, the conduct and the result gathering of each of these three case studies. The results of each of these case studies are presented with the use of footprint graphics and are discussed. The comments and the conclusion reports submitted to the software development organizations participating in the case studies are provided.

Chapter 6 concludes the research with the discussion of the proposed AiOLoS model, stating the claimed contributions of the study to the areas of OL. An evaluation of this thesis with respect to both rigor and relevance is provided. The strengths and weaknesses of the AiOLoS model are discussed, providing possible solutions for the identified limitations. Future studies and possible recommendations for further research are proposed and described.

CHAPTER 2

ORGANIZATIONAL LEARNING, LEARNING ORGANIZATIONS, KNOWLEDGE MANAGEMENT AND LEARNING SOFTWARE ORGANIZATIONS

"Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?"
(T.S. Eliot, Choruses from "*The Rock*")

Every living system is subject to different situations and circumstances within the span of its lifetime, where these situations and circumstances result in the system having to sense and process a vast amount of data. These experiences are the first step of learning, and as organizations are living systems, it can be argued that they learn too; whether they consciously choose to or not, learning is a fundamental requirement for their sustained existence [13], allowing them to acquire and obtain knowledge assets that at any given time provide an opportunity for sustainable competitive advantage [14]. However, how organizations learn and how OL is achieved is a vague topic, as summarized by Sinkula, Baker and Noordewier [15]:

> Organizations might learn actively or passively, by their own volition or through force, as a luxury or by necessity, through systematic analysis or by trial and error, and through long-term versus short-term feedback from a dynamic or stable environment.

This chapter surveys the subjects of OL and KM together, as they are complementary of each other and run in a parallel fashion [16], and focusing on their applications in the software engineering domain, tries to answer the questions "what is OL", "what a LO is" and "how KM can be utilized in terms of OL". Furthermore, in order to provide a ground on the discussion, definitions regarding some key concepts related to the subject are given.

2.1. Data, Information and Knowledge

Studies that describe, define and model OL and KM heavily utilize the concepts of *data*, *information*, *knowledge*, *explicit knowledge* and *tacit knowledge* [16] [9], thus making it necessary for the reader to have a common understanding of what these terms are, what are their differences and what are their structural and functional relationships. Data, information and knowledge are fundamental concepts in the context of different fields such as information science, KM, intellectual capital, and OL, and are considered to be their basic building blocks [17] [18] [19]. Although the difference between data, information and knowledge is crucial, some associate information with data, and others associate information with knowledge, using the terms interchangeably [20]. It is evident that these three concepts are interrelated, but not only their meanings but also the nature of the associations between them is controversial, therefore making it important to develop a formulation of methodical conceptions of data, information, and knowledge [18].

Discussions and definitions of data, information, and knowledge exist in a wide range of literature from introductory textbooks to research articles [18] but the first to be credited by combining all these three items in a single formula and developing the *data-information-knowledge-wisdom* (DIKW) hierarchy according to Rowley [21] is Ackoff, in 1989. DIKW is one of the fundamental, widely recognized and *taken-for-granted* models used implicitly to define data, information and knowledge within the scope of information management and KM [21], in which

DIKW hierarchy a class of models are defined for representing structural and/or functional relationships between data, information, knowledge, and wisdom [18]. The DIKW hierarchy has been investigated and analyzed in detail and referred to variously as the *Knowledge Hierarchy*, the *Information Hierarchy* and the *Knowledge* or *DIKW Pyramid*[9] in information and knowledge literature [21] but has also been described as a framework [22], as a chain [23], and as a continuum [24].

As a result, there are substantive differences regarding the definition of DIKW and its characteristics [21], and a vast list of definitions for data, information and knowledge within different perspectives is given in [23] and in [25]. However, according to Rowley [21] and Vandergriff [26] in all the proposed DIKW models there is a consensus that:

- data, information, knowledge, and wisdom are consistent and key elements;
- the arrangement orders between these terms are virtually always the same,
- the higher elements in the hierarchy can be explained in terms of the lower elements by identifying an appropriate transformation process,
- by adding something and reducing the volume levels are achieved, and
- each level reflects intellectual capital with different processing and application levels.

Even though the definitions of data, information and knowledge are vaguely defined when compared with respect to different research disciplines such as philosophy, natural sciences, management information systems and computer science [27], according to Frické [28], sufficient similarities exist that allow the extraction of a core definition of the hierarchy and its constituents, best expressed based on the sources of Ackoff, Adler and Zeleny, whose work in the area has been directive.

[9] Several representations of the DIKW pyramid include a level below Data named as Measurements which is defined as "physical readings of phenomena from scientific instruments (e.g., photons) or event/object observations by individuals or groups" [26]. Depending on the definition of Data, the level of Measurement can be viewed as part of Data and thus can be omitted, as in this study.

Ackoff explains each of the higher types[10] in the hierarchy by including and depending the categories that fall below it [29], thus the DIKW hierarchy is built on the foundation of data [28]. The essence of Ackoff's definitions of data, information, knowledge and wisdom[11], their associated transformation processes and Zeleny's definitions are given by Rowley [21] as follows:

- *Ackoff:* Data are defined as symbols that represent properties of objects, events and their environment, are the products of observation, but are of no use until they are in a useable form. The difference between data and information is functional, not structural.

  Zeleny: Know nothing.
- *Ackoff:* Information is contained in descriptions, answers to questions that begin with such words as who, what, when and how many. Information systems generate, store, retrieve and process data. Information is inferred from data.

  Zeleny: Know what.
- *Ackoff:* Knowledge is know-how, and by knowledge information are transformed into instructions. Knowledge can be obtained either by transmission from another who has it, by instruction, or by extracting it from experience.

  Zeleny: Know-how.
- *Ackoff:* Wisdom is the ability to increase effectiveness, adds value, and requires the mental function of judgement.

  Zeleny: Know why.

Liew [19] provides a literature survey of a list of definitions for data, information and knowledge, concluding with a refined definition of his own within the OL context. According to Liew [19]:

[10] The hierarchy of Ackoff includes a fifth level, that of "understanding" which is interposed between knowledge and wisdom. Further studies in DIKW usually have omitted that level.

[11] As the concept of "wisdom" is beyond the scope of this study, no further definitions of it in the literature are given. However, in order to establish an introductory understanding of the DIKW hierarchy Ackoff's and Zeleny's original definitions of "wisdom" are provided.

- data are recorded symbols and signal readings with the main purpose of recording activities or situations[12],
- information is a message that contains relevant meaning, implication, or input for decision or action,
- knowledge has the ultimate purpose of value creation for the organization and is either (1) know-what: cognition or recognition, (2) know-how: capacity to act, or (3) know-why: understanding.

According to Liew [19] the functional relationships between data, information and knowledge are two-way: data are converted to information by being processed and analyzed, whereas information is captured and stored as data, information is internalized, absorbed and understood as knowledge, which knowledge is externalized as information.

The research of Zins [18] contains the results from a Critical Delphi study conducted in 2003–2005 and titled as "Knowledge Map of Information Science", documenting 130 definitions of data, information, and knowledge formulated by 45 scholars, and maps the major conceptual approaches for defining these three key concepts. Based on the given definitions, Zins [18] concludes that data, information and knowledge should be defined as they are related and implemented in *inferential propositional knowledge*[13], and that data, information and knowledge have two different modes of existence, these of subjective and objective realms, therefore, they can be defined in subjective domain, but also in the universal[14] (objective) domain. Based on these considerations, Zins provides two definitions for each concept of data, information and knowledge, one in the subjective domain, and one in the universal domain [18]. In the universal domain data are sets of signs that represent empirical stimuli or perceptions, information is a set of signs, which represent

[12] According to Liew all data are historical, unless used for illustration purposes, such as forecasting.

[13]Propositional knowledge is the reflective and/or the expressed content of what a person thinks that he or she knows, and usually comes in the form of "knowing that". Propositional knowledge is divided into inferential and non-inferential knowledge. Inferential knowledge is a product of inferences, such as induction and deduction. According to Bernecker and Dretske apart from propositional knowledge, in traditional epistemology, there are two more main kinds of knowledge: practical knowledge and knowledge by acquaintance [18]

[14] In the universal domain, data, information, and knowledge are human artifacts. They are represented signs that one can sense through his/her senses (empirical signs). Universal data, universal information, and universal knowledge mirror their cognitive counterparts [18].

empirical knowledge, and knowledge is a set of signs that represent the meaning or the content of thoughts that are justifiably believed to be true [18].

Definitions of data, information and knowledge with complementary properties are given by Ruhe [9], whose approach to the subject is within the OL perspective. In Ruhe's definition [9]:

- Data are a set of discrete, objective facts about events, that provide nothing about they own importance or irrelevance but are essential raw material for the creation of information.
- Information is a message, usually in the form of a document or an audible or visible communication, with a sender and a receiver. Information is expected to change the way the receiver perceives something, to have an impact on his or her judgement and behavior.
- Data becomes information when its creator or receiver adds meaning.
- Knowledge is information combined with experience[15], context, interpretation and reflection. It is a high-value form of information. It is ready to be applied in decisionmaking and action taking.

In contrary to the DIKW hierarchy view where knowledge is intrinsically similar to information and data, and it is the richest, deepest and consequently the most valuable of the three, Becerra-Fernandez and Sabherwal [30] propose a different approach where knowledge is intrinsically different from information: instead of considering knowledge as a richer or more detailed set of facts, they [30] define it as "justified beliefs about relationships among concepts relevant to that particular area", where knowledge is used to produce information from data or more valuable information from less valuable information. The relationship between data (which has zero or low value in making the decision), information (which has greater value than data) and knowledge is depicted as an arrow denoting increasing value, where data of no or low value is transformed to information of medium, high or very high values, with the use and help of knowledge.

[15] According to Ruhe, experience describes results from historical, controlled or observational experiments; which experiments can be devoted to any kind of method, technique or tool for any stage of the software development process [9].

2.1.1. Knowledge

The scope of this study is to focus on OL in software organizations, and as knowledge is the building stone of OL and KM, then a more detailed approach is required in understanding what actually is *knowledge,* to provide ground for the following discussions of *OK, learning* and *KM*. The relationship between learning and knowledge is identified by Kolb, cited by [13], stating that "*learning is the process whereby knowledge is created through the transformation of experience*". The following sections provide a literature survey regarding the definitions and discussions around these two topics.

The term *knowledge* in Oxford English Dictionary[16] is defined as "*the fact of knowing or being acquainted with a thing, person, etc.; acquaintance; familiarity gained by experience*", "*the faculty of understanding or knowing; intelligence, intellect*", "*the fact or state of having a correct idea or understanding of something; the possession of information about something*", "*the fact or state of knowing that something is the case; the condition of being aware or cognizant of a fact, state of affairs, etc. (expressed or implied); awareness, consciousness*", and "*the fact or condition of having acquired a practical understanding or command of, or competence or skill in, a particular subject, language, etc., esp. through instruction, study, or practice; skill or expertise acquired in a particular subject, etc., through learning*".

Gherardi [31] provides metaphorical definitions of knowledge within the scope of OK and KM:

> Colourful metaphors abound. Knowledge is the root of production, while products and services are its fruits, so that competencies constitute the organization's genetic code (Prahalad and Hamel, 1990); distinctive skills are like passing the ball in soccer (Kay, 1993); organizational competence is like a chef 's ability to transfer his experience to new recipes (Miyazaki, 1994). Davenport and Prusak (1998: 17) define knowledge as a tangible resource which can be mobilized to obtain a competitive advantage. Dixon (2000) defines it as a resource which the members of an organization must share, although she does not indicate or discuss why workers would have reason to do so.

[16] http://www.oed.com

According to Becerra-Fernandez and Sabherwal [30], knowledge can be either viewed from a subjective stance, where it can be perceived as a state of mind or as a practice; or it can be viewed from an objective stance, where it can be perceived as an object, as access to information or as a capability.

Maier [27] provides a detailed literature survey where the historical evolution of the concept of knowledge within the viewpoints of different disciplines and its relationship to the construct of organization are given. A detailed list of knowledge dimensions with respect to the corresponding main area of intervention are given in [27], which main areas of intervention and the corresponding dimensions are listed as:

1. Content of knowledge or knowledge application, with the dimensions of abstraction, generalization, contextualization, and form.
2. Holder of knowledge or valuation of an individual, with the dimensions of value, relation to person, and existence.
3. Organizational design, with the dimensions of relevance, informal support, formal authorization, secrecy, truth, organizational scope, focus, holder, and integration.
4. Legal system and/or organizational boundaries, with the dimensions of security, legality, and ownership.
5. Information and communication systems, with the dimensions of access, medium, and codability.
6. Knowledge life cycle, with the dimensions of preservation, novelty, refinement, and actuality.
7. Business processes, with the dimension of relation to process.

Each one of these dimensions is populated with an amalgamated and extended list of paired opposite types of knowledge and with the use of a knowledge process one type of knowledge is transformed to its opposite type [27].

These dimensions have been pivotal in the development of both the AiOLoS model but also the AiOLoS measures proposed in this study. Each of the developed core process areas of the AiOLoS model in Section 4.1 and each of the proposed AiOLoS measures in Section 4.4 states which of the

aforementioned area of intervention, dimension and knowledge type they are related to or they assess, with each of the dimension details available at [27].

2.1.2. Differentiating Knowledge Types

Special importance should be given to declarative (substantive) vs. procedural knowledge as stated in [30]: *declarative knowledge* (characterized as "know what") focuses on beliefs about relationships among variables and can be stated in the form of propositions, expected correlations, or formulas relating concepts represented as variables. Whereas *procedural knowledge* (characterized as "know-how"), focuses on beliefs relating sequences of steps or actions to desired (or undesired) outcomes[17].

Within the perspective of OL, knowledge can be divided into two types, tacit and explicit knowledge [32] [33], which seperation is characterized as *knowledge abstraction* [34]. According to Nonaka, *tacit knowledge* is "subconsciously understood and applied, difficult to articulate, developed from direct experience and usually shared through highly interactive conversation and shared experience" [27]. In other words, it is the knowledge the person can not express explicitly, but guides his or her behaviour[18] [35]. Moreover, it is a kind of personal knowledge which is embedded in personal experience (e.g., subjective insights, intuitions, and hunches), thus it is hard to formalize and is generally in the heads of individuals and teams but it is often assumed to be the most valuable and untapped knowledge [9]. On the other hand, *explicit knowledge* "can be formally articulated and shared through meetings, conversations, mathematical formulas, models or even documents and similar ways or means, and it is removed from its original context of creation or use if it is

[17] An example is given in [30] of an automobile manufacturing firm: a set of justified beliefs about the effect that the quality of each component would have on the final product is declarative knowledge, whereas the set of beliefs about the process used to assemble a particular model of the car is procedural knowledge.

[18] An example of tacit knowledge is given by Nonaka and Takeuchi, cited in [35], were Japanese engineers struggle to construct a machine that makes bread, but in every trial the bread simply does not taste as well as the bread made by human bakers. The company NEC sends people to a local baker to see how the process of making bread is being carried out. The researchers return with new insight on the kneading process and are able to replicate this in their machine. This is an example of tacit knowledge that is difficult to transfer by other means than looking at someone who are actually baking bread [35].

documented" [27]. Therefore, explicit knowledge can be represented in both formal and informal communication (e.g., reports, books, talks, manuals, models) [35], and can be packaged as information [9]. Explicit knowledge can also be found in the representations that an organization has of itself: organizational charts, process models, mission statements, and domains of expertise[19] [9].

Blair [36] furthermore differentiates between two types of tacit knowledge: that which has not been expressed but is potentially expressible, and that which is not expressible.

According to Nonaka and Takeuchi [34] [37], knowledge is created through the interaction between tacit and explicit knowledge, thus resulting in four different modes of knowledge conversion which can be depicted within the "knowledge spiral":

1. from tacit to tacit knowledge, called "socialization" – sharing experiences with others;
2. from tacit to explicit knowledge, or "externalization" – articulate "conceptual" tacit knowledge explicitly through the use of such techniques as metaphors and models;
3. from explicit to explicit knowledge, or "combination" – manipulating explicit "systematic" knowledge through such techniques as sorting and combining; and
4. from explicit to tacit knowledge, or "internalization" – learning by doing and sharing mental models and technical know-how.

Recent advances in the topic of knowledge conversion between tacit and explicit knowledge are given in [38]. **Each of the measures of AiOLoS model clearly states which type of knowledge, tacit or explicit, it assesses, in Section 4.4.**

[19] Expertise in [30] is defined as knowledge of higher quality and as addressing the degree of knowledge, and it can be associational (black box), motor skills, and theoretical (deep) expertise.

2.1.3. Organizational Knowledge

The concept of *OK* is a much talked about, but little understood notion of knowledge, especially with respect to its relevance and distinction to individual (personal) knowledge [39]. According to Maier [27], an organization which (primarily) manages and/or sells knowledge (in other words follows the knowledge-based view), where knowledge is considered to be the most important asset which accordingly receives high management attention is called "intelligent organization", "knowledge-intensive organizations", "know-how organization", "knowing organization", "knowledge-based organization", "knowledge organization", "(distributed) knowledge system" or "*LO*", which LO will be described in detail in Section 2.3. OK is the form and nature of knowledge that is contained within organizations [40], and in detail is the capability that the members of an organization have developed to draw distinctions in the process of carrying out their work, in particular concrete contexts, by enacting sets of generalizations whose application depends on historically evolved collective understandings [39].

Nonaka [34] defines the knowledge creating company as an organization where everyone is a knowledge worker and as an organization whose sole business is continuous innovation, where inventing new knowledge is not a specialized activity, but it is a way of behaving, a way of being. This definition is the further extreme point that a LO can transform to, and this definition is provided here to describe how knowledge can be placed in the center of an organizational perspective.

The difference between individual and OK is discussed in detail in [39]. When knowledge is viewed as the outcome of OL (simply as information that has been understood by all or at least a critical mass of members of the organization) then a distinction between individual knowledge and OK is made [27]. Traditionally it was perceived that OL is directly related to individual learning, that organizational routines arise when individuals store components of a routine as a procedural memory [41] and that OK consists mostly by either explicit knowledge (represented by organizational charts, process models, mission statements etc.) or by tacit knowledge, as embedded in the members of the organization [42]. However, current studies show that the focus of knowledge has shifted from the individual to the

group: epistemological issues are addressed at the level of groups, and groups are taken as the primary unit of analysis [41]. Similarly, Nonaka [43] describes the OK creation process as a spiral, which starts at the individual level, expanding to the group, and then to the organizational levels. Furthermore, studies within the organization show that each form of knowledge (explicit or tacit) can be used as an aid to acquire the other, thus becoming a complementary of each other in the management of knowledge within the organization [41]. **Based on these findings, the AiOLoS model has been developed with the focus of assessing the OL capabilities of not only organizations as a whole, but also teams and groups within the organizations, as demonstrated in Chapter 5 through three case studies.**

2.1.4. Locations of Organizational Knowledge

In the development of the proposed model and its relevant measures it has been important to identify the locations where knowledge is located and stored within the organization. As stated in [44] and [45], knowledge may be embedded in the minds of the individual members of an organization or it can be held in an organization's files that record the organizations' actions, decisions, regulations, and policies as well as in formal and informal maps, through which organizations make themselves understandable to themselves and others. Moreover, according to [45], OK is embedded in routines and practices which may be inspected and decoded even when the individuals who carry them out are unable to put them into words. However, if knowledge is stored only in the minds of individuals, then it is probably that it will be lost if these individuals leave the organization [45].

Becerra-Fernandez and Sabherwal [30] provide an exhaustive list of the possible locations (named as *knowledge reservoirs*) in which knowledge may exist. According to this classification, knowledge may exist in people (individuals or groups), artifacts (practices, technologies or repositories) and organizational entities. These locations are related to each other and are complexly interwoven into knowledge networks which create competitive advantages and need to be handled with KM [27]. As the classification of Becerra-Fernandez and Sabherwal does not

explicitly identify "documents" under the category of artifacts, it is assumed that the term "artifacts" does cover them.

Maier defines the knowledge of people as the knowledge that is located in peoples' minds [27]. The amount of knowledge that resides in people is significant especially for knowledge intensive organizations, where organizations try to extract this knowledge in order not to be highly dependent to individuals. Blair [36] cites Miller[20] (1998) "*Every afternoon our corporate knowledge walks out the door and I hope to God they'll be back tomorrow*", and similarly Rus and Lindvall [46] state that "*the major problem with intellectual capital is that it has legs and walks home every day. At the same rate experience walks out the door, inexperience walks in the door*". Regarding knowledge stored in artifacts, practices consist of procedures, rules and norms that are developed through experience over time. Technology, systems (KM systems in particular) and repositories (both paper based and electronic) also store a considerable amount of knowledge. Moreover, organizational entities that hold knowledge are approached in three separate levels, within organization, the organization as a whole, and between organizations.

The location of knowledge being assessed is identified in every measure of the AiOLoS model, in Section 4.4.

2.2. Organizational Learning

Although *OL* is a term that exists in the lexicons since 1963[21], its importance has grown dramatically in both academia and practice with the increase of knowledge intensive organizations [47] [48], and also being recognized as a dynamic concept emphasizing the continually changing nature of organizations [49]. Crossan and Guatto [50] have shown with keyword searches (keywords being "organizational learning" and "learning organization") the increase in academic research and written articles in the area of OL, over time. All organizations learn, independent of their size and structure [51], and as stated by Kim [13], the fact that organizations are

[20] CEO of Documentum, a software organization, developer of an enterprise content management platform with the same name.

[21] Organizational learning was first defined by Cyert and March in 1963 as "change in behavior in a response to a stimulus", as cited in [52].

learning (and thus OL is being realized) is evident and cannot be disputed, but it is not clear and little consensus exists on what is meant by the term:

> All organizations learn, whether they consciously choose to or not — it is a fundamental requirement for their sustained existence. Some firms deliberately advance organizational learning, developing capabilities that are consistent with their objectives; others make no focused effort and, therefore, acquire habits that are counterproductive. Nonetheless, all organizations learn. But what does it mean that an organization learns?

[47], [48], [52], [53] and [54] also conclude that convergence and consensus has not been achieved on the subject – and the nature of OL – because the term has been applied by different researchers to different domains, with perspectives such as product innovation, information-processing, cognitive science, and etc. Romme and Dillen [55] categorize OL approaches into four research disciplines; namely contingency theory, psychology approach, information theory and system dynamics. On the other hand, according to Collinson and Cook [56] there exist four major schools of thought in the area of OL, these of Argyris and Schön, Draft and Weick, Fiol and Lyles and finally Levitt and March, which all four schools are surveyed in this study.

However, despite the amount of different approaches, definitions, and schools of thought, as Tarrini [57] states by referencing a plethora of authors, the central idea is that organizations cannot continue to perform and achieve competitive advantage in a global economy without OL. The idea is also supported by Dodgson [49], stating that the greater the degree of uncertainty faced by organization in the economic environment, the greater the need for learning, where learning is a dynamic concept that suggests a philosophy of continuous change. The aforementioned views of Tarrini [57] and Dodgson [49] are especially valid for software development organizations.

There is no agreement within disciplines as to what learning and OL are and how they are being realized [53] [49]. As different views exist on what OL is, it is important therefore to survey the definitions in order to accumulate an understanding of how the term can be viewed from different perspectives. Dodgson [49] provides a list of how OL is viewed from different disciplines, pointing out that these approaches examine the outcomes of learning, rather than delve into what learning

actually is and how these outcomes are achieved. Economists tend to view learning either as simple quantifiable improvement in activities, or as some form of abstract and vaguely defined positive outcome [49]. With respect to organizational terms, OL may be defined as the way an organization creates, accumulates, stores, supplements and organizes its knowledge and routines around its activities and culture in order to achieve competitive advantage [49] [58]. From the management, business and innovation literature, OL is seen as a purposive quest to retain and improve competitiveness, productivity, innovativeness, in uncertain technological and market circumstances [49]. Maier [27], citing Schüppel (1996), concludes that all these approaches can be classified according to the primary theoretical orientations as found in the literature body of organizational science: behaviorist theories, cognitive theories, personality/dominance oriented theories, systemic theories. The plethora of these approaches prove that OL is a multidimensional construct, which can be used to describe certain processes, together with types of activity and their outcomes which make up the *LO* [49].

It is therefore essential at this point to provide a list of the major definitions of OL available at the literature, to conclude the discussion regarding "what OL is". A list of major definitions of OL is given by Garvin [58], which is being extended with different authors and is provided below. Therefore, according to different authors *OL*:

- "is a process of detecting and correcting errors" [59].
- "is a system of actions, actors, symbols and processes that enables an organization to transform information into valued knowledge which in turn increases its long-run adaptive capacity" [60].
- "means the process of improving actions through better knowledge and understanding" [53].
- "is the ability of an organization to gain insight and understanding from experience through experimentation, observation, analysis, and a willingness to examine both successes and failures" [61].

- "is the development of knowledge held by organizational members, which is being accepted as knowledge and is applicable in organizational activities, therewith implying a potential change in those activities" [62].
- "is a cyclical process that links individual belief to individual action; to organizational action; to environmental response; and back to individual belief" [63].
- "is the learning process that results from the creation, maintenance, dissemination and exploitation of knowledge within an organization" [9].
- "is an experience-based process through which knowledge about action-outcome relationship develops, is encoded in routines, is embedded in organizational memory, and changes collective behavior" [64].
- "is the deliberate use of individual, group, and system learning to embed new thinking and practices that continuously renew and transform the organization in ways that support a shared aim" [56].
- "is the activity and the process by which organizations eventually reach the ideal of a LO" [65].

Furthermore, extensive and in-depth researches, surveying the literature, listing the key debates regarding the definition of OL and the different approaches to the subject are provided in [52], [64], [66] and [67].Wand and Ahmed [68] conclude the discussion of what OL is by quoting Cohen and Sproul (1991) that the concept is excessively broad, encompassing merely all organizational change, with insufficient agreement among those researching in the area; and by quoting Matlay (2000) that most of the definitions appear to be complementary rather than fundamentally original or conceptually different.

Moreover, it is important to identify what is meant with the term *organization*, as it is a highly debatable topic, similar to OL. In the context of this research, that is software development organizations, an organization is accepted as a Rational System[22] with a tight coupling among the elements that comprise the system, and is defined as a collectivity oriented to the pursuit of relatively specific

[22] The other two, according to Scott and Davis [69], being the Natural System and the Open System

goals and exhibiting relatively high formalized social structures [69]. **As the AiOLoS model is applicable to teams and groups within software development organizations, we also accept the definition of organization as a group of humans, composed of specialists working together on a common task** [70]. The relationship between individual, team and OL is further discussed in Section 2.2.4.

2.2.1. Organizational Values

Having surveyed the definitions of OL and drawn the borders of what this research views as an organization, the necessary organizational values (OVs) that influence the propensity of the organization to create and use knowledge should be investigated. A list of such OVs is given by Sinkula, Baker and Noordewier in [15], where the authors surveying relevant OL literatures and conclude on the following three important OVs, which are routinely associated with the inclination of the organization to learn:

1. *Commitment to learning*: is the value that the organization holds towards learning, and it is likely to define the amount of learning that will occur.
2. *Open-mindedness*: is linked to the notion of unlearning, where organizations proactively question long-held routines, assumptions, and beliefs.
3. *Shared vision*: in contrary to the first two OVs, which influence the intensity of OL, shared vision influences the direction of learning; direction in terms of a focus for learning that fosters energy, commitment, and purpose among organizational members.

The measures of the AiOLoS model have been selected and developed in order to access all three of the above mentioned OVs. In the definitions of the measures in Section 4.4, every measure states which of these OVs it assesses.

2.2.2. Levels of Organizational Learning

As stated by Fiol and Lyles [53], it is possible to distinguish a hierarchy and levels of OL within the category of cognition development, based on the level of insight and association building. These are namely *lower-level* and *higher-level* learning. Lower-level learning occurs within a given set of rules, such as an

organizational structure, and leads to the development of some elementary associations of behavior and outcomes, usually of short duration and impacting only a part of what organization does [53]. It occurs through repetition, has a well-understood context and occurs at all levels in organization. On the other hand higher-level learning aims at adjusting overall rules and norms rather than specific activities or behaviors, resulting to associations that have long term effects and impacts on the organization [53]. It occurs through the use of heuristics, has an ambiguous context and occurs mostly in upper levels.

The measures of the AiOLoS model have been selected and developed in order to access both lower-level and higher-level OL. In the definitions of the measures in Section 4.4 every measure states which of these levels it assesses.

2.2.3. Organizational Learning Loops

Dodgson [49], describes that OL involves the detection and correction of error, and cites Argyris and Schön (1978) who differentiate between types of OL developing a three-fold typology of learning, namely *single-loop, double-loop,* and *deutero-learning*[23], which are further described in [71], and [59]. These three concepts demonstrate some of the forms of collective learning and its significance to the organization [49].

In single-loop learning[24], the detected and corrected error permits the organization to carry on its present policies or achieve its present objectives. Dodgson [49] equates single-loop learning with activities that add to the knowledge-base or organization specific competences or routines of the organization without altering the nature of their activities. According to Romme and Dillen [55], single-loop learning is particularly important in situations in which the organization controls its environment and concentrates on a specific activity or direct effect (described as functional rationality and is based on knowledge of simple problems acquired in the past). Single-loop learning in certain aspects is similar to lower-level learning proposed by [53].

[23] In some studies deutero-learning is named as triple-loop learning.
[24] According to Argyris, single-loop learning is usually related to routine and immediate tasks.

On the other hand, if the error detection and correction occurs in ways that involve the modification of an organization's underlying norms, policies and objectives then it is double-loop learning[25]. Dodgson [49] equates double-loop learning with changing the organizations' knowledge-base, organization specific competences and routines. According to Romme and Dillen [55], double-loop learning has long-term effects with consequences for the whole organization, with a more complex and unclear context, a type of learning which is directed toward the development of frames of reference and interpretation. Double-loop learning in certain aspects is similar to higher-level learning proposed by [53].

Finally, when an organization's members learn about, reflect upon and inquire into previous episodes of OL, or failure to learn, discover what they did that facilitated or inhibited learning, invent and produce new strategies for learning, and finally they evaluate and generalize what they have produced, then this organization is practicing or engaging deutero-learning. Deutero-learning, according to Visser [72] was first proposed by Bateson (1972), a part of his four leveled[26] learning process description.

According to Dodgson [49], both double-loop and deutero-learning involve considerations of why and how to change. Slater and Narver [73] equate the single-loop learning to *adaptive learning* of Senge [74], where learning occurs within a set of recognized and unrecognized constraints that reflect the organization's assumptions about its environment and itself; and double-loop learning to generative learning of Senge [74], which occurs when the organization is willing to question long-held assumptions about its mission, customers, capabilities, or strategy.

The measures of the AiOLoS model have been selected and developed in order to access all three types of the three-fold typology of OL proposed by Argyris and Schön (1978) and cited in [49]**. In the definitions of the measures, in Section 4.4, every measure states which of these learning loops it assesses.**

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[25] According to Argyris, double-loop learning is related to the non-routine, the long range outcome.

[26] Bateson distinguishes four levels when ordering learning processes: these are zero-learning, proto-learning, deutero-learning and trito-learning. Zero-learning can be associated with single-loop learning and proto-learning with double-loop. Trito-learning, according to Bateson, is very rare and is result from an important reconstruction of life, psychotherapy or religious conversion [72].

2.2.4. The Relationship between Organizational Learning, Individual Learning and Team Learning

Many authors ([13], [49], [45], [58]) argue that organizations learn ultimately via their members' collective capability to learn, that no OL can exist without individual learning and when their members carry out on their behalf a process of inquiry[27] that results in a learning product; similar to the transformation of individual knowledge to OK discussed previously on Section 2.1.3. The importance of individual learning for OL is obvious because all organizations are composed of individuals, and subtle because organizations can learn independent of any specific individual but not independent of all individuals [13]. Therefore organization can learn in only two ways, either by the learning of its members or by ingesting to the organization new members who have knowledge the organization did not have before [75]. However, OL is more than the sum of the parts of organizations members' learning [49] and although individual learning is a necessary condition it is insufficient for OL [13]. This view is also supported by [47], which states that even though individuals may come and go, the knowledge does not necessarily leave with them as some learning is embedded in the systems, structures, strategy, routines, prescribed practices of the organization and investments in information systems and infrastructure, and in [76] which states that OL is not the accumulation of all members learning, as organizations consist of systems, values, cultures and regulations which remain even though employees leave. Therefore, when assessing the learning capabilities of an organization, individual and OL need to be addressed separately, a differentiation between levels of learning and types of organizations need to be taken into account and the mechanism between individual and OL should be identified [13].

As Kim [13] is apprehensive that if an explicit distinction is not made between the individual and the organization, a framework of OL will either obscure the actual learning process by ignoring the role of the individual or becoming a

[27] According to [45] "inquiry" begins with an indeterminate, problematic situation whose inherent conflict, obscurity, or confusion blocks action and then the enquirer seeks to make that situation determinate, thereby restoring the flow of activity.

simplistic extension of individual learning by concealing organizational complexities, **the measures of the AiOLoS model have been designed to take into account separately the individual learning capacities of the members of the organization which is being assessed**. One of these approaches is related to the distinction proposed by Kim [13], who differentiates individual learning within the organization to *operational*, the acquisition of skill or *know-how*[28], which implies the physical ability to produce some action, learning at the procedural level and *conceptual*, the acquisition of *know-why*, which implies the ability to articulate a conceptual understanding of an experience, thinking about why things are done, challenging the very nature or existence of conditions and procedures[29]. **Each of the proposed measures of AiOLoS in Section 4.4, states whether it assesses operational or conceptual learning.**

In [77], as a result of an extensive literature survey, a typology of the different approaches to OL and LO research has been placed in a framework according to their emphasis and learning level perspectives. Based on this typology, the literature has been grouped on studies that research either individual level learning or organizational level learning, focusing either on learning processes or on preconditions for learning. The authors in [77] conclude that in the existing reviewed studies there is too much emphasis on the learning of individuals instead of on the learning of organizations, that in order to validate the LO models the need for detailed empirical studies is urgent and crucial, and that there is lack of conceptualization of the true nature of OL process or descriptions. From the literature it is evident that OL and individual learning are interrelated and complement each other in different ways, and a two-way transformation exists between the two. The transformation of individual learning to OL and the related literature are discussed in detail in [13] and [49]. Furthermore, a KM perspective of the relationship between individual, group (team) and OL is given in [78].

[28] This know-how is captured in routines, such as filling out entry forms or operating a machinery (or a tool) [13]

[29] Usually this know-why leads to new frameworks, which in turn, can open up opportunities for steps of improvement

Moreover, as argued by Edmondson [79], an organizations ability to learn is dependent on the ability of its teams (or groups as defined in [47]) to learn; that is an organization learns through actions and interactions that take place between people who are typically situated within smaller groups or teams. The idea is supported by Senge [74], who states that teams are the fundamental learning unit in an organization[30]. Teams, are defined by Hackman (1987) and cited in [80], as work groups that exist within the context of a larger organization and share responsibility for a team product or service and are a design choice for accomplishing work.

As stated in [47], there exists a relationship between individual, team and OL, but there is no agreement on how these three levels are linked to each other. One of the models that links individual, team and OL is given by Kim [13], which incorporates Senge's mental model and Argyris and Schön's single-loop and double-loop learning approaches[31]. Kim's framework combines individual learning and OL to express the importance of relationship between them, where individual learning is informed by OK and equally OK is produced by individuals collectively. Other models that link these three levels of learning within the organization are given in [47] and in [81]. **In the development of the AiOLoS measures, the model proposed by Kim** [13] **has been taken into account, as it depicts the relationship between OL perspectives that have been previously utilized in AiOLoS, namely organizational and individual learning using the single-loop and double-loop learning approaches.**

2.2.5. Organizational Learning Activities

Individuals, groups or organizations conduct or undertake different activities to gather and digest information, imagine and plan new actions and implement change, and through these activities OL is realized [82]. OL activities can be defined as the activities realized by an organization to capture new knowledge, to modify and use this knowledge within its organizational context and to disseminate it within the organization. Yang, Watkins and Marsick [83] provide a brief list of both individual

[30] Senge uses the metaphor of jazz ensembles that "play as one" in alignment to create music [74].
[31] Kim although does not identify team learning in his proposed model, he considers teams as an extension of individuals

and group learning activities in abstract level, namely creating continuous learning opportunities, promoting dialogue and inquiry, encouraging collaboration and team learning, empowering people toward a collective vision, connecting the organization to its environment, establishing systems to capture and share learning and providing strategic leadership for learning. More tactual examples of organizational learning activities are provided by Carroll [82], these are: self-checking, daily meetings, incident reviews, post-job critiques, peer visits, exchanges of best practices, benchmarking and audits.

The measures of the AiOLoS model have been developed considering the OL related activities of software development organizations and surveying the activities covered in ISO/IEC 12207 [84]**. A brief list of these activities that have been taken into consideration is given in Section 4.4.**

2.2.6. Measuring Organizational Learning

It is of critical importance to develop a model and relevant measurements in order to measure OL. A contemporary survey of existing models for the measurement of OL is that of Spector and Davidsen [85], where four papers addressing the topic are investigated to conclude with the following list of measurable aspects of OL [85]:

- actions as reflected in terms of information flow, innovation, involvement, and results;
- goal formation processes, including the ability to identify instances of goal cohesion and goal erosion;
- leadership engagement, including vision sharing and non-hierarchical exchanges;
- reflective activities, including open exchanges to identify problems, assess situations and consider alternative solutions;
- sentiments as reflected in attitudes and preferences pertaining to cohesion, respect, support, and trust;
- team processes, including measures of collaboration, coordination, communication and co-mentoring; and,

– tolerance for errors, including the encouragement of experimental and evidence-based reasoning.

The measures of the AiOLoS model have been selected and developed in order to meet the list of measurable OL aspects provided by [85]**. In the definitions of the measures in Section 4.4, each of the measure identifies which of these measurable aspects it is related to.**

2.3. Learning Organizations

The term *LO* was first introduced by Senge's *The Fifth Discipline* [74], in the 1990's, and flourished with countless other publications, workshops and websites [67]; the next organizational paradigm in the organizational evolution [86], following the bureaucratic organization of Max Weber and the performance based organization of Peter Drucker.

Senge [74] defined LOs as organizations "*where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together*". Further authors working on the field proposed different definitions, some of which are given here, but like the definition of OL, these definitions show that there is no consensus on what a LO is. According to Garvin [58], the topic of LO in large part remains murky, confused and difficult to penetrate, partly a fault of the authors working on the area as their discussions of LOs have often been reverential and utopian, filled with near mystical terminology.

Yang, Watkins and Marsick [83] argue that in the past organizational researchers have focused their work on conceptualization of the LO, with four major approaches emerging in order to define the construct in question, namely: systems thinking, learning perspective, strategic perspective, and integrative perspective.

In [87], a list of sample definitions of the LO construct is given. Jamali, Khoury and Sahyoun [88], citing a plethora of authors, describe a LO as "*a journey, rather than a destination, a dynamic quest, rather than a concrete outcome, a tentative road map, still indistinct and abstract*". Garvin [58] defines the LO as an

organization which is skilled at creating, acquiring and transferring knowledge, and at modifying its behavior to reflect new knowledge and insights. Moilanen [89] [90] defines the LO as a consciously managed organization with learning as a vital component in its values, visions and goals, as well as in its everyday operations and their assessment, an organization which eliminates structural obstacles of learning, creates enabling structures and takes care of assessing its learning and development, invests in leadership to assist individuals in finding the purpose, in eliminating personal obstacles and in facilitating structures for personal learning and getting feedback and benefits from learning outcomes. Dodgson [49] describes LOs as organizations that build, supplement and organize knowledge and routines around their activities and within their cultures, and adapt and develop organizational efficiency by improving the use of the broad skills of their workforces. Ruhe [9], who uses the definition of LO to define the term LSO, identifies LOs as a group of people who systematically extend their capacities so as to accomplish organizational goals. Leitch et al. [91] citing Calvert (1994) provide a checklist to identify what a LO is, with three major questions: 1) *What does a learning company learn?* 2) *What does a learning company look like?* and 3) *How does a LO evolve?*

Senge [74] further describes five core disciplines[32] (or pillars) of LOs, which are a) personal mastery, b) mental models, c) shared vision, d) team learning and e) systems thinking. According to Senge, although these disciplines are never fully mastered, need to develop as an ensemble, and are gradually nurtured by the best organizations. **The measurements of the AiOLoS model were developed considering these five disciplines, and in Section 4.4, each measure states to which of these core disciplines it is related.**

Yang, Watkins and Marsick [83] conclude that common characteristics can be derived from these different approaches and definitions of LOs:

- All approaches to the LO construct assume that organizations are organic entities like individuals and have the capacity to learn, a capacity and

[32] According to Senge, a discipline is a body of theory and technique that must studied and mastered to be put into practice. These disciplines are never fully mastered but gradually nurtured by the best organizations that can develop gradual proficiency through practice and by acquiring new competencies over time [74].

capability that will be the only sustainable competitive advantage in the future

- There is a difference between two related and yet distinct notions: the LO and the OL (described in detail in Section 2.3.1)
- The characteristics of a LO should be reflected at different organizational levels (generally these levels are individual, team or group, and structural or system)

Hitt [86] emphasizes the participative, dynamic and synergistic nature of LO in comparison with traditional organizations, with respect to eight characteristics. An ontological approach regarding four understandings of the idea of LO is presented by Örtenblad [92] under a typology that implies different perspectives of the ontology of LO. These perspectives are the "old OL" where knowledge actually used in practice is stored in the organizational memory[33] or mind, "learning at work" where the LO is an organization where individuals learn at workplace and not on formalized courses, "learning climate" where the LO is an organization that facilitates the learning of its members, and "learning structure" where the LO is flexible with respect to learning, employees learn from the environment and learning processes are means, not ends. Örtenblad argues that these four perspectives appear mostly separately in the literature, are presented too distinctly to be considered part of a whole, and sometimes mixed understandings can occur. **The measures of the AiOLoS model were developed considering these four perspectives, and in Section 4.4, each measure states to which of these four perspectives it is related to.**

According to Garvin [58], a LO needs to be skilled in five main activities, characterized as building blocks by Garvin, namely systematic problem solving, experimentation with new approaches, learning from their own experience and past history, learning from the experiences and best practices of others, and transferring knowledge quickly and efficiently throughout the organization. Although organizations practice these to some degree, most of them are not consistently successful. Garvin [58] argues that by only creating systems and processes that

[33] Örtenblad quoting Blackler (1995) describes the memory of the organization as routines, dialogue or symbols, where knowledge is embedded, encultured or encoded [92].

support these activities and integrate them into daily operations can organizations manage their learning effectively.

Jamali, Sidani and Zouein [87] provide a list of seven imperatives or dimensions from Marsick and Watkins (1999, 2003), which dimensions characterize companies striving to become LOs. These seven dimensions are 1) create continuous learning opportunities, 2) promote inquiry and dialogue, 3) encourage collaboration and team learning, 4) establish systems to capture and share learning, 5) empower people towards a collective vision, 6) connect the organization to its environment, and 7) leaders model and support learning [87]. The results obtained from these dimensions are evaluated based on two performance factors, namely *financial performance*, that is the financial health and resources available for growth in the organization, and *knowledge performance*, that is the enhancement of products and services because of learning and knowledge capacity. These dimensions are further integrated into the *Learning Organization Model* given by Marsick and Watkins (1999, 2003) quoted in [87], a model that addresses the two building blocks of an organization: people and structure. At this model, collaboration and team learning are encouraged by being an intersection between organizational policies of empowering people towards a collective vision and creating systems to capture and share learning, and individuals' approaches of promoting inquiry and dialogue and creating continuous learning opportunities. As stated in [87] there are two important features in the *Learning Organization Model*: a) the model emphasizes continuous learning for individuals, teams and the organization as a whole, and b) management of knowledge outcomes is the result of intentional learning and learning is the process through which the use of knowledge becomes meaningful. **The measures of the AiOLoS model were developed considering these seven dimensions, and in Section 4.4, each measure states to which of these dimensions it is related to.**

2.3.1. Learning Organization and Organizational Learning

The LO, in some researches is sometimes used synonymously with OL. According to Maier [27], the term LO was coined in order to stress an organization's skills in performing OL, and both OL and LO approaches resemble early definitions of KM.

However, other authors ([16], [93]) argue that there is an important distinction between the two. According to Tsang [93], the dichotomy between prescriptive and descriptive research is the main reason of distinction between the two. According to Spender [16], OL refers to the study of the learning processes of and within organizations, thus allowing the idea of a "LO" to emerge, a coherent entity that, having the ability to learn like a biological organism, can adapt purposively and so survive in a changing environment. In [83] it is stated that the construct of the LO normally refers to organizations that have displayed the continuous learning and adaptive characteristics or have worked to instill them, whereas in contrast, OL denotes collective learning experiences used to acquire knowledge and develop skills. Easterby-Smith, Crossan and Nicolini [66] discuss that, finally, the debate between OL and the LO appears to have perished down. According to them [66], researchers and practitioners studying learning in organizations appeared to be talking about the same phenomenon but in different ways: the community of practitioners was using the term in a prescriptive way, and the community of academics was using the term in a descriptive way; this distinction was resolved due to Tsang [93] and Leitch et al [91]. Leitch et al, quoting Calvert (1994) describe the LO as an organization that excels at advanced, systematic collective learning[34] whereas OL refers to methods of collective learning.

2.4. Learning Software Organization

The concepts of *LO* and *OL* are of greater importance for software developing organizations, as these organizations use and depend extensively on knowledge and produce knowledge intensive artifacts and products. Human skills, expertise and relationships are the most valuable assets of software organizations [94]. From the definitions of the LO construct given in Section 2.3, it is apparent that learning is not a separate task or process, but it is embodied and spread throughout the organization and that the learning process should be tailored, designed and applied accordingly to serve the overall goals of the organization, resulting to OL, in

[34] Dixon defines collective learning as "the intentional action of an organization to continuously transform itself through both adaptive and innovative learning" [91]

accordance to the definitions given in Section 2.2. As stated previously, because software organizations develop knowledge intensive artifacts with the use of very knowledge intensive processes, but also because software organizations have a higher maturity on information technology usage, OL becomes an item of extreme importance for them and it is expected that they would make better use of available tools [95]. Holz and Melnik [94] argue that software organizations need to change in order to be competitive, and for the required changes to happen the learning capabilities of the organization have to be enhanced, being an essential part of producing more effective and efficient work practices. On the other hand, the need for further development of software engineering practices within organizations escalates the demand for systematic knowledge and skill management in combination with active usage of this knowledge to support decision making at all stages of the software lifecycle [96]. Therefore, it is possible to differentiate LOs that are functioning in the domain of software development but also to rationalize the need of software organizations for KM, OL and continuous learning practices[35].

As defined by Ruhe [9], a LSO is an organization that learns within the domain of software development, evolution and application where the objects of learning can consist of models, knowledge and lessons learned related to the different processes, products, tools, techniques and methods applied during the different stages of the software development process. It is apparent from the given definition that the learning process in a LSO is not a separate process, but instead it is embodied within the overall development process and is differentiating within stages. Ruhe and Bomarius [10] further state that establishing a LSO is not just a technical issue but it is a major cultural change within the organization. On the other hand, OL for software organizations and software development is defined in [97] as a process capturing project-related information during the creation of individual software products, which information can then be disseminated to subsequent projects to provide experience-based knowledge of development issues encountered at the organization. A LSO is defined also as a software organization that develops or

[35] Weinberg in 1971 recognized software development as learning stating: "writing a program is a process of learning – both for the programmer and the person who commissions the program" [94]

maintains software and intentionally acts as a LO [95] that creates a culture to promote continuous learning and fosters the exchange of experience [98] and promotes improved actions through better knowledge and understanding [99].

Summarizing the aforementioned definitions and approaches, in this study we define LSO as "a software development organization that learns according to organizational goals while developing software artifacts; that is *obtains the required knowledge* to develop the artifacts, *uses and captures knowledge* through the development of the artifacts, and finally *passes the acquired knowledge* within the organization for the development of new artifacts". **These three building blocks of the LSO definition have been pivotal in the development of the AiOLoS model and its major process areas.**

In Chapter 3, a detailed literature review of software organizations' experiences with OL, a list of developed models and approaches to the construct of LO within the context of software development are given.

2.5. Knowledge Management

The transition from OL and LO to KM is clearly presented in a detailed way in [27] and [78]. Maier [27] argues that the most important influences on KM come from the fields of organizational change and the management of change, from organizational development, particularly from OL and organizational memory, from organizational intelligence, organizational culture and from theories of the evolution of organizations. Moreover he adds that both OL and the LO resemble the early definitions of knowledge [27]. Gherardi [31], citing different authors, states that the term KM has supplanted OL and that the interest has switched from questions concerning the appropriation of knowledge by individuals and organizations to ones concerning the techniques and technologies of KM. In [51] the relationship of OL with concepts of KM such as knowledge sharing and knowledge use is given, further stating that OL and KM share the same aims, namely to enhance performance quality and quantity, allowing the firm to improve its sales, achieve more support and create, maintain and enlarge its customer base. Lakomski [100] points on the connections between OL and KM and the fact that they provide competitive weapons to generate

productivity and secure organizational survival, citing different authors and contemporary researches.

Rus and Lindvall [46] draw attention to the fact that employees have to learn the shared OK before they can use it to perform specific tasks, showing that learning is a fundamental part of KM activities. The main limitation of the major SPI approaches, such as the CMMi, is that they do not explicitly state what knowledge needs to be managed and how, when, where, or by and for whom, a limitation that can be addressed by KM because it acknowledges the importance of individuals having access to the correct information and knowledge when they need to complete a task or make a decision and works toward SPI by explicitly and systematically addressing the management of OK [46].

In [14] the implications of KM to OK and to learning capability and design of LO are identified as one of the major KM studies being undertaken currently, and a list of the related literature is given. Vera and Crossan [101] draw the domains and boundaries of the OL and OK, as overlapping fields of research, recognizing though that some topics are dealt primarily in one of the two fields and some topics are more advanced in its thinking than the other. Vera and Crossan define that in the intersection of OL and OK, learning consists of the processes of knowledge creation, knowledge retention and knowledge transfer, situated learning and knowing is realized in communities of practice and that the main focus is on the cognitive and behavioral aspects of learning, knowledge and knowing.

To underline the necessity of researching knowledge in the domain of OL, Gherardi [31], cites Lyles and Easterby (2003):

> Few studies address when knowledge is used and the timeliness of that usage. Examining real-time learning poses many difficulties beyond access to organization and data. (...). We want to understand organizational learning, but lack research on actual learning processes and actual knowledge.

Therefore, as a result of the aforementioned literature survey regarding KM, it is evident that it is important to define and utilize the concepts of KM within the framework of the AiOLoS model which aims to assess the OL of software organizations.

2.5.1. Defining Knowledge Management

Similar to the terms of knowledge, OL and LO, there are many different interpretations of how KM can be defined, within different domains [27] [102] and a universally accepted definition does not yet exist [103]. Oxford English Dictionary[36] has an entry about the term, defining it as "*the use of management techniques to optimize the acquisition, dissemination, retention and use of information, especially within an organization*".

Wiig [102], not only approaches the subject of KM from different angles, such as that of a discipline, an economic model, a strategy model and an evolutionary perspective, but also he gives a working definition of what *KM* is: advanced organizations build, transform, organize, deploy, and use knowledge assets effectively in order to reach the goals of 1) making the enterprise act as intelligently as possible to secure its viability and overall success and 2) otherwise realizing the best value of its knowledge assets. Wiig [102] also provides a 20-year history of the developments in the area of KM and LOs from 1975 to 1996.

Oliveira and Goldoni [104] define KM as a collection of processes that regard both explicit and tacit knowledge and aim at creation, utilization and dissemination of knowledge in the organization. According to Gherardi [31], the initial idea behind KM is that if organizations can induce their employees to store the knowledge that they produce while they work, and if they can draw on the knowledge stored by others, then a network will be created which will enable firms to work more efficiently. This requires knowledge to be "achievable" in some form, and to be "reusable" by others. Becerra-Fernandez and Sabherwal [30] give a simple definition of KM as "*doing what is needed to get the most out of knowledge resources*", where KM helps the organization compete by "*performing the activities involved in discovering, capturing, sharing, and applying knowledge so as to enhance, in a cost-effective fashion, the impact of knowledge on the unit's goal achievement*" [30].

Maier [27], arguing on the importance of defining the term correctly and completely, also provides an extensive list of definitions of KM in the literature, with

[36] http://www.oed.com

respect to focus areas of the definition in question: definitions focusing a) on a life cycle of knowledge tasks, functions or processes, b) on strategy or management, c) on technology, d) on collective or OK and finally e) not explicit definitions. Maier [27] argues that a working comprehensive definition of KM that will be used to serve as a basis and context for a subsequent investigation into the potentials of systems needs to consider the areas of strategy, knowledge life cycle tasks, instruments and objects, but also has to address the link to OL.

In this study the definition provided by Maier [27] **is considered to be the most complete one with respect to the fact that the construct of KM is utilized and used as basis in the development of the AiOLoS model:**

> Knowledge management is defined as the management function responsible for the regular selection, implementation and evaluation of goal-oriented knowledge strategies that aim at improving an organization's way of handling knowledge internal and external to the organization in order to improve organizational performance. The implementation of knowledge strategies comprises all person-oriented, organizational and technological instruments suitable to dynamically optimize the organization-wide level of competencies, education and ability to learn of the members of the organization as well as to develop collective intelligence.

2.5.2. Knowledge Management in Software Engineering

Bjornson and Dingsoyr [105] citing Edwards (2003) state that KM in software engineering is somewhat distanced from mainstream KM, and proceed with a survey of the existing researches of KM topics within the domain of software engineering, thus providing a solid list of arguments why KM is important and critical for software organizations. They [105] argue that KM approaches have been proposed as a solution for the failure of information system developing software organizations, and the way the organizations develops software affects the way knowledge is managed. Similarly Rus and Lindvall [46] provide a list of motivations for KM in software engineering, grouping them under major areas of "needs", namely a) business needs, providing solutions to pressing business issues, and b) knowledge needs, the vast amount of knowledge belonging to the software organization and that is critical to achieve business goals. They deepen their analysis by addressing issues such as the role of KM in software engineering, supporting

learning and improvement, and implementing KM. A more detailed list of case studies and industry practices of KM systems within the domain of software engineering is given in [35], analyzing what systems are in use and what is the impact of these systems on work in a software development organization.

2.5.3. Human Oriented Knowledge Management

According to Maier [27], there is a distinction between human and technology oriented KM, an approach that has a long tradition in organization science. However, new holistic concepts that encompass both directions emerge, where human-oriented KM mentions technology as an enabling factor, or technology-oriented KM pays more attention to the human side, and the gap between the two can be bridged with the use of integrating instruments [27].

On the same topic, Becerra-Fernandez and Sabherwal [30] argue that even though technology has provided the impetus for managing knowledge, it is known that effective KM initiatives are not only limited to a technological solution, implying that there exists an important human component[37]. As a result KM practices, methodologies and technologies a) must identify ways to encourage and stimulate the ability of employees to develop new knowledge, b) must enable effective ways to elicit, represent, organize, reuse, and renew this knowledge, and c) should not distance themself from the knowledge owners but instead celebrate and recognize their position as experts in the organization.

As the AiOLoS model aims at assessing software organizations, the developed measures focus mostly on the human factor and not on knowledge stored in tools and knowledge bases, acknowledging the importance of humans and groups in the OL process, as summarized in [42]**. With that viewpoint, the AiOLoS model tries to capture and assess the OL realized in human agents and teams but also on human developed artifacts, such as documents, practices and processes, and human related activities, such as tasks.**

[37] An old adage states that effective KM is 80 percent related to organizational culture and human factors and 20 percent related to technology [30]

CHAPTER 3

LITERATURE SURVEY

"*Those who are in love with practice without knowledge are like the sailor who gets into a ship without rudder or compass and who never can be certain whether he is going. Practice must always be founded on sound theory, and to this Perspective is the guide and the gateway; and without this nothing can be done well in the matter of drawing.*"

(Leonardo da Vinci, "*The Notebooks of Leonardo da Vinci*")

In Chapter 2, the concepts of OK, OL and KM, and the constructs of LOs and LSOs were discussed in detail, with respect to their theoretical studies and approaches. This chapter provides a literature survey of major methodologies, models and measures proposed in the areas of KM, OL and LOs, focusing especially to the domain of software engineering and the mapping of this survey to the core processes and measurements of the AiOLoS model.

3.1. Knowledge Management Models

In [105] and [35], extensive literature surveys are given, which list in detail empirical studies of KM initiatives in software engineering, showing that the majority of studies of KM in software engineering relate to technocratic and

behavioral aspects of KM, with few studies relating to SPI activities, and none providing a complete model of SPI with the utilization of KM.

In [106], a literature survey regarding the role of KM and experience management in software engineering is presented, showing that none KM approach is actually integrated to the software development environment. [106] concludes that although the researched studies contend that issues related to knowledge creation, modification and sharing have important place in SPI initiatives, there is not enough information to understand where and how to use KM insights to improve SPI practice, and there is a need to for different KM insights within the domain of software engineering.

Although the investigated models are not specific to software development organizations, an extensive bibliographical research is provided regarding the identification of KM phases in [104], and it forms the basis of the major processes and core processes of the AiOLoS model. Oliveira and Goldoni [104] group the processes proposed in each model under four stages; namely the stage of creation – addition of new knowledge and settling of existent knowledge; the stage of storage – codification of knowledge for its storage in knowledge databases; the stage of dissemination – communication or distribution of knowledge within the organization; and finally the stage of utilization – application of knowledge; with the supplementary phase of measurement – evaluation of the KM process phases and results. The models in [107], [108], [109], and [110] have a parallel distribution of four stages. On the other hand in [111], [112], [113], [114], and [103] the focus is shifted to the stages of creation, dissemination and utilization, and thus omitting the stage of storage. Alternatively [107], [111] and [104] all propose a measurement phase, either embedded within the model or conducted by the management, which overlaps and supports all stages, thus resulting in conducting measurements at each stage. Wiig [102], surveying the literature concludes that from a managerial perspective systematic KM comprises four areas of emphasis, namely a) top down-monitoring and facilitation of knowledge related activities, b) creation and maintenance of knowledge infrastructure, c) renewing, organizing, and transferring knowledge assets, and d) leveraging (using) knowledge assets to realize their value.

Two extensive surveys of proposed KM process phases are given in [103] and [104], and the obtained results are quoted from these two researches in this section. Chen and Chen [103] define the 4C process of KM activities, namely "creation", "conversion", "circulation" and "completion", which activities follow each other in that order and form a loop through vision and strategy. Oliveira and Goldoni [104] propose the stages of "creation", "storage", "dissemination", and "utilization" that follow each other in that order and "measurement" which is occurring parallel and interacting with the other four. These two models are deduced from two separate surveys. However, it is discovered from these two surveys that a) the given KM processes, although very similar, they are aggregated and consisting of very distinctive sub-processes, b) KM needs to have a continuous nature, and c) KM processes needs to be measured. **Based on these findings, the AiOLoS model a) has two process levels: the major process areas that are in accordance with almost every KM model proposed, and the core process areas, which provide the granularity required to distinguish each separate and distinct KM sub-process, b) has been developed in a circular structure to depict the continuous nature of KM, and c) provides a set of measurements for the assessment of each core process.**

[115] defines the knowledge evolution cycle which consists of five phases of OK, namely originate/create knowledge, capture/acquire knowledge, transform/organize knowledge, deploy/access knowledge and apply knowledge, linked to each other in a cyclic fashion. In a similar vein, [27] defines the KM lifecycle, where different types of knowledge are used for different types of KM processes: create, identify, formalize, organize, share, distribute, refine, apply and feedback. These processes are further embedded within the OL cycle in the operational level. In [109], a literature survey of KM studies, a list of KM studies related to the research of OK, learning capability and design of LO, all within the perspective of LOs is given.

Investigating the proposed KM models and schemes, and summing the findings, two important conclusions may be drawn: firstly, KM is not a monolithic process but instead it consists of several different processes that need to be addressed and measured separately and secondly that the KM process is of continuous nature.

Based on these finding the AiOLoS model has been constructed as a cycle of a number of core processes, grouped under three major process areas. Both the major process areas and core processes of the AiOLoS model have been borrowed from the different KM studies and models provided in this section, considering their suitability to the software development organization.

Several models and approaches that assess the KM in organizations have been reviewed also. One of these models is the work of McAdam and McCreedy [116], which primarily assesses the understanding of the theory and practice of KM in organizations. McAdam and McCreedy [116] follow the KM model of Demarest [107] where KM consists of four processes, namely Knowledge Construction, Embodiment, Dissemination and Use, which four processes are all interrelated and interconnected with each other. **Both the identified processes and their interconnected nature are similar to the AiOLoS model.** KM understanding in the organizations was assessed with the use of questionnaires and participative workshops, in order to identify key trends in each main area of KM. **Several of these high-ranking trends were used in the development of the measures of the AiOLoS model.** The results of the study can be found in detail in [116].

Gold, Malhotra and Segars [117] analyze the concept of effective KM from the perspective of organizational capabilities, suggesting that a knowledge infrastructure consisting of technology, structure, and culture along with knowledge process architecture of acquisition, conversion, application, and protection are essential organizational capabilities for effective KM. Using a subjective questionnaire they try to model and uncover the key aspects of the aforementioned dimensions. **Several of these key aspects have been used in the development of the AiOLoS measures. Moreover, the proposed knowledge process architecture is mapped completely to the major process areas and core processes of the AiOLoS model.**

3.2. Organizational Learning Models

Huber [52], as a result of a broad and evaluative literature survey of many theorists proposes a comprehensive framework[38] of OL processes that includes four constructs and related sub-constructs and sub-processes. Huber [52] identifies knowledge acquisition as the first construct that has five related sub-constructs: drawing on knowledge available at and before the organization's birth; learning from experience; learning by observing other organizations; grafting on components that possess knowledge not already possessed by the organization and intentional searching for information about the environment and performance of the organization within the environment. Learning from experience is broken down into five additional sub-constructs that include experiments and experimentation, self-appraisals and intentional and unintentional efforts to acquire knowledge; and learning from searching and noticing is broken into three more sub-constructs, namely scanning, focused search and performance monitoring. The next construct is information distribution, the dissemination of information to those in the organization who need it, and is followed from information interpretation which is affected by these sub-constructs: the uniformity of prior cognitive maps in the organization, the uniformity of the framing of the information, the richness of the media used to convey the information, the information load on the interpreting units and the amount of unlearning required before generating a new interpretation. Finally, Huber defines organizational memory, the store and retrieval of information and the computer-based organizational memory.

The major and core process areas AiOLoS model can be mapped to the constructs given by Huber, and the mapping is given in detail in Table 3 in Section 4.2, following the definition of the model. Only the sub-constructs of

[38] Huber uses the terms "information" and "knowledge" interchangeably, explaining that he uses the term information when referring to "data that gives meaning by reducing ambiguity, equivocality, or uncertainty, or when referring to data which indicate that conditions are not pre-supposed", and he has used the term knowledge when referring to "the more complex products of knowledge, such as interpretation of information, beliefs about cause-effect relationships or, more generally "know-how" [52].

Media Richness and Information Overload were not mapped to AiOLoS processes.

Similar to Huber's constructs, Dixon [118] and Nevis, DiBella and Gould [119] provide learning cycles for organizations. Dixon's [118] model consists of the following processes:

1. Acquisition of Knowledge
2. Sharing of Knowledge
3. Constructing of Memory
4. Organizational Memory
5. Retrieval of Information

Whereas Nevis, DiBella and Gould's [119] cycle consists of: 1) Knowledge Acquisition, 2) Knowledge Sharing, and 3) Knowledge Utilization.

AiOLoS major process areas are in a cyclic fashion, as the cycle of Dixon's [118] **and Nevis, DiBella and Gould's** [119] **OL model processes. The mapping of these models to the AiOLoS is given in Table 3.**

In [77], instead of a learning cycle or a straightforward procedural step-by-step change model, a two-way affective and interactive process model is given, based primarily on Kolb's (1984), Kline and Saunder's (1993) and Dixon's [118] models. In this model the learning process includes the change process and vice versa. These steps are namely: step 1 – ability to learn, step 2 – collaborative setting of missions and strategies, and step 3 – making the future together. Step 3 is the implemented change that results to making the personnel commit to the mission and creating favorable conditions for learning, which in turn is the starting point and precondition of Step 1, thus forming a cycle, which cycle can only be broken with a resistance to change. The authors in [77] propose 20 measurement indicators for the measurement of learning at these three steps, formed using 75 items from an original pool of 110 items. **These 20 measurement indicators have been essential in the development of the measures of the AiOLoS model, given in Section 4.4.**

An important and extensive review of the OL capability measurement approaches and tools is given by Jerez-Gomez, Cespedes-Lorante and Valle-Cabrera [120]. The OL capability dimensions identified are a) managerial commitment, b) systems perspective, c) openness and experimentation and d) knowledge transfer and

integration, with a plethora of common factors from the OL literature underlying each one of these dimensions. **The proposed OL capability dimensions are mapped to the AiOLoS major process areas and core processes in Table 3.** The authors [120] argue that although each of these dimensions is different, they are related with interactions existing between the four. **Parallel to that, the major processes of AiOLoS model are interrelated in a continuous fashion.** Furthermore, the authors [120] provide a measurement model, based on the reviewed literature with 16 items (23 originally), measured with the use of a subjective questionnaire with a Likert-type scale.

3.3. Learning Organization Models

Jamali, Sidani and Zouein [87] reviewing the LO literature, and drawing on the work of Moilanen [89], identify seven measurement instruments constructed or suitable for measuring and diagnosing LOs, which are compared in [87] with respect to scope, depth and reliability. Six of these seven tools are briefly introduced in this section, as surveyed in [87] and in [89], and they relation to the AiOLoS model, both in terms of processes and measures are given:

1. *The Learning Company Questionnaire* (Pedler et al., 1988 and Pedler et al., 1991), and further described in detail by Leitch et al. [91], is one of the major diagnostic tools for LOs, comprising of 11 dimensions and which has been used in a research study conducted in several British companies. These 11 dimensions are:
   - A learning approach to strategy
   - Participative policy making
   - Informating
   - Formative accounting and control
   - Internal exchange
   - Reward flexibility
   - Enabling structures
   - Boundary workers as environmental scanners
   - Inter-company learning

- A learning climate
- Self-development opportunities for all

The Learning Company Questionnaire is a subjective survey and an application of it can be found in [91], where the 11 characteristics of the LO were assessed with the use of 55 stated elements comprising of two parts: the current state of the organization (named as "how it is") and the envisioned state of the organization (name as "how I would like it to be"). The measure of each of the 11 characteristics was the dissatisfaction index, a ratio defined on the basis of the two answers given to each one of the 55 questions in the questionnaire.

The mapping of the above dimensions to the major process areas and core processes of the AiOLoS model are given in Table 4. The dimensions of "formative accounting and control" as it is closely related to accounting and budgeting systems within an organization, and "reward flexibility" as it is based on reward policies regarding OL, could not be mapped to the AiOLoS processes.

2. *The Learning Environment Survey,* although not comprehensive as the Learning Company Questionnaire, was developed and tested scientifically by Tannenbaum [121], and can be used for diagnosing the LO. The attention of the Learning Environment Survey is on the learning environment with focus given to existing processes, including opportunities for learning, tolerance for mistakes, accountability and high performance expectations, openness to new ideas, in addition to policies and practices supportive of training and learning. Moreover, Tannenbaum [121] also provides a continuous learning cycle consisting of Motivation to Learn, Learning Experience, Application and Recognition. **The cyclic nature of the model and the areas of the model are correlated to the major process areas of AiOLoS.**

   The Learning Environment Survey consists of 13 scales which in turn are constructed of 66 items. All the items are of subjective nature, designed to capture the facilitators and inhibitors in the learning environment**. However, because all the given scales in the survey are related to the**

characteristics of the learning environment, the Learning Environment Survey model can only be mapped to the Obtaining Knowledge major process area and to Knowledge Identification, Acquisition and Development core processes of the AiOLoS model.

3. *The Learning Audit*, developed by Pearn et al. (1995), although not tested scientifically, consists of five components and examines the role of the organization as a whole, the individual's specific role, focusing on measuring participant's perceptions of the learning environment and assessing the role of departments and managers in fostering learning within their respective organizations. Moreover, Pearn [122] provides a list of ten key actions to be followed and used by the individual, a group of individuals or the organization in whole. The Learning Audit depends on subjective perceptions of the individuals. **As the Learning Audit does not provide any specific model or measures, it has only effected the development of the AiOLoS in the concept that it should allow the assessment of the OL characteristics in different levels, including personal, teams and organization as a whole.**
4. *The Complete Learning Organization Benchmark*, developed by Mayo and Lank (1994) consists of 187 questions grouped into nine dimensions, and is designed to collect data from both managers and lower level employees. The dimensions are grouped under four headings: enablers, environment, learning and value. The questionnaire diagnoses the practices that should be taken to achieve maximum impact on the development of a LO, emphasizing organizational factors, individual and team-based learning, and managing and leading. The questionnaire mostly depends on subjective questions. **The proposition of this model that learning should be assessed in all three levels, that is personal, team and organizational, has been utilized in the development of the measures of the AiOLoS model.**
5. *The Recognizing Your Organization*, introduced by Sarala and Sarala (1996), is used to identify whether an organization qualifies as a LO studying these organizational dimensions:

- philosophy and values,
- structure and processes,
- leading and making decisions,
- organizing the work,
- training and development
- internal and external interactions of the organization.

These dimensions are then evaluated across different archetypes of organizations, including bureaucratic organizations, quality management and process oriented firms, and LOs**. The mapping of the above dimensions to the major process areas and core processes of the AiOLoS model are given in Table 4.**

6. *The Dimensions of the Learning Organization Questionnaire (DLOQ),* developed by Watkins and Marsick (1998), is a tool which addresses individual level, team level, and organization level learning, and measuring the financial performance of the organization. The questionnaire is organized around the seven dimensions given in Section 2.3, therefore it is closely related to the LO model of Marsick and Watkins (1999, 2003). The DLOQ is intended to measure the perceptions of employees regarding these seven constructs at a particular point in time, *"i.e. to take the pulse of an organization at a particular moment in time"*, but also the changes in OL practices and culture. In [123], an application of the DLOQ questionnaire is provided with 62 questions to be answered by the employees of the organization, with only 43 questions directly related to the OL capabilities, all in a Likert scale of 1 to 6. Another implementation of the DLOQ is given in [83], with a detailed statistical analysis and validation of the model, however with half of the original questionnaire items being deleted to simplify the model. **The mapping of the above dimensions to the major process areas and core processes of the AiOLoS model are given in Table 4.**

In Table 1 [87], which is adapted from Moilanen (2001) a comparison of the aforementioned LO questionnaires with respect to scope, depth and validity. Örtenblad [92] compares the understandings of the idea of LO in the literature with respect to the perspectives of LOs. The models overviewed in Table 1 and compared by Örtenblad [92] are given in Table 2.

Table 1 Comparison of Learning Organization Questionnaires [87]

Name of the Instrument	Holistic	Profound	Tested
Pedler et al. (1991,1997): *The Learning Company Questionnaire*	Yes	Yes	-
Mayo and Lank (1994): *The Complete Learning Organization Benchmark*	Yes	Yes	-
Tannenbaum (1997): *Learning Environment Survey*	-	Yes	Yes
Pearn et al. (1995): *The Learning Audit*	-	-	-
Sarala and Sarala (1996): *Recognizing Your Organization*	-	Yes	-
Watkins and Marsick (1998): *DLOQ*	Yes	Yes	Yes

Table 2 Understandings of the Idea of LO in the Literature [92]

Author(s)	Old OL	Learning at Work	Learning Climate	Learning Structure
Pedler et al. (1991)			Primary focus	Minor focus
Watkins and Marsick (1998)	Primary focus	Primary focus	Primary focus	Primary focus

Garvin, Edmondson and Gino [67] characterize existing models for assessing LOs and the existing discussion on the subject as incomplete because a) they are not concrete prescriptions but rather recommendations that are difficult to implement, b) they aim upper level management rather than smaller units were critical organizational work is actually done, and c) standards and tools for assessment are lacking. **The AiOLoS model has been developed keeping in mind these deficiencies, and the way AiOLoS addresses these deficiencies is given in detail in Section 4.1.**

Garvin, Edmondson and Gino [67] present a survey instrument, named as the Learning Organization Survey[39], to assess learning within any organizational unit that has meaningful shared or overlapping work activities (i.e. department, office, project, division) which is based on comparisons rather than absolute scores. This survey allows the company to compare itself against benchmark scores gathered from other companies, to make assessments across areas within the organization and to look deeply within individual units**. The AiOLoS model has been developed taking into account these capabilities of the model proposed by Garvin, Edmondson and Gino** [67]**.** Moreover, the structure of the model, like AiOLoS, employs a granular analysis as it measures separately three different factors of the organization that are essential for OL and adaptability, referred to as the *building blocks of the learning organization*. These building blocks are a supportive learning environment, the concrete learning processes and practices, and the leadership behavior that provides reinforcement. According to [67], organizations do not perform consistently across the three blocks, nor across the various subcategories and subcomponents. **Following this idea, the AiOLoS model structure consists of many separately measurable processes of different granularities.** However, the survey [67] consists of 55 subjective questions; answered using a Likert scale based solely on the perceptions of the organization's learning environment, processes, and leadership by the person who is answering the survey.

Another questionnaire based measurement tool is the Learning Organization Diamond by Moilanen [89], based on a holistic view of LOs, consisting of 40 statements grouped under five main factors, namely manager's role in OL, connection between learning and strategy, unlearning, new means of learning and assessing learning and rewarding. The questionnaires are subjective, with questions trying to assess the driving forces, the purpose, the questioning, the empowering and the evaluating of the organization with respect to OL. Learning Organization Diamond has been developed examining and analyzing the strengths and weaknesses of many LO models, especially these given in Table 1.

[39] Available online at: https://surveys.hbs.edu/perseus/se.ashx?s=381B5FE533C282FF

Leitch et al. [91] citing Jones and Hendry (1992) refer to the Perfect Learning Company model, where at the *foundation* and *formation* phases the organization ensures that basic social survival skills are acquired and new learning is created, focusing on employee's perceptions on alternative modes of thinking, *continuation* phase where the organization becomes self-motivated with respect to learning, *transformation* phase where power relationships, culture and decision-making strategies are re-evaluated and finally the *transfiguration* phase, where the organization after progressing through a number of phases including philosophical, ethical and moral becomes a fully developed organization. **The transfiguration of an organization to a "perfect LO" on this model, is parallel to the proposed maturity levels of AiOLoS as future study, given in Section 0, where an organization matures to higher levels of OL maturity.**

Hitt [86], in a quest for a meaningful framework that will clearly depict a LO, utilizes the McKinsey 7-S framework as it is comprehensive and practical providing a systems view of practically all aspects of an organization – and in a communicable language for practitioners. Addressing 8 questions to understand the LO, Hitt proposes a framework for the LO, consisting of 8 S's, namely "shared values", "style", "structure", "skills", "systems", "staff", "strategy", and "synergistic teams". Hitt [86] proposes the measurement of a LO to be conducted with the use of balanced scorecards to collect data on the critical success indicators, that will be followed by review meetings to answer the questions of "what did we learn during the past review period?" and "how can we best use this knowledge to improve our performance during the coming period?".

Redding [124], proposes a step-by-step guide to conduct LO assessments, consisting of 6 steps and requiring periodic reassessments. **AiOLoS, due to its cyclic fashion, captures the connection and the evolution between sequential projects conducted by the same organization over time, and its continuous nature is appropriate to be used as an assessment tool in the LO assessment model proposed by Redding** [124]**.**

Specific to LSOs, Ruhe and Bomarius [10] associating OL with organizational improvement, propose the use of Quality Improvement Paradigm (QIP) framework[40], to guide the activities and goals of a LSO[41]. QIP is comprised of six steps, characterization of the current environment that will be subject to change, the definition of goals[42], the planning of the improvement activity with the selection of methods, techniques or tools to be applied, the execution of the plan, the analysis and interpretation of experiences and finally the packaging of the experiences. QIP makes it clear from these steps the need for an assessment model that will a) characterize the current status of the software development organization, b) will provide a basis for the selection of methods, techniques or tools for the improvement activity, and c) will allow the analysis and interpretation of the acquired knowledge in order to be classified or to be abandoned if it is irrelevant or false. **The AiOLoS model has been developed in order to allow the realization and accomplishment of the aforementioned requirements.**

Moreover, there are several similarities of the AiOLoS model with respect to the way QIP is executed and realized: QIP is an iterative process that repeatedly performs the basic six steps that it consists of, and it also has a modular structure that allows a wide applicability and integration with existing methods, techniques and tools [10].

3.4. Final Remarks

Several models and approaches proposed and actually implemented by studies in the areas of KM, OL and LOs have been reviewed in this chapter. **The KM models have been pivotal in the development of the major process areas and core processes of the AiOLoS model and their installment in a circular fashion to denote both the relation between processes and the continuity of the OL process as a whole.** The diagnosis tools to assess OL and LOs have shown that a

[40] Although proposed for software development organizations, QIP is not restricted to them [10].
[41] The authors clearly use the terms “learning” and “improvement” interchangeably, another evidence that learning is closely related to SPI.
[42] The GQM approach is proposed as the widely used industry-strength means to systematically capture and model goals [10].

high variation exists among them with respect to their focus and dimensions they are assessing. However, the common points in the reviewed models are firstly that they depend on subjective questionnaires, filled by persons at different organizational levels with different agendas, and secondly that minor empirical evidences do exist, with only few models being tested with respect to the validity of their tools.

Analyzing and reviewing these tools has shown that in order to develop a reliable and valid model, the construction of a solid base between the theories and practices of OL, LO and KM is required. Moreover, this survey has proven the need of developing less subjective and more objective measurement tools to assess the OL characteristics. The reviewed models mostly do assume that learning is taking place when managerial goals and outcomes are realized. However, as this approach is highly subjective the previous assumption may not be true, and therefore measuring indicators that are related to OL and KM but are less subjective would provide a better basis for the assessment of the organization. **The AiOLoS model has received significant influences from these theories and practices and these influences were pointed out accordingly in Chapters 2, and 3, with further mappings of the AiOLoS to the reviewed literature given in Chapter 4**.

CHAPTER 4

THE PROPOSED MODEL

"O Muses, O high genius, aid me now!
O memory that engraved the things I saw,
Here shall your worth be manifest to all!"

(Dante Alighieri, "*The Inferno*", Canto II
Esolen's translation)

The literature reviews both in theoretical and application areas of OL, LOs and KM displays the tendency of organizations in general, and software development organizations in particular, to manage their learning capabilities and KM practices, transforming eventually into a LO. However, there is a need for a specific model that will allow the assessment of these capabilities and practices, as stated by Lyles and Easterby-Smith [125]:

> Few studies address when knowledge is used and the timeliness of that usage. Examining real-time learning poses many difficulties beyond access to organization and data. (..) We want to understand organizational learning, but lack research on actual learning processes and actual knowledge.

Based on the literature survey in OL, LOs, LSOs and KM, we are proposing AiOLoS, a model for the assessment of OL in software development organizations. As stated by Ruhe and Bomarius [10]:

> Models are abstract and simplified descriptions of reality. In the context of software development, a model is an idealized representation of a process, product or an abstract description of quality. The different kinds of models to support individual and organizational learning are contained in an experience base of a LSO. Modeling forms the basis for understanding and improving software processes. This is especially true because of the fact that software development is a human and team based activity.

This concept of assessment is closely related to "understanding" of OL, as stated by Gherardi [31]:

> Therefore the interest of knowledge shifts from the question "how does an organization learn or should learn?" to the question "if we depict an organization as a system which learns, are we able to see something new and to see something that we already know differently?" The former question mainly concerns explanation of organizational learning, while the latter more closely relates to understanding of it.

4.1. The AiOLoS Model

The main aims of the AiOLoS model are:

a) to provide a framework for comparison between software organizations with respect to their OL capabilities,
b) to allow software organizations to identify their deficiencies and shortcomings,
c) to offer the means for the measurement of the realized improvement in OL, and
d) to provide a starting point for SPI.

The motivations for performing measurement within the domain of a LSO, or assessing the learning characteristics of a software organization are given by Ruhe and Bomarius [10] as:

a) evaluation of knowledge assets with respect to the intellectual capital of an organization for survival, renewal and growth,

b) evaluation of the performance of an organization, to get the right things to the attention of managers, for short-term and long-term decision making,
c) controlling performance of the knowledge-related activities by continuously measuring performance indicators of these activities and quality indicators of the knowledge handled as well as of the results created with the help of the knowledge.

As stated in [126], commercial software development is performed by teams or groups of varying sizes (from tens to thousands), in which teams people are working via an organizational structure and reporting to a manager or set of managers. Guzzo and Dickson [127] define teams as units consisting of individuals who see themselves and who are seen by others as a social entity, who are interdependent because of the tasks they perform as members of a team, who are embedded in one or more larger social systems such as an organization, and who perform tasks that affect others. In [128] members of software development teams are characterized as "intellect or knowledge workers" that have high levels of education and specialist skills, and the ability to apply these skills to identify and solve problems. However, as Senge [74] clearly points out, even though teams are made up of talented individuals, it is team learning and not individual learning that adds to OL. Teams are the key learning group of organizations and team learning is the building block for OL [74]. Based on these software organization characteristics, AiOLoS focuses specifically on assessing software development teams functioning within software development organizations, where the assessment can be conducted in the context of project development, as shown in the case studies detailed in Chapter 5. However, the overall structure of AiOLoS given in Figure 5 and the generic measures detailed in Section 4.4 can be generalized and applied to assess the overall OL capabilities of the software development organization. However, this has not been demonstrated in the conducted case studies.

The AiOLoS model proposed in this study is a refinement of the existing KM models for organizations investigated in Chapter 3, with respect to the theoretical aspects of OL, LOs and KM and the definition of LSO provided in Chapter 2, and the special characteristics of software developing organizations. It consists of three

major process areas that map to the three major objectives of a LSO, namely obtaining, using and passing knowledge. These major process areas have resulted from the extensive literature survey conducted in Chapters 2 and 3, and are derived from the definition of LSO we provided as well as from [74] and [9]. AiOLoS proposes that the learning activity can be assessed with respect to 12 core processes that are an elaboration of the 3 major process areas. The 3 major process areas are connected to each other in a continuous fashion to depict the continuity of the learning activity. This cyclic fashion is consistent with the cognitivist models as identified in [77], which are Dixon's cyclical collective learning, Kolb's cyclic learning and Nonaka's spiral, but also with the KM models surveyed in Section 3.1. Moreover, it was developed accordingly to the Knowledge Life Cycle area of intervention proposed by Maier [27], with the knowledge dimensions of preservation, novelty, refinement and actuality covered. The basic structure of the proposed AiOLoS model is shown in Figure 5, and has been summarized previously on Figure 3.

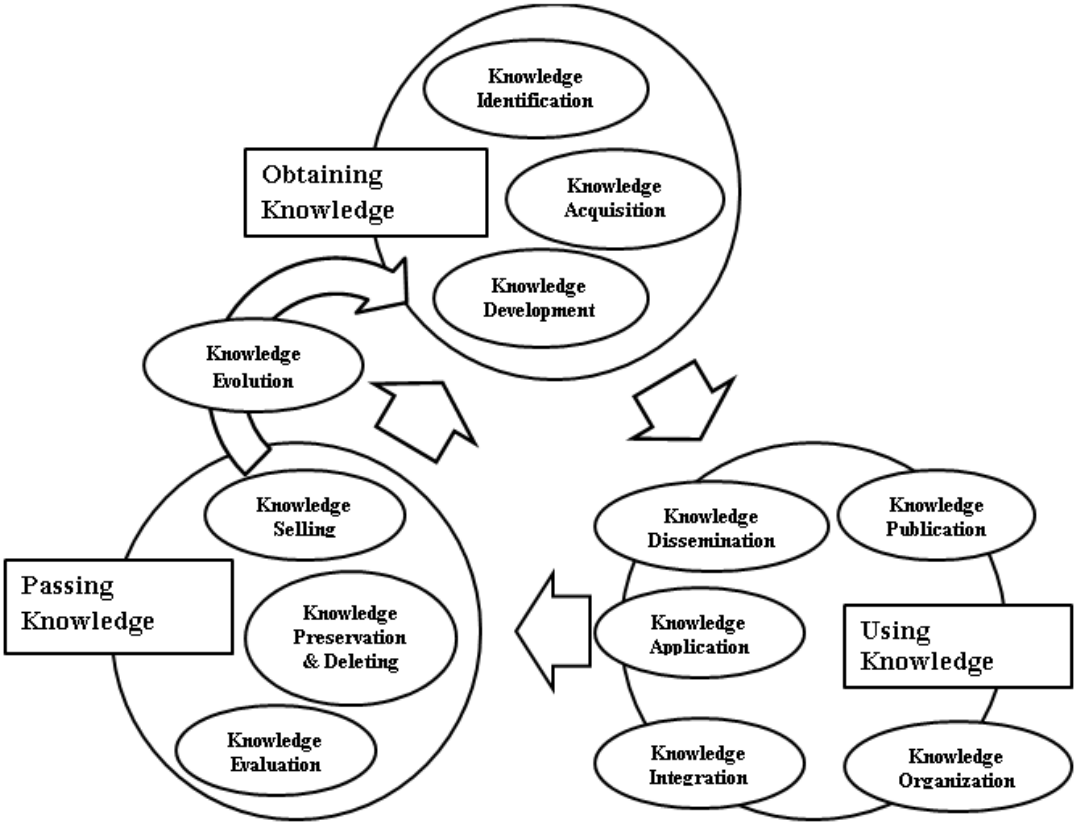

Figure 5 The Basic Structure of the AiOLoS Model

4.1.1. The Major Process Areas and Core Processes of AiOLoS

Below, the three major process areas and the 12 core processes of the AiOLoS model are described.

Obtaining Knowledge

Obtaining knowledge processing starts with either the identification of existing knowledge or the development of new tacit or explicit knowledge in the organization with the use of internal or external data and information perceived by organizational agents (human or computer agents) [27] [30]. Once knowledge is obtained, it can be passed to the next major process area to be used. Obtaining knowledge should be a permanent task as skills and competencies evolve and the environment the software organization functions evolves. It is related to the knowledge preservation and knowledge novelty dimensions [27].

- **Knowledge Identification (Discovery or Capturing)** is revealing and achieving transparency on already existing knowledge in the organization, either within people, artifacts or organizational entities [30] by making the organization's knowledge assets visible, thus providing an initial knowledge structure and then mapping the findings [27]. Further, it can provide the basis for knowledge acquisition by identifying industry best practices, competencies of experts and consultants that are outside the organization. Within the dimension of knowledge preservation it is related to "preserved knowledge", within the dimension of knowledge novelty is related to "existing knowledge" and within the dimension of knowledge existence is related to "knowledge" [27].
- **Knowledge Acquisition (Buying)** is realized predominantly from outside the organization, although in some cases it can be achieved within the organization with internal trainings [9]. Maier [27] distinguishes three knowledge acquisition processes: a) the permanent or temporary engagement of individuals or experts, the development of joint ventures, strategic alliances or merger with other companies, b) accessing documented knowledge and c) participating in knowledge related events and processes. Within the dimension of knowledge preservation it is related to "newly acquired knowledge" and within the dimension of knowledge novelty is related to "new knowledge" [27].
- **Knowledge Development (Creation or Construction)** is the generation of new ideas, models, skills and product innovations [9] within the organization. New knowledge can be developed either through combination that is communication, integration and systemization of multiple streams of explicit knowledge; or through socialization, that is the synthesis of tacit knowledge with joint activities [30]. Within the dimension of knowledge novelty it is related to "new knowledge" and within the dimension of business process is related to "knowledge derived from the process" [27].

Using Knowledge

The obtained knowledge needs to be used within the organization in order to create value. Knowledge can be used by either applying or integrating it to existing or newly formed processes or tasks, organizing it with other knowledge elements, disseminating it through organization or publicizing it outside the organizational boundary. It is related to the Content of Knowledge and Knowledge Application, Organizational Design, Information and Communication Systems and Business Processes areas of intervention [27].

- **Knowledge Organization** is the association of knowledge elements with each other, resulting in the development of an OK structure such as ontology or a knowledge map [27]. Whenever a new knowledge element is obtained, it is mapped within the existing knowledge structure of the organization, either by linking or integrating it to other knowledge elements. It is related with all dimensions under the Organizational Design area of intervention [27].
- **Knowledge Dissemination (Sharing or Distribution)** is the communication of obtained knowledge throughout the organization [107] [113] [114]. It consists of two major tasks that support internalization of knowledge at the receiving ends: a) knowledge push; the systematic processes of bringing knowledge to the employees who need it and b) knowledge pull; the search and retrieval of knowledge by the employees [9]. Within the dimension of knowledge access it is related to "accessible knowledge", within the dimension of knowledge codability is related to "codable knowledge" and within the dimension of knowledge medium is related to both "not electronic/not computer-resident knowledge" and "electronic/computer-resident knowledge" [27].
- **Knowledge Publication** is the codification of knowledge, putting it in various forms that can be stored and thus retained, leveraged and transferred, both in a centralized or decentralized way [27], making it a form of articulation or externalization of obtained knowledge [43]. Within the dimension of knowledge codability it is related to "codable

knowledge", within the dimension of knowledge medium is related to both "not electronic/not computer-resident knowledge" and "electronic/computer-resident knowledge", within the dimension of generalization is related to "universal/general knowledge", within the dimension of contextualization is related to "contextualized knowledge", within the dimension of form is related to "procedural knowledge" and within the dimension of knowledge abstraction is related to "scientific, abstract and deep knowledge" [27].

- **Knowledge Usage (Application or Utilization)** is the application of obtained knowledge to organizational elements and processes wherever it is useful [27], benefiting from direction, which is the process through which the individual who possesses the knowledge directs the action of another individual without transferring to that individual the knowledge underlying the direction [30]. Direction or knowledge substitution, involves the transfer of instructions or decisions and not the transfer of the knowledge required to make those decisions [30]. Within the dimension of organizational scope it is related to "knowledge spanning functional areas" or "restricted to a single functional area" and within the dimension of business process is related to "knowledge about the process", "knowledge within the process" and "knowledge derived from the process" [27].
- **Knowledge Integration (Routines)** is not only the utilization of knowledge that exists in procedures, rules, and norms and guides future behavior (in other words the routines of the organization), but also the embodiment of the obtained knowledge in these procedures, rules and norms [30]. Within the dimension of knowledge integration it is related to "knowledge", and within the dimension of business process is related to "knowledge within the process" [27].

Passing Knowledge

The obtained knowledge needs to be passed to forthcoming phases to form the basis of new knowledge obtaining, or to entities outside the organizational boundaries. In order to manage the passing of knowledge with respect to its prioritization, knowledge needs to be evaluated. Moreover, considering the change in the environment, the organization needs also to manage the evolution of knowledge within. It is related to the knowledge preservation, knowledge refinement, knowledge value, knowledge security, knowledge ownership, knowledge generalization, knowledge medium and knowledge actuality dimensions [27].

- **Knowledge Preservation (Retention or Archiving and Deleting)** is both the elusion of knowledge loss in the organization through storage and archiving, but also the systematic deletion of irrelevant or outdated knowledge from the organization's active knowledge base [9]. To prevent the loss of valuable knowledge and expertise, the processes of selecting the knowledge to be preserved and ensuring that it is stored appropriately, should be planned by the organization [129]. Within the dimension of knowledge preservation it is related to "preserved knowledge", within the dimension of value it is related to "knowledge valuable for storing", within the dimension of knowledge medium it is related to both not electronic/not computer-resident knowledge and electronic/computer-resident knowledge and within the dimension of actuality is related to both "obsolete knowledge" and "actual knowledge" [27].
- **Knowledge Evaluation (Valuation)** is the process of assessing the "value of knowledge" in terms of monetary vs. non-monetary value, value in use vs. value in future use, and return on investment to knowledge [130], consequently resulting in a modification of knowledge goals [9]. One important evaluation criteria is the degree to which knowledge can be used at the workplace. The organization should view acquired and accumulated knowledge as an asset of the organization, and as every tangible and intangible asset in an organization it should have a value. Within the dimension of knowledge value it is related to "knowledge valuable for storing" [27].

- **Knowledge Selling** is the counterpart of knowledge acquisition and it is the flow of obtained knowledge from the organization to external entities in the form of knowledge products and services such as patents or consulting [27]. The marketability of knowledge is closely related to its evaluation. Within the dimension of knowledge generalization it is related to "universal knowledge", within the dimension of knowledge security is related to "public knowledge" and within the dimension of knowledge ownership is related to "organizational-external knowledge" [27].
- **Knowledge Evolution** is the improvement of obtained knowledge before passing it, assuring that knowledge is timely, relevant and actualized. Participants might comment on existing knowledge or subject matter specialists might refine knowledge, translate it, summarize it, provide additional context, explain terms and definitions or repackage it for the use by different groups of users [27]. Within the dimension of knowledge refinement it is related to "refined knowledge" [27].

4.2. The Mapping of the AiOLoS Model to the Literature

Several previous studies have been pivotal to the development of the AiOLoS model, which were described in detail in Chapters 2 and 3. The major studies utilized from the domain of OL are the work of Huber [52], Dixon [118], Nevis, DiBella and Gould [119], and Jerez-Gomez et al. [120] which was given in detail in Section 3.2, and the mapping of these models to the major process areas and core processes of AiOLoS is given in Table 3. Regarding LOs and the models in the area, the foremost models surveyed are The Learning Company Questionnaire (Pedler et al., 1988 and Pedler et al., 1991) [87] [89] [91], The Recognizing Your Organization (Sarala & Sarala, 1996) [87] [89] and DLOQ (Watkins and Marsick,1998) [87] [89], and the mapping of these models to the major process areas and core processes of AiOLoS is given in Table 4. Finally, in the theoretical area of KM the major work surveyed regarding the dimensions of knowledge is Maier's Knowledge Management Systems [27] and the mapping to AiOLoS is given in Table 5.

Table 3 Mapping of the AiOLoS Major Process Areas and Core Processes to OL Literature

AiOLoS Major Process Areas and Core Processes	**Huber's** [52] **Constructs and Sub-Constructs**	**Dixon's** [118] **Processes**	**Nevis, et al.** [119] **Cycle**	**Jerez-Gomez et al.** [120] **Survey**
Obtaining Knowledge	1.0 Knowledge Acquisition	Acquisition of Knowledge	Knowledge Acquisition	Managerial Commitment
- Knowledge Identification	1.1 Congenital Learning			
- Knowledge Acquisition	1.3 Vicarious Learning 1.4 Grafting 1.5 Searching and Noticing			
- Knowledge Development	1.2 Experimental Learning			Openness and Experimentation
Using Knowledge			Knowledge Utilization	Systems Perspective
- Knowledge Organization	3.1 Cognitive Maps and Framing	Retrieval of Information		
- Knowledge Dissemination	2. Information Distribution	Sharing of Knowledge	Knowledge Sharing	Knowledge Transfer and Integration
- Knowledge Publication				
- Knowledge Usage	3. Information Interpretation			
- Knowledge Integration				Knowledge Transfer and Integration
Passing Knowledge		Sharing of Knowledge	Knowledge Sharing	Knowledge Transfer and Integration
- Knowledge Preservation and Deleting	3.4 Unlearning 4. Organizational Memory 4.1 Storing and Retrieving Information 4.2 Computer-Based Organizational Memory	Constructing of Memory Organizational Memory		
- Knowledge Evaluation				
- Knowledge Selling				
- Knowledge Evolution				

Table 4 Mapping of the AiOLoS Major Process Areas and Core Processes to LO Literature

AiOLoS Major Process Areas and Core Processes	**The Learning Company Questionnaire** (Pedler et al., 1988 and Pedler et al., 1991) [87] [89] [91]	**The Recognizing Your Organization** (Sarala & Sarala, 1996) [87] [89]	**DLOQ** (Watkins and Marsick,1998) [87] [89]
Obtaining Knowledge	- Self-development opportunities for all	- Training and development	- Create continuous learning opportunities
- Knowledge Identification	- Internal exchange		
- Knowledge Acquisition	- Inter-company learning - Boundary workers as environmental scanners		
- Knowledge Development	- Participative policy-making - A learning climate - Self-development opportunities for all		- Promote inquiry and dialogue - Encourage collaboration and team learning
Using Knowledge			- Leaders model and support learning
- Knowledge Organization		- Structure and processes - Organizing the work	- Connect the organization to its environment
- Knowledge Dissemination	- Informating - Internal exchange	- Internal and external interactions of the organization	- Establish systems to capture and share learning
- Knowledge Publication	- Inter-company learning	- Internal and external interactions of the organization	
- Knowledge Usage	- A learning approach to strategy	- Leading and making decisions	- Empower people towards a collective vision
- Knowledge Integration	- Enabling structures	- Structure and processes - Organizing the work - Internal and external interactions of the organization	- Connect the organization to its environment
Passing Knowledge			
- Knowledge Preservation and Deleting	- Enabling structures		
- Knowledge Evaluation		- Philosophy and values	
- Knowledge Selling	- Inter-company learning	- internal and external interactions of the organization	
- Knowledge Evolution	- Learning climate	- Philosophy and values	

Table 5 Mapping of the AiOLoS Major Process Areas and Core Processes to KM Literature

AiOLoS Major Process Areas and Core Processes	**Maier's** [27] **Knowledge Dimensions and Main Areas of Intervention**
Obtaining Knowledge	- Knowledge Preservation - Knowledge Novelty
- Knowledge Identification	- Knowledge preservation →Preserved knowledge - Knowledge novelty →Existing knowledge - Knowledge existence→Knowledge
- Knowledge Acquisition	- Knowledge preservation →Newly acquired knowledge - Knowledge novelty→New knowledge
- Knowledge Development	- Knowledge novelty→New knowledge - Business process→Knowledge derived from the process
Using Knowledge	- Content of Knowledge - Knowledge Application - Organizational Design - Information and Communication Systems - Business Processes
- Knowledge Organization	- All dimensions under the Organizational Design
- Knowledge Dissemination	- Knowledge access → Accessible knowledge - Knowledge codability →Codable knowledge - Knowledge medium→Not electronic/not computer-resident knowledge - Knowledge medium→Electronic/computer-resident knowledge
- Knowledge Publication	- Knowledge codability→Codable knowledge - Knowledge medium→Not electronic/not computer-resident knowledge - Knowledge medium→Electronic/computer-resident knowledge - Knowledge generalization → Universal/general knowledge - Knowledge contextualization → Contextualized knowledge - Form → Procedural knowledge - Knowledge abstraction → Scientific, abstract and deep knowledge
- Knowledge Usage	- Organizational scope → Knowledge spanning functional areas - Organizational scope → Restricted to a functional area - Business process → Knowledge about the process - Business process → Knowledge within the process - Business process → Knowledge derived from the process
- Knowledge Integration	- Knowledge integration → Knowledge - Business process → Knowledge within the process
Passing Knowledge	- Knowledge preservation - Knowledge refinement - Knowledge value - Knowledge security - Knowledge ownership - Knowledge generalization - Knowledge actuality

(Table 5 continues on next page)

(Table 5 continues from previous page)

AiOLoS Major Process Areas and Core Processes	**Maier's** [27] **Knowledge Dimensions and Main Areas of Intervention**
- Knowledge Preservation and Deleting	- Knowledge preservation → Preserved knowledge - Knowledge value → Knowledge valuable for storing - Knowledge actuality → Obsolete knowledge - Knowledge actuality → Actual knowledge - Knowledge medium→Not electronic/not computer-resident knowledge - Knowledge medium→Electronic/computer-resident knowledge
- Knowledge Evaluation	- Knowledge value → Knowledge valuable for storing
- Knowledge Selling	- Knowledge generalization → Universal knowledge - Knowledge security → Public knowledge - Knowledge ownership → Organizational-external knowledge
- Knowledge Evolution	- Knowledge refinement → Refined knowledge

4.3. Conduct Modes of the AiOLoS Model

The AiOLoS model, and the measures proposed in Section 4.4 have been developed considering four different modes of conduct:

a) Horizontal assessment, as shown in Figure 6, where the OL capabilities of the same organization (group, team, or company) are compared within different phases of the development process. Horizontal assessment has been employed in Case Study B – A Public Sector Organization.

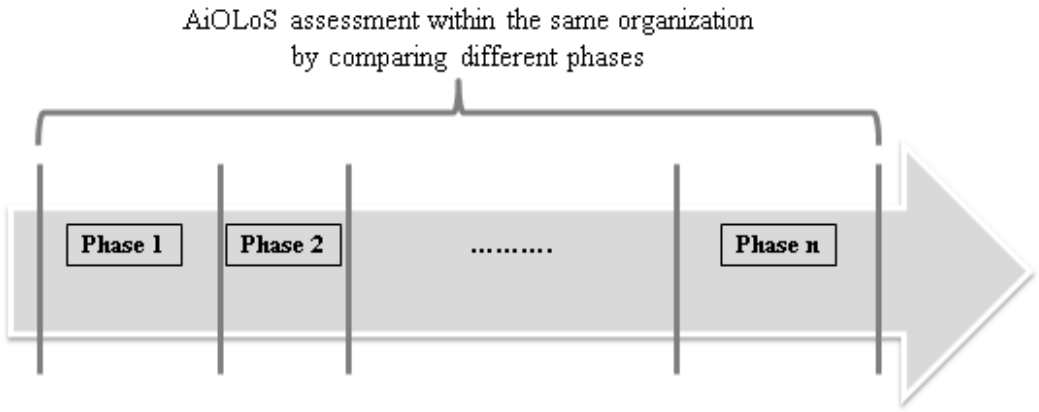

Figure 6 Horizontal Assessment Mode of AiOLoS

b) Vertical assessment, as shown in Figure 7, where the OL capabilities of different organizations (groups, teams or companies) are compared with each other. This mode has been employed in Case Study C – A Company from the Private Sector.

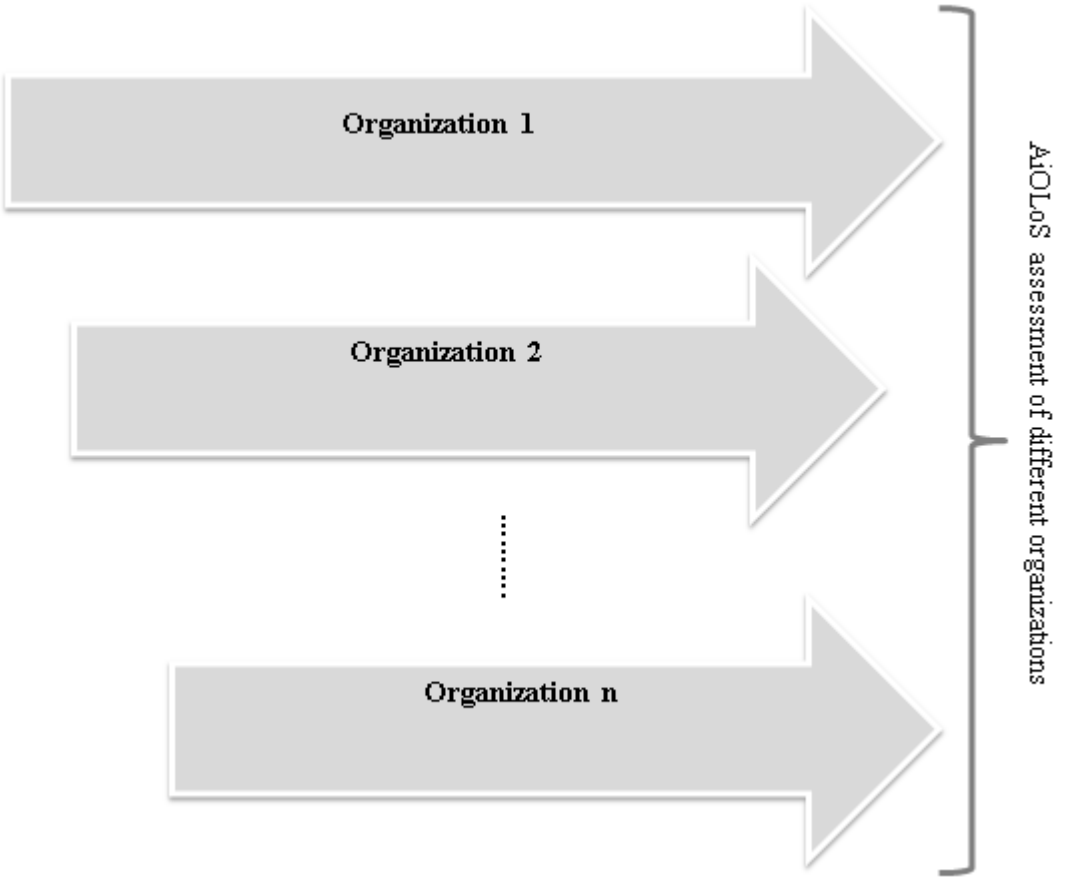

Figure 7 Vertical Assessment Mode of AiOLoS

c) Hybrid assessment, as shown in Figure 8, is a combination of the horizontal and vertical assessment modes, where the OL capabilities of different organizations (groups, teams or companies) are compared with each other within different reciprocal phases of each organizations development processes. Hybrid assessment has been employed in Case Study A – The Classroom Experience.

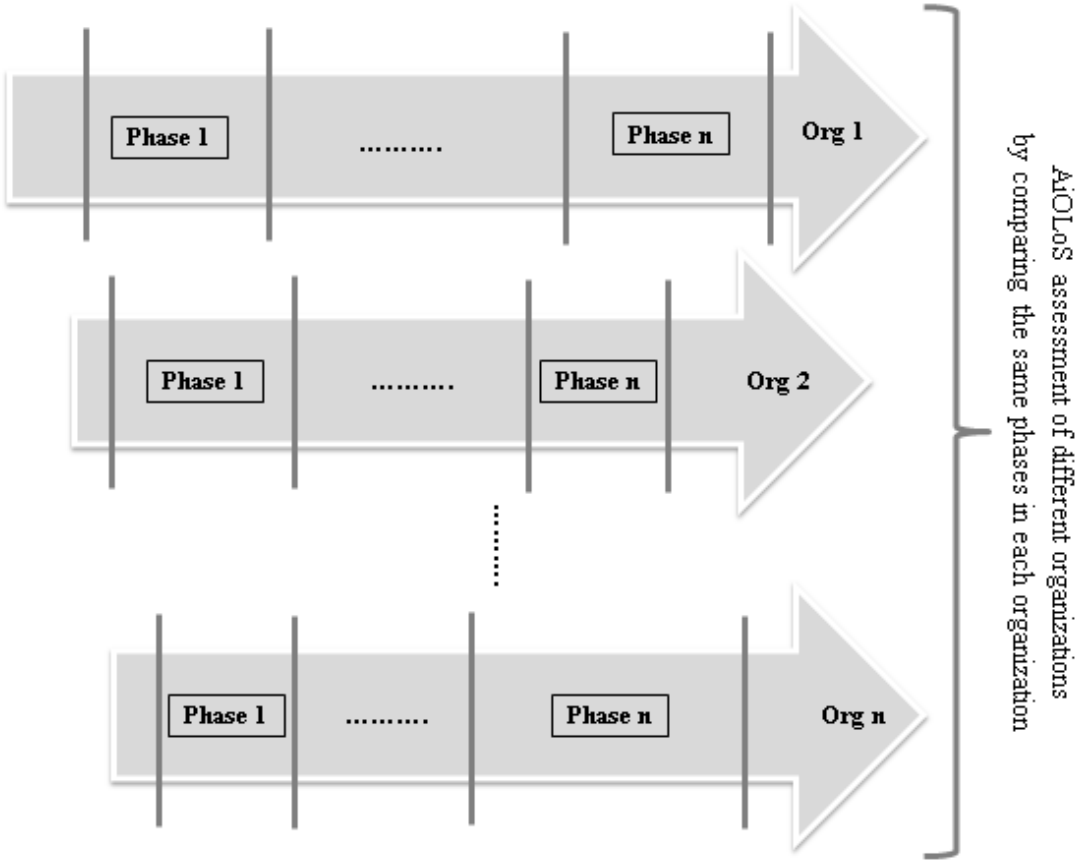

Figure 8 Hybrid Assessment Mode of AiOLoS

d) Best practice benchmark assessment, where the OL capabilities of an organization (group, team, or company) are assessed compared to best practice benchmark OL values, either defined by the organization (as goals), or obtained through third parties.

4.4. The Measures of the AiOLoS Model

The AiOLoS model is a collection of processes that allow a software organization to obtain, use and pass knowledge, with respect to OL. Therefore in order to assess a software organization within the proposed model, appropriate indicators are necessary. There exist a number of practical guides for conducting measurements in the software domain, with some of the most renowned being the Software Measurement Guidebook [131] and the Goal-Driven Measurement

Guidebook [132]. Moreover, the importance of measuring the KM process is discussed in [112], [107], and [111], and a list of measurement models in literature related to a KM process is provided in detail in [104], stating explicitly that the indicators need to be chosen carefully, and only a well-balanced indicator collection is capable to reflect the organization's reality. To proceed with assessment of a set of subjects, that is ie. employees in a software development organization etc., the evaluator must prepare the evaluation framework. This may entail, among other activities, listing all knowledge items expected to be acquired by the subjects over the evaluation period. Individual projects phases, project builds or the whole project may constitute this evaluation period.

On the other hand, in [77] authors citing the works of Collis (1996), Kirjavainen (1997) and Moilanen (1999) argue that the existence and affectiveness of OL cannot be measured directly but only in the long run, through business results because of the complicated nature of the OL process. The same identification is made by Garvin [58], who states that many companies in the aerospace, defense and electronic industries use learning curves and experience curves, that focus on a single measure of output such as cost or price. However, the authors [77] referencing a plethora of works in the literature conclude that "*focusing on the process and the people instead of the structural change reveals more of the OL*", thus allowing the measurement of the OL process step by step:

> Changes in the capability to learn, should be revealed through attitudes towards change (internalization versus coercion) within the organization, whereas the capability to set objectives and start constructing their future together could be measured through adopted new behaviours.

Similarly Garvin [58] argues that for companies hoping to become LOs, the use of measures such as learning curves and experience curves are incomplete as they overlook OL that influences other competitive variables like quality or novel product introductions.

The measurements of the AiOLoS model, according to the aforementioned reasons by [77] **and** [58]**, were developed focusing on the process and the people, their attitudes towards change and the adoptation of**

new behaviors, instead of the stuctural change, and taking into account competitive variables like quality.

Moreover, all the investigated LO measurement models in Section 3.3 are based on subjective questionnaires, where the answers of one individual with respect to another may differ significantly, depending on the way they are related to the software development process, their viewpoint and they own personal beliefs and characteristics.

The subjectivity of the existing LO assessment models constituted it a necessity to develop less subjective measurements for the AiOLoS model, measurements that would be quantifiably assessed and would yield the same results when measured by different entities and assessors.

Ruhe and Bomarius [10] provide a guideline for performing a measurement within the domain of a LSO, and Differding [133] describes in detail the *Measurement Planning* that needs to be undertaken for such an assessment model, both approaches being a guide to development of the measures of AiOLoS model.

As stated in [104], [10] and [133], metrics are used to aid managers to identify if their organizations are "better than yesterday and if they are better or worse, or doing just as well as their competitors are", in other words to evaluate the changes in the software process. The three qualities of performance indicators are given in [104], which are a) trust, which is the capacity of a measuring instrument that always attributes the same value to something invariable that is being measured, b) effectivenes, which is the capacity of a measuring instrument to attribute the correct value, in other words to measure that which is to be measured and c) importance, which is the capacity of a measuring instrument to contain useful information not found within other measurements. Indicators may be qualitative and quantitative, financial or non-financial, and internal or external.

In [134] it is discussed that due to the fact that the measurement object is something novel and therefore unknown, defining useful metrics in improvement projects is often a challenging undertaking. The goal-oriented measurement approach is the common point in majority of the software measurement guides, and allows adequacy, consistency and completeness of the measurement plan and the data collection processes [135]. In order to identify and define the appropriate

measurements for the AiOLoS model according to the aforementioned goals, the GQM approach [135] [136] has been utilized.

In [137] and [138] the GQM approach is described as a pragmatic approach, which is specifically appropriate to select and apply relevant measures and indicators for goal-oriented measurement in software projects, teams and organizations. Ruhe and Bomarius [10] define the GQM approach as "a flexible and effectively applicable approach to perform measurement of software processes, products and projects". When the GQM approach is applied, relevant information to answer specific problems (goals) is identified. This information can be represented in a practical, applicable and interpretable way. The hierarchical structure of the GQM model and the main features are in detail:

- Goal-orientation through top-down definition of metrics via questions;
- Detailed characterization of important environmental factors that affect underlying knowledge processes;
- Guiding the bottom-up analysis and interpretation of measured data; and
- Active involvement of staff in defining, collecting, analyzing and interpreting the data that is measured.

Basili, Caldiera and Rombach [135] identify the three levels of the GQM structure as the a) *conceptual level (goal)*, where goals are defined with respect to different models of quality, from different points of view, *b) operational level (question)*, where a set of questions is used to describe the way the assessment of a particular goal will be performed, and *c) quantitative level (metric)*, where a set of data are associated with every question in order to answer it in a quantitative way.

In the development of the AiOLoS measurements, the goals of each core process area were defined in a comprehensible, organized and structured way. Purpose, perspective and context characteristics of each goal, according to the specifications of GQM approach were included. As stated in [133], the parameters object, purpose, quality attribute, viewpoint and context are defined by the GQM goals; in result each of these parameters is used to determine which questions are relevant for the goal and which measures are required to answer these questions. According to the description given in [133], the goals were refined by questions, and

the questions were refined through appropriate metrics that make it possible to answer the corresponding question. These metrics then would allow the measurement and assessment of the core process area.

The goals and eventually the measures of the AiOLoS have been developed taking into account the special characteristics of software organizations but also the work activities and OL activities that software development organizations put into practice. Software projects differ from projects in other areas as they do not focus on the mass production of artifacts based on economies of scale, but on the production of a single product based on planning, development and coordination of the developers. As stated in [128], members of software development organizations work with intangible cognitive processes rather than physical tangibles, the rules for developing tangible goods do not apply and knowledge sharing transformed to a key process in software development. The organization tries to empower its employees by providing them the appropriate knowledge and skills. The OL activities taken into account have been identified by considering the software development process of different methodologies and approaches and the ISO/IEC12207 activities [84]. The following major OL activities in software development organizations have been derived based on the activities and tasks described in the processes of ISO/IEC12207 and have been used in the definition of the GQMs and measures of each core process:

- Trainings, both within the organization and from external entities
- Meetings
- Software document development
- Software development
- Error/bug correction
- Communication and message exchanging
- KM tools and OK storing and retrieval
- Benchmarking

The goals, questions and the relative metrics and measurements of each core process that are derived for the AiOLoS model are given in Table 6 through Table 17.

Table 6 GQM of Knowledge Identification

Major Process Area	Obtaining Knowledge
Core Process	Knowledge Identification
Goal	1. Analyze internal training data with respect to their pervasion to personnel and training efficiency, and use work products to identify the number and variety of personnel skills that exist.
Question	1.1 How many document sections/headings were completed without the need for any external information or knowledge or training?
Metric (m1.1)	Number of document sections/headings completed without the need of any external information or knowledge
Question	1.2 How many document sections/headings were completed, in total?
Metric (m1.2)	Number of document sections/headings completed, in total
Question	1.3 What is the percentage of internally completed document sections/headings to total document sections?
Metric (m1.3)	m1.3=(m1.1./m1.2) *100
Question	1.4 How many personnel received/conducted internal training sessions on that phase?
Metric (m1.4)	Number of internally trained personnel
Question	1.5 How many tasks were completed without the need for any external information or knowledge or training?
Metric (m1.5)	Number of tasks completed without the need for any external information or knowledge or training
Question	1.6 How many tasks were completed, in total?
Metric (m1.6)	Number of tasks completed, in total
Question	1.7 What is the percentage of tasks completed with existing knowledge to total tasks?
Metric (m1.7)	m1.7=(m1.5/m1.6) *100
Question	1.8 How many internal training sessions were conducted?
Metric (m1.8)	Number of conducted internal trainings, in total
Question	1.9 How many personnel were employed in the organization/team/group?
Metric (m1.9)	Number of personnel employed
Question	1.10 What is the percentage of personnel participation to internal trainings?
Metric (m1.10)	m1.10=(m1.4/(m1.9*m1.8))
Derived Measurements	– Internal Trainings – Internal Trainings Pervasion – Tasks Completed with Internal Knowledge – Documents Completed with Internal Knowledge

Table 7 GQM of Knowledge Acquisition

Major Process Area	Obtaining Knowledge
Core Process	Knowledge Acquisition
Goal	2. Analyze external training data with respect to their pervasion to personnel and efficiency, and use work products to identify the number and variety of personnel skills that exist.
Question	2.1 Did you receive/acquire external training sessions on that phase?
Metric (m2.1)	Number of externally trained personnel
Question	2.2 How many questions were asked to external entities?
Metric (m2.2)	Number of questions asked to external entities
Question	2.3 How many responses to the questions asked to external entities were helpful?
Metric (m2.3)	Number of helpful responses to questions asked to external entities
Question	2.4 What is the percentage of helpful responses to total questions?
Metric (m2.4)	m2.4=(m2.3/m2.2)*100
Question	2.5 What is the number of topics in external trainings?
Metric (m2.5)	Number of topics in external trainings
Question	2.6 What is the number of external written documents (either hard or softcopy) that were used?
Metric (m2.6)	The number of external written documents (either hard or softcopy) used.
Question	2.7 How many external training sessions were conducted?
Metric (m2.7)	Number of conducted external trainings, in total
Question	2.8 What is the percentage of personnel participation to external trainings?
Metric (m2.8)	m2.8=(m2.1/(m1.9*m2.7))
Derived Measurements	– External Trainings – External Trainings Pervasion – Utilized External Communication – Trained Topics – Utilized External Documents

Table 8 GQM of Knowledge Development

Major Process Area	Obtaining Knowledge
Core Process	Knowledge Development
Goal	3. Analyze meeting minutes with respect to proposed and applied creative ideas and identify the amount of created knowledge.
Question	3.1 How many creative ideas (original ideas) were developed?
Metric (m3.1)	Number of creative ideas developed
Question	3.2 How many creative ideas developed were considered to be applicable by the organization?
Metric (m3.2)	Number of creative ideas considered to be applicable by the organization
Question	3.3 What is the ratio of applicable creative ideas to total creative ideas?
Metric (m3.3)	m3.3=(m3.2/m3.1)*100
Question	3.4 How many creative were actually applied/implemented?
Metric (m3.4)	Number of applied/implemented creative ideas
Question	3.5 What is the ratio of applied/implemented creative ideas to total creative ideas?
Metric (m3.5)	m3.5=(m3.4/m3.1)*100
Derived Measurements	– Creative Idea Development – Creative Idea Evaluation

Table 9 GQM of Knowledge Organization

Major Process Area	Using Knowledge
Core Process	Knowledge Organization
Goal	4. Analyze each developed / used work artifact (document) with respect to cross-referencing between documents to identify the number of linked / cross-referenced documents and how knowledge is organized between work artifacts.
Question	4.1 How many distinct links/references exist from a document to other documents developed in the same phase?
Metric (m4.1)	Number of links/references from a document to other documents developed in the same phase
Question	4.2 How many new documents were developed in that phase?
Metric (m4.2)	Number of developed documents in that phase
Question	4.3 What is the horizontal linking/referencing number of that document?
Metric (m4.3)	m4.3=m4.1/m4.2
Question	4.4 What is the horizontal linking/referencing number of that phase?
Metric (m4.4)	m4.4= $\sum_{i=1}^{x} m4.3i$
Question	4.5 How many links/references exist from a document to other documents created in previous phases?
Metric (m4.5)	Number of links/references from a document to other documents developed in previous phases
Question	4.6 How many documents were developed in all phases?
Metric (m4.6)	Total number of documents developed in all phases
Question	4.7 What is the vertical linking/referencing number of a document?
Metric (m4.7)	m4.7=m4.5/m4.6
Question	4.8 What is the vertical linking/referencing number of that phase?
Metric (m4.8)	m4.8=$\sum_{i=1}^{x} m4.7i$
Derived Measurements	– Horizontal document linking – Vertical document linking

Table 10 GQM of Knowledge Dissemination

Major Process Area	Using Knowledge
Core Process	Knowledge Dissemination
Goal	5. Analyze upper management messages sent to personnel with respect to their informative nature and the stored meeting minutes with respect to attendants, issues raised / discussed and duration, to identify the amount of disseminated knowledge with the use of messages and meetings.
Question	5.1 How many informative/explanatory messages were sent from the management to personnel?
Metric (m5.1)	Number of informative/explanatory messages sent from management to personnel
Question	5.2 What is the number of push information messages sent from the management to personnel?
Metric (m5.2)	m5.2=m5.1
Question	5.3 How many meetings were held in total?
Metric (m5.3)	Number of meetings held in total
Question	5.4 How many man hours were spent attending meetings?
Metric (m5.4)	Number of man hours spent in meetings
Question	5.5 How many topics/issues were raised on all meetings?
Metric (m5.5)	Number of topics/issues raised on all meetings
Question	5.6 How many topics/issues were discussed on all meetings?
Metric (m5.6)	Number of topics/issues discussed on all meetings
Question	5.7 What is the percentage of discussed to raised topics on all meetings?
Metric (m5.7)	m5.7=(m5.6/m5.5)*100
Question	5.8 How many people attended to a meeting?
Metric (m5.8)	Number of people who attended a meeting
Question	5.9 How many topics/issues were discussed in a meeting?
Metric (m5.9)	Number of topics/issues discussed in a meeting
Question	5.10 How many people discussed how many topics/issues in a meeting?
Metric (m5.10)	m5.10=m5.8*m5.9
Question	5.11 What is the pervasion of discussed topics/issues in meetings to personnel?
Metric (m5.11)	m5.11=$\sum_{i=1}^{x} m5.10i$ / (m1.9 * $\sum_{i=1}^{x} m5.9i$)
Derived Measurements	– Information messages from management – Amount of meetings – Length of meetings – Meeting Discussion Efficiency (Topics discussed/Topics Raised) – Meeting pervasion

Table 11 GQM of Knowledge Publication

Major Process Area	Using Knowledge
Core Process	Knowledge Publication
Goal	6. Analyze developed guidelines and academic publications with respect to their relevance to the conducted work and embodied knowledge items to identify the amount of publicized knowledge.
Question	6.1 How many internally developed guidelines were used internally?
Metric (m6.1)	Number of internally developed guidelines used internally
Question	6.2 How many internally developed guidelines were distributed externally?
Metric (m6.2)	Number of internally developed guidelines distributed externally
Question	6.3 How many publications were published in academic terms?
Metric (m6.3)	Number of publications published in academic terms
Derived Measurements	– Internally Distributed Guidelines – Externally Distributed Guidelines – Academic Publications

Table 12 GQM of Knowledge Usage

Major Process Area	Using Knowledge
Core Process	Knowledge Usage
Goal	7. Analyze meeting minutes with respect to applied creative ideas and resolved issues, and project artifacts with respect to their quality to identify the amount of knowledge used.
Question	7.1 What is the percentage of used/utilized creative ideas to all creative ideas?
Metric (m7.1)	m7.1=m3.5
Question	7.2 What is the quality of produced project artifacts?
Metric (m7.2)	Quality of produced project artifacts
Question	7.3 How many issues were resolved on all meetings?
Metric (m7.3)	Number of resolved issues on all meetings
Question	7.4 What is the percentage of resolved issues to raised issues on all meetings?
Metric (m7.4)	m7.4=(m7.3/m5.5)*100
Derived Measurements	– Creative Idea Application – Deliverable Quality – Meeting Functional Efficiency

Table 13 GQM of Knowledge Integration

Major Process Area	Using Knowledge
Core Process	Knowledge Integration
Goal	8. Analyze tasks and developed work artifacts (documents) with respect to stable/unchanging parts in time, and made corrections to identify the amount of integrated knowledge with respect to time.
Question	8.1 How many tasks were done in a phase, that are similar with tasks in previous phases?
Metric (m8.1)	Number of tasks done in a phase that are similar to tasks in previous phases
Question	8.2 How many of these tasks in m8.1 were conducted differently (due to learning something) in that phase?
Metric (m8.2)	Number of tasks in m8.1 conducted differently in that phase
Question	8.3 What is the percentage of differently done tasks in this phase to total tasks that are similar within phases?
Metric (m8.3)	m8.3=(m8.2/m8.1)*100
Question	8.4 How many document sections/headings were prepared in that phase that are similar with document sections/headings written in previous phases?
Metric (m8.4)	Number of document sections/headings prepared in that phase that are similar with document sections/headings written in previous phases
Question	8.5 How many of document sections/headings in m8.4 were prepared differently (due to learning something) on the documents in that phase?
Metric (m8.5)	Number of document sections/headings in m8.4 prepared differently on the documents in that phase
Question	8.6 What is the percentage of differently prepared document sections/headings in this phase to total document sections/headings that are similar within phases?
Metric (m8.6)	m8.6=(m8.5/m8.4)*100
Question	8.7 How many erroneous document sections/headings were identified in reviews?
Metric (m8.7)	Number of erroneous document sections/headings identified in reviews
Question	8.8 How many of the erroneous document sections/headings were corrected after the reviews?
Metric (m8.8)	Number of erroneous document sections/headings corrected after reviews
Question	8.9 What is the percentage of corrected document sections/headings to total found erroneous document sections/headings?
Metric (m8.9)	m8.9=(m8.8/m8.7)*100
Derived Measurements	– Task Differentiation within phases – Deliverable Differentiation within phases – Deliverable Correction

Table 14 GQM of Knowledge Preservation and Deleting

Major Process Area	Passing Knowledge
Core Process	Knowledge Preservation and Deleting
Goal	9. Conduct knowledge preservation tests and analyze tasks and developed work artifacts (documents) with respect to changes in time, and analyze knowledge storing tools and systems used with respect to their effectiveness to identify the amount of knowledge that is preserved or deleted intentionally / due to request of upper management.
Question	9.1 How much knowledge was preserved from previous phases to this phase?
Metric (m9.1)	Amount of preserved knowledge from previous phases to this phase
Question	9.2 How many tasks on that phase were done differently (due to request of management) with respect to the guidelines?
Metric (m9.2)	Number of tasks done differently with respect to the guidelines
Question	9.3 What is the percentage of tasks done differently (due to request of management) with respect to guidelines?
Metric (m9.3)	m9.3=(m9.2/m1.6)*100
Question	9.4 How many document sections/headings were prepared differently (due to request of management) with respect to document templates?
Metric (m9.4)	Number of document sections/headings prepared differently with respect to document templates
Question	9.5 What is the percentage of document sections/headings prepared differently (due to request of management) with respect to document templates?
Metric (m9.5)	m9.5=(m9.4/m1.2)*100
Question	9.6 What is the number of utilized knowledge preservation, storing, archiving, usage tools utilized?
Metric (m9.6)	Number of utilized knowledge preservation, storing, archiving, usage tools utilized
Question	9.7 What is the number of knowledge items stored in the utilized knowledge preservation, storing, archiving, usage tools utilized?
Metric (m9.7)	Amount of stored knowledge items in the utilized knowledge preservation, storing, archiving usage tools
Question	9.8 What is the number of knowledge items NOT stored in the utilized knowledge preservation, storing, archiving, usage tools utilized?
Metric (m9.8)	Amount of NOT stored knowledge items in the utilized knowledge preservation, storing, archiving usage tools
Question	9.9 What is the ratio of stored knowledge items in the utilized knowledge preservation, storing, archiving, usage tools to total knowledge items?
Metric (m9.9)	m9.9=m9.7/(m9.7+m9.8)
Derived Measurements	– Knowledge evaluation and assessment – Task differentiation from guidelines – Deliverable differentiation from templates – Knowledge Preservation Tool Usage – Knowledge Preservation Tool Efficiency

Table 15 GQM of Knowledge Valuation

Major Process Area	Passing Knowledge
Core Process	Knowledge Evaluation
Goal	10. Analyze knowledge items used and produced with respect to their evaluations by the personnel to identify the amount of knowledge that can be evaluated.
Question	10.1 How much of the acquired/used knowledge items on that phase the personnel can valuate with respect to its value to them?
Metric (m10.1)	Number of valuated knowledge items
Question	10.2 How much of the acquired/used knowledge items on that phase the personnel cannot valuate with respect to its value to them?
Metric (m10.2)	Number of non-valuated knowledge items
Question	10.3 What is the percentage of valuated knowledge items to total knowledge items?
Metric (m10.3)	m10.3=(m10.1/(m10.2+m10.1))*100
Derived Measurements	– Valuated Items

Table 16 GQM of Knowledge Selling

Major Process Area	Passing Knowledge
Core Process	Knowledge Selling
Goal	11. Analyze internally developed and externally distributed documents and given external trainings with respect to the knowledge residing in these items to identify the amount of knowledge flow towards outside of the organization
Question	11.1 How many patents/licenses/studies were developed?
Metric (m11.1)	Number of patents/licenses/studies developed
Question	11.2 How many guidelines/templates were given to external organizations?
Metric (m11.2)	Number of guidelines/templates given to external organizations
Question	11.3 How many educations/ trainings/ consulting services/ conferences/ seminars were given to external organizations?
Metric (m11.3)	Number of educations/ trainings/ consulting services/ conferences/ seminars given to external organizations
Derived Measurements	– Shared Documents – Shared Tasks – Trainings Given

Table 17 GQM of Knowledge Evolution

Major Process Area	Passing Knowledge
Core Process	Knowledge Evolution
Goal	12. Analyze work products, documents and tasks with respect to changes realized in these items between successive projects to identify the evolution of knowledge within projects.
Question	12.1 How many guidelines are used?
Metric (m12.1)	Number of guidelines used
Question	12.2 How many guidelines have been edited before being used in the next project?
Metric (m12.2)	Number of edited guidelines before used in the next project
Question	12.3 What is the percentage of edited guidelines to total guidelines?
Metric (m12.3)	m12.3=(m12.2/m12.1)*100
Question	12.4 How many tasks are defined?
Metric (m12.4)	Number of tasks defined
Question	12.5 How many tasks have been redefined before being used in the next project?
Metric (m12.5)	Number of redefined tasks before used in the next project
Question	12.6 What is the percentage of redefined tasks to total tasks?
Metric (m12.6)	m12.6=(m12.4/m12.5)*100
Question	12.7 How many deliverable templates are used?
Metric (m12.7)	Number of deliverable templates used
Question	12.8 How many deliverable templates have been edited before being used in the next project?
Metric (m12.8)	Number of edited deliverable templates before used in the next project
Question	12.9 What is the percentage of edited deliverable templates to total deliverable templates?
Metric (m12.9)	m12.9=(m12.7/m12.8)*100
Derived Measurements	– Guideline Evolution between Projects – Task Evolution between Projects – Deliverable Evolution between Projects

Generic measures and indicators derived from the GQM process that are being utilized in the proposed model are listed in Table 18. Some clarifications regarding the terminology used in the generic measures and within the AiOLoS model are given below:

- "Internal" stands for actions or artifacts completed within the assessed entity[43].
- "Internally" stands for actions or artifacts completed using only internal, that is existing knowledge by the assessed entity or stands for artifacts that are being used by the assessed entity.
- "External" stands for actions or artifacts completed outside the assessed entity.
- "Creative Idea" stands for any idea that is developed by the assessed entity members to solve a problem or a problematic situation, and that has not been thought or proposed before within that entity.
- "Linking" stands for the associations between two different documents
- "Pervasion" stands for the extent ratio an activity or artifact has reached the population of the assessed entity.

[43] Assessed entity can be a team, a group or the whole organization

Table 18 The AiOLoS Model and the Relative Generic Measures

Major Process Area	Core Process	Generic Measure	Short Name
Obtaining Knowledge	Knowledge Identification	Internal Trainings	KId1 / IT
		Tasks Completed Internally	KId2 / TCI
		Documents Completed Internally	KId3 / DCI
		Internal Trainings Pervasion	KId4 / ITP
	Knowledge Acquisition	External Trainings	KAcq1 / ET
		Utilized External Communication	KAcq2 / UEC
		Trained Topics	KAcq3 / TT
		Utilized External Documents	KAcq4 / UED
		External Trainings Pervasion	KAcq5 / ETP
	Knowledge Development	Creative Idea Development	KDev1 / CID
		Creative Idea Evaluation	KDev2 / CIE
Using Knowledge	Knowledge Organization	Horizontal Document Linking	KOrg1 / HDL
		Vertical Document Linking	KOrg2 / VDL
	Knowledge Dissemination	Information Messages from Management	KDis1 / IMM
		Amount of Meetings	KDis2 / AM
		Length of Meetings	KDis3 / LM
		Meeting Discussion Efficiency	KDis4 / MDE
		Meeting Pervasion Measure	KDis5 / MP
	Knowledge Publication	Internally Distributed Guidelines	KPub1 / IDG
		Externally Distributed Guidelines	KPub2 / EDG
		Academic Publications	KPub3 / AP
	Knowledge Usage	Creative Idea Application	KUse1 / CIA
		Deliverable Quality	KUse2 / DQ
		Meeting Functional Efficiency	KUse3 / MFE
	Knowledge Integration	Task Differentiation within Phases	KInt1 / TDP
		Deliverable Differentiation within Phases	KInt2 / DDP
		Deliverable Correction	KInt3 / DC
Passing Knowledge	Knowledge Preservation and Deleting	Knowledge Evaluation and Assessment	KPD1 / KEA
		Task Differentiation from Guidelines	KPD2 / TDT
		Deliverable Differentiation from Templates	KPD3 / DDT
		Knowledge Preservation Tool Usage	KPD4 / KPTU
		Knowledge Preservation Tool Efficiency	KPD5 / KPTE
	Knowledge Evaluation	Valuated Items	KEval1 / VI
	Knowledge Selling	Shared Documents	KSel1 / SD
		Shared Tasks	KSel2 / ST
		Trainings Given	KSel3 / TG
	Knowledge Evolution	Guideline Evolution between Projects	KEvol1 / GEP
		Task Evolution between Projects	KEvol2 / TEP
		Deliverable Evolution between Projects	KEvol3 / DEP

The measure definitions of each core process are detailed using the fields listed in Table 19.

Table 19 Generic Measure Details

Name	Name of the measure
Short name	Short name of the measure
Major process area	Name of the major process area the measure applies to
Core process	Name of the core process the measure applies to
Detail	Detail information of the measurement process
Measurement scale	Scale of the measurement , either “nominal”, “ordinal”, “interval” or “ratio”
Measurement focus	Type of the measure, either “internal”, “external”, or “quality in use”
Measurement method	Type of the measurement, either “objective”, or “subjective”
Inputs	The inputs that are required for the measurement
Measurement formula	Measurement formula and an explanation of the element meanings
Interpretation	Interpretation method of measure
Knowledge dimension	According to Knowledge Dimensions of Maier [27], given in Section 2.1.1
Knowledge type	Either “tacit” or “explicit”, according to Section 2.1.2
Knowledge location	According to Knowledge Reservoirs of Becerra-Fernandez and Sabherwal [30], given in Section 2.1.4
Assessed OV	Either “Commitment to learning”, “Open-mindedness” or “Shared vision”, according to Sinkula, Baker and Noordewier [15], given in Section 2.2.1
Level of OL	Either “Lower-Level” or “Higher-Level”, according to Fiol and Lyles [53], given in Section 2.2.2
OL loop	Either “single-loop”, “double-loop” or “deutero-learning”, according to Dodgson [49], given in Section 2.2.3
Individual learning	Either “operational” or “conceptual”, according to Kim [13], given in Section 2.2.4
OL measure	According to Spector and Davidsen [85], given in Section 2.2.6
LO discipline	According to Senge’s [74] Five Core Disciplines, given in Section 2.3
LO dimension	According to Marsick and Watkins [123], given in Section 2.3
LO perspective	According to Örtenblad [92], given in Section 2.3
Learning Level	Either “personal”, “team” or “organizational”

In the following Table 20 through Table 58, the details of the generic measures of AiOLoS are given.

Table 20 Internal Trainings Measure

Name	Internal Trainings
Short name	KId1 / IT
Major process area	Obtaining Knowledge
Core process	Knowledge Identification
Detail	Count the number of internally trained personnel and count the number of total personnel
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Training Plan
Measurement formula	$= \frac{\text{Number of internally trained personnel}}{\text{Number of total personnel}} \times 100$
Interpretation	The closer to 100% the higher the dissemination of internal trainings
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge novelty → Existing knowledge – Knowledge existence → Knowledge
Knowledge type	Explicit
Knowledge location	Individuals, Groups
Assessed OV	Commitment to learning
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	Create continuous learning opportunities
LO perspective	Learning at work
Learning Level	Personal

Table 21 Tasks Completed Internally Measure

Name	Tasks Completed Internally
Short name	KId2 / TCI
Major process area	Obtaining Knowledge
Core process	Knowledge Identification
Detail	Count the number of tasks completed with existing knowledge and count the number of total tasks
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Questionnaires
Measurement formula	$= \frac{\text{Number of tasks completed with existing knowledge}}{\text{Number of total tasks}} \times 100$
Interpretation	The closer to 100% the higher the ratio of internally completed tasks to total tasks
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge novelty → Existing knowledge – Knowledge existence → Knowledge
Knowledge type	Tacit and/or Explicit
Knowledge location	Practices
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	Create continuous learning opportunities
LO perspective	Old OL
Learning Level	Team

Table 22 Documents Completed Internally Measure

Name	Documents Completed Internally
Short name	KId3 / DCI
Major process area	Obtaining Knowledge
Core process	Knowledge Identification
Detail	Count the number of document sections/headings completed with existing knowledge and count the number of total documents sections/headings
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Questionnaires, Deliverables
Measurement formula	$= \frac{\text{Number of document sections or headings completed with existing knowledge}}{\text{Number of total document sections or headings}} \times 100$
Interpretation	The closer to 100% the higher the ratio of internally completed document sections/headings to total document sections/headings
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge novelty → Existing knowledge – Knowledge existence → Knowledge
Knowledge type	Explicit
Knowledge location	Artifacts
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	Create continuous learning opportunities
LO perspective	Old OL
Learning Level	Team

Table 23 Internal Trainings Pervasion Measure

Name	Internal Trainings Pervasion
Short name	KId4 / ITP
Major process area	Obtaining Knowledge
Core process	Knowledge Identification
Detail	Count the number of internally trained personnel, count the number of total personnel and count the total number of internal trainings conducted
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Training Plan
Measurement formula	$= \frac{\text{Number of internally trained personnel}}{\text{Number of total personnel}} \times 100$ x Number of total internal trainings
Interpretation	The closer to 100% the higher the pervasion of internal trainings
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge novelty → Existing knowledge – Knowledge existence → Knowledge
Knowledge type	Explicit
Knowledge location	Individuals, Groups
Assessed OV	Commitment to learning
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	Create continuous learning opportunities
LO perspective	Learning at work
Learning Level	Personal

Table 24 External Trainings Measure

Name	External Trainings
Short name	KAcq1 / ET
Major process area	Obtaining Knowledge
Core process	Knowledge Acquisition
Detail	Count the number of externally trained personnel and count the number of total personnel
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Training Plan
Measurement formula	$= \frac{\text{Number of externally trained personnel}}{\text{Number of total personnel}} \times 100$
Interpretation	The closer to 100% the higher the dissemination of external trainings
Knowledge dimension	– Knowledge preservation → Newly acquired knowledge – Knowledge novelty → New knowledge
Knowledge type	Explicit
Knowledge location	Individuals, Groups
Assessed OV	Commitment to learning
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	– Create continuous learning opportunities – Connect the organization to its environment
LO perspective	Learning climate
Learning Level	Personal

Table 25 Utilized External Communication Measure

Name	Utilized External Communication
Short name	KAcq2 / UEC
Major process area	Obtaining Knowledge
Core process	Knowledge Acquisition
Detail	Count the number of questions asked to external entities and count the number of helpful responses to these questions
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Subjective
Inputs	Questionnaires
Measurement formula	$= \frac{\text{Number of helpful responses to questions asked to external entities}}{\text{Number of questions asked to external entities}} \times 100$
Interpretation	The closer to 100% the higher the utilization of external communication
Knowledge dimension	– Knowledge preservation → Newly acquired knowledge – Knowledge novelty → New knowledge
Knowledge type	Tacit and/or Explicit
Knowledge location	Organizations, Interorganizational networks
Assessed OV	Commitment to learning
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	– Create continuous learning opportunities – Connect the organization to its environment
LO perspective	Learning structure
Learning Level	Personal

Table 26 Trained Topics Measure

Name	Trained Topics
Short name	KAcq3 / TT
Major process area	Obtaining Knowledge
Core process	Knowledge Acquisition
Detail	Count the number of topics in external trainings and find the maximum number of topics in external trainings achieved by N other organizations in the same phase **or** achieved by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Software Project Plan, Training Plan
Measurement formula	$= \frac{\text{Number of topics in external trainings}}{\max\{TT\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of trained topics in comparison to other organizations or to other phases
Knowledge dimension	– Knowledge preservation → Newly acquired knowledge – Knowledge novelty → New knowledge
Knowledge type	Explicit
Knowledge location	Individuals, Groups
Assessed OV	Commitment to learning
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	– Create continuous learning opportunities – Connect the organization to its environment
LO perspective	Learning climate
Learning Level	Personal

Table 27 Utilized External Documents Measure

Name	Utilized External Documents
Short name	KAcq4 / UED
Major process area	Obtaining Knowledge
Core process	Knowledge Acquisition
Detail	Count the number of external written documents (either hard or softcopy) used and find the maximum number of external written documents (either hard or softcopy) by N other organizations in the same phase **or** used by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Software Project Plan, Questionnaires
Measurement formula	$= \frac{\text{Number of utilized external documents}}{\max\{\text{UED}\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of utilized external documents in comparison to other organizations or to other phases
Knowledge dimension	– Knowledge preservation → Newly acquired knowledge – Knowledge novelty → New knowledge
Knowledge type	Explicit
Knowledge location	Artifacts
Assessed OV	Commitment to learning
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	– Create continuous learning opportunities – Connect the organization to its environment
LO perspective	Learning structure
Learning Level	Personal

Table 28 External Trainings Pervasion Measure

Name	External Trainings Pervasion
Short name	KAcq5 / ETP
Major process area	Obtaining Knowledge
Core process	Knowledge Acquisition
Detail	Count the number of externally trained personnel, count the number of total personnel and count the total number of external trainings conducted
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Training Plan
Measurement formula	$= \frac{\text{Number of externally trained personnel}}{\text{Number of total personnel}} \times 100$ x Number of external trainings conducted
Interpretation	The closer to 100% the higher the pervasion of external trainings
Knowledge dimension	– Knowledge preservation → Newly acquired knowledge – Knowledge novelty → New knowledge
Knowledge type	Explicit
Knowledge location	Individuals, Groups
Assessed OV	Commitment to learning
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	– Create continuous learning opportunities – Connect the organization to its environment
LO perspective	Learning climate
Learning Level	Personal

Table 29 Creative Idea Development Measure

Name	Creative Idea Development Measure
Short name	KDev1 / CID
Major process area	Obtaining Knowledge
Core process	Knowledge Development
Detail	Count the number of creative ideas developed and find the maximum number of creative ideas developed by N other organizations in the same phase **or** developed by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Subjective
Inputs	Questionnaires, Meeting minutes
Measurement formula	$= \frac{\text{Number of creative ideas developed}}{\max\{\text{CID}\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of developed creative ideas in comparison to other organizations or to other phases
Knowledge dimension	– Knowledge novelty → New knowledge – Business process → Knowledge derived from the process
Knowledge type	Tacit and/or Explicit
Knowledge location	Individuals
Assessed OV	Open-mindedness
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Reflective activity
LO discipline	Mental models
LO dimension	– Promote inquiry and dialogue – Empower people towards a collective vision
LO perspective	Learning structure
Learning Level	Personal

Table 30 Creative Idea Evaluation

Name	Creative Idea Evaluation
Short name	KDev2 / CIE
Major process area	Obtaining Knowledge
Core process	Knowledge Development
Detail	Count the number of creative ideas developed and count the number of creative ideas considered to be applicable by the organization
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Subjective
Inputs	Questionnaires, Meeting minutes
Measurement formula	$= \frac{\text{Number of creative ideas considered to be applicable}}{\text{Number of creative ideas developed}} \times 100$
Interpretation	The closer to 100% the higher the ratio of developing valuable creative ideas
Knowledge dimension	– Knowledge novelty → New knowledge – Business process → Knowledge derived from the process
Knowledge type	Tacit and/or Explicit
Knowledge location	Individuals, Groups
Assessed OV	Open-mindedness
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Tolerance
LO discipline	Mental models, Shared vision
LO dimension	– Promote inquiry and dialogue – Empower people towards a collective vision
LO perspective	Learning structure
Learning Level	Personal

Table 31 Horizontal Document Linking Measure

Name	Horizontal Document Linking
Short name	KOrg1 / HDL
Major process area	Using Knowledge
Core process	Knowledge Organization
Detail	Count the number of links/references from a document to other documents in the same phase, count the number of documents developed in that phase, and find the maximum number of links/references from a document to other documents by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Deliverables
Measurement formula	$$HDL_i = \sum_i \frac{\text{Number of links and references to other documents in that phase}}{\text{Number of total documents in that phase}} \times 100$$ $$= \frac{HDL_i}{\max\{HDL\}_{i=1}^{N}} \times 100$$
Interpretation	The closer to 100% the higher the ratio of horizontal document linking with respect to other organizations or other phases
Knowledge dimension	– Knowledge relevance → Relevant knowledge – Informal support → Supported/dominant knowledge – Formal authorization → Authorized/formal knowledge – Knowledge secrecy → Secret/confidential knowledge – Truth → True/supported knowledge – Organizational scope → Knowledge spanning functional areas – Organizational scope → Knowledge restricted to a functional area – Knowledge focus → Focused knowledge – Knowledge holder → Collective/public/social knowledge – Knowledge integration → Knowledge
Knowledge type	Explicit
Knowledge location	Artifacts
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	Create continuous learning opportunities
LO perspective	Old OL
Learning Level	Team

Table 32 Vertical Document Linking Measure

Name	Vertical Document Linking
Short name	KOrg2 / VDL
Major process area	Using Knowledge
Core process	Knowledge Organization
Detail	Count the number of links/references from a document to other documents in previous phases, count the number of documents developed in all phases, and find the maximum number of links/references from a document to other documents in previous phases by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Deliverables
Measurement formula	$$VDL_i = \sum_i \frac{\text{Number of links and references to other documents in previous phases}}{\text{Number of total documents in all phases}} \times 100$$ $$= \frac{VDL_i}{\max\{VDL\}_{i=1}^{N}} \times 100$$
Interpretation	The closer to 100% the higher the ratio of vertical document linking with respect to other organizations or other phases
Knowledge dimension	– Knowledge relevance → Relevant knowledge – Informal support → Supported/dominant knowledge – Formal authorization → Authorized/formal knowledge – Knowledge secrecy → Secret/confidential knowledge – Truth → True/supported knowledge – Organizational scope → Knowledge spanning functional areas – Organizational scope → Knowledge restricted to a functional area – Knowledge focus → Focused knowledge – Knowledge holder → Collective/public/social knowledge – Knowledge integration → Knowledge
Knowledge type	Explicit
Knowledge location	Artifacts
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Personal mastery
LO dimension	Create continuous learning opportunities
LO perspective	Old OL
Learning Level	Team

Table 33 Information Messages from Management Measure

Name	Information Messages from Management
Short name	KDis1 / IMM
Major process area	Using Knowledge
Core process	Knowledge Dissemination
Detail	Count the number of push informative/explanatory messages sent from the management to personnel and find the maximum number of push informative/explanatory messages sent from management in N other organizations in the same phase **or** in the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Questionnaires, Meeting minutes
Measurement formula	$= \frac{\text{Number of push informative or explanatory messages sent from management}}{\max\{\text{IMM}\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of push informative/explanatory messages with respect to other organizations or other phases
Knowledge dimension	– Knowledge access → Accessible knowledge – Knowledge codability → Codable knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge
Knowledge type	Explicit
Knowledge location	Organizational units, Individuals, Groups
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Leadership engagement
LO discipline	Shared vision
LO dimension	Leaders model and support learning
LO perspective	Learning climate
Learning Level	Organizational

Table 34 Amount of Meetings Measure

Name	Amount of Meetings
Short name	KDis2 / AM
Major process area	Using Knowledge
Core process	Knowledge Dissemination
Detail	Count the number of meetings held and find the maximum number of meetings held by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Meeting minutes, Software Project Plan
Measurement formula	$= \frac{\text{Number of meetings held}}{\max\{AM\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of meetings held with respect to other organizations or other phases
Knowledge dimension	– Knowledge access → Accessible knowledge – Knowledge codability → Codable knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge
Knowledge type	Explicit
Knowledge location	Groups
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Team process
LO discipline	Team learning
LO dimension	Encourage collaboration and team learning
LO perspective	Learning at work
Learning Level	Team

Table 35 Length of Meetings Measure

Name	Length of Meetings
Short name	KDis3 / LM
Major process area	Using Knowledge
Core process	Knowledge Dissemination
Detail	Count the number of hours spent in meetings, count the number of persons attending the meetings and find the maximum number of man hours spent in meetings by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Meeting minutes, Software Project Plan
Measurement formula	$LM_j = \sum_i \frac{\text{Number of hours in meeting}_i}{\text{Number of persons attending meeting}_i}$ $= \frac{LM_j}{\max\{LM\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of meetings length with respect to other organizations or other phases
Knowledge dimension	– Knowledge access → Accessible knowledge – Knowledge codability → Codable knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge
Knowledge type	Explicit
Knowledge location	Groups
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Team process
LO discipline	Team learning
LO dimension	Encourage collaboration and team learning
LO perspective	Learning at work
Learning Level	Team

Table 36 Meeting Discussion Efficiency Measure

Name	Meeting Discussion Efficiency
Short name	KDis4 / MDE
Major process area	Using Knowledge
Core process	Knowledge Dissemination
Detail	Count the number of topics/issues raised on all meetings and count the number of topics/issues discussed on all meetings
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Meeting minutes
Measurement formula	$= \frac{\text{Number of topics or issues discussed on all meetings}}{\text{Number of topics or issues raised on all meetings}} \times 100$
Interpretation	The closer to 100% the higher efficiency of the meetings
Knowledge dimension	– Knowledge access → Accessible knowledge – Knowledge codability → Codable knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge
Knowledge type	Explicit
Knowledge location	Groups
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Team process
LO discipline	Team learning
LO dimension	Encourage collaboration and team learning
LO perspective	Learning at work
Learning Level	Team

Table 37 Meeting Pervasion Measure

Name	Meeting Pervasion
Short name	KDis5 / MP
Major process area	Using Knowledge
Core process	Knowledge Dissemination
Detail	Count the number of topics/issues discussed in each meeting and count the number of people in each meeting
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Meeting minutes
Measurement formula	$$\sum_i \frac{\text{Number of people in meeting i} \times \text{Number of topics in meeting i}}{\text{Number of topics or issues discussed on all meetings} \times \text{Number of total personnel}} \times 100$$
Interpretation	The closer to 100% the higher pervasion of meeting topics
Knowledge dimension	– Knowledge access → Accessible knowledge – Knowledge codability → Codable knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge
Knowledge type	Explicit
Knowledge location	Groups
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Team process
LO discipline	Team learning
LO dimension	Encourage collaboration and team learning
LO perspective	Learning at work
Learning Level	Team

Table 38 Knowledge Internally Distributed Guidelines Measure

Name	Internally Distributed Guidelines
Short name	KPub1 / IDG
Major process area	Using Knowledge
Core process	Knowledge Publication
Detail	Count the number of internally developed and distributed guidelines and find the maximum number of internally developed and distributed guidelines by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Guidelines, Interviews
Measurement formula	$= \frac{\text{Number of internally developed and distributed guidelines}}{\max\{\text{IDG}\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of internally distributed guidelines with respect to other organizations or other phases
Knowledge dimension	– Knowledge codability → Codable knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge – Knowledge generalization → Universal/general knowledge – Knowledge contextualization → Contextualized knowledge – Form → Procedural knowledge – Knowledge abstraction → Scientific, abstract and deep knowledge
Knowledge type	Explicit
Knowledge location	Artifacts, Organizational units
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Reflective activity
LO discipline	Shared vision
LO dimension	Empower people towards a collective vision
LO perspective	Learning at work
Learning Level	Organizational

Table 39 Externally Distributed Guidelines Measure

Name	Externally Distributed Guidelines
Short name	KPub2 / EDG
Major process area	Using Knowledge
Core process	Knowledge Publication
Detail	Count the number of internally developed guidelines that are externally distributed and find the maximum number of internally developed guidelines that are externally distributed by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Guidelines, Interviews
Measurement formula	$= \frac{\text{Number of internally developed and externally distributed guidelines}}{\max\{EDG\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of externally distributed guidelines with respect to other organizations or other phases
Knowledge dimension	– Knowledge codability → Codable knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge – Knowledge generalization → Universal/general knowledge – Knowledge contextualization → Contextualized knowledge – Form → Procedural knowledge – Knowledge abstraction → Scientific, abstract and deep knowledge
Knowledge type	Explicit
Knowledge location	Artifacts, Organizations, Interorganizational networks
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Reflective activity
LO discipline	Shared vision
LO dimension	– Empower people towards a collective vision – Connect the organization to its environment
LO perspective	Learning at work
Learning Level	Organizational

Table 40 Academic Publications Measure

Name	Academic Publications
Short name	KPub3 / AP
Major process area	Using Knowledge
Core process	Knowledge Publication
Detail	Count the number of publications in academic terms and find the maximum number of publications in academic terms by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Publications, Interviews
Measurement formula	$= \frac{\text{Number of academic publications}}{\max\{AP\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of academic publications with respect to other organizations or other phases
Knowledge dimension	– Knowledge codability → Codable knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge – Knowledge generalization → Universal/general knowledge – Knowledge contextualization → Contextualized knowledge – Form → Procedural knowledge – Knowledge abstraction → Scientific, abstract and deep knowledge
Knowledge type	Explicit
Knowledge location	Artifacts, Interorganizational networks
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Reflective activity
LO discipline	Systems thinking
LO dimension	– Empower people towards a collective vision – Connect the organization to its environment
LO perspective	Learning structure
Learning Level	Organizational

Table 41 Creative Idea Application Measure

Name	Creative Idea Application
Short name	KUse1 / CIA
Major process area	Using Knowledge
Core process	Knowledge Usage
Detail	Count the used/utilized creative ideas and count the number of all creative ideas developed
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Questionnaires, Meeting minutes
Measurement formula	$= \frac{\text{Number of used or utilized creative ideas}}{\text{Number of creative ideas developed}} \times 100$
Interpretation	The closer to 100% the higher the ratio of creative idea application
Knowledge dimension	– Organizational scope → Knowledge spanning functional areas – Organizational scope → Knowledge restricted to a single functional area – Business process → Knowledge derived from the process
Knowledge type	Tacit and/or Explicit
Knowledge location	Individuals, Practices
Assessed OV	Open-mindedness
Level of OL	Higher-level
OL loop	Double-loop
Individual learning	Conceptual
OL measure	Tolerance
LO discipline	Mental models, Shared vision
LO dimension	– Promote inquiry and dialogue – Empower people towards a collective vision
LO perspective	Learning structure
Learning Level	Personal, Organizational

Table 42 Deliverable Quality Measure

Name	Deliverable Quality
Short name	KUse2 / DQ
Major process area	Using Knowledge
Core process	Knowledge Usage
Detail	Evaluate the quality of software deliverables quantitatively and find the maximum scores of the same deliverables by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Subjective
Inputs	Deliverables, Software Artifacts, Interviews
Measurement formula	$= \frac{\text{Quality score of deliverable}}{\max\{DQ\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the ratio of deliverable quality with respect to other organizations or other phases
Knowledge dimension	– Organizational scope → Knowledge spanning functional areas – Organizational scope → Knowledge restricted to a single functional area Business process → Knowledge derived from the process
Knowledge type	Tacit and/or Explicit
Knowledge location	Artifacts
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Mental models
LO dimension	Promote inquiry and dialogue
LO perspective	Old OL
Learning Level	Team

Table 43 Meeting Functional Efficiency Measure

Name	Meeting Functional Efficiency
Short name	KUse3 / MFE
Major process area	Using Knowledge
Core process	Knowledge Usage
Detail	Count the number of resolved issues in meetings and count the number of raised issues in meetings
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Meeting minutes
Measurement formula	$= \frac{\text{Number of resolved issues in meetings}}{\text{Number of raised issues in meetings}} \times 100$
Interpretation	The closer to 100% the higher the functional efficiency of meetings
Knowledge dimension	– Organizational scope → Knowledge spanning functional areas – Organizational scope → Knowledge restricted to a single functional area – Business process → Knowledge derived from the process
Knowledge type	Explicit
Knowledge location	Groups
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Team process
LO discipline	Team learning
LO dimension	Encourage collaboration and team learning
LO perspective	Learning at work
Learning Level	Team

Table 44 Task Differentiation within Phases Measure

Name	Task Differentiation within Phases
Short name	KInt1 / TDP
Major process area	Using Knowledge
Core process	Knowledge Integration
Detail	Count the number of tasks in that phase that are similar with tasks in previous phases and count the number of tasks in that phase that are similar with tasks in previous phases but were conducted differently
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Interviews
Measurement formula	$= \frac{\text{Number of tasks in that phase that are similar with the tasks in previous phases but were conducted differently}}{\text{Number of tasks in that phase that are similar with the tasks in previous phases}} \times 100$
Interpretation	The closer to 100% the higher the task differentiation between phases
Knowledge dimension	– Knowledge integration → Knowledge – Business process → Knowledge within the process
Knowledge type	Tacit and/or Explicit
Knowledge location	Practices
Assessed OV	Open-mindedness
Level of OL	Higher-level
OL loop	Double-loop
Individual learning	Conceptual
OL measure	Reflective activity, Tolerance
LO discipline	Mental models
LO dimension	Create continuous learning opportunities
LO perspective	Learning structure
Learning Level	Team, Organizational

Table 45 Deliverable Differentiation within Phases Measure

Name	Deliverable Differentiation within Phases
Short name	KInt2 / DDP
Major process area	Using Knowledge
Core process	Knowledge Integration
Detail	Count the number of document sections/headings in that phase that are similar with document sections/headings in previous phases and count the number of document sections/headings in that phase that are similar with document sections/headings in previous phases but were conducted differently
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Interviews, Deliverables
Measurement formula	$$= \frac{\begin{array}{c}\text{Number of document sections or headings} \\ \text{in that phase that are similar with document} \\ \text{sections or headings in previous phases} \\ \text{but were conducted differently}\end{array}}{\begin{array}{c}\text{Number of document sections or headings} \\ \text{in that phase that are similar with the document} \\ \text{sections or headings in previous phases}\end{array}} \times 100$$
Interpretation	The closer to 100% the higher the deliverable differentiation between phases
Knowledge dimension	– Knowledge integration → Knowledge – Business process → Knowledge within the process
Knowledge type	Explicit
Knowledge location	Practices
Assessed OV	Open-mindedness
Level of OL	Higher-level
OL loop	Double-loop
Individual learning	Conceptual
OL measure	Reflective activity, Tolerance
LO discipline	Mental models
LO dimension	Create continuous learning opportunities
LO perspective	Learning structure
Learning Level	Team, Organizational

Table 46 Deliverable Correction Measure

Name	Deliverable Correction
Short name	KInt3 / DC
Major process area	Using Knowledge
Core process	Knowledge Integration
Detail	Count the number of erroneous document sections/headings identified in reviews and count the erroneous document sections/headings corrected after reviews
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Deliverables, Review minutes
Measurement formula	$$= \frac{\text{Number of corrected erroneous document sections or headings after reviews}}{\text{Number of identified erroneous document sections or headings in reviews}} \times 100$$
Interpretation	The closer to 100% the higher the deliverable correction level
Knowledge dimension	– Knowledge integration → Knowledge – Business process → Knowledge within the process
Knowledge type	Explicit
Knowledge location	Artifacts
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Mental models
LO dimension	Promote inquiry and dialogue
LO perspective	Learning structure
Learning Level	Team

Table 47 Knowledge Evaluation and Assessment Measure

Name	Knowledge Evaluation and Assessment
Short name	KPD1 / KEA
Major process area	Passing Knowledge
Core process	Knowledge Preservation and Deleting
Detail	Apply knowledge assessment tests to personnel and quantitatively assess test results. Count the level of current knowledge in this phase (KL_n) based on test scores and count the level of knowledge in previous phase (KL_{n-1}) based on previous test scores
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Subjective
Inputs	Interviews, Questionnaires, Tests
Measurement formula	$= \begin{cases} 100\% & \text{if } KL_n \geq KL_{n-1} \\ \frac{KL_n}{KL_{n-1}} \times 100 & \text{if } KL_n < KL_{n-1} \end{cases}$
Interpretation	The closer to 100% the higher the level of knowledge preservation
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge value → Knowledge valuable for storing – Knowledge actuality → Actual knowledge
Knowledge type	Tacit and/or Explicit
Knowledge location	Individuals, Groups
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Mental models
LO dimension	Promote inquiry and dialogue
LO perspective	Learning structure
Learning Level	Personal, Team

Table 48 Task Differentiation from Guidelines Measure

Name	Task Differentiation from Guidelines
Short name	KPD2 / TDT
Major process area	Passing Knowledge
Core process	Knowledge Preservation and Deleting
Detail	Count the number of tasks done differently due to request of management with respect to guidelines and count the number of total tasks
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Interviews, Questionnaires
Measurement formula	$$= \frac{\text{Number of tasks done differently with respect to guidelines due to requests of management}}{\text{Number of total tasks}} \times 100$$
Interpretation	The closer to 100% the higher the level of task differentiation from guidelines
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge value → Knowledge valuable for storing – Knowledge actuality → Actual knowledge – Knowledge actuality → Obsolete knowledge
Knowledge type	Tacit and/or Explicit
Knowledge location	Practices, Artifacts
Assessed OV	Open-mindedness
Level of OL	Higher-level
OL loop	Double-loop
Individual learning	Conceptual
OL measure	Reflective activity, Leadership engagement
LO discipline	Mental models, Shared vision
LO dimension	Leaders model and support learning
LO perspective	Learning climate
Learning Level	Team, Organizational

Table 49 Deliverable Differentiation from Templates Measure

Name	Deliverable Differentiation from Templates
Short name	KPD3 / DDT
Major process area	Passing Knowledge
Core process	Knowledge Preservation and Deleting
Detail	Count the number of document sections/headings prepared differently due to request of management with respect to templates and count the number of total document sections/headings
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Software Project Plan, Interviews, Questionnaires, Deliverables
Measurement formula	$$= \frac{\text{Number of document sections or headings prepared differently with respect to templates due to requests of management}}{\text{Number of total document sections or headings}} \times 100$$
Interpretation	The closer to 100% the higher the level of deliverable differentiation from templates
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge value → Knowledge valuable for storing – Knowledge actuality → Actual knowledge – Knowledge actuality → Obsolete knowledge
Knowledge type	Explicit
Knowledge location	Artifacts
Assessed OV	Open-mindedness
Level of OL	Higher-level
OL loop	Double-loop
Individual learning	Conceptual
OL measure	Reflective activity, Leadership engagement
LO discipline	Mental models, Shared vision
LO dimension	Leaders model and support learning
LO perspective	Learning climate
Learning Level	Team, Organizational

Table 50 Knowledge Preservation Tool Usage Measure

Name	Knowledge Preservation Tool Usage
Short name	KPD4 / KPTU
Major process area	Passing Knowledge
Core process	Knowledge Preservation and Deleting
Detail	Count the number of knowledge preservation/storing/archiving/usage tools utilized and find the maximum number of knowledge preservation/storing/archiving/usage tools utilized by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Project Tools, Software Project Plan, Interviews, Questionnaires
Measurement formula	$$= \frac{\text{Number of utilized knowledge preservation, storing, archiving, usage tools}}{\max\{\text{KPTU}\}_{i=1}^{N}} \times 100$$
Interpretation	The closer to 100% the higher the level of knowledge preservation tool usage
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge value → Knowledge valuable for storing – Knowledge actuality → Actual knowledge – Knowledge actuality → Obsolete knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge
Knowledge type	Explicit
Knowledge location	Technologies, Repositories
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Shared vision
LO dimension	Establish systems to capture and share learning
LO perspective	Old OL
Learning Level	Organizational

Table 51 Knowledge Preservation Tool Efficiency Measure

Name	Knowledge Preservation Tool Efficiency
Short name	KPD5 / KPTE
Major process area	Passing Knowledge
Core process	Knowledge Preservation and Deleting
Detail	Count the number of knowledge items stored within the knowledge preservation/storing/archiving/usage tools utilized and count the number of knowledge items not stored within these tools but stored elsewhere
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Project Tools, Software Project Plan, Interviews, Questionnaires
Measurement formula	$= \frac{\text{Number of knowledge items stored in knowledge preservation, storing, archiving, usage tools}}{\text{Number of knowledge items stored in knowledge preservation, storing, archiving, usage tools} + \text{Number of knowledge items NOT stored in knowledge preservation, storing, archiving, usage tools}} \times 100$
Interpretation	The closer to 100% the higher the level of knowledge preservation tool efficiency
Knowledge dimension	– Knowledge preservation → Preserved knowledge – Knowledge value → Knowledge valuable for storing – Knowledge actuality → Actual knowledge – Knowledge actuality → Obsolete knowledge – Knowledge medium → Not electronic/not computer-resident knowledge – Knowledge medium → Electronic/computer-resident knowledge
Knowledge type	Explicit
Knowledge location	Technologies, Repositories
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Shared vision
LO dimension	Establish systems to capture and share learning
LO perspective	Old OL
Learning Level	Organizational

Table 52 Valuated Items Measure

Name	Valuated Items
Short name	KEval1 / VI
Major process area	Passing Knowledge
Core process	Knowledge Evaluation
Detail	List the acquired or used knowledge items related to the evaluation period, ask personnel to categorize each knowledge item on a Likert scale of 0 to 5 including an option for not evaluated. Count the number of evaluated knowledge items and count the number of not evaluated knowledge items
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Subjective
Inputs	Interviews, Questionnaires
Measurement formula	$= \frac{\text{Number of acquired or used knowledge items the personnel can evaluate}}{\left(\text{Number of acquired or used knowledge items the personnel can evaluate}\right) + \left(\text{Number of acquired or used knowledge items the personnel cannot evaluate}\right)} \times 100$
Interpretation	The closer to 100% the higher the ratio of valuated items by the personnel
Knowledge dimension	– Knowledge value → Knowledge valuable for storing
Knowledge type	Tacit and/or Explicit
Knowledge location	Individuals, Groups
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Conceptual
OL measure	Action
LO discipline	Mental models
LO dimension	Promote inquiry and dialogue
LO perspective	Learning structure
Learning Level	Personal

Table 53 Shared Documents Measure

Name	Shared Documents
Short name	KSel1 / SD
Major process area	Passing Knowledge
Core process	Knowledge Selling
Detail	Count the number patents/licenses/studies developed internally and find the maximum number of patents/licenses/studies developed by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Patents, Licenses, Studies
Measurement formula	$= \frac{\text{Number of internally developed patents, licenses and studies}}{\max\{SD\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the level of shared documents with respect to other organizations or other phases
Knowledge dimension	– Knowledge generalization → Universal knowledge – Knowledge security → Public knowledge – Knowledge ownership → Organizational-external knowledge
Knowledge type	Explicit
Knowledge location	Artifacts, Organizations, Interorganizational networks
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Shared vision
LO dimension	Empower people towards a collective vision
LO perspective	Learning structure
Learning Level	Organizational

Table 54 Shared Tasks Measure

Name	Shared Tasks
Short name	KSel2 / ST
Major process area	Passing Knowledge
Core process	Knowledge Selling
Detail	Count the number guidelines/templates given to external organizations and find the maximum number of guidelines/templates given by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Guidelines, Templates
Measurement formula	$= \frac{\text{Number of guidelines and templates given to external organizations}}{\max\{ST\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the level of shared tasks with respect to other organizations or other phases
Knowledge dimension	– Knowledge generalization → Universal knowledge – Knowledge security → Public knowledge – Knowledge ownership → Organizational-external knowledge
Knowledge type	Explicit
Knowledge location	Practices, Organizations, Interorganizational networks
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Shared vision
LO dimension	Empower people towards a collective vision
LO perspective	Learning structure
Learning Level	Organizational

Table 55 Trainings Given Measure

Name	Trainings Given
Short name	KSel3 / TG
Major process area	Passing Knowledge
Core process	Knowledge Selling
Detail	Count the number educations/ trainings/ consulting services/ conferences/ seminars given to external organizations and find the maximum number of educations/ trainings/ consulting services/ conferences/ seminars given by N other organizations in the same phase **or** by the same organization in N previous phases
Measurement scale	Ratio
Measurement focus	Internal or External
Measurement method	Objective
Inputs	Software Project Plan, Training Plan, Interviews, Questionnaires
Measurement formula	$= \frac{\text{Number of educations, trainings, consulting services, conferences and seminars given to external organizations}}{\max\{TG\}_{i=1}^{N}} \times 100$
Interpretation	The closer to 100% the higher the level of trainings given with respect to other organizations or other phases
Knowledge dimension	– Knowledge generalization → Universal knowledge – Knowledge security → Public knowledge – Knowledge ownership → Organizational-external knowledge
Knowledge type	Explicit
Knowledge location	Individuals, Organizations, Interorganizational networks
Assessed OV	Shared vision
Level of OL	Lower-level
OL loop	Single-loop
Individual learning	Operational
OL measure	Action
LO discipline	Team learning, Shared vision
LO dimension	Connect the organization to its environment
LO perspective	Learning structure
Learning Level	Personal, Organizational

Table 56 Guideline Evolution between Projects Measure

Name	Guideline Evolution between Projects
Short name	KEvol1 / GEP
Major process area	Passing Knowledge
Core process	Knowledge Evolution
Detail	Count the number guidelines used and count the number of edited guidelines before used in the next project
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Guidelines, Document Version History
Measurement formula	$= \frac{\text{Number of edited guidelines before being used in the next project}}{\text{Number of guidelines}} \times 100$
Interpretation	The closer to 100% the higher the level of guideline evolution between projects
Knowledge dimension	– Knowledge refinement → Refined knowledge
Knowledge type	Explicit
Knowledge location	Artifacts
Assessed OV	Open-mindedness
Level of OL	Higher-level
OL loop	Double-loop
Individual learning	Conceptual
OL measure	Reflective activity, Tolerance
LO discipline	Mental models, Systems thinking
LO dimension	Empower people towards a collective vision
LO perspective	Learning structure
Learning Level	Organizational

Table 57 Task Evolution between Projects Measure

Name	Task Evolution between Projects
Short name	KEvol2 / TEP
Major process area	Passing Knowledge
Core process	Knowledge Evolution
Detail	Count the number tasks defined and count the number of redefined tasks before being used in the next project
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Guidelines, Document Version History, Software Project Plan
Measurement formula	$= \frac{\text{Number of redefined tasks before being used in the next project}}{\text{Number of defined tasks}} \times 100$
Interpretation	The closer to 100% the higher the level of task evolution between projects
Knowledge dimension	– Knowledge refinement → Refined knowledge
Knowledge type	Tacit and/or Explicit
Knowledge location	Practices
Assessed OV	Open-mindedness
Level of OL	Higher-level
OL loop	Double-loop
Individual learning	Conceptual
OL measure	Reflective activity, Tolerance
LO discipline	Mental models, Systems thinking
LO dimension	Empower people towards a collective vision
LO perspective	Learning structure
Learning Level	Organizational

Table 58 Deliverable Evolution between Projects Measure

Name	Deliverable Evolution between Projects
Short name	KEvol3 / DEP
Major process area	Passing Knowledge
Core process	Knowledge Evolution
Detail	Count the number of deliverable templates used and count the number of edited deliverable templates before being used in the next project
Measurement scale	Ratio
Measurement focus	Internal
Measurement method	Objective
Inputs	Document Templates, Document Version History, Software Project Plan
Measurement formula	$= \frac{\text{Number of edited deliverable templates before being used in the next project}}{\text{Number of deliverable templates used}} \times 100$
Interpretation	The closer to 100% the higher the level of deliverable evolution between projects
Knowledge dimension	– Knowledge refinement → Refined knowledge
Knowledge type	Explicit
Knowledge location	Artifacts
Assessed OV	Open-mindedness
Level of OL	Higher-level
OL loop	Double-loop
Individual learning	Conceptual
OL measure	Reflective activity, Tolerance
LO discipline	Mental models, Systems thinking
LO dimension	Empower people towards a collective vision
LO perspective	Learning structure
Learning Level	Organizational

Table 59 presents a list of the inputs that each defined generic measure requires in order to be calculated. It should be noted though that these inputs are developed only for the generic model discussed above. These inputs may have to be revised according to appropriateness and availability when evaluation is being carried out in a specific organizational setting.

Table 59 Inputs of the Generic Measures

Inputs / Measures	Deliverables	Software Project Plan	Training Plan	Questionnaires	Interviews	Meeting Minutes	Software Artifacts	Review Minutes	Patents, Licenses, Studies	Publications	Guidelines	Document Ver. History	Document Templates	Tests	Project Tools
KId1 / IT		√	√												
KId2 / TCI		√		√											
KId3 / DCI	√	√		√											
KId4 / ITP		√	√												
KAcq1 / ET		√	√												
KAcq2 / UEC				√											
KAcq3 / TT		√	√												
KAcq4 / UED		√		√											
KAcq5 / ETP		√	√												
KDev1 / CID				√		√									
KDev2 / CIE				√		√									
KOrg1 / HDL	√														
KOrg2 / VDL	√														
KDis1 / IMM						√					√				
KDis2 / AM		√				√									
KDis3 / LM		√				√									
KDis4 / MDE						√									
KDis5 / MP						√									
KPub1 / IDG					√						√				
KPub2 / EDG					√						√				
KPub3 / AP					√					√					
KUse1 / CIA				√		√									
KUse2 / DQ	√				√		√								
KUse3 / MFE						√									
KInt1 / TDP		√			√										
KInt2 / DDP	√	√			√										
KInt3 / DC	√							√							
KPD1 / KEA				√	√									√	
KPD2 / TDT		√		√	√										
KPD3 / DDT	√	√		√	√										
KPD4 / KPTU		√		√	√										√
KPD5 / KPTE		√		√	√										√
KEval1 / VI				√	√										
KSel1 / SD									√						
KSel2 / ST											√		√		
KSel3 / TG		√	√	√	√										
KEvol1 / GEP											√	√			
KEvol2 / TEP		√									√	√			
KEvol3 / DEP		√										√	√		

4.5. Applying the Measures of the AiOLoS Model

Although the AiOLoS measures proposed in Section 4.4 have been constructed specifically focusing on software development organizations and using possible goals of such organizations at the GQM process, not all measures may be applicable to all software organizations. This may be due to several reasons:

- The organizational activity related to that measure is not conducted in the organization
- Even though the measure related activity is conducted, the organization may not be keeping or recording the measure data
- The recorded data are partial, thus not allowing the calculation of the measure
- The measure is calculated, however there is no other relevant data to be compared to (from other organizations/teams, from other phases, from benchmarking)

For any AiOLoS measure that is non-applicable (NA), the organization or the assessor can undertake three actions:

a) the measure can be eliminated from the assessment process
b) the measure can be adjusted to meet the data that is actually gathered or recorded from the organization
c) A new measure for the measured core process can be proposed based on the data at hand

In all three case studies provided in Chapter 5, several measures have been considered NA and were eliminated without being assessed. However, in Case Study A – The Classroom Experience as the development process and teams were manageable through the assessor, the measures were adjusted according to the specifications of the teams.

The adjustment of the measures, the proposal of new measures or the elimination of a measure by the assessor is a structured process and is given in Figure 9 as a flowchart. This decision process has been utilized in the adjustment or elimination of the measures in all three case studies in Chapter 5.

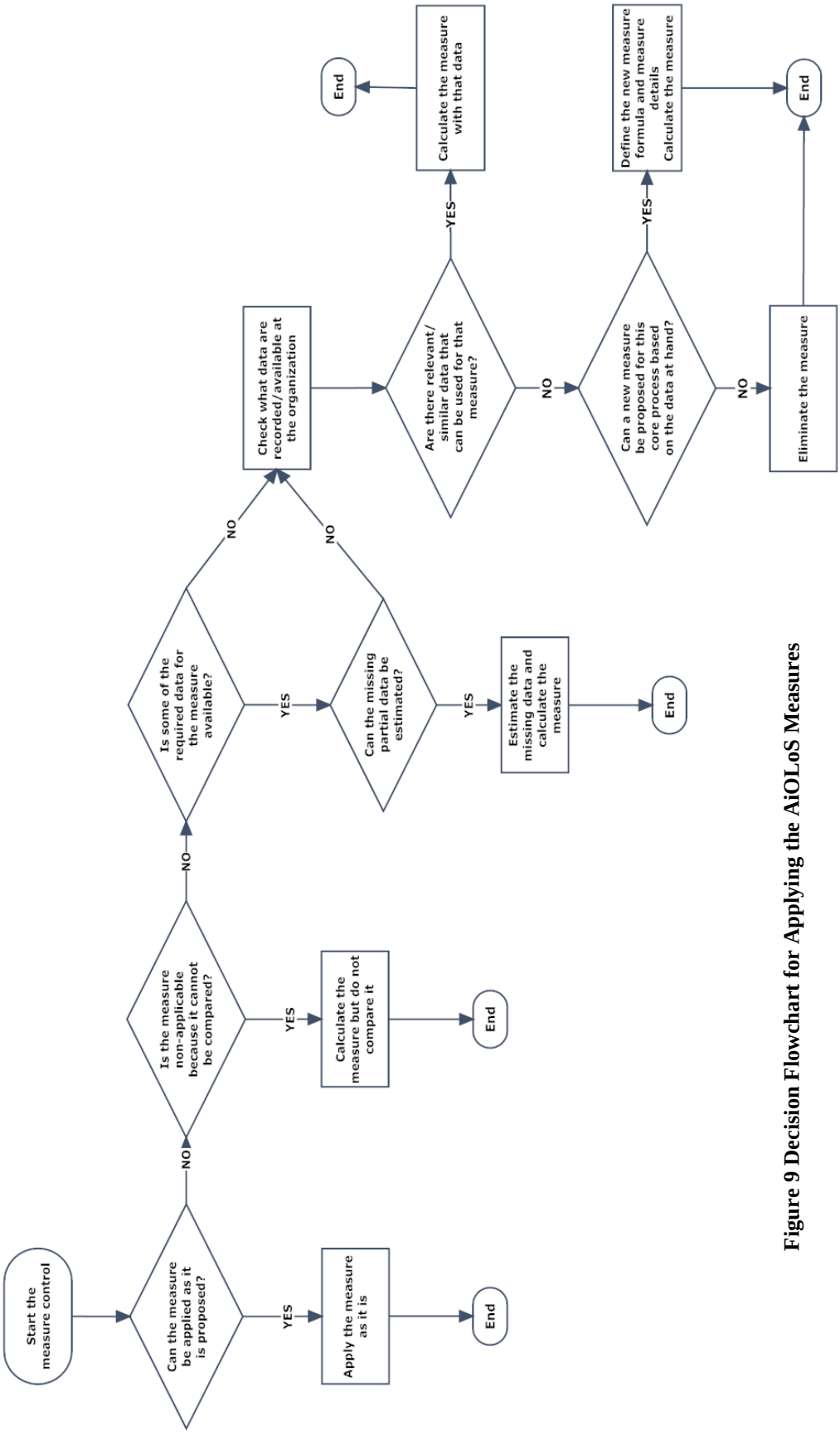

Figure 9 Decision Flowchart for Applying the AiOLoS Measures

All measures can be used in all four conduct modes of AiOLoS, as the formulas can be adjusted a) to compare phases with each other, b) to compare assessed entities such teams or organizations with each other, and c) for measurement against a benchmark value. When all three case studies given in Chapter 5 are summed, it can be seen that all measures have been utilized, but not all in every single case study. The reason for that is not the conduction mode but the lack of appropriate data to be used in the measurement.

However, as described in Chapter 5, the gathering and mining of the data for AiOLoS assessment can be a laborious and time-consuming process. In order to expedite the collection of the required data, a list of techniques is given in Table 60, together with the measures that these techniques will affect.

Table 60 Measurement Collection Techniques

Measurement Collection Technique	**Measure**
Collect timely and detailed training reports and clearly state: – How it is related to the conducted job and assessed entity – Is it internal or external – Who is participating – Who are the trainers/tutors – Duration – The covered topics – Number of given trainings	KId1 KId4 KAcq1 KAcq3 KAcq5 KSel3
Require the employees to manage a "conducted tasks" list that is updated synchronously and timely after the conclusion of any task conducted by the assessed entity, clearly stating: – The required knowledge to conduct this task and whether it is internal or external – How tasks from previous phases change between phases – Whether they are different from guidelines – Whether tasks change/evolve between projects	KId2 KInt1 KPD2 KEvol2
Require the employees to manage a "completed document sections" list that is updated synchronously and timely after the conclusion of any document section prepared by the assessed entity, clearly stating: – The required knowledge to prepare this document section and whether it is internal or external – The references from this document to other documents in the same phase or previous phases – How document sections from previous phases change between phases – Whether they are different from templates – Whether documents change/evolve between projects	KId3 KOrg1 KOrg2 KInt2 KPD3 KEvol3

(Table 60 continues on next page)

(Table 60 continues from previous page)

Measurement Collection Technique	**Measure**
Require the employees to keep a track of the exchanged information messages by the assessed entity, clearly stating: – Who the message was sent to or from, either upper management, or external entities – Whether the response was helpful or not	KAcq2 KDis1
Require the employees to keep a track of the utilized and developed documents clearly stating: – Whether they are internal to external – Whether they are internally developed and distributed guidelines – Whether they are internally developed but externally distributed guidelines or given to external organizations guidelines/templates – The number of publications in academic terms – The number of patents/licenses/studies developed – Whether guidelines change/evolve between projects	KAcq4 KPub1 KPub2 KPub3 KSel1 KSel2 KEvol1
Require the employees to keep a track of the creative ideas they develop, clearly stating: – Number of creative ideas developed – Number of creative ideas considered to be applicable – Number of creative ideas actually utilized	KDev1 KDev2 KUse1
Require the employees to keep a track of the meetings held, clearly stating: – Length of each meeting – Personnel attending to each meeting – Number of topics/issues raised in each meeting – Number of topics/issues discussed in each meeting – Number of resolved issues in each meeting	KDis2 KDis3 KDis4 KDis5 KUse3
Perform periodic quality valuations and defect measurements on developed software artifacts, clearly stating: – The quality value as perceived of the artifact valuated – Corrected defects	KUse2 KInt3
Perform periodic tests to employees, to assess their knowledge level and whether they can valuate the knowledge items they should have acquired, clearly stating: – The scores each employee scores in a specific knowledge area – The knowledge items an employee can valuate	KPD1 KEval1
Assess and evaluate the knowledge preservation/storing/archiving tools utilized, clearly stating: – The number of these tools at each phase – The amount of knowledge items stored in these tools – The amount of knowledge items not stored in these tools	KPD4 KPD5

4.5.1. Normalization of the AiOLoS Model Measures

In order to achieve comparability, a normalization process can be undertaken for several measures. Based on the composition specificities of the assessed organizational entities such as number of team members, some of the proposed measures can be divided by the number of team members in order to obtain per person measures. Each measure in Section 4.4 is defined in generic terms and is not normalized per person. However, the organization or the assessor can redefine the proposed generic measure formula if required. Such redefinitions of the measurement formula were undertaken in all three case studies for some measures, when necessary, and the details of obtaining per person measures are given in sections 5.1.2.1, 5.2.2.1, and 5.3.2.1 respectively. Moreover, it is important to pinpoint that not all measures of the AiOLoS model shall be meaningful on a per-person basis. The organization or assessor should evaluate whether the assessment process requires such a modification of the calculation formula and whether normalization would be revelatory.

Moreover, to allow comparability between measures, AiOLoS requires the conversion of each obtained metric to a proportion of the upper bound value that the respective measure has. For those measures for which there is no upper bound, the maximum observed value among the assessed entities or phases can be accepted as the upper bound. Examples of this upper bound conversion are given in all three case studies for several measures.

The normalization process can require the adjustment of measures based on a coefficient that will allow the comparison of assessed entities and phases. In this study it is proposed that the effort spent by the assessed entities in each assessed phase is an appropriate coefficient for such a normalization process and it has been utilized in all three case studies. However, different size related approaches can also be used for normalization.

CHAPTER 5

CASE STUDIES

"Thought and theory must precede all action that moves to salutary purposes.
Yet action is nobler in itself than either thought or theory."

(William Wordsworth)

In Chapter 2 and 3 we surveyed in detail the related literature on OL, LOs and KM, and in Chapter 4 we introduced AiOLoS, a model to assess the OL capabilities of software development organizations, which has been developed based on the aforementioned literature. The authors in [77], [87] and [35] argue that the need to validate OL, LO and KM models and approaches with the use of rich empirical studies, is urgent. On the other hand Glass, Ramesh and Vessey [139] have found in 2004 that empirical studies constitute about 5% of published research in software engineering as a whole. Due to the nature and properties of the proposed AiOLoS model, but also in accordance with the fact that the contributions of empirical studies in software engineering are continuously increasing [11], case studies have been utilized for the investigation and validation of the AiOLoS model. Within the perspective and goals of this research three different case studies, specifically field studies, were conducted in three different environments, each one of them using a different conduct approach of the AiOLoS model. We have selected

surveying as our research method since our research presents "who", "what", "where", "how many" and "how much" questions to understand and assess the OL capabilities of organizations. The behavioral nature of the assessment and the difficulties of observing results in an experimental setting prevent the utilization of other methods that are required to modify the behavior that is being investigated.

In summary, **Case Study A** has been conducted utilizing the **hybrid assessment mode** on **three teams** within a specially constructed **software engineering course** environment. It was an exploratory case study, conducted in order to have insight about the strengths and weaknesses of the preliminary model, to seek new insights and to develop new hypotheses and ideas [11]. The case study was formulated and conducted by means of action research methodology, using a classroom environment consisting of both undergraduate and graduate students, modeled according to the CSCI577ab course [12]. The aim of the action research approach was to both influence and change the way students were developing software and learning from the development process, but also to influence and change the AiOLoS model processes and measures [11].

Case Study B has been conducted utilizing the **horizontal assessment mode** on a **single team** within a **public sector** software development organization, and finally **Case Study C** has been conducted utilizing the **vertical assessment mode** on **three teams** within a **private sector** software development organization. Both case studies basically formulated as *descriptive* case studies in order to portray the OL aspects of these four different project groups, but also in an *improving* mode in order to find the OL shortcomings and improvement areas [11]. The research methodology in both case studies was surveying, as information and data were collected from a specific population without manipulating any variables or changing the model or the way things are being conducted in the project groups [11]. The major aims of these two case studies were to: a) demonstrate that the AiOLoS model can be employed in professional software development organizations, and b) understand whether the findings of the AiOLoS model can be actually used for SPI.

5.1. Case Study A – The Classroom Experience

5.1.1. Description of Case Study A Environment

The first case study, namely Case Study A, has been conducted to validate the proposed AiOLoS model and measures in the context of a one semester software engineering course, İST478, offered in the Department of Statistics and Computer Science, Başkent University, Turkey. 15 undergraduate and 4 graduate level students were enrolled in İST478 in which 4 software development groups were formed, with each graduate student assigned as a team leader (project manager) to each group. In order to achieve fairness in the workload, each group was assigned the development of systems similar in size and context, but with significant requirement and development differences[44].

The course followed a customization of the outline provided by CSCI577ab Software Engineering [12], a graduate software engineering course at University of Southern California, being offered since 1996. CSCI577ab focuses on software plans, processes, requirements, architectures, risk analysis, feasibility analysis, software product creation, integration, test, and maintenance with an emphasis on quality software production [140]. Moreover, CSCI577ab has been used as an experimental test-bed to deploy various research tools and approaches for validation of new methods and tools, leading to twelve PhD dissertations until 2008. İST478 followed the Incremental Commitment Spiral Model (ICSM) [141] [142], a new generation process model developed specifically for CSCI577ab and the architected agile approach for software development. İST478 covered the full system development life cycle of ICSM, which consisted of the Exploration phase, Valuation phase, Foundations phase, Development phase, and Operation phase. The deliverable deadlines and the items to be delivered for each of these phases were predefined. The tasks and artifacts to be developed by the students in İST478 were based to specific templates and they were described in detail in the Incremental Commitment Spiral process model – Electronic Process Guide (ICSM-EPG) [143].

[44] Specifically, each group was assigned the development of a score tracking software respectively for chess, tennis, basketball and football.

Table 61 provides the list of conducted phases, the dates and the artifacts delivered by groups in each phase.

Table 61 İST478 Course Outline

Phase	#	Dates	Deliverable	Artifact
Exploration	1	29.02.12 - 07.03.12	Customer Interaction Package	Customer Interaction Report
Valuation	2	08.03.12 - 21.03.12	Valuation Commitment Package	Customer Interaction Package +
				Life Cycle Plan
				Operational Concept Description
				Feasibility Evidence Description
Foundation	3	22.03.12 - 11.04.12	Foundation Commitment Package	Valuation Commitment Package +
				System and Software Architecture Description
				System and Software Requirements Description
				Prototype Report
				Supporting Information Document
Development	4	12.04.12 - 02.05.12	Development Commitment Package	Foundation Commitment Package +
				Quality Management Plan
				Acceptance Test Plan and Cases
				Iteration Plan
Transition	5	03.05.12 - 24.05.12	Transition Readiness Package	Development Commitment Package +
				Iteration Assessment Report
				Training Plan
				User Manual
				Transition Plan
				Test Procedures and Results
				Functioning product

5.1.2. Administration of Case Study A

In order to control whether the AiOLoS model assesses the difference of OL capabilities between different groups, two of the groups were assigned a differentiated development method, SQ4R [144], based on critical thinking, to enhance their OL experience. The two groups implementing SQ4R were provided with prior knowledge of the phase they were conducting, the artifacts they were expected to develop and the deliverables to submit. During SQ4R, before working on and developing the deliverable, the students were given the deliverable name and

were asked to conduct a small “survey” on the subject. After the survey, the team members were asked to write a brief reflection paper where they “questioned” and discussed why they thought the phase and the related deliverables are of importance for the software development process. Then all teams were given the guidelines and templates of the deliverables to be developed. The teams, while developing the deliverables, “read” the documents provided by the instructor and team members would “recite” to each other what they have understood on the material provided by the instructor. After the submission of the deliverable, the members of the teams conducting SQ4R would conduct a “review” session with the instructor where they discussed their understanding of the process they have concluded/undertaken and the deliverable they have submitted. Finally they would write a closure paper, where they discussed what they have done, if they have understood it, what were their initial thoughts and final thoughts on the process, if they would change some or all parts of the deliverable or process, and their final comments/proposals. Figure 10 depicts the SQ4R approach which was undertaken by two randomly assigned groups (namely Group 2 and Group 3) in all five phases of the software development lifecycle of İST478 course.

Figure 10 The Undertaken SQ4R Approach

In order to assess the OL capabilities of each team during the lifetime of the corresponding developed project, the core processes in Table 18 have been investigated with respect to their applicability to the course structure and specifications. Out of the 39 proposed measures in AiOLoS model, 25 of them have been considered applicable, have been converted to metrics and have been actually

assessed in Case Study A. The 14 NA generic measures have been eliminated and therefore have not been assessed. Moreover, the generic measures proposed have been refined with respect to course characteristics, the artifacts produced and the deliverables developed by the project groups, and the generic measures have been transformed into actual metrics. Table 62 provides the core process areas that have been measured, the actual metrics used in order to measure them, and the NA measures.

The conduct mode utilized in Case Study A has been the hybrid approach, where the OL capabilities of each team have been compared with each other within different reciprocal phases of the undertaken ICSM life cycle, given in Table 61. The applied metrics of Case Study A are provided in [145], including the description of the applied metric in the case study, considering each project group as a development team within the same organization. The NA generic measures are not described in [145] as they were not assessed in the case study. The measurement inputs do differ from the generic measures because several input documents (such as Software Project Plan and Training Plan) were not available at the early stages of the case study, therefore the necessary data was collected primarily with the use of questionnaires. Moreover, in order to avoid inconsistencies or errors of comprehension, after the submission of each questionnaire exit interviews were conducted with each student to validate the submitted data. The evaluation period of the measures has been identified as the development phases given in Table 61. The measures were calculated and assessed at the end of each of the five predefined phases in Table 61, therefore the explanation of each measure in [145] is given according to the phase calculation of the measure. As the groups were of varying sizes, in order to achieve comparability several measures were calculated as per person by dividing the obtained result by number of team members. These measures are pointed accordingly in the description of the applied measure. One of the measures, KPD1 was assessed twice using two different approaches, which both are discussed accordingly in [145].

Table 62 Core Process Areas, Generic Measures and Corresponding Metrics in Case Study A

Core Processes	Generic Measure	Metrics (Measures Applied as)
Knowledge Identification	KId1	Percentage of internally trained personnel
	KId2	Percentage of completed tasks with existing knowledge
	KId3	Percentage of completed document sections with existing knowledge
	KId4	NA
Knowledge Acquisition	KAcq1	Percentage of externally trained personnel Hours of external training
	KAcq2	Percentage of helpful external messages (email/face-to-face/forums)
	KAcq3	Number of trained topics
	KAcq4	Number of utilized external documents
	KAcq5	NA
Knowledge Development	KDev1	Number of developed creative ideas
	KDev2	Percentage of accepted creative ideas
Knowledge Organization	KOrg1	Number of references from documents to documents on the same phase
	KOrg2	Number of references from documents to documents throughout the project
Knowledge Dissemination (Sharing)	KDis1	Number of push information messages from management
	KDis2	Number of meetings
	KDis3	Length of meetings in hours
	KDis4	Percentage of topics discussed in meetings to topics raised in meetings
	KDis5	NA
Knowledge Publication	KPub1	NA
	KPub2	NA
	KPub3	NA
Knowledge Usage (application)	KUse1	Percentage of applied creative ideas to total creative ideas
	KUse2	Grades of submitted deliverables
	KUse3	Percentage of topics resolved in meetings to topics discussed in meetings
Knowledge Integration	KInt1	Percentage of differently conducted tasks
	KInt2	Percentage of differently developed deliverables
	KInt3	Percentage of done corrections to determined defects
Knowledge Preservation and Deleting	KPD1	Exam results within phase Exam results overall project
	KPD2	Percentage of tasks done different from templates
	KPD3	Percentage of deliverables developed different from templates
	KPD4	NA
	KPD5	NA
Knowledge Evaluation	KEval1	Percentage of valuated knowledge items to total knowledge items
Knowledge Selling	KSel1	NA
	KSel2	NA
	KSel3	NA
Knowledge Evolution	KEvol1	NA
	KEvol2	NA
	KEvol3	NA

In order to measure the metrics provided in Table 62, several evaluation and assessment techniques have been utilized. After the end of each phase, the students were given individual questionnaires which consisted of approximately 40 questions (the number and content of questions varied with respect to the characteristics of each phase) and a template to submit the meeting minutes. A sample questionnaire is given in Appendix A1 and a sample meeting minute template in Appendix A2. Students were asked to fill and submit them electronically. After the processing of the questionnaires an exit interview was conducted with each group and the results of the questionnaires were discussed with the members, thus resolving any inconsistencies or anomalies on the submitted data. Each student submitted 5 questionnaires. The times required for filling and submitting each questionnaire are given in Table 63. The average time for filling a single questionnaire is calculated as 17.4 mins and the median as 15 mins. The average time for processing a single questionnaire is calculated as 35 mins.

Table 63 Questionnaire Filling and Submitting Times (in mins) of Students

		Students														
		S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**
Phases	**CIR**	15	25	5	30	10	30	15	5	15	20	25	25	15	5	30
	VCP	30	5	15	25	10	20	15	7	20	15	20	25	20	10	30
	FCP	15	10	20	20	10	15	15	5	15	10	10	15	20	10	30
	DCP	30	10	25	30	10	25	15	10	20	15	25	20	20	10	30
	TCP	50	15	15	10	10	10	15	15	20	10	15	15	20	5	30

From Phase 2 and onwards the students would undertake an in-class close-book/close-notes group based examination to measure the amount of preserved knowledge within the group (KPD1). Each exam consisted of 2 parts: the first part was used to measure the preservation of a single knowledge item throughout the project lifecycle. The second part was used to measure the preservation of another knowledge item but only within the period of a given phase. The groups undertook 7 exams and each exam were constructed to last 60 minutes. The groups spent 52

minutes in average to finish a single exam, and in average a single exam paper was graded in 20 minutes. Finally, as another measurement method the submitted documents of the groups were graded to assess the product quality of the deliverables (KUse2), but also to identify the defects in these documents and the ratio of defect removal by the groups (KInt3). Grading of each document deliverable required 18.8 minutes in average. Each of the 7 exams is given in Appendix A3.

During the course period one of the groups (namely Group 4), submitted no acceptable documents and deliverables, thus metrics were collected only from the remaining 3 groups.

5.1.2.1. Normalization of Obtained Metrics

As the groups consisted of different number of members, in order to achieve the comparability of the obtained measurements, a normalization process has been undertaken for several metrics. The appropriate metrics[45] have been divided to the number of team members in order to obtain measure per person. Moreover, all measured values have been converted to a proportion of the upper bound value that the respective metric has. For these metrics for which there is no upper bound, the maximum observed value between the four groups has been accepted as the upper bound. The normalization process was finalized by multiplying each metric to the Phase Coefficient (PC), which is the ratio of the phase effort to total effort.

5.1.3. Results of Case Study A

In Table 64 the metrics obtained from these three groups after the conclusion of each phase are shown. The graphical representation of the results of Table 64 is given in Figure 11, where the results are not distributed into phases but are assessed for the whole project. Furthermore, in order to visualize the improvement of OL in each group, to identify the weak core process areas and to compare the groups with each other, the OL capability progress footprint of each group with respect to the development phases has been drawn. Figure 12, Figure 13 and Figure 14 display the OL progress of each group with respect to the measured key process areas.

[45] KAcq3, KDev1, and KDis1

Between these three groups, only Group 1 has not undertaken the SQ4R approach. Analyzing the footprints briefly, it can be seen that Group 1 scores low in knowledge identification, knowledge organization, knowledge integration and knowledge preservation. On the other hand Group 2 scores low almost in all key processes, except knowledge acquisition and knowledge integration. Group 3 also scores low in knowledge identification and knowledge integration. As the majority of the students in these groups are undergraduate students and thus have no professional software engineering development practice experience or relative knowledge, we were expecting low scores in the key process area of knowledge identification and knowledge development, but higher in knowledge acquisition. The results of Group 2 can be justified by the fact that a communication problem between group members was detected during the exit interviews. On the other hand Group 1 has scored high due to the high cohesion between its group members. The high scores of Group 3 we believe have resulted from the SQ4R approach that allowed the group members to build a commitment towards the software development process.

Table 64 Case Study A - Obtained Normalized Metrics for the Specific Core Processes from Each Group in Each Development Phase

	Group1					Group2					Group3				
	Phases					Phases					Phases				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
PC	**8,0**	**35,7**	**29,2**	**14,9**	**12,2**	**9,3**	**28,5**	**28,5**	**16,0**	**17,8**	**10,0**	**40,5**	**23,3**	**14,9**	**11,2**
KId1	2,0	19,8	27,2	30,9	33,9	3,7	9,4	9,4	9,4	9,4	0,0	33,8	45,4	50,4	50,4
KId2	3,8	27,7	48,9	53,4	54,4	6,2	20,4	31,8	34,1	36,1	1,7	25,8	40,1	44,3	47,2
KId3	3,7	23,6	30,0	31,2	33,2	2,9	17,1	27,4	32,3	36,9	0,5	26,9	36,6	43,0	46,6
KAcq1	6,0	23,8	38,4	49,6	49,6	3,7	9,4	9,4	15,8	15,8	1,7	22,0	37,5	52,4	54,2
KAcq2	8,0	21,7	43,6	54,0	63,8	9,3	28,2	51,9	63,0	71,9	10,0	44,5	61,3	74,5	84,0
KAcq3	8,0	30,1	57,9	72,8	85,0	1,1	11,6	27,2	32,8	36,2	0,0	40,5	63,8	74,9	75,6
KAcq4	8,0	43,7	72,9	87,8	96,0	5,9	30,0	38,9	42,1	59,9	0,0	19,1	29,6	38,2	44,7
KDev1	8,0	15,1	44,3	59,2	71,4	0,0	28,5	28,5	28,5	28,5	2,5	10,6	12,6	17,5	17,5
KDev2	8,0	25,8	47,7	62,6	74,8	0,0	0,0	0,0	0,0	0,0	10,0	50,6	73,9	88,8	88,8
KOrg1	0,0	10,2	39,4	46,0	47,8	0,0	12,2	14,4	18,4	19,3	0,0	40,5	60,3	75,1	86,4
KOrg2	0,0	35,7	46,3	61,2	67,3	0,0	28,5	33,6	40,7	49,6	0,0	40,5	63,8	77,0	88,2
KDis1	8,0	43,7	72,9	87,8	100,0	3,1	13,0	20,9	29,3	34,5	1,7	36,8	56,5	61,0	62,9
KDis2	8,0	43,7	72,9	72,9	72,9	2,5	11,6	24,6	31,0	41,8	4,5	42,3	55,6	70,5	81,7
KDis3	8,0	19,6	40,1	40,1	40,1	0,5	9,6	38,1	50,9	68,7	0,9	41,4	59,6	74,5	80,7
KDis4	8,0	43,7	72,9	72,9	72,9	9,3	37,7	66,2	66,2	84,0	10,0	47,7	71,0	81,9	89,4
KUse1	8,0	25,8	47,7	62,6	74,8	0,0	0,0	0,0	0,0	0,0	10,0	50,6	73,9	88,8	88,8
KUse2	8,0	41,0	62,7	71,2	78,8	9,0	37,3	54,7	64,2	74,9	9,8	49,7	67,1	78,9	88,0
KUse3	8,0	43,7	68,0	68,0	68,0	0,0	0,0	28,5	28,5	46,3	10,0	50,6	73,9	88,8	100,0
KInt1	0,0	19,5	19,5	26,5	32,6	0,0	14,2	40,3	51,6	59,0	0,0	0,0	18,6	22,5	29,0
KInt2	0,0	17,9	32,1	45,0	48,1	0,0	28,5	39,9	55,0	67,4	0,0	40,5	52,2	63,0	67,9
KInt3	8,0	43,7	64,5	74,3	79,2	9,3	9,3	28,2	35,0	38,0	10,0	10,0	14,7	23,2	32,6
KPD1	0,0	28,6	57,8	72,7	81,8	0,0	28,5	56,9	67,5	85,3	0,0	40,5	63,8	63,8	75,1
KPD1	0,0	35,7	64,9	79,8	89,6	0,0	28,5	39,9	51,9	69,7	0,0	34,9	58,2	58,2	69,4
KPD2	3,0	34,8	38,4	49,2	60,1	0,8	6,0	6,0	11,8	11,8	1,7	15,6	34,5	43,2	48,2
KPD3	2,1	10,1	23,4	24,4	28,4	1,7	8,8	13,6	13,8	15,0	2,0	7,7	13,5	18,4	20,1
KEval1	2,6	25,4	53,6	67,2	76,8	4,6	26,8	35,1	49,8	64,8	5,6	25,2	40,9	55,5	66,7

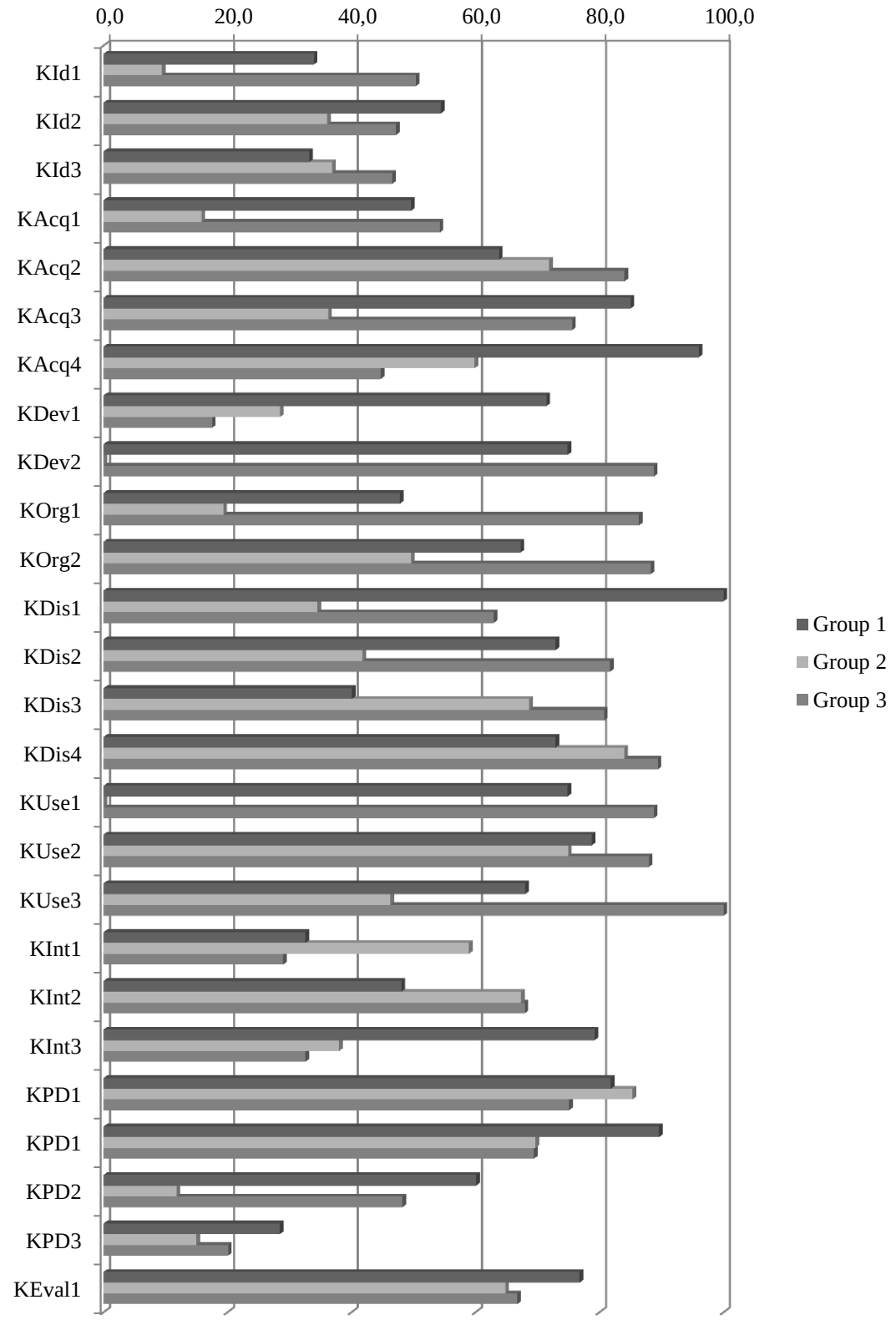

Figure 11 Case Study A - Bar Chart Representation of Adjusted Metric Results

As it can be seen from the footprints, with the use of appropriate and correct metrics, the organization can easily identify its weak learning process areas and thus develop a strategy to address and to provide a solution for these weaknesses. Although the metrics which have been used in Case Study A were coined from the generic proposed measures in order to meet the specific requirements of an in-class software development group, this has shown that if required, the proposed generic measures can be easily modified to match the needs of any software organization.

5.1.4. Expert Opinions for Case Study A

After the conclusion of Case Study A and the collection of data and measures, the team leaders (project managers) have been given a brief training regarding the developed AiOLoS model, its goals, the measurement process and the results and findings of the case study. As two of the four team leaders are actively employed in software industry and the other two actively employed in the IT industry they were asked to evaluate and assess the AiOLoS model and provide their expert opinions. The team leaders were asked four questions regarding the model and they submitted their results using a Likert Scale. The questions and the Likert scores of the answers are given in Table 65.

Table 65 Case Study A - Expert Opinion Questions and the Likert Scores of the Answers

Question	Fully	Mostly	Somewhat	Very Little	Not at all
Q1) Does the AiOLoS model measure the learning ability of a software organization?	2	1	1		
Q2) Do you think that the assessed learning ability can provide a competitive advantage to the organization?	3		1		
Q3) Does the conducted measurements and obtained footprints assess the learning ability of the groups?	1	3			
Q4) Can the learning ability assessed in the AiOLoS model be used for process improvement?	4				

The frequency of the results regarding the answers given in expert opinion questionnaires are: 2 out of 4 believe that the AiOLoS model **fully** measures the OL capability of a software organization (mode value being Fully, median value being 4,5 out of 5), 3 out of 4 believe that the assessed OL ability can **fully** provide a competitive advantage to the organization (mode value being Fully, median value being 5), 3 out of 4 believe that the conducted measurements and obtained footprints **mostl**y assess the OL ability of the development groups (mode value being Mostly, median value being 4) and finally 4 out of 4 believe that the OL ability assessed in the AiOLoS model can be **fully** used in SPI (mode value being Fully, median value being 5).

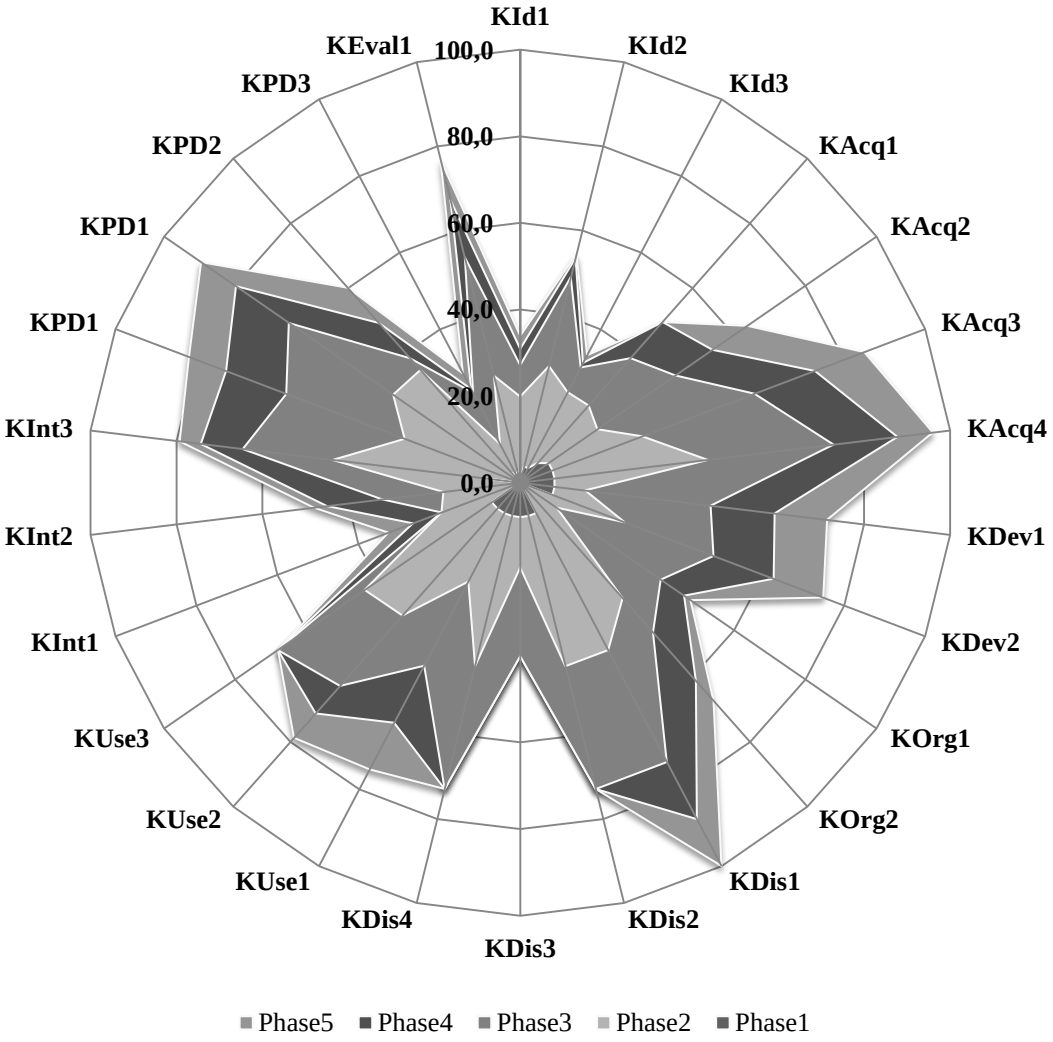

Figure 12 Case Study A - The OL Footprint of Group 1

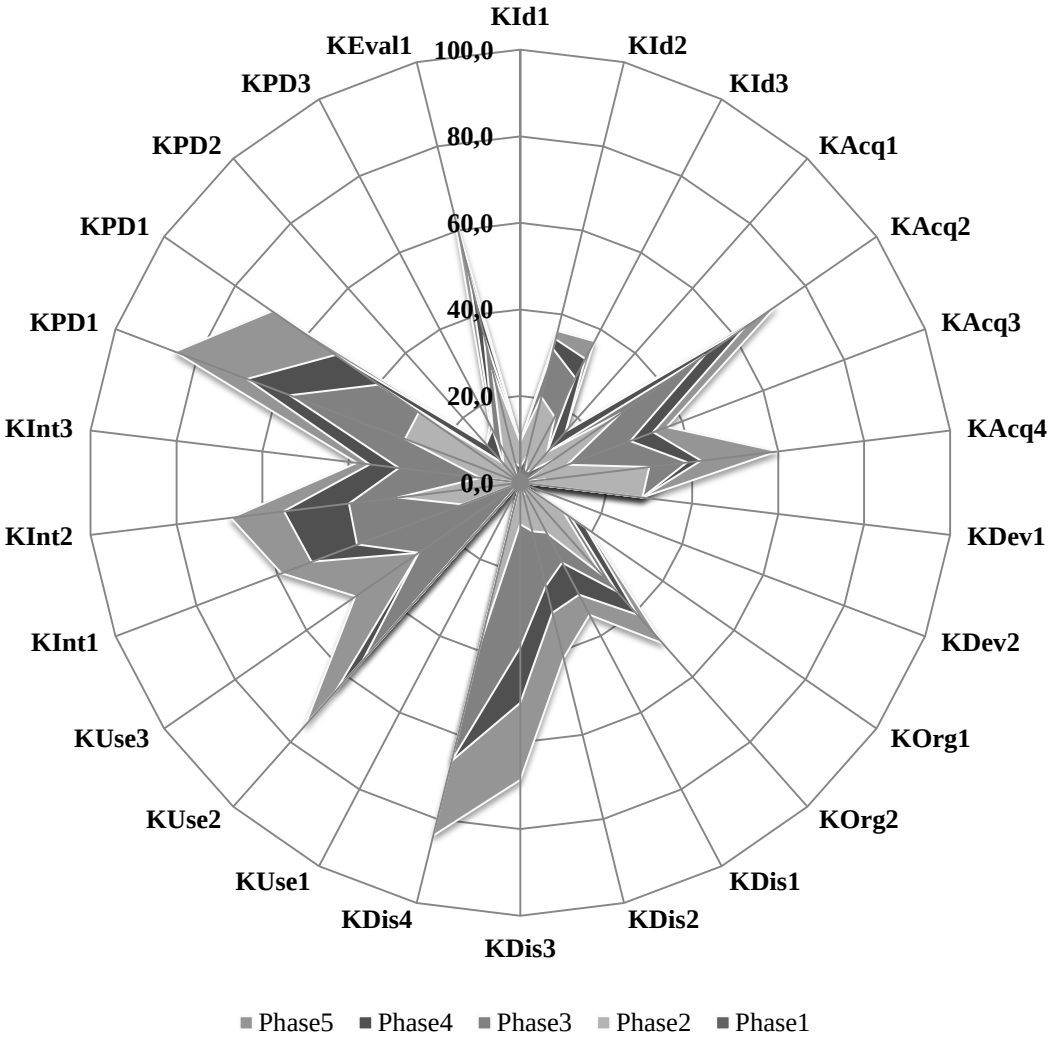

Figure 13 Case Study A - The OL Footprint of Group 2

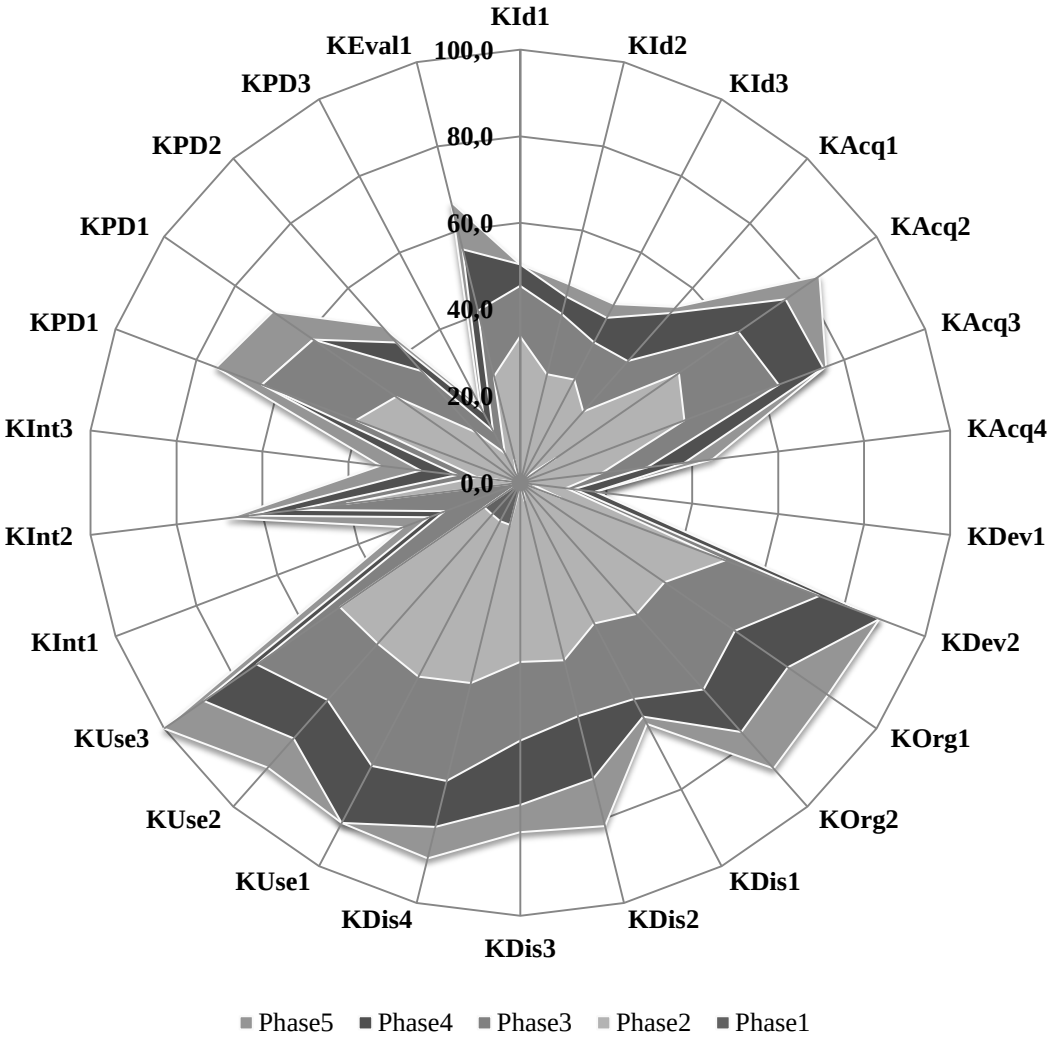

Figure 14 Case Study A - The OL Footprint of Group 3

5.2. Case Study B – A Public Sector Organization

5.2.1. Description of Case Study B Environment

Case Study B has been undertaken in the Middle East Technical University Computer Center (METU-CC), in Ankara, Turkey, with the aim of assessing the OL capabilities of the team working on the development of Integrated Information System[46] (BBS).

As Middle East Technical University (METU) is a public technical university in Turkey, METU-CC is an organization operating in the public domain. The mission of the METU-CC, as stated by the organization itself[47], is to provide information technologies (IT) services and the needed support, consultancy and training to do with these services which are required for the education, instruction, research and development, social duty, scientific activities as well as administrative and managerial functions of METU, to take an important role in the structuring of IT policies and strategies of METU; to be involved in research and development, and to devise national and international projects and institutional collaborations and organizational ventures and contributing to already existing formations be of guidance to them. METU-CC, although never assessed, shows indicators of being a CMM 1 level organization with respect to its organizational and software development maturity. The organizational structure of METU-CC is given in Figure 15. With the support of the METU-CC upper management, a case study was conducted in METU-CC to assess the OL capabilities of the METU-CC team working on the development of BBS.

[46] Bütünleşik Bilgi Sistemi
[47] http://www.cc.metu.edu.tr/296-1-mission-amp-vision

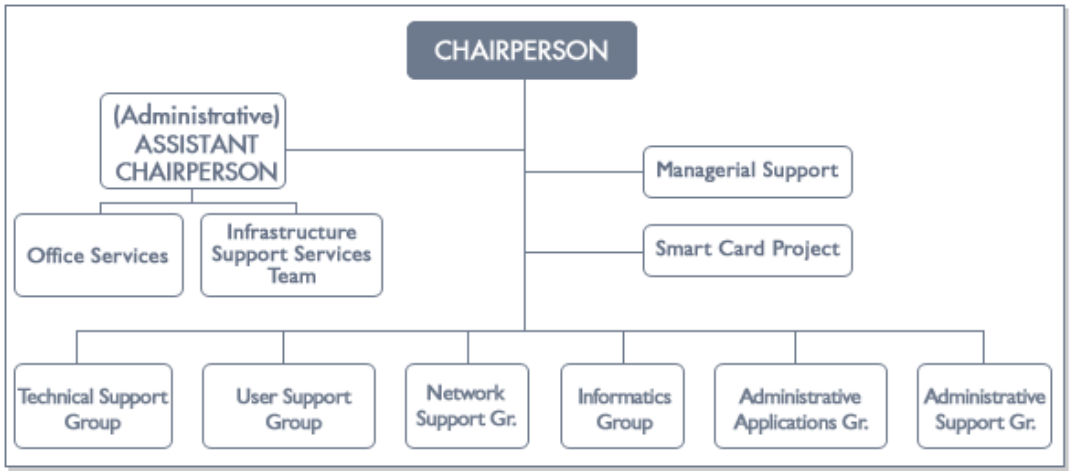

Figure 15 Organizational Structure of METU-CC[48]

BBS[49], which started on 2009, is an ongoing IT project, developed under METU-CC, to unify and integrate all existing individual IT systems and services in METU, with the aim of increasing the efficiency and user satisfaction in the processes of education, research and administration in METU. The integration process is being conducted in accordance with the strategic goals of METU. The main principles of BBS are to provide IT services that are "user centered" and in accordance to "strategic goals" of METU, and guaranteeing the agreed upon "quality requirements". Although METU-CC is familiar with the development of software and IT projects, the BBS project with respect to its size, complexity and nature is a "terra incognita" to METU-CC.

Three different groups are participating actively in the development of BBS, as depicted in Figure 16. These groups are:

- The "*METU-CC BBS Team*", an assembly of METU-CC employees from different groups that are given in Figure 15, contributing to BBS based on their existing skills and expertise, with the main responsibility of

[48] http://www.cc.metu.edu.tr/319-2-organizational-structure
[49] http://bbs.metu.edu.tr/

identifying the requirements of BBS based on the information gathered from university units, namely:

  - Academic units
  - Administrative units, and
  - Coordination committees.

- A group of "*consultants*" external to METU-CC, providing expertise, knowledge and guidance to the METU-CC BBS Team. The main consultants to BBS are TEKİM[50], which developed the University Generic Process Model by assessing the business processes of METU based on 5 main process areas, and Elif Yılal.
- The "*supplier company*", namely OYTEK[51], an external organization to METU-CC, having the main responsibility of developing the BBS code.

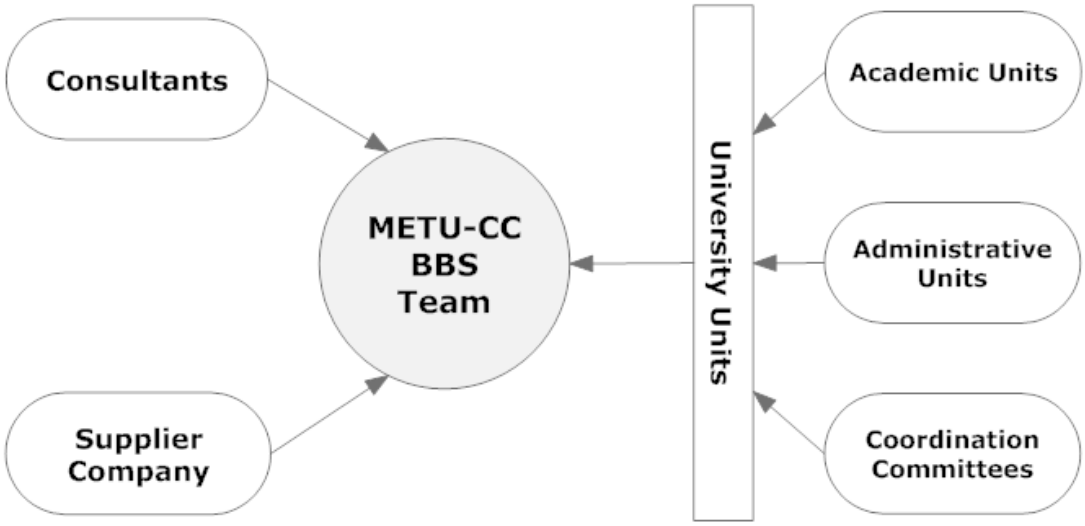

Figure 16 Parties Contributing to BBS

[50] http://tekim.com.tr/
[51] http://www.oytek.com.tr/

The supplier company and the consultants, although actively participating in the BBS development process, and the university units, even though they are providing the necessary data and information for the elicitation of BBS requirements, have been assumed as external entities with respect to the AiOLoS assessment process, as they are not organic part of METU-CC, and therefore they have not been assessed in the undertaken case study. Consequently, the only assessed entity is the METU-CC BBS Team.

The development process of BBS as applied so far in the project can be divided into four phases, as shown in Table 66, each phase consisting of different tasks and different number of personnel. In Phase 1, the Cobit and ITIL frameworks were investigated and work plan was devised. The eUniversity Management Information System Reference Model by TEKİM was adapted to be used in METU and based on this reference model a process maturity model analysis was conducted. As an output of this analysis the existing business processes within METU were identified, the current maturity level of METU was estimated, the goals to be achieved were put forth and a gap analysis was conducted. Following the gap analysis, the METU business processes were prioritized and the subsystems of BBS (namely BBS management subsystem, Process management subsystem, Data dictionary subsystem, Information security management subsystem and Information technologies subsystem) that make up the overall organizational structure of the BBS system to be developed were identified. In Phase 2 organizational trainings were conducted to deliver the outcomes of Phase 1 to the enlarged METU-CC BBS Team. BBS was defined and based on this definition the organization of BBS was designated and the related work assignments were conducted. Phase 3 and Phase 4 accordingly are the two outsourcing phases, where the Supplier Company started delivering the software components described by the METU-CC BBS Team.

5.2.2. Administration of Case Study B

Case Study B has not been conducted in a parallel and simultaneous fashion with the lifecycle of BBS project; instead the assessment has been realized using historical data from the BBS project, which data were accumulated over time in different documents and different project management software. The historical data

has been collected by the AiOLoS assessor with the help and guidance of program manager of BBS. The metric collection and assessment efforts are given in Table 67.

The period subject to the AiOLoS assessment was accepted as starting from 01.01.2009 and ending at 31.07.2012, thus spanning a period of 43 months. The actual assessment has been conducted between 01.07.2012 and 31.07.2012. The historical data assessed has been gathered primarily from the Feng Office[52] and Redmine[53] installations of METU-CC for the BBS project. An important elimination process was undertaken during the investigation of this historical data: as the members of METU-CC BBS Team are actively employed in other projects and duties within METU-CC, only data related to the BBS project has been used in the assessment process, all irrelevant data was discarded. The investigated items for the calculation of the metrics, their corresponding numbers and actual times of calculation (in man-hours) are given in Table 67.

Table 66 BBS Development Phases

Phase #	Dates	Phase Brief Description	Personnel #	Effort (in man/ months)
Phase 1	01.01.09 - 31.10.09	Process Maturity Assessment and Process Prioritization	6	6
Phase 2	01.11.09 - 31.05.11	Organizational Trainings, Definition of BBS, Organization of BBS and Work Assignments	44	308,75
Phase 3	01.06.11 - 31.07.12	Outsourcing I	46	203,5
Phase 4	01.06.12 - 31.07.12 [54]	Outsourcing II	44	44,55

[52] Feng Office is a web-based collaboration platform, allowing project management operations. The METU-CC installation of BBS Feng Office is accessible at https://www.bbs.metu.edu.tr/fengoffice

[53] Redmine is a web-based Project management and bug and issue tracking tool. The METU-CC installation of BBS Redmine is accessible at https://tracker.cc.metu.edu.tr/redmine

[54] The BBS project is an ongoing project and has not been completed yet. Therefore, this date denotes the end of the period that was assessed in Case Study B and not the actual end of Phase 4.

In order to assess the OL of the METU-CC BBS Team during this aforementioned period of the BBS project, the core processes in Table 18 were investigated with respect to their applicability to the METU-CC BBS Team and BBS project structures. Out of the 39 proposed measures in AiOLoS model, 30 of them have been considered applicable and were actually assessed in Case Study B. The 9 NA measures were eliminated and therefore were not assessed. The metrics (applied measures) of Case Study B and the NA measures are shown in Table 68.

Table 67 Items Used and Metric Collection and Processing Times in Case Study B

Item Type	Number of Investigated Items	Total Processing Time (in man-hours)
Tasks	310	6
External documents	264	4
Internal documents from previous projects	9	1
Guidelines	17	2
Templates	18	2
Developed documents	360	32
Meeting Minutes	189	48
Training Reports	63	3
Questionnaires	20	1

The conduct mode utilized in Case Study B was the horizontal assessment approach, where the OL capabilities of a single team, namely METU-CC BBS Team, have been assessed within the four different phases of the development process. The applied metrics of Case Study B are not differentiated from the proposed generic measures of the AiOLoS model; however, only 30 of these measures have been applied. The measurement inputs do differ from the generic measures because several input documents (such as Software Project Plan and Training Plan) were not

available when Case Study B was conducted; therefore the necessary data has been collected primarily with the use of different input documents and interviews. A single questionnaire has been conducted to METU-CC BBS Team members to measure the knowledge items and learning outcomes they can valuate, with respect to measure KEval1. The metrics KPD4, KPD5 and KEvol2 were gathered using interviews. Moreover, in order to avoid inconsistencies or errors of comprehension, after the gathering of data from different documents exit interviews were conducted with the appropriate project coordinators and upper management to validate the submitted data. The evaluation period of the measures has been identified as the start and end of the four development phases given in Table 66 and the metrics were calculated and assessed with respect to each of the four predefined phases in Table 66.

Table 68 Core Process Areas, Generic Measures and Corresponding Metrics in Case Study B

Core Processes	Generic Measure	Metrics (Measures Applied as)
Knowledge Identification	KId1	Internal Trainings
	KId2	Tasks Completed Internally
	KId3	Documents Completed Internally
	KId4	Internal Trainings Pervasion
Knowledge Acquisition	KAcq1	External Trainings
	KAcq2	NA
	KAcq3	Trained Topics
	KAcq4	Utilized External Documents
	KAcq5	External Trainings Pervasion
Knowledge Development	KDev1	NA
	KDev2	NA
Knowledge Organization	KOrg1	Horizontal Document Linking
	KOrg2	Vertical Document Linking
Knowledge Dissemination	KDis1	NA
	KDis2	Amount of Meetings
	KDis3	Length of Meetings
	KDis4	Meeting Discussion Efficiency
	KDis5	Meeting Pervasion Measure
Knowledge Publication	KPub1	Internally Distributed Guidelines
	KPub2	Externally Distributed Guidelines
	KPub3	Academic Publications
Knowledge Usage	KUse1	NA
	KUse2	Deliverable Quality
	KUse3	Meeting Functional Efficiency
Knowledge Integration	KInt1	Task Differentiation within Phases
	KInt2	Deliverable Differentiation within Phases
	KInt3	Deliverable Correction
Knowledge Preservation and Deleting	KPD1	NA
	KPD2	NA
	KPD3	Deliverable Differentiation from Templates
	KPD4	Knowledge Preservation Tool Usage
	KPD5	Knowledge Preservation Tool Efficiency
Knowledge Evaluation	KEval1	Valuated Items
Knowledge Selling	KSel1	Shared Documents
	KSel2	Shared Tasks
	KSel3	Trainings Given
Knowledge Evolution	KEvol1	NA
	KEvol2	Task Evolution between Projects
	KEvol3	NA

5.2.2.1. Normalization of Obtained Metrics

A normalization process has been undertaken for several metrics. All measured values have been converted to a proportion of the upper bound value that the respective metric has. For these metrics for which there is no upper bound[55], the maximum observed value between the four phases has been accepted as the upper bound. Furthermore, in order to adjust the phases with respect to their relevant size in the overall project, the effort spent in each phase was used as a coefficient. However, as no effort information is recorded about the METU-CC BBS Team regarding the BBS project, the effort information was gathered and calculated within the case study prior to the calculation of the AiOLoS metrics by conducting interviews and effort estimations with group leaders. The obtained effort values of each phase are given in Table 66. The normalization process was finalized by multiplying each metric to the Phase Coefficient (PC), which is the ratio of the phase effort to total effort.

5.2.3. Results of Case Study B

In Table 69 the metrics obtained from the METU-CC BBS Team after the conclusion of each phase are shown (the non-normalized metrics with respect to PC and the bar chart representation of these metrics are given in Appendix B1).

The graphical representation of the results of Table 69 is given in Figure 17, where the results are distributed into phases, displaying how much METU-CC BBS Team scores in any given metric at each phase. As expected the group scores respectively high in phases 2 and 3 as the effort-based size of these two phases is considerably very high. Furthermore, in order to visualize the improvement of OL in METU-CC BBS Team between phases, to identify the weak core process areas and to compare the phases with each other, the OL capability progress footprint of the METU-CC BBS Team with respect to the development phases has been drawn. Figure 18 displays the OL progress of METU-CC BBS Team within phases, with respect to the measured key process areas.

[55] KAcq3, KAcq4, KOrg1, KOrg2, KDis2, KDis3, KPub1, KPub3, KInt3, KPD4, KSel2, and KSel3

Table 69 Case Study B - Obtained Normalized Metrics for the Specific Core Processes from METU-CC BBS Team in Each Development Phase

	METU-CC BBS Team			
	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
PC	**1,06**	**54,86**	**36,15**	**7,92**
KId1	0	54,8645	11,78896	0
KId2	0	30,72412	33,91194	7,476677
KId3	0,355398	53,55821	36,15282	7,916482
KId4	0	54,8645	11,78896	0
KAcq1	0,710795	44,88914	24,36386	0,71968
KAcq3	0,253855	54,8645	18,07641	0,565463
KAcq4	0,125197	48,6299	35,05728	7,916482
KAcq5	0,266548	3,699198	2,357793	0,239893
KOrg1	1,066193	14,08462	0	0
KOrg2	0	54,8645	0	0
KDis2	0,110773	49,87682	36,15282	2,261852
KDis3	0,188044	54,8645	22,88028	2,206855
KDis4	1,066193	54,8645	36,15282	7,916482
KDis5	1,066193	10,98796	4,479482	1,30442
KPub1	0	54,8645	7,747033	0
KPub2	0	0	0	0
KPub3	0	54,8645	0	0
KUse2	0,93825	26,33496	15,90724	0
KUse3	1,041961	54,8645	36,15282	7,916482
KInt1	0	0	0,042648	0
KInt2	0	0	0,045191	0,017592
KInt3	1,066193	27,39503	5,197446	0,959574
KPD3	0,088849	11,23416	14,29298	0,879609
KPD4	0,177699	27,43225	36,15282	7,916482
KPD5	0,852954	36,57634	28,92226	6,333185
KEval1	1,012883163	40,61311504	24,94544647	5,429288475
KSel1	0	0	0	0
KSel2	0	54,8645	15,49407	0
KSel3	0	0	36,15282	0
KEvol2	0	10,9729	0,746959	1,759218

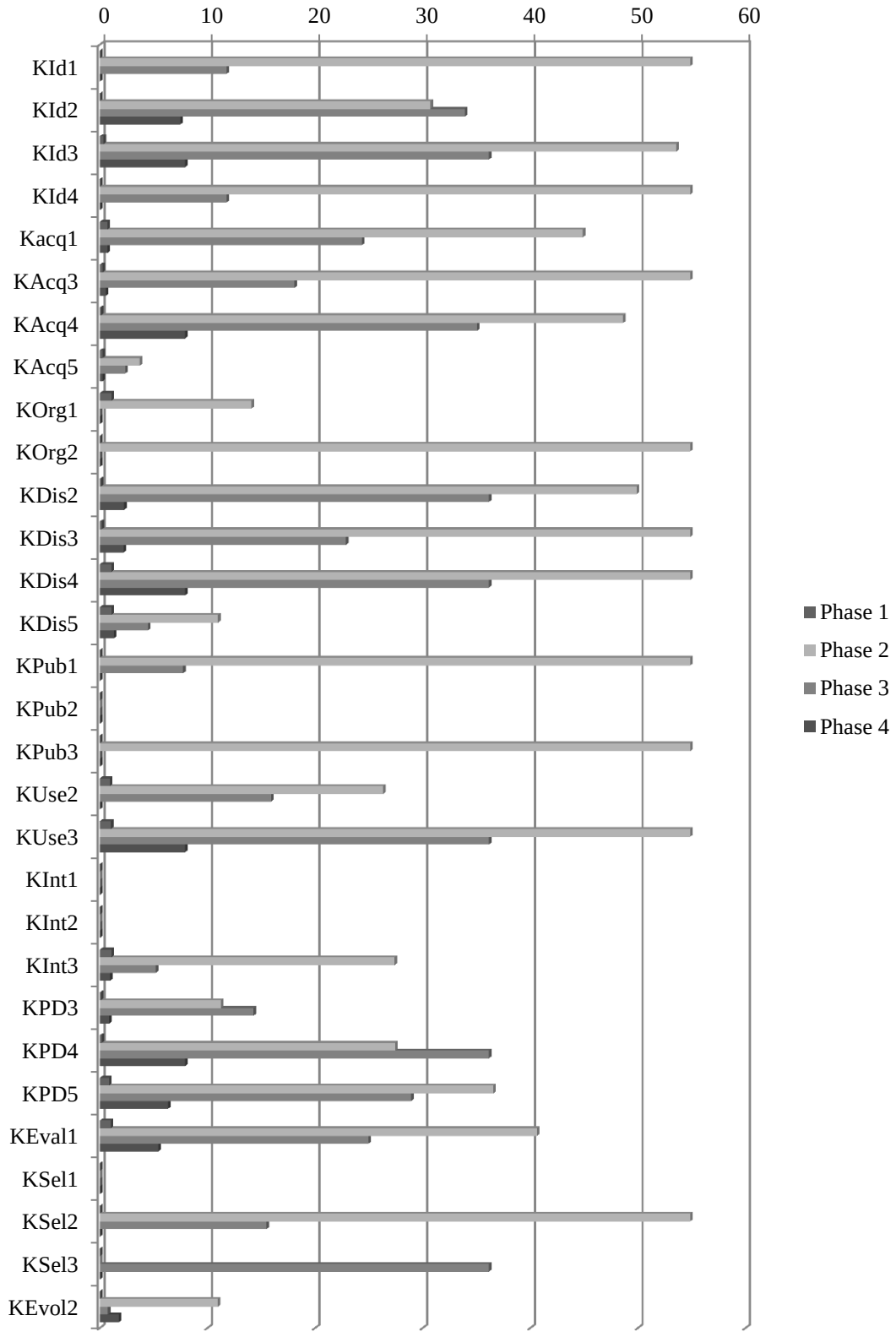

Figure 17 Case Study B - Bar Chart Representation of Adjusted Metric Results

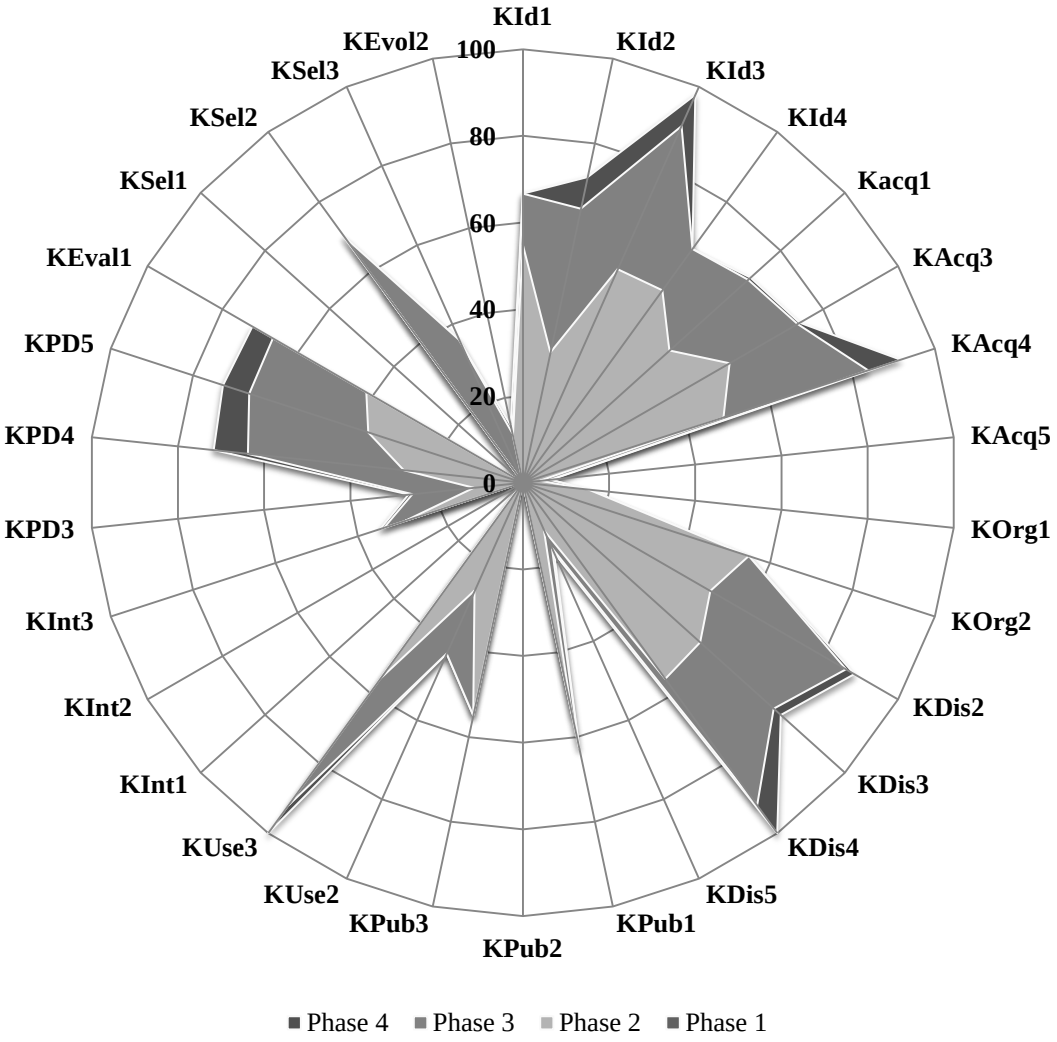

Figure 18 Case Study B - The OL Footprint of METU-CC BBS Team

Analyzing the obtained results from the AiOLoS assessment the following statements can be inferred:

– Except from KAcq5, the external trainings pervasion measure, the METU-CC BBS Team scores highly in every measure related to major process area of Obtaining Knowledge, both internal and external. During the conduct of Case Study B, the fact that the BBS project is unfamiliar to both the members of the METU-CC BBS Team and the METU-CC as

an organization was mentioned. This is revealed also with the outputs obtained from the AiOLoS assessment.

- The low score in KAcq5 is due to the fact that although METU-CC BBS Team is undertaking numerous external trainings, the number of personnel actively participating to these external trainings is a trivial ratio of the total personnel in METU-CC BBS Team. That is, although the participant numbers to the external trainings is high, not all personnel is subject to them, but the same employees are externally trained in different training instances.
- The low scores in the core process area of Knowledge Organization are due to the fact that no clear references exist between the developed documents by METU-CC BBS Team.
- METU-CC BBS Team scores high in the core process area of Knowledge Dissemination as the group is actively using meetings and the meeting minutes are important instruments for the storage of important information for the group, such as action items, decisions and even knowledge. However, three important problems have been identified whilst gathering and calculating the meeting metrics, namely KDis2, KDis3, KDis4, and KDis5:
  1. Not all meetings are being recorded with the use of meeting minutes, thus important information is being lost. Especially in Phase 3, only 25 meetings of the actually conducted 154 meetings and in Phase 4, only 8 meetings of the actually conducted 44 meetings have been recorded with the use of meeting minutes.
  2. The current format used for recording meeting minutes is inefficient for the storage of important information as the use of text documents makes search, retrieval and linking of information items between different documents impractical.
  3. The proposals and developed ideas of the participants in the meetings are not recorded appropriately in the meeting minutes, thus making it impossible to track the individual contribution of members.

- METU-CC BBS Team scores mainly high in the core process area of Knowledge Publication, with the only exception being the case of guidelines distributed to external organizations.
- METU-CC BBS Team scores extremely high in the process area of Knowledge Usage. However, this is mainly due to the fact that proposed and applied ideas and resolved issues in the meetings are poorly recorded in the meeting minutes.
- METU-CC BBS Team scores low in Knowledge Integration mainly because tasks and documents are not repeated between phases.
- METU-CC BBS Team scores high in the core process area of Knowledge Preservation and Deleting as the group uses efficiently a plethora of tools and software for the storage of acquired knowledge.
- METU-CC BBS Team members were asked to evaluate 69 different learning outcomes and knowledge items related to BBS using a single questionnaire. These learning outcomes and the phases they are related with are given in Appendix B2. Out of these 69 different learning outcomes 3 are related with Phase 1, 41 with Phase 2, 65 with Phase 3 and 67 with Phase 4. The obtained results were used for the calculation of KEval1 measurement. In Phase 1 the METU-CC BBS Team members could valuate 95% of knowledge items, but this number gradually declined to 74% in Phase 2, 69% in Phase 3 and %68.5 in Phase 4. The decline in KEval1 can be explained with the increase and diversification of conducted activities and the related learning outcomes in the later phases of the BBS project.
- METU-CC BBS Team scores average to low in the major process area of Passing Knowledge. In detail, they score average in the core process area of Knowledge Selling as the group has not developed any patents/licenses or is not providing any external training regarding BBS to external entities. However, all of these metrics assessed in this major process area are mostly outcomes that are realized at the final stages of

software development, and as BBS is not close to completion the low scores are coherent with respect to the expectations.

5.2.4. Expert Opinions for Case Study B

After the conclusion of Case Study B and the collection of data and measures, the project manager and sub-group managers (seven in total) of METU-CC BBS team have been given a brief training regarding the developed AiOLoS model, its goals, the measurement process and the results and findings of the case study. Then the managers were requested to evaluate and assess the AiOLoS model and provide their expert opinions. Project managers were asked four questions regarding the model and they submitted their results using a Likert Scale. The questions and the Likert scores of the answers are given in Table 70.

Table 70 Case Study B - Expert opinion Questions and the Likert Scores of the Answers

Question	Fully	Mostly	Somewhat	Very Little	Not at all
Q1) Does the AiOLoS model measure the learning ability of a software organization?		6	1		
Q2) Do you think that the assessed learning ability can provide a competitive advantage to the organization?	2	3	2		
Q3) Does the conducted measurements and obtained footprints assess the learning ability of the groups?		5	2		
Q4) Can the learning ability assessed in the AiOLoS model be used for process improvement?	1	4	1	1	

The frequency of the results regarding the answers given in expert opinion questionnaires are: 6 out of 7 believe that the AiOLoS model **mostly** measures the OL capability of a software organization (mode value being Mostly, median value being 4 out of 5), 3 out of 7 believe that the assessed OL ability can **mostly** provide

a competitive advantage to the organization (mode value being Mostly, median value being 4 out of 5), 5 out of 7 believe that the conducted measurements and obtained footprints **mostl**y assess the OL ability of the development groups (mode value being Mostly, median value being 4 out of 5) and finally 4 out of 7 believe that the OL ability assessed in the AiOLoS model can be **mostly** used in SPI (mode value being Mostly, median value being 4 out of 5).

The project managers were interviewed regarding the respective results and findings of AiOLoS to their team. The original interview records are given in Appendix B3.

5.3. Case Study C – A Company from the Private Sector

5.3.1. Description of Case Study C Environment

Case Study C has been conducted in Organization X[56], a software development organization operating in the private sector, with SPICE capability level of 2 and with organizational and software development maturity being above average in Turkey software organization standards. Organization X provides platform-independent solutions for a wide variety of sectors, including banking and finance, telecommunication, insurance, manufacturing and service, oil and energy, automotive and government and military. Organization X provides consultancy, application development, technical support and training services in a wide range of fields from determining corporate information systems strategies to correct architectural construction; to fortification with backbone applications; to integrating new technological solutions required by constant change with previous investments and to operational support which will lead to the optimum functioning of systems. The solutions provided by Organization X range in diverse fields, such as electronic payment infrastructures, electronic bill issuance and collection, corporate resource planning, operational systems, portals, corporate security and kiosk systems carry our business partners forward to e-business processes through new business models. Therefore, different software development groups exist within Organization X's organizational body. Three of these groups, each from a different sector and field, have been selected to be assessed using the AiOLoS model.

The first assessed group is the software quality assurance team of Organization X, Team 1, consisting of 2 team members and 1 team leader. The project used in the assessment is the application of the ISO/IEC27001 and ISO/IEC20000 standards in different parts and projects of Organization X.

The second assessed group is a software development team, Team 2, consisting of 14 to 20 members, primarily Computer Engineers. The assessed project of Team 2 is the Juridical Automation System (JAS) that allows companies to

[56] Due to request by the organization, the name of the organization is not revealed in this research. Instead, the appellative "Organization X" has been used throughout the document.

automate their legal processes regarding accounts receivable, fulfillment of decisions or decrees and case files. JAS is a web based project consisting of 6 sub-modules. JAS primarily makes usage of several web technologies such Ajax, Oracle JRockIt, Java JSF, PL/SQL, Oracle Weblogic and Spring Webflow. Team 2 follows the Incremental software development life-cycle in JAS.

The third assessed group is a software development team, Team 3, consisting of 10 members. The assessed project of Team 3 is the e-Health automation project. The project is being developed for a public sector organization with the aim of providing integrated automation on health services to the organization employees. The project is planned to serve 100.000 people, with future aims of being transformed to a nation-wide health solution. The project consists of a health portal, a health decision support system, integration of contractual institutions, a polyclinic management system, a radiology information system and mobile applications platform. Team 3 follows the Waterfall software development life-cycle in e-Health project.

The projects selected from each team to be assessed in Case Study C are the latest developed or being developed projects of each team. The project assessment start and end dates, effort details and personnel numbers of each team are given in Table 72.

5.3.2. Administration of Case Study C

Case Study C has not been conducted in a parallel and simultaneous fashion with the lifecycle of the selected projects; instead the assessment has been realized using historical data from each project, which data has been collected by the project managers, team leaders and project team members and submitted to the AiOLoS assessor with the use of questionnaires and interviews. Each of these questionnaires is given in Appendix C1. The questionnaire filling times for team members of both teams (as an average value communicated by project managers) and each project manager are given in Table 71. Organization X has not allowed the investigation of project documents and artifacts by the assessor, therefore all data has been collected via the project managers. This has been accepted as a validity threat and has been discussed in Section 5.5.

Table 71 Case Study C - Questionnaire Filling and Submitting Times (in mins) of Team Members and Project Managers

	Team 1	Team 2	Team 3
Team Members (average)	-	20	20
Project Manager	40	120	150

The period of assessment differs for each investigated project, and these periods and the total effort spent in each project between the assessed periods are given in Table 72.

Table 72 Case Study C - Assessed Projects

Team #	Assessment Dates	Brief Project Description	Personnel #	Effort (in man/ months)
Team 1	01.10.10 - 31.07.12	Application of ISO/IEC27001 and ISO/IEC20000	3	9,1
Team 2	01.09.09 - 16.08.12	JAS, web based automation tool that allows companies to automate their legal processes regarding accounts receivable, fulfillment of decisions or decrees and case files.	14-20	480
Team 3	01.03.11 - 31.07.12	e-Health automation project, being developed for a public sector organization with the aim of providing integrated automation on health services to the organization employees	10	177

Not all metrics have been measured for all three teams. Except for KPD1 (knowledge evaluation and assessment), all other metrics have been measured either for all three or for some of these three teams. The list of which metric is assessed for

which team is given in Table 73. For these metrics that an assessment from a team is missing, this measurement has been accepted as zero.

As the projects followed differentiated development lifecycles and for some metrics the data collected could not be divided into the project development phases, all three projects have been considered as a whole and no phase based metric collection has been conducted; that is the metrics are not divided to phases, contrary to the assessments conducted in cases A and B.

5.3.2.1. Normalization of Obtained Metrics

A normalization process has been undertaken for several metrics. All measured values have been converted to a proportion of the upper bound value that the respective metric has. For these metrics for which there is no upper bound, the observed metric, if required, was first adjusted with respect to the workload of each project, which is the effort spent by each team at the assessed project was used as a Team Coefficient (TC). These metrics[57] were multiplied with TC, which is calculated as 1 / [team effort]. The normalization process was finalized by accepting for all the metrics that there is no upper bound[58] the maximum observed value between the three teams as the upper bound.

5.3.3. Results of Case Study C

In Table 74 the normalized metrics obtained from the three teams are shown. The graphical representation of the results of the three team metrics is given in Figure 19, where the results are not distributed to phases as the assessment was conducted for the entirety of each of the three projects. Furthermore, in order to visualize the OL capabilities of Team 1, 2 and 3, and to identify the weak core process areas, the OL capability comparison footprints of the Organization X teams has been drawn. Figure 20, Figure 21, and Figure 22 display the OL capabilities of Team 1, Team 2 and Team 3, with respect to the measured key process areas. As it is expected, because Team 1 is conducting a knowledge intensive project where both

[57] KDev1, KDis1, KDis2, KDis3, KPub1, KPub2, KPub3, and KPD4
[58] KAcq3, KAcq4, KDev1, KOrg1, KOrg2, KDis1, KDis2, KDis3, KPub1, KPub2, KPub3, KInt3, KPD4, KSel2, and KSel3

existing knowledge of its members and newly acquired knowledge items are applied to Organization X's different parts, Team 1 scores high with respect to Team 2 and Team 3.

Table 73 Core Process Areas, Generic Measures and Corresponding Metrics in Case Study C

Core Processes	Generic Measure	Metrics (Measures Applied as)	Team 1	Team 2	Team 3
Knowledge Identification	KId1	Internal Trainings	√	√	√
	KId2	Tasks Completed Internally	√	√	√
	KId3	Documents Completed Internally	√	√	√
	KId4	Internal Trainings Pervasion	√	√	√
Knowledge Acquisition	KAcq1	External Trainings	√	√	√
	KAcq2	Utilized External Communication	√	√	√
	KAcq3	Trained Topics	√	√	√
	KAcq4	Utilized External Documents	√	√	√
	KAcq5	External Trainings Pervasion	√	√	√
Knowledge Development	KDev1	Creative Idea Development	NA	√	√
	KDev2	Creative Idea Evaluation	√	√	√
Knowledge Organization	KOrg1	Horizontal Document Linking	√	NA	NA
	KOrg2	Vertical Document Linking	√	NA	NA
Knowledge Dissemination	KDis1	Information Messages from Management	√	√	√
	KDis2	Amount of Meetings	√	√	√
	KDis3	Length of Meetings	√	√	√
	KDis4	Meeting Discussion Efficiency	√	√	√
	KDis5	Meeting Pervasion Measure	√	√	√
Knowledge Publication	KPub1	Internally Distributed Guidelines	√	√	√
	KPub2	Externally Distributed Guidelines	√	√	√
	KPub3	Academic Publications	√	√	√
Knowledge Usage	KUse1	Creative Idea Application	√	√	√
	KUse2	Deliverable Quality	√	√	√
	KUse3	Meeting Functional Efficiency	√	√	√
Knowledge Integration	KInt1	Task Differentiation within Phases	√	√	√
	KInt2	Deliverable Differentiation within Phases	√	√	√
	KInt3	Deliverable Correction	√	√	√
Knowledge Preservation and Deleting	KPD1	Knowledge Evaluation and Assessment	NA	NA	NA
	KPD2	Task Differentiation from Guidelines	√	√	√
	KPD3	Deliverable Differentiation from Templates	√	√	√
	KPD4	Knowledge Preservation Tool Usage	√	√	√
	KPD5	Knowledge Preservation Tool Efficiency	√	√	√
Knowledge Evaluation	KEval1	Valuated Items	√	NA	NA
Knowledge Selling	KSel1	Shared Documents	√	√	√
	KSel2	Shared Tasks	√	√	√
	KSel3	Trainings Given	√	√	√
Knowledge Evolution	KEvol1	Guideline Evolution between Projects	NA	√	√
	KEvol2	Task Evolution between Projects	NA	√	√
	KEvol3	Deliverable Evolution between Projects	NA	√	√

Table 74 Case Study C - Obtained Normalized Metrics for the Specific Core Processes from Team 1, Team 2 and Team 3

	Organization X		
	Team 1	**Team 2**	**Team 3**
TC	**1**	**0,01895**	**0,05141**
KId1	100	64,28571	50
KId2	16,86047	58,07692	41,42857
KId3	76,92308	60,76923	47,85714
KId4	100	7,142857	25
KAcq1	100	71,42857	62,5
KAcq2	90	61,07143	69,625
KAcq3	100	57,69231	43,75
KAcq4	90,27778	100	44,01042
KAcq5	100	7,142857	12,5
KDev1	NA	100	0,178515
KDev2	100	90,94017	84,61538
KOrg1	100	NA	NA
KOrg2	100	NA	NA
KDis1	19,18756	100	1,367807
KDis2	100	12,73321	11,51025
KDis3	72,03907	61,45833	100
KDis4	100	80	80
KDis5	100	100	100
KPub1	100	3,791667	0
KPub2	100	0	0
KPub3	100	0	0
KUse1	98	84,95726	80
KUse2	97,5	75	75
KUse3	100	60	90
KInt1	0	10	15
KInt2	0	5	25
KInt3	91,6	100	97
KPD2	10	80	0
KPD3	10	30	0
KPD4	50	100	100
KPD5	80	95	70
KEval1	100	NA	NA
KSel1	0	0	0
KSel2	0	0	0
KSel3	0	15,87302	100
KEvol1	NA	0	0
KEvol2	NA	20	0
KEvol3	NA	10	10

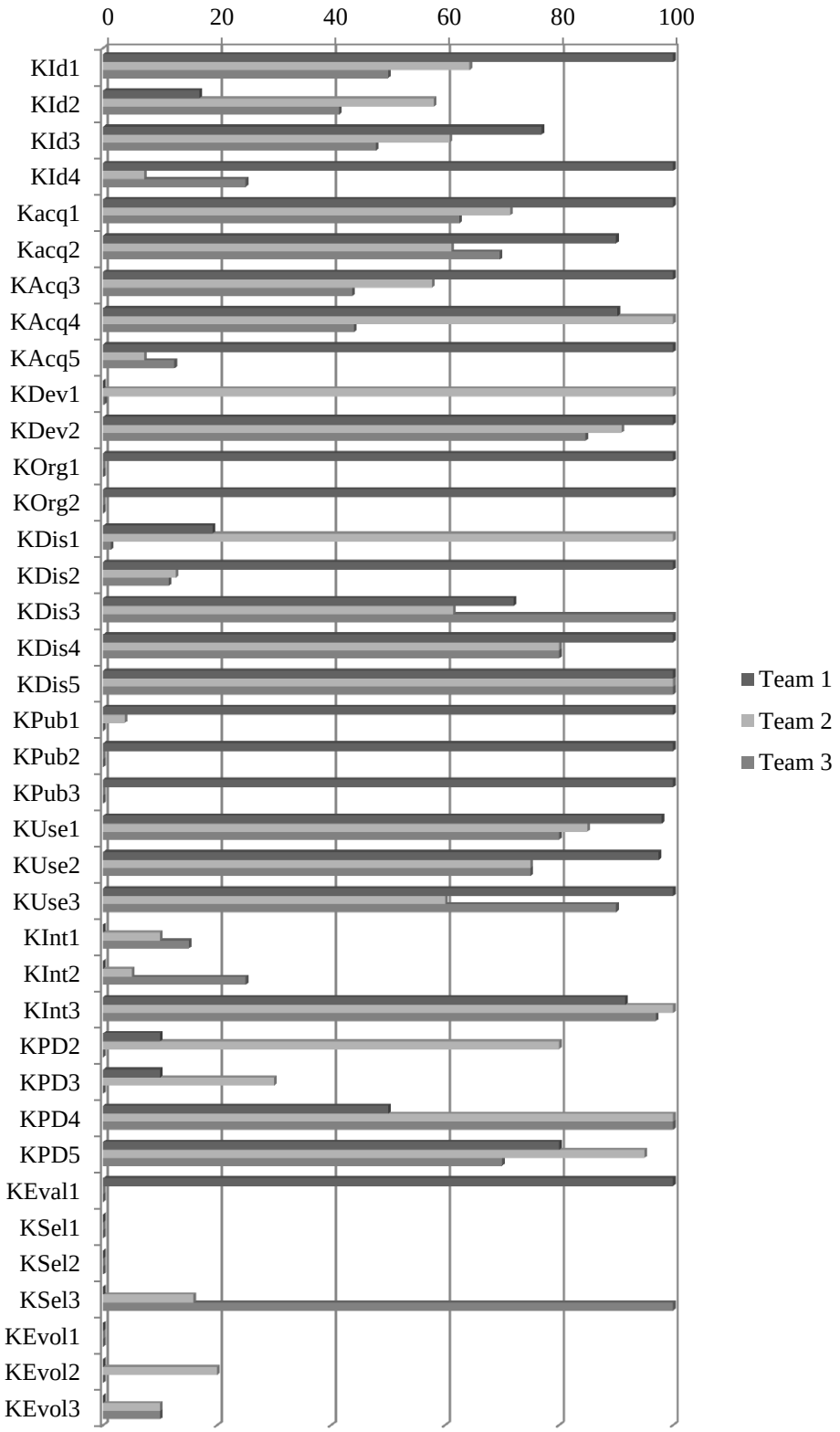

Figure 19 Case Study C - Bar Chart Representation of Adjusted Metric Results

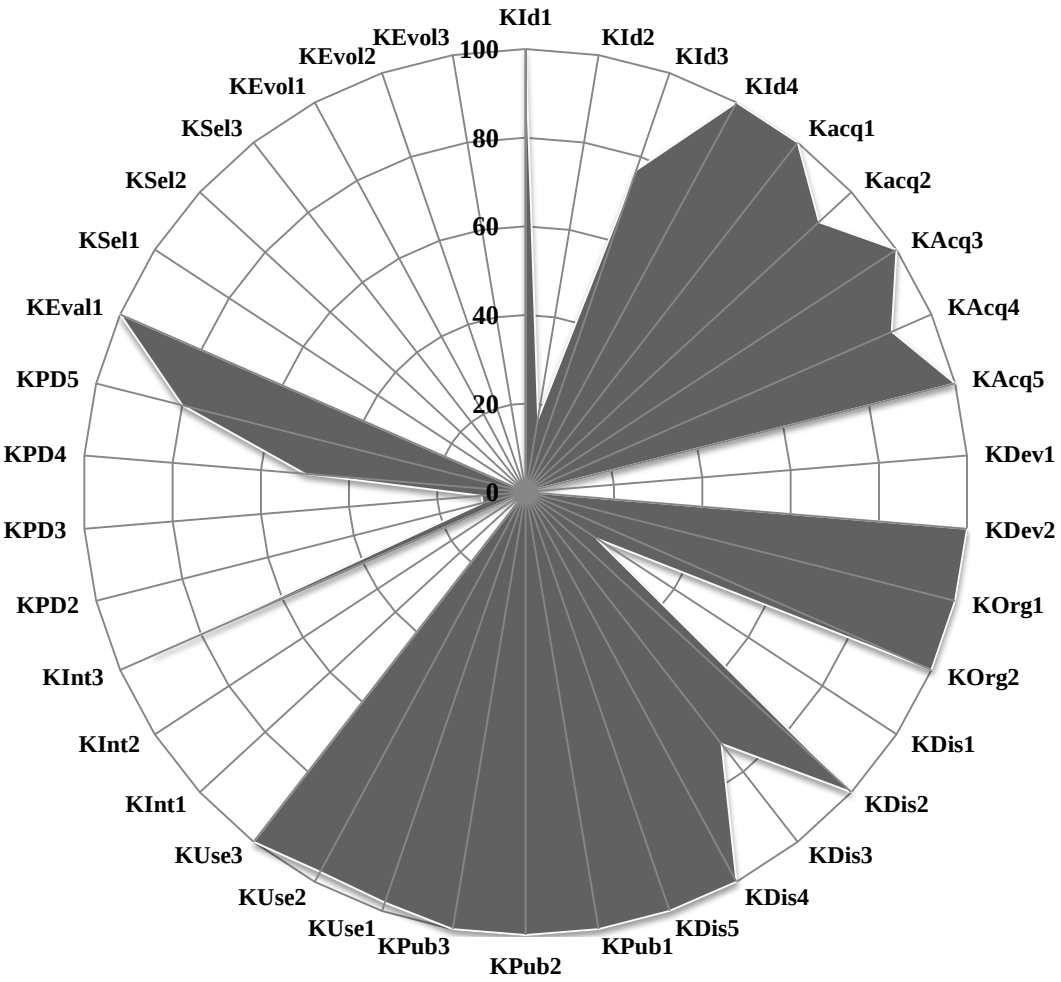

Figure 20 Case Study C - The OL Footprint of Team 1

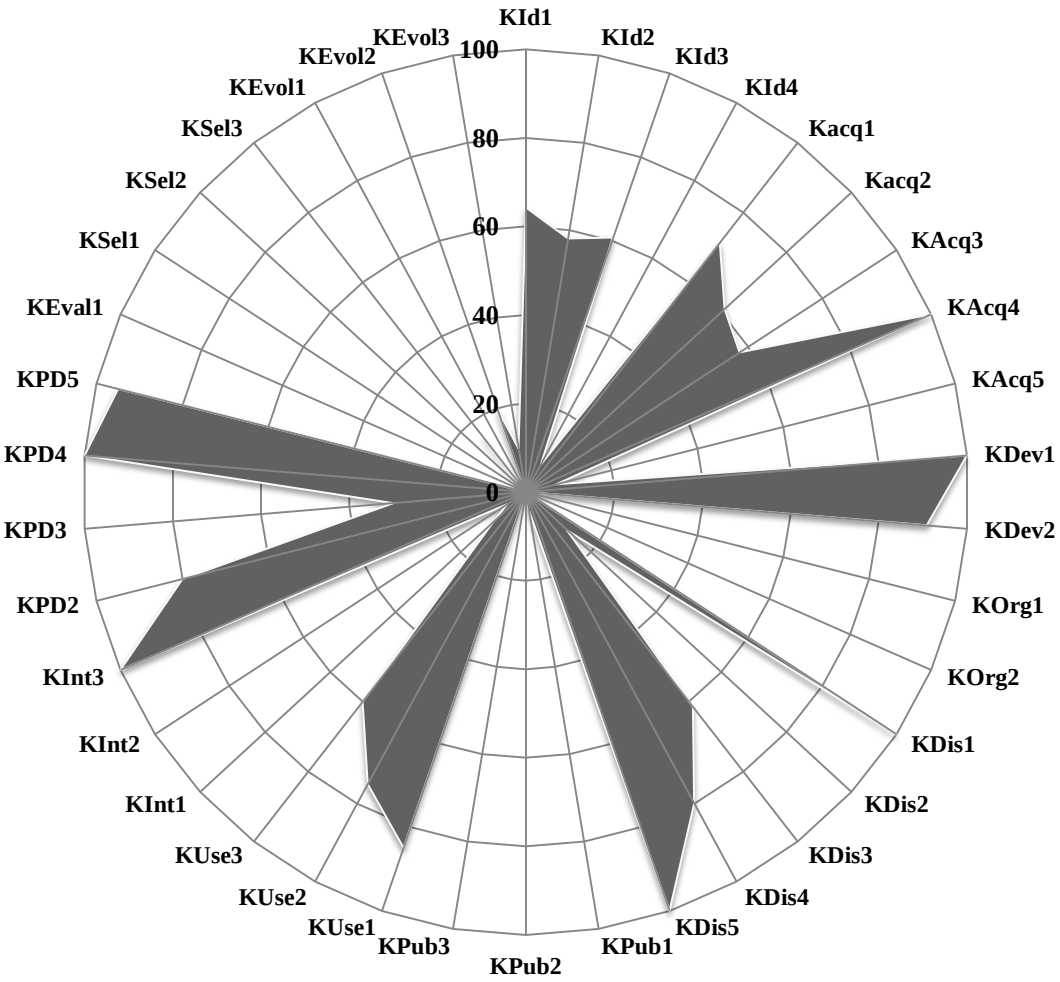

Figure 21 Case Study C - The OL Footprint of Team 2

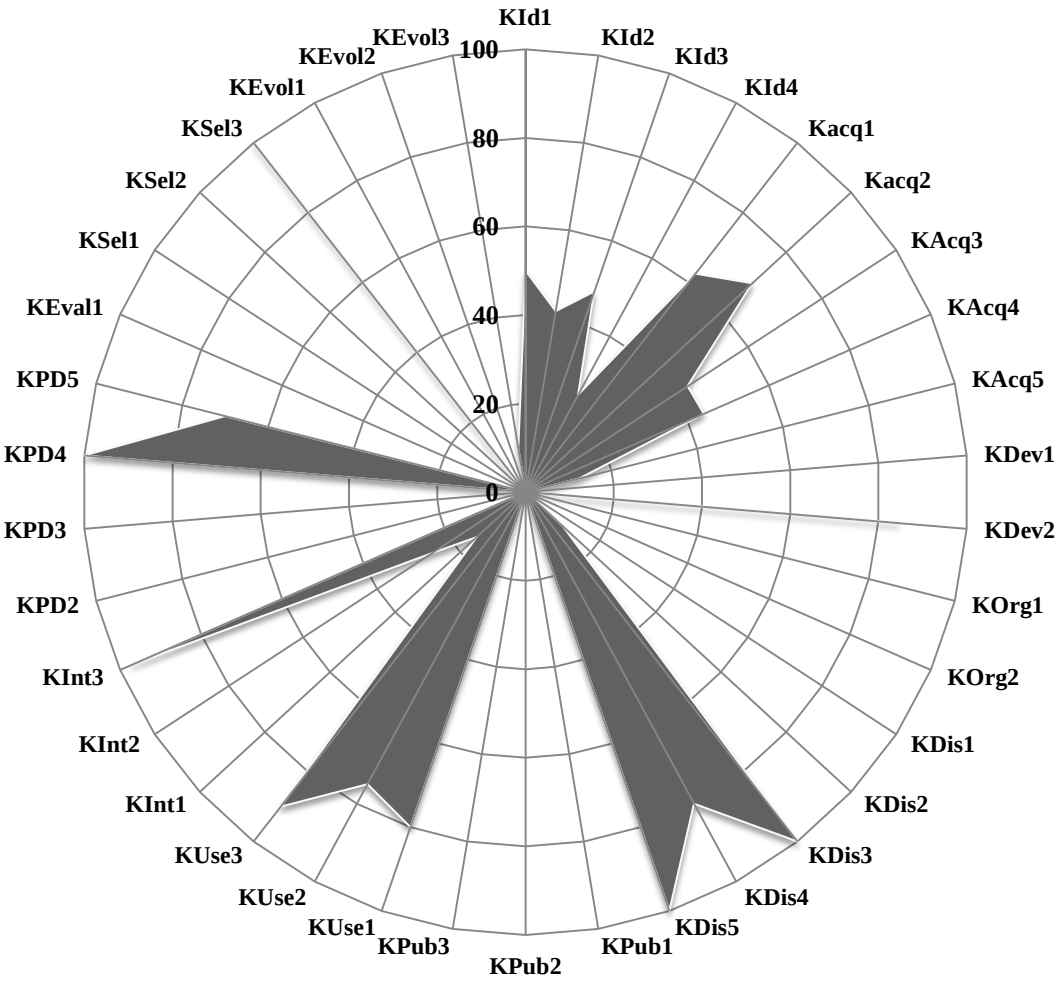

Figure 22 Case Study C - The OL Footprint of Team 3

Analyzing the obtained results from the AiOLoS assessment the following statements can be inferred, together with some relevant comments from project managers, which are taken from Appendix C2:

- Knowledge Identification: Except for KId2 (tasks completed with existing knowledge), Team 1 scores higher than the other two teams. This is due to the fact that Team 1 consists of members that already do have some knowledge of the project they are conducting but also on the fact they are relatively a small team and thus the pervasion of trainings is higher. Team 2 project manager commented: *"As internal trainings we conduct peer-programming activities, I assign an expert and a novice together to tasks so that the expert can train the novice by conducting the task. However, the team members do not consider that as training but as conducting the job itself"*.
- Knowledge Acquisition: As in knowledge identification, Team 1 scores higher than Team 2 and Team 3. Apart from KAcq5 (external trainings pervasion), teams 2 and 3 exhibit also high scores. However, as both Team 2 and Team 3 consist of a high number of members, the low score on KAcq5 is explicable. The high scores of Team 1 can be explained with the fact that the project depends on the application of knowledge items that are well-structured and clearly defined in standards and related documents and guidelines. Team 3 project manager commented (and Team 2 project manager agreed) that: *"We prefer specialization within the team, instead of sending everybody to all trainings, we send only a single or sometimes two employees to external training so that they can acquire the expertise. Moreover, our project budget requires us to plan our training program very carefully. That is another reason of not sending more people to these external trainings"*.
- Knowledge Development: Team 1, in the conducted interviews has stated that no track of the developed creative ideas is kept; however, all developed ideas are being applied. Team 3 scores extremely low relatively to Team in KDev1. Team 2 project manager commented: *"As a*

team, we have a process of Idea Development within our project. All employees are encouraged to develop ideas and to share them with me or other team members. The fact that project members view the project as a product helps in the idea development. Many employees, even knowing that the idea they are developing is increasing they workload, they still comment on the work they have done and state new ideas". On the other hand Team 3 project manager stated that: *"We do not have a special process for Idea Development and the team members do not view the project as a product, yet. Moreover, even though some of my team members regularly develop ideas, they have not stated that. I believe that they have not considered their contributions as ideas"*.

- Knowledge Organization: Team 2 and Team 3 have not submitted any data regarding the linking between the created documents.
- Knowledge Dissemination: In the assessment it is displayed that Team 2 receives the highest volume of messages from upper management. This can be explained by the nature of the conducted project. Regarding the use of meetings for knowledge dissemination, all three teams score high. Team 1 resolves more issues in meetings and conducts more meetings, however, the meetings of Team 3 are lengthier. Team 2 project manager commented: *"Upper management intervenes highly with the way we are conducting the project by sending information messages and dictating and controlling the way the team functions".* Team 1 and Team 3 project managers stated that even though the upper management is involved with their projects to, the involvement is not that ample.
- Knowledge Publication: As the project conducted by Team 1 requires the development and distribution of documents related to several standards to be used by different entities of Organization X, Team 1 scores extremely high in all areas of knowledge publication. These findings were confirmed strongly by all three project managers.
- Knowledge Usage: All three teams score high; however, Team 1's higher scores can be explained with both the nature of the conducted projects

but also with the relative size of the teams. These explanations were accepted by Team 1 project manager as reasonable.

- Knowledge Integration: The structure of project conducted by Team 1 requires following straightforward tasks and steps with no differentiations, therefore Team 1 scores 0 in KInt1 and KInt2. The scores of teams 2 and 3 although low, display that teams slowly change they tasks and deliverables with respect to acquired knowledge. Deliverable correction (KInt3) is high for all three teams. Team 3 project manager commented: *"If this assessment had started together with the project, we would collect data while the project progressed. This data would have been more accurate and more explanatory regarding the Knowledge Integration core process".* Team 1 and Team 2 project managers agreed with this statement.
- Knowledge Preservation and Deleting: KPD1 (knowledge evaluation and assessment) has not been conducted. Due to the reason explained in knowledge integration, Team 1 scores low in KPD2 and KPD3 and so does Team 3. On the other hand Team 2 displays that both tasks and deliverables are conducted differently from the existing guidelines and templates. Team 1 is using only one knowledge preservation tool[59], whereas teams 2 and 3 use two[60]. The knowledge preservation tool efficiency is high for all three teams as team members record all items and artifacts in the appropriate knowledge preservation tools. Team 3 scores relatively low in KPD5 due to the fact that some knowledge items are stores in meeting minutes documents.
- Knowledge Evaluation: Team 2 and Team 3 have not submitted a list of learning outcomes, thus KEval1 has not been measured for these two teams. However, Team 1 members have evaluated all learning outcomes of the project they are conducting.

[59] JIRA, http://atlassian.com/software/jira/overview
[60] JIRA and MS Team Foundation Server, http://msdn.microsoft.com/en-us/vstudio/ff637362.aspx

- Knowledge Selling: Due to the nature of the projects, all three teams score low in knowledge selling, except for KSel3 (trainings given), were Team 2 and Team 3 have given trainings to the customers of the conducted projects. Team 3 scores higher because their project is close to completion. Team 1, is also giving trainings but only to other entities in Organization X, thus scoring 0 in KSel3.
- Knowledge Evolution: Team 1, due to fact that the project they are conducting is based on international standards and therefore can only be evolved based on an evolution in these standards, has stated that these metrics are NA. Team 2 and Team 3 project managers have stated that in the next project they would use the same guidelines without any change and would produce the same deliverables with only 10% change. Team 2 project manager requires a 20% evolution in tasks.

5.3.4. Expert Opinions for Case Study C

After the conclusion of Case Study C and the collection of data and measures, the project managers of teams 1, 2 and 3 respectively have been given a brief training regarding the developed AiOLoS model, its goals, the measurement process and the results and findings of the case study. Project managers then were requested to evaluate and assess the AiOLoS model and provide their expert opinions. Project managers were asked four questions regarding the model and they submitted their results using a Likert Scale. The questions and the Likert scores of the answers are given in Table 75.

The frequency of the results regarding the answers given in expert opinion questionnaires are: all 3 believe that the AiOLoS model **mostly** measures the OL capability of a software organization (mode value being Mostly, median value being 4 out of 5), 2 out of 3 believe that the assessed OL ability can **somewhat** provide a competitive advantage to the organization (mode value being Somewhat, median value being 3 out of 5), all 3 believe that the conducted measurements and obtained footprints **mostly** assess the OL ability of the development groups (mode value being Mostly, median value being 4 out of 5) and finally 2 out of 3 believe that the OL

ability assessed in the AiOLoS model can be **mostly** used in SPI (mode value being Mostly, median value being 4 out of 5).

The project managers were interviewed regarding the respective results and findings of AiOLoS to their team. The original interview records are given in Appendix C2.

Table 75 Case Study C - Expert opinion Questions and the Likert Scores of the Answers

Question	Fully	Mostly	Somewhat	Very Little	Not at all
Q1) Does the AiOLoS model measure the learning ability of a software organization?		3			
Q2) Do you think that the assessed learning ability can provide a competitive advantage to the organization?		1	2		
Q3) Does the conducted measurements and obtained footprints assess the learning ability of the groups?		3			
Q4) Can the learning ability assessed in the AiOLoS model be used for process improvement?	1	2			

5.4. Generalizations of Case Study Results

Several findings from the case studies can be generalized to provide a basis of interpretation for future AiOLoS assessments. These can be summarized as:

- For the measures that the number of personnel is used in the calculation formula (KId1, KId4, KAcq1, KAcq5, KDis5), when the number of personnel in assessed entities increases, the measure value decreases.
- Assessment based on historical data requires more time and effort as the organization is not storing the essential data appropriately but the assessor is required to mine it from voluminous records and documents.

- For the measure of KPD1 which requires the conduction of knowledge assessment and preservation tests, for the case studies B and C that were conducted in professional software development organizations, upper management of the organization, team leaders and team members were reluctant to undertake these tests and therefore this measure was not utilized in these two case studies.
- The terms specific for AiOLoS measures such as “creative idea”, “internal knowledge” or “external knowledge” can be understood differently from participating personnel so the terms need to be communicated clearly without leaving any room for ambiguity and vagueness. This has also been perceived as a validity threat and is discussed in Section 5.5 with the undertaken solutions, which solutions can be generalized to any future AiOLoS assessments to be conducted.
- Analysis of the AiOLoS assessment results can provide further insights for the assessed entities, other than these specific to OL terms, such as inter-team conflicts (Case Study A) or hidden good practices that have not been shared with other organizational units (Case Study C). These insights and findings need to be discussed with upper management, in order to allow the upper management to undertake preventive or promotive actions.

5.5. Validity Threats

The survey design requires a software development organization with defined processes and willing to be assessed with respect to its OL capabilities. However, the case studies and the resulting methods have been designed in such a way that they can be applied to organizations having an intention to understand their OL capabilities and develop methods for enhancing them. It would be greatly valuable to perform a similar case study by applying the AiOLoS model concurrently with CMMi efforts, both to understand the effect the OL has in CMMi but also to consume the AiOLoS assessment effort within the CMMi effort.

In case studies A and C the data was collected primarily with the use of questionnaires and interviews, and in Case Study B the assessor collected the data from existing artifacts. In all three case studies, a single assessor who had prior knowledge and experience with the AiOLoS model performed the analysis, finalization and interpretation of the data. This would imply increased effort for an assessor with no existing background knowledge and experience on AiOLoS model, to conduct a similar case study or apply the AiOLoS model. In Case Study B, as the assessment was conducted primarily by analysis of the assessor, the setting was larger with multiple groups, more complex structure and many different artifacts and knowledge items to be investigated, help from the organization was necessary. Such help may be necessary in all organizations with similar characteristics. AiOLoS model does not have inherent complexity in its execution, as it relies primarily on the understanding of the OL activities and processes within the organization. Thus, if the assessment is to be conducted with the help of organizational members, an initial briefing of the AiOLoS measures would be recommended and satisfactory. Furthermore, as conducted in all three case studies, after the assessment is completed, consistency of the assessment should be provided with the normalization of the obtained measurements.

Specifically for Case Study A – The Classroom Experience, the major validity threat was the instructor-student relationship that existed between the assessor and the assessed team members. This relationship could force the students to alter their answers in the questionnaires to more favorable ones, believing that such answers would contribute to their grades. In order to resolve this, the students were informed that they would not be graded based on the answers they provide but instead that they will be graded with respect to the way they provide them; that is whether the answers are timely, well organized and coherent. In order to achieve coherency, exit interviews were conducted with each team member to cross-check the answers they have provided in the questionnaires. Any discovered inconsistencies or misunderstandings were resolved during these exit interviews. The expert opinions of team leaders, who are also students, have been collected after the submission of the grades, so that they would not feel compelled to provide answers that do not depict their true opinions about AiOLoS.

In Case Study B – A Public Sector Organization the main validity threat was the size of the project and the volume of the accumulated project documents, making the AiOLoS assessment process a time-consuming task and thus resulting in the threat of being viewed as a burden. The solution was the conduction of document analysis, data collection and interview processes by the external assessor. However, to avoid losing any valuable data due to the fact that the assessor is unfamiliar with the BBS project and the organizational structure of METU-CC, the project manager was directly involved in the data collection and interview processes, providing valuable expertise and background information.

In Case Study C – A Company from the Private Sector, as the external assessor was not allowed access to project documents and data, the major threat was the misperception of AiOLoS by the project team managers and the miscommunication of AiOLoS requirements and characteristics to team members by the managers. In order to address this risk, several trainings were given to team managers, in which training sessions the AiOLoS model was presented and discussed in detail. After the collection of the data, team managers and the external assessor were gathered together to review the submitted data in order to identify any possible miscomprehensions and irregularities. Any discovered problematic or inconsistent data would be communicated to the team member providing the data in question and team members were requested to resubmit the data.

A validity threat for all three case studies has been the correct communication of terms specific to AiOLoS such as “creative idea”, “internal knowledge” or “external knowledge” to the personnel contributing to the collection of data and metrics. In order to resolve this, examples of what is meant by each term and clear definitions what they are and they are not were developed and have been communicated to all parties. Moreover, at exit meetings or interviews where participants from different assessed entities would participate, discussion sessions have been conducted to reevaluate these terms and build a common ground of understanding.

CHAPTER 6

DISCUSSION AND CONCLUSION

"Now this is not the end. It is not even the beginning of the end.
But it is, perhaps, the end of the beginning."

(Sir Winston Churchill,
referring to British victory over the German Afrika Korps
at the Second Battle of El Alamein in Egypt, the turning point of World War II)

Through this thesis, a research related to assessing OL capabilities of software development organizations by using the AiOLoS assessment model developed through the use of ideas and methodologies in OL, LO and KM has been explored and reported. The research has provided valuable insights regarding the applicability, strengths and weaknesses, and contributions of AiOLoS.

This chapter sums up the major findings of the research, presents the conclusions on the research problem and research questions, describes the limitations of the proposed model and states the contributions of this research. Finally, the chapter outlines possible future works based on these findings.

6.1. Discussion

During the initial stages of this study four major research questions were raised. First, the answers obtained to those questions and then a discussion regarding the research problem shall be presented below.

Research Question 1: *What are the major process areas and core processes of OL in software development organizations?*

In the survey conducted in the areas of OL and LOs, it has been realized that these study areas are not sufficiently extensive for the codification of the OL processes in software organizations; therefore the area of KM was surveyed, following the suggestions of [27], [31], [46], [51], [78], and [100]. The identified major process areas and core processes constitute the AiOLoS model and are depicted in Figure 5 and detailed in Table 18. The major process areas are in accordance with almost every KM model proposed and surveyed in sections 2.5 and 3.1, and the core process areas, provide the granularity required to distinguish each separate and distinct KM sub-process. Both the major process areas and core processes of the AiOLoS model have been borrowed from the different KM studies and models provided in section 3.1, considering their suitability to the software development organization. However, as detailed in sections 3.2 and 3.3, the major and core process areas can be mapped to different OL and LO constructs and dimensions in the literature and a summary of this napping is provided in Section 4.2. The processes have been constructed in a circular structure to depict the continuous nature of KM, as proposed in several surveyed KM models. The conducted case studies have shown that the major process areas and core processes are actually related to the OL process of software organizations.

Research Question 2: *How can the core processes of OL be measured?*

The surveyed existing OL and LO models in sections 3.2 and 3.3 have shown that these models utilize the use of questionnaires based on subjective questions and metrics for the measurement of the OL capabilities of the organizations. However, the AiOLoS model requires a more objective measurement based on metrics that can

be obtained from the organization data. Using the GQM approach and considering the specific characteristics of software development organizations, the 39 measures of the AiOLoS model that are depicted in Figure 3 and detailed in Table 18 have been developed. Except from the core process of Knowledge Evaluation, all other core processes can be measured by more than one measure. Although not all measures have been used in a single case study, all 39 measures have been measured in the three case studies and therefore their applicability has been shown. Every measure has been linked to various theories, researches and models in the surveyed literature, thus providing the theoretical ground of each measure. The project managers in Case Study A have been interviewed after the conclusion of the case study and they have stated that AiOLoS fully measures the OL capability of a software organization (2 out of 4 answering Fully, mode value being Fully and median value being 4,5 out of 5) and that the obtained metric results mostly assess the OL capability of the development groups (3 out of 4 answering Mostly, mode value being Mostly, median value being 4 out of 5) . A guideline for the resolution of NA measures has been provided in Section 4.5, displaying the elastic nature of the AiOLoS model. The generic measures have been converted to actual metrics using this guideline in Case Study A – The Classroom Experience. Four different assessment conduct modes have been proposed and are described in Section 0. Three of these four modes have been utilized and tested in case studies.

Research Question 3: *How can the measurement results be used for SPI?*

AiOLoS has been designed in order to provide a starting point for the enhancement of OL capabilities of software development organizations based on their assessment, which in turn should provide the basis to conduct SPI activities. After the conclusion of the case studies, the project managers and team leaders who participated in the assessment have been given a brief training regarding the AiOLoS model, its goals, the measurement process and the results and findings of the respective case study. The participants have answered questions regarding the applicability of AiOLoS to SPI. In Case Study A, all four project managers have stated that the AiOLoS assessment can be fully used in SPI (mode value being Fully, median value being 5 out of 5). However, the mapping of AiOLoS to SPI has not

been validated in the case studies, but a proposal for that mapping is given in Section 6.3.1 as future work.

Research Question 4: *Can an approach be proposed to enhance the OL capability of software development organizations and teams?*

In Case Study A, the SQ4R method that is based on critical thinking, was utilized in order to enhance the OL capability of two of the four assessed software development teams. The details of the SQ4R method are given in Section 0. Even though the enhancement of OL capabilities with the use of SQ4R has not been validated, the applicability of SQ4R in software development organizations and teams has been shown in Case Study A. However, Case Study A was constructed in a controlled environment; therefore further case studies from the professional domain are required to measure the actual benefits of using SQ4R. The case studies B and C have been conducted in professional organizations and they were based on surveys, as information and data were collected from a specific population without manipulating any variables or changing the model or the way things are being conducted in the assessed project teams or organization. Therefore, the SQ4R approach was not used in these case studies.

Research Problem: *How can we model and assess the OL capabilities of software development organizations?*

AiOLoS has provided the structure to model the OL capabilities of software development organizations with respect to three major process areas and 12 core processes. The AiOLoS model is an amalgamation of three major theoretical fields, these of OL, LO and KM, and their respective practices. For the assessment of these 12 core processes, 39 different measures have been proposed, each of them with different specifications measuring different areas of the OL capability of an organization.

The applicability of the model and of the measures, but also the validity of the assessment has been investigated via three case studies. To show the generalizability of AiOLoS to different software development organizations, in case studies B and C two different organizations were selected; one from the public

domain and one from the private sector domain. The assessed teams and projects had a diverse nature, development lifecycles, and organizational and hierarchical structures. Furthermore, AiOLoS has been applied successfully in all three case studies and the expert opinions collected after the conclusion of these case studies have shown that AiOLoS displays positive outcomes in the measurement of the learning abilities of organizations and the obtained results assess the learning ability of the investigated entities.

6.1.1. Strengths of AiOLoS

Compared to other existing or proposed LO assessment models, AiOLoS displays several strengths:

- 33 of the AiOLoS measures are objective and only 6 measures[61] are subjective. One of the goals of the GQM approach employed while developing the metrics has been the development of objective measures, so that the assessment would generate consistent results when conducted by different assessors. Objective measures are extremely important when comparing two separate organizations, as the perception of key items may differ between organizations. Thus, the objective nature of the measures of the AiOLoS model allows the comparability of different organizations with the use of AiOLoS.
- Several LO models and approaches have proposed the assessment of OL capabilities to be conducted based on financial results of the organization being assessed. However, OL capability may be one of the many factors that are influencing the financial success of an organization. The measures of the AiOLoS model have been developed to measure the actual sub-processes and items of the software development process, and are not focusing on the financial result or other results of the organization. This allows the assessment of smaller organizational units such as teams or groups and the conduction of assessment while the project is still ongoing.

[61] KAcq2, KDev1, KDev2, KUse2, KPD1, and KEval1

– AiOLoS, as described in Section 0, allows conduction in four different modes: comparing organizations with each other (vertical assessment), comparing phases with each other (horizontal assessment), comparing different phases of different organizations with each other (hybrid assessment) and comparing organizations with benchmark values (best practice benchmark assessment). This allows the upper-management to assess the OL capability of a software development team even though there are no other teams for comparison, or to set benchmark values and compare the team with respect to these values.

6.1.2. Weaknesses and Limitations of AiOLoS

With respect to other proposed models but mostly with respect to its own structure, AiOLoS has several weaknesses and limitations that constitute deficiencies and problems for its conduct:

– Even though AiOLoS has been developed based on an extensive literature survey on OL, LOs and KM with respect to both theoretical and practical approaches, its applicability has been validated with the use of different case studies and the first case study has been constructed specifically for the adjustment of its structure and measures, the question "How well does AiOLoS model and assess the real OL capabilities of software development organizations?" remains. Although this question can never be completely refuted, conducting a plethora of case studies and analyzing the results with the assessed organizations can provide a safer ground on how well AiOLoS models and measures reality.

– The AiOLoS assessment is conducted by using mainly comparisons: either comparing the organization to other organizations or a phase of its activities to some other phase. Such comparisons may provide incorrect conclusions, as the results are highly dependent on the compared counterpart. A partial solution to this limitation could be the use of benchmarking values for the comparison. However, both obtaining these benchmark values but also adjusting them in order to be used by a specific type of software organization is a challenging task.

- The measures of AiOLoS do not measure informal ways of learning within the organization, whereas informal learning can be an important constituent of OL. As an example of these informal ways of learning Seely-Brown [146] narrates the story of copier repairers who exchange tips at the water cooler stating that they learn more through these informal exchanges than in the programmed instruction provided by their organization. Conner [147] identifies these places (e.g. water cooler, stairwells, printer or copy machine) and opportunities for informal learning and provides several solutions for capturing these informal learning opportunities. AiOLoS should also provide measures for the assessment of informal OL instances for every major process area and core process.
- The generic measures of AiOLoS are taken with respect to an independent upper bound value, and based on that value they are normalized to a value between 0 and 100. However, 15[62] of the developed measures do not have an upper bound value. For these measures, AiOLoS proposes the use of the maximum number obtained among the compared teams or phases as the upper bound. This solution results in a differentiation between the measurement formulas among the measures. A different solution should be provided so that the measurements do not have different measurement formulas.
- In the graphical depiction of the obtained OL assessment footprints of Case Study C, the famous "problem of zeros" [148] has been encountered. The NA (both in terms of not applicable but also not assessable) metrics have also been presented as a zero in the footprints, thus being depicted the same with the metrics that have actually been assessed as zeros. In order for the footprints to be comparable, these metrics were not deleted from the graphical representations (and in the data tables are given as NA). The solution provided in [148] of assigning

[62] KAcq3, KAcq4, KDev1, KOrg1, KOrg2, KDis1, KDis2, KDis3, KPub1, KPub2, KPub3, KInt3, KPD4, KSel2, and KSel3

very small values to these measurements is not appropriate as the small values will still be shown as zeros in the footprints. A solution can be the use of colored areas, however this solution has not been implemented in the case studies.

- None of the developed measures is related to deutero-learning which is described in Section 2.2.3. Further measures should be developed or the existing measures should be adjusted in order to assess deutero-learning in organizations.
- The majority of the developed measures assess the OL capabilities of the organization primarily with the utilization of documents that the assessed entity develops over time. However, not all organizational effort and OL activity is reflected on the developed documents or not all software development organizations produce the same amount of documents having the same information detail. Valuable information regarding OL resides in different software artifacts and other tangible by-products, that are produced by the organization during the software development process but are not taken into account by the AiOLoS measures that are proposed in this study.

6.2. Contributions

The main objective of the thesis was to provide a way of modeling and measuring OL in software development organizations. With respect to this objective, AiOLoS, a unified model for assessing the OL capabilities of software development organizations has been developed. Further contributions of this research are:

- An extensive literature survey in the areas of OL, LO and KM, both in theory (Chapter 2) and practice (Chapter 3), to provide the basis of AiOLoS but also the basis for comprehending LSOs.
- An extensive list of generic measures (Section 4.4), mapped to OL, LO and KM theory and practices (Section 4.4), developed to be utilized in the assessment of the core processes defined by AiOLoS. In contrast to

the existing LO assessment models, the measures of AiOLoS are predominantly objective.

- A guideline (Section 4.5) for the development of new measures or the adjustment of the existing measures of AiOLoS.
- With the interpretation of the obtained results from the assessment (as in case studies A, B and C) a starting point for the enhancement of OL capabilities within the organization can be realized. That enhancement will constitute a basis for the conduction of SPI activities.
- The use of critical thinking based SQ4R methodology (Case Study A) for the enhancement of OL in teams, groups or organizations in general.

6.3. Future Work

The aforementioned weaknesses and limitations of AiOLoS indicate several potentials for further research. These possibilities are briefly summarized in this section. Furthermore, three extensive potentials for further development are given, namely the modeling of the relationship of AiOLoS to SPI, the addition of the maturity dimension to AiOLoS and statistical studies on the metrics and results obtained in case studies.

The future work regarding the limitations and weaknesses of AiOLoS can be listed as:

- Further case studies to better comprehend “how good AiOLoS assesses the real OL capabilities of software development organizations”.
- Case studies to validate that AiOLoS can be used within the context of the software development organization as a whole and not only in the context of software projects developed by teams.
- The effects of organizational structure and the applied development process model on OL assessment, and the proposal of measures specific for different organizational structures and development models.
- Development of benchmark values and the assessment of OL in case studies based on these benchmark values.
- Development of new measures for the assessment of informal OL.

- As the structure of AiOLoS and the nature of the developed generic measures are very specific to software development organizations, the modification and enhancement of the AiOLoS model and the development of new measures that can assess OL in organizations that are not operating in the domain of software development can provide important insights on the generalizability and applicability of AiOLoS.
- Development of new measures that will allow the assessment of software artifacts and by-products other than software documents, that are produced during the development of software products by the organization.
- Adjustment of the existing measures to resolve the inconsistency problem between the measures with an independent upper bound value and measures that do not have an upper bound value.
- A solution for the graphical representation of the measures that are NA and the measures that have been calculated as zero.
- Development of new measures to assess deutero-learning in different major process areas and core processes.

6.3.1. Relationship of AiOLoS to Software Process Improvement

Even though this was not a major objective of the present study, the AiOLoS model structure, the major process areas and core processes, and the corresponding generic measures can obviously provide a basis for SPI. It is worth investigating whether the structure of the AiOLoS model is appropriate to be accepted and used as a process assessment model in the software process assessment context of SPICE. Such a proposal is given Figure 23, where AiOLoS is used as the process assessment model within the SPICE framework [5].

Redding [124] proposes a step-by-step guide to conduct LO assessments, consisting of 6 steps and requiring periodic assessments. By modifying the proposed guide by Redding [124], we propose a similar guide for conducting periodic assessments of OL for the development of LO and SPI initiatives with the use of AiOLoS model, as depicted in Figure 24. As the OL and SPI goals of the organization may change over time, the periodic assessment covers all steps of the

guide, in contrary to the original proposed model by Redding which covered only steps 3 to 6 in periodic assessments.

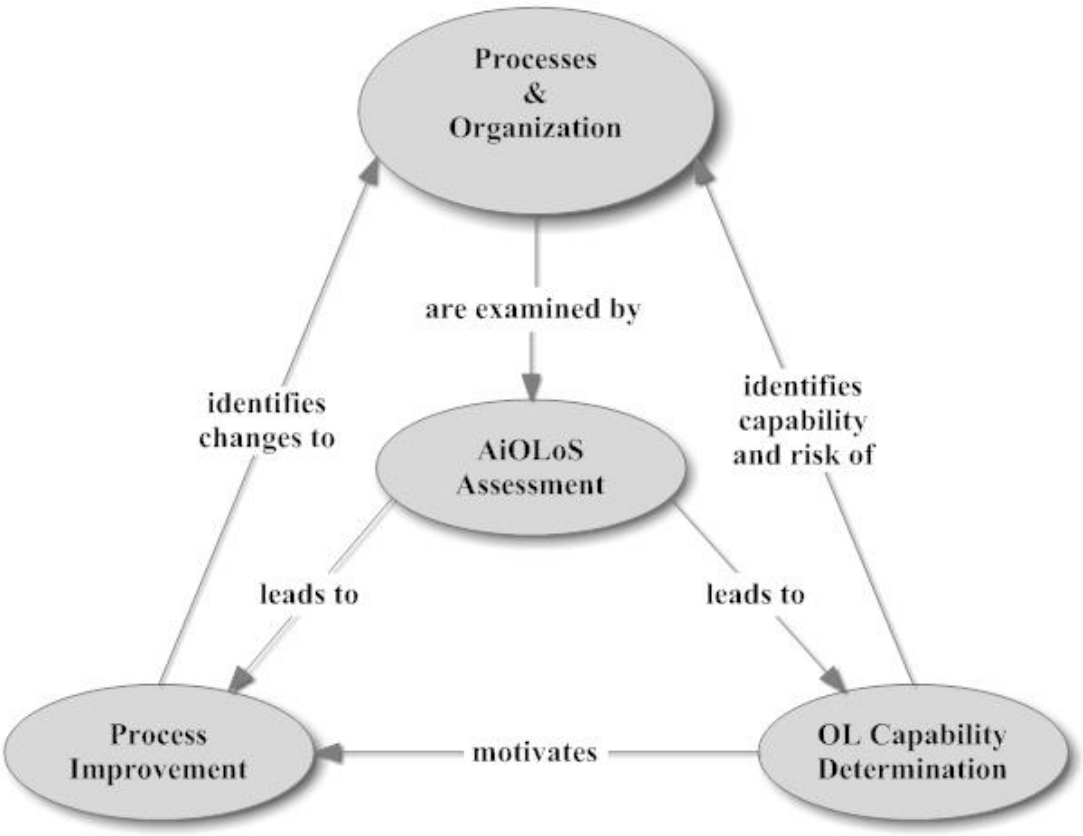

Figure 23 The AiOLoS Model in the Context of Software Process Assessment, a Modification of the Model Provided in ISO/IEC TR 15504-1:2004

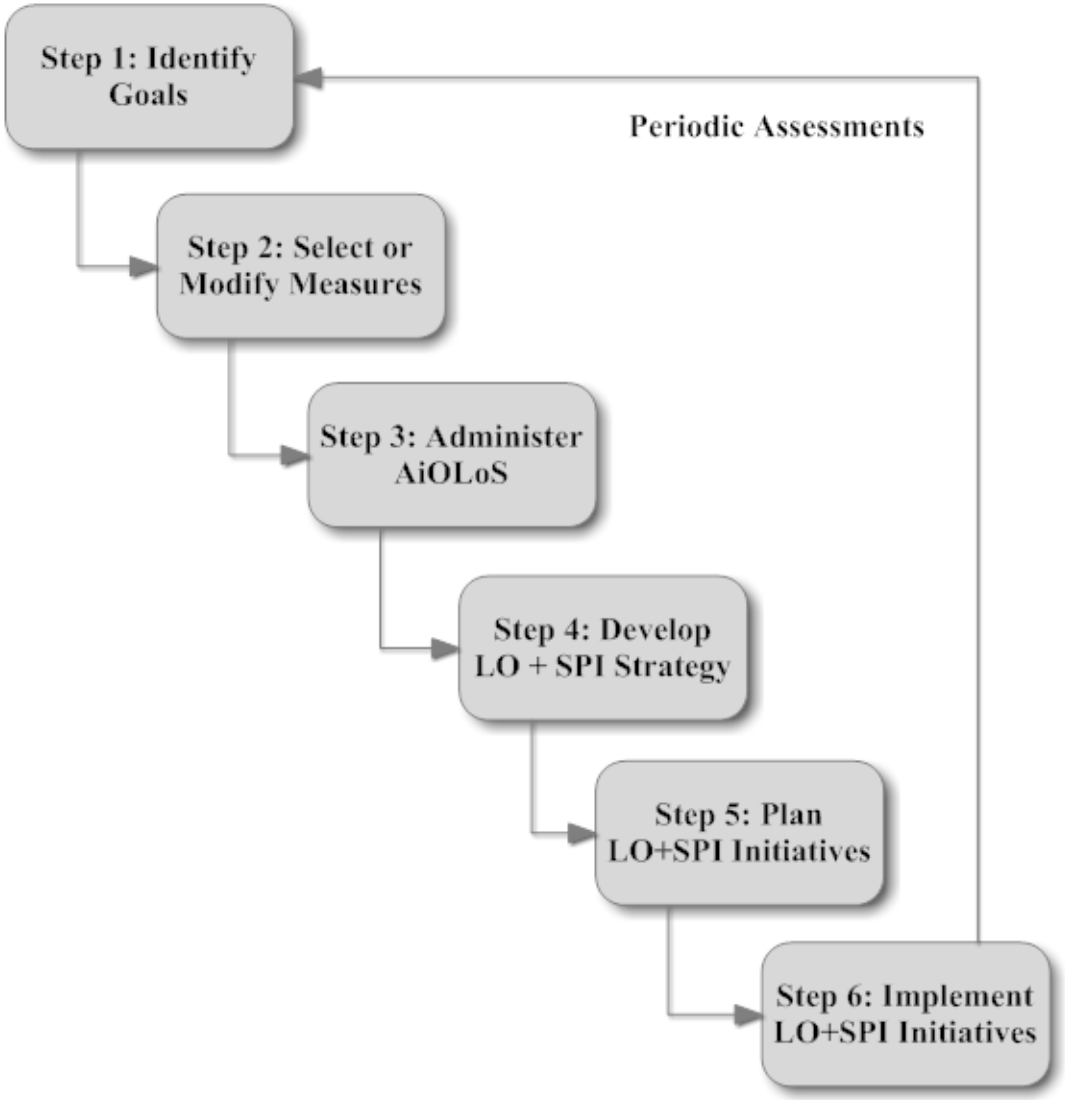

Figure 24 LO+SPI Assessment Model Using AiOLoS, a Modification of the Model Proposed by Redding [124]

6.3.2. Maturity Dimension Enhancement to AiOLoS Model

Although AiOLoS provides the measures and ways to assess OL capabilities, it does not provide a classification scheme for the assessment of how mature is the organization with respect to its OL capabilities. Similar to CMMi, a maturity dimension may be added to AiOLoS model, in accordance to the existing core processes, to assess the OL maturity of the software development organization.

As in the development of the major process areas and core processes, the KM literature can be utilized in the development of the OL maturity dimension of AiOLoS. Liebowitz and Beckman [149] describe the Knowledge Management Maturity Model (K3M), which being similar to CMM, blends diverse schools of thought to better structure the assessment and formulation of KM related competencies and capabilities, trying to determine the KM maturity level of an organization based upon its KM, learning, competency and business strategies. K3M consists of 6 maturity levels, and the related learning strategies are [149]:

0. Nonawareness: steady state
1. Awareness: curiosity
2. Initiation: indoctrination
3. Intrigue and interest: enthusiasm
4. Penetration: replication and discovery
5. Utility: renewal and creation

Ehms and Langen [150] describe the K3M model of Siemens AG, namely Siemens KMMM, developed along the lines of the CMM. The analysis model creates transparency in all key areas of KM and demonstrates the potential for improvement. The levels of maturity provided by Ehms and Langen are similar to CMM, namely initial, repeated, defined, managed and optimized.

Liebowitz and Beckman [149] and Ehms and Langen [150] provide a basis for linking business and knowledge strategies toward developing an OL maturity model for a software development organization. Based on these definitions n initial mapping between AiOLoS core processes and maturity levels is given in Table 76. This research provides the underlying literature to construct a basis and the initial roadmap to move in this direction and to enhance AiOLoS with an OL maturity dimension. Future work needs to be conducted to apply this initial framework to software organizations, and to flesh out the necessary AiOLoS metrics at each maturity level.

Table 76 Mapping of AiOLoS Core Processes to K3M Levels

	Obtaining Knowledge	Using Knowledge	Passing Knowledge
Nonawareness	–	–	–
Awareness	– Knowledge Acquisition	– Knowledge Dissemination	– Knowledge Preservation and Deleting
Initiation	– Knowledge Acquisition – Knowledge Identification	– Knowledge Dissemination – Knowledge Usage	– Knowledge Preservation and Deleting
Intrigue and interest	– Knowledge Acquisition – Knowledge Identification – Knowledge Development	– Knowledge Dissemination – Knowledge Usage	– Knowledge Preservation and Deleting – Knowledge Valuation
Penetration	– Knowledge Acquisition – Knowledge Identification – Knowledge Development	– Knowledge Dissemination – Knowledge Usage – Knowledge Organization – Knowledge Integration	– Knowledge Preservation and Deleting – Knowledge Valuation – Knowledge Selling
Utility	– Knowledge Acquisition – Knowledge Identification – Knowledge Development – Knowledge Evolution	– Knowledge Dissemination – Knowledge Usage – Knowledge Organization – Knowledge Integration – Knowledge Publication – Knowledge Evolution	– Knowledge Preservation and Deleting – Knowledge Valuation – Knowledge Selling – Knowledge Evolution

6.3.3. Statistical Studies on AiOLoS Model Measures

The case studies undertaken and given in detail in Chapter 5 where in qualitative nature and thus they did not allow the conduction of advanced statistical work. However, to uncover the true capabilities of AiOLoS and of the developed measures, and to understand the extent at which AiOLoS can be generalized it is important to statistically support the results that are obtained with the conduct of

AiOLoS in different environments. In this respect, the following items are planned to be investigated by performing a number of future case studies:

- The identification of correlated measures, and the description of the correlation and correlation direction between these measures. Correlation between several developed measures of AiOLoS is evident as these measures use common data items. However, it would be of greater importance to discover correlations between measures that do not have common measurement characteristics and especially between measures from different core process and major process areas.
- The development of prediction mechanisms based on statistical data that will allow the prediction of NA measures with the use and utilization of data obtained by correlated measures that can be actually measured.
- The investigation of correlations between AiOLoS measures and measures or data within the organization that are obtained by other measurement or assessment tools, such as project performance measures. Determining associations between AiOLoS measures and important project performance measures such as schedule variance, cost variance, schedule performance index and cost performance index can be of critical importance for the estimation of project success by using AiOLoS.
- The investigation of correlations between AiOLoS measures and product quality. If such associations can be identified, then a possible theoretical contribution can be developed that will state the effect OL can have on the quality of the developed software product, based on empirical data.

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APPENDICES

APPENDIX A1: Case Study A – Sample Questionnaire

Soru		Cevap
0	Adınız	
0	Yapmakta olduğunuz sürecin adı	
0	Sorumluğunuzda olan dokümanın adı	
1	Hazırladığınız dokümanda, kaç başlık herhangi harici bir bilgi kaynağından faydalanılmadan hazırlanmıştır?	
2	Hazırladığınız dokümanda toplam olarak kaç başlık hazırladınız?	
3	Bu süreç içinde birey olarak grup içi eğitim aldınız mı? (proje yöneticinizden veya diğer proje grubu elemanlarından) EVET veya HAYIR olarak cevaplayın	
Bu süreç içinde tamamlamanız gereken (grup olarak) toplam iş sayısı: 9 Bu işlerin ne olduğu ek dosya olarak verilmiştir		
5	Bu süreç içinde herhangi bir bilgi kaynağından faydalanmadan, yanda verilen işlerden tamamladığınız iş/görev sayısı nedir?	
7	Bu süreç içinde birey olarak harici (grup içi olmayan) eğitim aldınız mı? EVET veya HAYIR olarak cevaplayın	
9	Moodle'da verilmiş olan cevaplardan (sizin veya diğer grupların sorularına fark etmez) kaç tanesi sizin için faydalıydı? (örneğin bir problemi çözmenizi sağladı veya dokümanda bir kısmı tamamlamanızı sağladı)	
10	Birey olarak bu süreç içinde dersin hocasına email ile kaç soru sordunuz? (Bir email içinde birden fazla soru sormuşsanız o zaman her birini ayrı sayın)	
11	Emaillerinize aldığınız cevaplardan kaç tanesi sizin için faydalıydı?	

12	Birey olarak bu süreç içinde dersin hocasına yüz yüze kaç soru sordunuz? (Bir yüz yüze görüşmede birden fazla soru sormuşsanız o zaman her birini ayrı sayın)	
13	Yüz yüze almış olduğunuz cevaplardan kaç tanesi sizin için faydalıydı?	
14	Bu süreç içinde birey olarak toplam olarak kaç farklı konu hakkında eğitim aldınız? (derslerdeki konu başlıklarını birbirinden farklı sayabilirsiniz. Ayrıca bu soruda herhangi bir kaynaktan, örneğin proje yöneticiniz, başka proje elemanı, bir kitap, internet sitesi vs. öğrendiğiniz konu başlıklarını sayın)	
15	Bu süreç içinde kaç tane harici yazılı kaynaktan (dokümandan) faydalandınız?	
16	Bu süreç içinde kaç saat derse katıldınız?	
17	Bu süreç içinde siz bir birey olarak kaç tane orijinal fikir ürettiniz? (orijinal fikir, dersin hocasının size dağıtmış olduğu şablonlar haricinde bir işi yapmak veya bir doküman parçasını tamamlamak için ürettiğiniz fikirdir. Burada bu fikrin uygulanmış veya uygulanmamış olması önemli değildir)	
18	Bu süreçte bir birey olarak toplam kaç saat çalıştınız?	
18a	Bu süreç içinde kaç tane orijinal fikriniz (birey olarak size ait fikirleri sadece sayın) proje yöneticisi veya diğer proje arkadaşlarınız tarafından "uygulanabilir" olarak düşünüldü?	
19	Bu süreç içinde kaç tane orijinal fikriniz (birey olarak size ait fikirleri sadece sayın) siz veya proje ekibi tarafından projenizde uygulandı?	
20	Bu süreç içinde hazırlamış olduğunuz dokümanlardan, bu süreçteki diğer dokümanlara kaç tane referans verilmektedir? (verdiğiniz linkleri her bir doküman için ayrı ayrı verin, dokümanların her birini farklı sütunlara yazın)	
21	Bu süreç içinde hazırlamış olduğunuz dokümanlardan, bu süreç hariç, bu süreçten önceki süreçlerde hazırlanmış olan diğer dokümanlara kaç tane referans verilmektedir? (verdiğiniz linkleri her bir doküman için ayrı ayrı verin, dokümanların her birini farklı sütunlara yazın)	
22	Bu süreç içinde Proje yöneticiniz tarafından size kaç tane bilgi verici email/mesaj geldi?	
23	Bu süreç içinde dersin hocasından en üst yönetici kimliği ile size kaç tane bilgi verici email/mesaj geldi?	
24	Bu süreç içinde proje yöneticiniz tarafından size gelen toplam email/mesaj sayısı ne kadardır?	
25	Bu süreç içinde kaç tane bilgilendirici/problem çözücü/iş üretici toplantıya katıldınız? (sayı olarak)	

26	Bu süreç içinde kaç saat bilgilendirici/problem çözücü/iş üretici toplantıya katıldınız? (saat olarak)	
27	Bu süreç içinde katıldığınız toplantıların tamamında toplam olarak kaç tane konu gündeme getirdiniz (sadece sizin tarafınızdan gündeme getirilen konuları sayın)	
28	Bu süreç içinde katıldığınız toplantıların tamamında toplam olarak kaç tane konu başlığı konuşuldu/üstünden gidildi? (sadece sizin tarafınızdan gündeme getirilen ve görüşülen konuları sayın)	
29	Bu süreç içinde katıldığınız toplantıların tamamında toplam olarak kaç tane konu/sorun çözüme kavuşturuldu? (sadece sizin tarafınızdan gündeme getirilen ve çözülen konuları sayın)	
30	Bu süreçte yanda verilmekte olan görevlerden sizin yapmış olduğunuz toplam kaç iş/görev vardı? (bireysel olarak cevaplayın)	
31	Bu süreç içinde yanda verilmekte olan yapmış olduğunuz işlerin/görevlerin kaç tanesi daha önceki süreçlerde yapmış olduğunuz görevlere benziyordu? (bireysel olarak cevaplayın)	
32	Bu süreç içinde ekte verilmekte olan yapmış olduğunuz işlerin/görevlerin kaç tanesi yeni öğrenmiş olduğunuz bir bilgiye göre daha önceki süreçlerde yapmış olduğunuz görevlerden farklıydı (sadece sizin yaptığınız)?	
33	Bu süreç içinde hazırlamış olduğunuz/tamamladığınız doküman başlığı ne kadardır (sadece sizin hazırladığınız)?	
34	Bu süreç içinde hazırlamış olduğunuz/tamamladığınız doküman başlıklarının ne kadarını daha önceki süreçlerde yaptığınız şekilde hazırladınız (sadece sizin hazırladığınız)?	
35	Bu süreç içinde hazırlamış olduğunuz/tamamladığınız doküman başlıklarının ne kadarını yeni öğrenmiş olduğunuz bir bilgiye göre daha önceki süreçlerde yaptığınız şekilden farklı bir şekilde hazırladınız (sadece sizin hazırladığınız)?	
36	Bu süreçte yapmakta olduğunuz (ekte verilen görevlerden) fakat yapma şeklinin değiştirilmesi için grup içinden önerilen/teklif edilen kaç tane iş/görev vardı?	
37	Bu süreçte yapmakta olduğunuz (ekte verilen görevlerden) fakat yapma şeklinin değiştirilmesi için dersin hocası tarafından önerilen/teklif edilen kaç tane iş/görev vardı?	
38	Bu süreçte yapmakta olduğunuz fakat yapma şeklinin değiştirilmesi için grup içinden önerilen/teklif edilen kaç doküman başlığı vardı?	

39	Bu süreçte yapmakta olduğunuz fakat yapma şeklinin değiştirilmesi için dersin hocası tarafından önerilen/teklif edilen kaç doküman başlığı vardı?	
	Aşağıdaki konular bu aşamada öğrenmenizi beklediğim konular/başlıklar. Bu öğrendikleriniz hakkında sizin için profesyonel anlamda ne kadar değerli olduklarını yanlarına yazın. 1: hiç değerli/anlamlı değil 5: çok değerli/çok anlamlı. 0: hiç öğrenmedim! **ÖNEMLİ: Eğer öğrendiğiniz şeyin ne kadar değerli olduğunu ölçemiyorsanız değer kısmını boş bırakın!**	
39.1	Test sonuçlarını dokümante etmeye	
39.2	Test sonuçlarını değerlendirmeyi	
39.3	Eski sistemden yeni sisteme geçiş planı tanımlamayı ve alternatifleri değerlendirmeyi	
39.4	Kullanım kılavuzu yazmayı	
39.5	SSS yazmayı	
39.6	Eğitim planı oluşturmayı	
39.7	Eğitim vermeyi	
39.8	Eğitim kaynaklarını yönetmeyi	
39.9	Sistem kurulumunu sağlamayı	
39.10	Sistem geçişini tamamlamayı	
40	Bu süreç içinde yeni öğrenmiş olduğunuz bilgiler nedir? Hepsini sırası ile aşağıdaki listeye ekleyiniz. Daha sonra bu bilginin yanına sizin için ne kadar "değerli" olduğunu 0-5 arasında bir sayı kullanarak belirtin (0 hiç değerli/anlamlı değil… 5 çok değerli/çok anlamlı. **ÖNEMLİ: Eğer öğrendiğiniz şeyin ne kadar değerli olduğunu ölçemiyorsanız değer kısmını boş bırakın!**	

APPENDIX A2: Case Study A – Sample Meeting Minutes Document

Süreç Adı: -->					
Toplantı sayısı ve tarihi	**Kimler katıldı?**	**Toplantı kaç saat sürdü?**	**Kaç konu gündeme geldi?**	**Kaç konu konuşuldu/üstünden geçildi?**	**Kaç konu/sorun çözüme kavuşturuldu?**

APPENDIX A3: Case Study A – Exams Given To Groups

Exam 1

Soru 1: Bir tablet bilgisayar için integral hesaplama (çözme) programı yazdığınızı varsayarak bu program için bir fonksiyonel gereksinimi (capability/functional requirement) aşağıdaki tabloyu kullanarak tanımlayın.

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

Soru 2: Birinci soruda tanımlamış olduğunuz fonksiyonel gereksinimin tamamı veya bir süreci için bir use-case diyagram oluşturun ve aşağıdaki usa-case tablosunu uygun şekilde doldurun.

Table - Process Description

Identifier	
Purpose	
Requirements	
Development Risks	
Pre-conditions	
Post-conditions	

Table - Typical Course of Action

Seq#	Actor's Action	System's Response
1		
2		
…		
n		

Table - Alternate Course of Action

Seq#	Actor's Action	System's Response
1		
2		
…		
n		

Table - Exceptional Course of Action

Seq#	Actor's Action	System's Response
1		
2		
…		
n		

Soru 3: Aşağıdaki DOĞRU/YANLIŞ sorularını uygun şıkkı işaretleyerek cevaplayın ve yanlarına kısaca neden böyle düşündüğünüzü açıklayın (hazırladığınız dokümanlardan örnek verebilirsiniz)

Gereksinim dokümanı (Requirements document) sadece sistemin fonksiyonalitesini tanımlamaya odaklanmaktadır.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

Tasarım ve geliştirme/kodlama süreçleri gereksinim spesifikasyonlarını çalıştırılabilir bir programa dönüştürmektedirler.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

Gereksinim yönetimi projeyi etkileyebilecek olan riskleri tanımlamak ve bu risklerin proje için "büyük bir soruna" dönüşmesini engelleyecek planları geliştirmek ile ilgilidir.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

Bir sistem tarafından sunulmakta olan hizmetler veya fonksiyonalite üstündeki kısıtlamalar/sınırlamalar fonksiyonel-olmayan (non-functional) gereksinimlerdir.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

“Maintainability” (bakılabilirlilik, bakım kolaylığı, sürdürebilirlilik), **“dependability”** (güvenilebilirlik), **“efficiency”** (etkinlik), **“usability”** (kullanılabilirlilik) iyi bir yazılım sisteminin öznitelikleri arasındadır.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

Exam 2

Soru 1: Bir tablet bilgisayar için bir QR kod okuma programı yazdığınızı varsayarak bu program için bir fonksiyonel gereksinimi (capability/functional requirement) aşağıdaki tabloyu kullanarak tanımlayın.

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

Soru 2:
a) Prototip kullanmanın amaçları nedir? Neden prototip kullanıyoruz?
b) Prototip dokümanında bir prototip ile ilgili hangi bilgileri bulundurmalısınız?

Soru 3: Aşağıdaki DOĞRU/YANLIŞ sorularını uygun şıkkı işaretleyerek cevaplayın ve yanlarına kısaca neden böyle düşündüğünüzü açıklayın (hazırladığınız dokümanlardan örnek verebilirsiniz)

Gereksinimleri matematiksel ve kurallı notasyonlar (şekiller ve anlatımlar) ile ifade etmek anlaşırlılığı artırır, bir başka deyişle gereksinim daha az karmaşık, daha net olmaktadır.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

“Kullanıcı istediği zaman şifresini değiştirebilmelidir” gereksinimi bir fonksiyonel gereksinimdir.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

“14 gün boyunca süren belli bir kullanımdan sonra, ortalama bilgiye sahip bir kullanıcı sistemi en az 4 saat boyunca yardım bilgisi almadan, kullanım kılavuzuna bakmadan ve iş arkadaşlarından destek istemeden kullanabilmelidir” gereksinimi bir fonksiyonel gereksinimdir.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

Gereksinim analizi (Requirements analysis) sistemin nasıl tasarlanacağına ve nasıl “inşa edileceğine” odaklanmaktadır.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

“Kullanıcı kabul edilebilir zamanda sistem tarafından cevaplandırılmalıdır” iyi/güzel bir gereksinim olarak nitelendirilebilir.

Doğru □ Yanlış □

Açıklama:

_____

_____

_____

Exam 3

Soru 1: Aşağıdaki “kullanıcı” gereksinimlerini inceleyin. Sizce aşağıdaki gereksinimlerin her biri:

a) Tam (complete)
b) Açık, anlaşılır (clear)
c) Ölçülebilir (measurable)
d) Doğrulanabilir (verifiable)

Eğer değillerse, yukarıdaki özellikleri sağlayacak şekilde her bir gereksinimi tekrar yazın, tanımlayın, detaylar verin ve tekrar formüle edin.

Gereksinim 1: Sistem, personelin minimum eğitim alması ile kolay kullanılabilir olması lazım
Gereksinim 2: Veritabanı 10 yıllık kayıtlara kadar saklamalı
Gereksinim 3: Sistemin ürettiği satış raporunun üretimi ile müşteriye iletilmesi arasındaki maksimum gecikme 2 saat olmalı.
Gereksinim 4: Kullanıcı istediği zaman şifresini değiştirebilmelidir

Soru 2: Aşağıdaki UML Use Case diyagramını kullanarak Fonksiyonel (Behavior) analiz kapsamında bir fonksiyonel yeteneğini (Capability) aşağıdaki tabloları doldurarak açıklayın/tanımlayın.

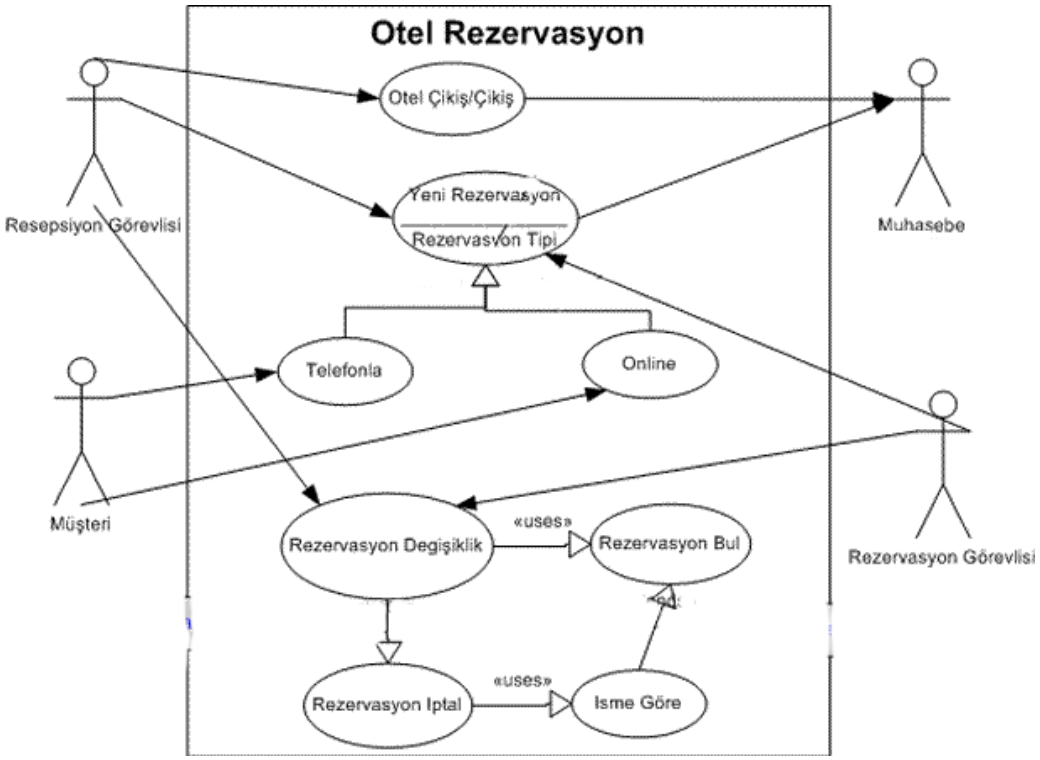


Table - Process Description

Identifier	
Purpose	
Requirements	
Development Risks	
Pre-conditions	
Post-conditions	

Table - Typical Course of Action

Seq#	Actor's Action	System's Response
1		
2		

Table - Alternate Course of Action

Seq#	Actor's Action	System's Response
1		
2		

Table - Exceptional Course of Action

Seq#	Actor's Action	System's Response
1		
2		

Exam 4

Soru 1: Üniversitemiz için yapılacak olan yeni öğrenci kayıt sistemi için gereksinim tanımlaması yapmaktasınız. Bu sistem için 1 Fonksiyonel (Functional), 1 Hizmet seviyesi (Level of Service), ve 1 tane de Kullanıcı Arayüz (User Interface Standards) gereksinimi tanımlayınız

Functional Requirement

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

LOS Requirement

Level of Service Requirement:	
Description:	
Priority:	
Desired Level:	
Accepted Level:	
Measurable:	
Achievable:	
Relevant:	
Specific:	

User Interface Standards Requirement

System Interface Requirement:	
Description:	
Priority:	

Soru 2: Yukarıda tanımlamış olduğunuz fonksiyonel gereksinim için bir Test Case hazırlayın

Test Case Number	
Test Item	
Test Priority	
Pre-conditions	
Post-conditions	
Input Specifications	
Expected Output Specifications	
Pass/Fail Criteria	
Assumptions and Constraints	
Dependencies	
Traceability	

Exam 5

Soru 1: Aşağıdaki senaryoyu okuyun:

Öğrenciliğim yıllarında ODTÜ İşletme bölümünde öğrencilerin seçmeli dersleri seçmeleri için bir "açık artırma" yöntemi kullanılmaktaydı. Bu yönteme Online Bidding System (OBS) adı verilmekteydi. Bölüm öğrenim hayatı başında öğrencilerin seçebileceği 9 tane seçmeli ders için, her öğrenciye 900 puan verilirdi. Her dönem öğrenci maksimum 5 seçmeli ders seçebiliyordu. (5 dersten daha fazlasını seçemez fakat daha az ders seçebilirdi) Öğrenci OBS'ye öğrenci no ve şifresi ile bağlanırdı. Bu öğrenci no ve şifreler bir Kullanicilar dosyasında saklanmaktaydı, eğer öğrenci doğrulanmışsa (dosyada kaydı varsa) öğrenci sisteme giriş yapardı. Eğer öğrenci no veya şifresi yanlışsa, veya öğrenci Kullanicilar dosyasında kayıtlı değilse, sistem tarafından öğrenciye uygun hata mesajı gönderilirdi. Başarı ile sisteme girmiş olan (login) olmuş olan öğrencilere "teklif" verebilecekleri derslerin listesi gelirdi. Öğrenci bu listeden dersin kodunu ve vermek istediği puanı seçerek teklif verirdi. Teklif kaydedilmeden önce, sistem öğrencinin bu derse o kadar puan verip veremeyeceğini kontrol ederdi (verdiği puanların toplamı 900'ü geçmemesi gerekir). O ana kadar verilmiş puanların kontrolü için sistem Kullanicilar dosyasında her öğrenci kaydının yanında Kalan Puanlar diye bir alan tutmaktaydı. Eğer teklif "geçerli" ise, öğrencinin teklifi ÖğrenciNo, DersKodu ve Puan şeklinde Teklifler isimli dosyaya kaydedilirdi ve Kullanicilar dosyasında öğrencinin kaydının yanındaki Kalan Puanlar alanı güncellenirdi. Eğer teklif geçerli değilse OBS öğrenciye bir hata mesajı gönderirdi. Eğer öğrenci teklifini artırmak veya iptal etmek istiyorsa ilk baştan teklif verirmiş gibi o derse teklif veriyordu. Eğer öğrenci bir derse 0 puan verirse bu "teklifi iptal et" anlamını taşımaktaydı. Eğer öğrenci 5 tane derse teklif vermişse, öğrenci 6. derse teklif vermeye çalıştığında sistem hata mesajı veriyordu. Tekliflerini tamamlayan öğrenci Çıkış düğmesine tıklayarak sistemden çıkışını sağlıyordu. Öğrenci yeni teklif vermek veya mevcut tekliflerini değiştirmek için tekrar sisteme bağlanabiliyordu. Sistem bir gün boyunca sabah saat 9:00'dan akşam saat 17:00'e kadar açık kalıyordu. Saat 17:00'de teklif verme süreci bitiyordu. Tüm verilmiş olan puanlar alınıp, sırasıyla her derse öğrenciler yerleştirilmeye başlanıyordu. Derslerin kapasitesi 30 kişiydi. Bir derse en yüksek puanı (en yüksek teklifi) vermiş olan ilk 30 kişi derse yerleştiriliyordu. Derse teklif vermiş (puan vermiş) olan fakat dersi alamamış olan kişilere puanları iade ediliyordu (daha sonraki dönemlerde kullanabilmeleri için).

Bu sistem için 1 Fonksiyonel (Functional), 1 Hizmet seviyesi (Level of Service), ve 1 tane de Kullanıcı Arayüz (User Interface Standards) gereksinimi tanımlayınız

Functional Requirement

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

LOS Requirement

Level of Service Requirement:	
Description:	
Priority:	
Desired Level:	
Accepted Level:	
Measurable:	
Achievable:	
Relevant:	
Specific:	

User Interface Standards Requirement

System Interface Requirement:	
Description:	
Priority:	

Soru 2: Yukarıda tanımlamış olduğunuz fonksiyonel gereksinim için bir Test Case hazırlayın

Test Case Number	
Test Item	
Test Priority	
Pre-conditions	
Post-conditions	
Input Specifications	
Expected Output Specifications	
Pass/Fail Criteria	
Assumptions and Constraints	
Dependencies	
Traceability	

Exam 6

Soru 1: Geçen hafta da işlemiş olduğunuz, aşağıdaki senaryoyu okuyun:

Öğrenciliğim yıllarında ODTÜ İşletme bölümünde öğrencilerin seçmeli dersleri seçmeleri için bir "açık artırma" yöntemi kullanılmaktaydı. Bu yönteme Online Bidding System (OBS) adı verilmekteydi. Bölüm öğrenim hayatı başında öğrencilerin seçebileceği 9 tane seçmeli ders için, her öğrenciye 900 puan verilirdi. Her dönem öğrenci maksimum 5 seçmeli ders seçebiliyordu. (5 dersten daha fazlasını seçemez fakat daha az ders seçebilirdi) Öğrenci OBS'ye öğrenci no ve şifresi ile bağlanırdı. Bu öğrenci no ve şifreler bir Kullanicilar dosyasında saklanmaktaydı, eğer öğrenci doğrulanmışsa (dosyada kaydı varsa) öğrenci sisteme giriş yapardı. Eğer öğrenci no veya şifresi yanlışsa, veya öğrenci Kullanicilar dosyasında kayıtlı değilse, sistem tarafından öğrenciye uygun hata mesajı gönderilirdi. Başarı ile sisteme girmiş olan (login) olmuş olan öğrencilere "teklif" verebilecekleri derslerin listesi gelirdi. Öğrenci bu listeden dersin kodunu ve vermek istediği puanı seçerek teklif verirdi. Teklif kaydedilmeden önce, sistem öğrencinin bu derse o kadar puan verip veremeyeceğini kontrol ederdi (verdiği puanların toplamı 900'ü geçmemesi gerekir). O ana kadar verilmiş puanların kontrolü için sistem Kullanicilar dosyasında her öğrenci kaydının yanında Kalan Puanlar diye bir alan tutmaktaydı. Eğer teklif "geçerli" ise, öğrencinin teklifi ÖğrenciNo, DersKodu ve Puan şeklinde Teklifler isimli dosyaya kaydedilirdi ve Kullanicilar dosyasında öğrencinin kaydının yanındaki Kalan Puanlar alanı güncellenirdi. Eğer teklif geçerli değilse OBS öğrenciye bir hata mesajı gönderirdi. Eğer öğrenci teklifini artırmak veya iptal etmek istiyorsa ilk baştan teklif verirmiş gibi o derse teklif veriyordu. Eğer öğrenci bir derse 0 puan verirse bu "teklifi iptal et" anlamını taşımaktaydı. Eğer öğrenci 5 tane derse teklif vermişse, öğrenci 6. derse teklif vermeye çalıştığında sistem hata mesajı veriyordu. Tekliflerini tamamlayan öğrenci Çıkış düğmesine tıklayarak sistemden çıkışını sağlıyordu. Öğrenci yeni teklif vermek veya mevcut tekliflerini değiştirmek için tekrar sisteme bağlanabiliyordu. Sistem bir gün boyunca sabah saat 9:00'dan akşam saat 17:00'e kadar açık kalıyordu. Saat 17:00'de teklif verme süreci bitiyordu. Tüm verilmiş olan puanlar alınıp, sırasıyla her derse öğrenciler yerleştirilmeye başlanıyordu. Derslerin kapasitesi 30 kişiydi. Bir derse en yüksek puanı (en yüksek teklifi) vermiş olan ilk 30 kişi derse yerleştiriliyordu. Derse teklif vermiş (puan vermiş) olan fakat dersi alamamış olan kişilere puanları iade ediliyordu (daha sonraki dönemlerde kullanabilmeleri için).

Bu sistem için geçen hafta tanımlamış olduğunuz fonksiyonel gereksinimden farklı 4 tane Fonksiyonel (Functional) gereksinimi tanımlayınız

Functional Requirement -1

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

Functional Requirement -2

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

Functional Requirement -3

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

Functional Requirement -4

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

Exam 7

Soru 1: Twitter için bir okuyucu program yazdığınızı varsayarak bu program için bir fonksiyonel gereksinimi (capability/functional requirement) aşağıdaki tabloyu kullanarak tanımlayın.

Capability Requirement:	
Description:	
Priority:	
Input(s):	
Source(s):	
Output(s):	
Destination(s):	
Precondition(s):	
Post conditions(s):	

Soru 2: Birinci soruda tanımlamış olduğunuz fonksiyonel gereksinimin tamamı veya bir süreci için bir use-case diyagram oluşturun ve aşağıdaki usa-case tablosunu uygun şekilde doldurun.

Table - Process Description

Identifier	
Purpose	
Requirements	
Development Risks	
Pre-conditions	
Post-conditions	

Table - Typical Course of Action

Seq#	Actor's Action	System's Response
1		
2		
…		
n		

Table - Alternate Course of Action

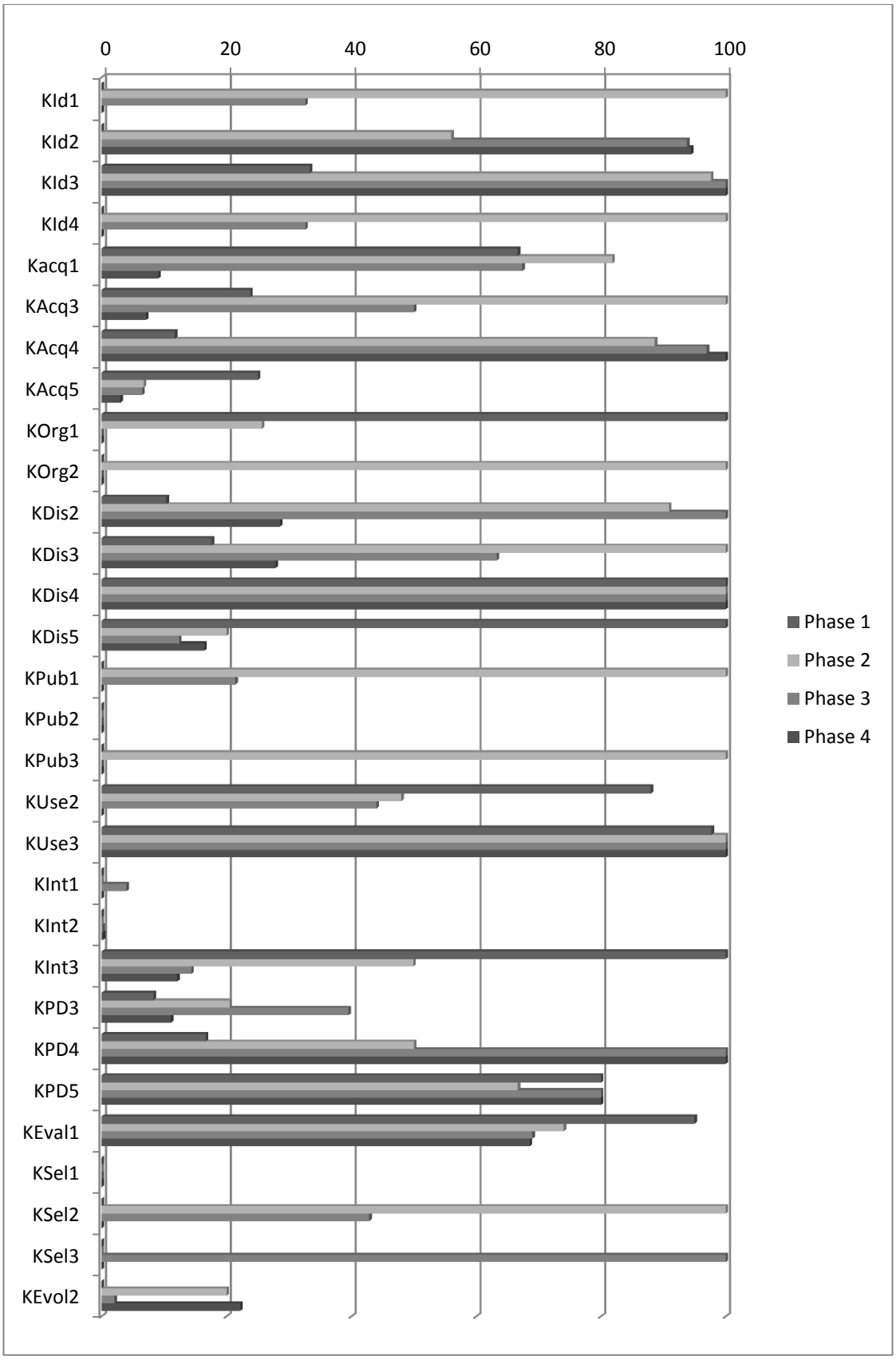
Seq#	Actor's Action	System's Response
1		
2		
…		
n		

Table - Exceptional Course of Action

Seq#	Actor's Action	System's Response
1		
2		
…		
n		

APPENDIX B1: Case Study B – Non-Normalized Metrics With Respect to PC and Corresponding Bar Chart

	METU-CC BBS Team			
	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
KId1	0	100	32,6087	0
KId2	0	56	93,80165	94,44444
KId3	33,33333	97,61905	100	100
KId4	0	100	32,6087	0
KAcq1	66,66667	81,81818	67,3913	9,090909
KAcq3	23,80952	100	50	7,142857
KAcq4	11,74242	88,63636	96,9697	100
KAcq5	25	6,742424	6,521739	3,030303
KOrg1	100	25,67164	0	0
KOrg2	0	100	0	0
KDis2	10,38961	90,90909	100	28,57143
KDis3	17,63699	100	63,28767	27,87671
KDis4	100	100	100	100
KDis5	100	20,02746	12,39041	16,47727
KPub1	0	100	21,42857	0
KPub2	0	0	0	0
KPub3	0	100	0	0
KUse2	88	48	44	0
KUse3	97,72727	100	100	100
KInt1	0	0	4	0
KInt2	0	0	0,125	0,222222
KInt3	100	49,93216	14,37632	12,12121
KPD3	8,333333	20,47619	39,53488	11,11111
KPD4	16,66667	50	100	100
KPD5	80	66,66667	80	80
KEval1	95	74,02439	69	68,58209
KSel1	0	0	0	0
KSel2	0	100	42,85714	0
KSel3	0	0	100	0
KEvol2	0	20	2,066116	22,22222


0
20
40
60
80
100
KId1
KId2
KId3
KId4
Kacq1
KAcq3
KAcq4
KAcq5
KOrg1
KOrg2
KDis2
KDis3
KDis4
KDis5
KPub1
KPub2
KPub3
KUse2
KUse3
KInt1
KInt2
KInt3
KPD3
KPD4
KPD5
KEval1
KSel1
KSel2
KSel3
KEvol2
Phase 1
Phase 2
Phase 3
Phase 4

APPENDIX B2: Case Study B – List of METU-CC BBS Team Learning Outcomes

No	Öğrenme Çıktısı	Edinildiği Faz
1	CASE Araçları ve Teknikleri	P3,P4
2	- ANT	P3,P4
3	- Çevik Yazılım Geliştirme	P3,P4
4	- Eclipse	P3,P4
5	- ERWin	P3,P4
6	- Hibernate (Object-Relation Mapping)	P3,P4
7	- JAVA	P3,P4
8	- Jquery, AJAX	P3,P4
9	- JSF, JSP	P3,P4
10	- Kod Analiz Araçları	P3,P4
11	- Konfigürasyon Yönetimi	P3,P4
12	- Sürekli Entegrasyon	P3,P4
13	- Test Yönetim Araçları	P2,P3,P4
14	5018 Sayılı Kanun	P2
15	5651 Kanun ve Hukuki Mevzuat	P2
16	Acceptance Test	P2,P3,P4
17	Activiti	P4
18	Atlassian JIRA ile Uymazlık Raporu Girişi	P3,P4
19	Başbakanlık Birlikte Çalışabilirlik Esasları Rehberi	P2,P3,P4
20	BPMN	P3,P4
21	BPMN Kullanımı	
22	Dublin Core Metadata Seti	P2,P3,P4
23	Fikri Mülkiyet Hakları	P3,P4
24	Genel BBS Mimarisi	P1,P2,P3,P4
25	Genel ODTÜ İşleyişi	P1,P2,P3,P4
26	Güvenlik Bileşenleri (Sunucu, Ağ, Firewall, vb.)	P2,P3,P4
27	Güvenlik Katmanları	P2,P3,P4
28	Güvenlik Yaklaşımı Hakkında Genel Fikir	P2,P3,P4
29	ISO 11179 Data Dictionary	P2,P3,P4
30	ISO 27000 Serisi	P2,P3,P4
31	ITIL	P2,P3,P4
32	JAVA ile Ontoloji Görüntüleme ve İşleme Çözümleri Geliştirme	P3,P4
33	JENA	P4
34	Jmeter	P2,P3,P4
35	Kamu İhale Kanunu	P2,P3,P4

No	Öğrenme Çıktısı	Edinildiği Faz
36	Kişisel Verilerin Korunması	P2,P3,P4
37	Liferay Portlet Geliştirme	P2,P3,P4
38	Liferay Yönetimi	P2,P3,P4
39	Load Test	P2,P3,P4
40	ODTÜ Üniversite Organizasyonu	P1,P2,P3,P4
41	Ontoloji Okur Yazarlığı	P3,P4
42	OWL	P3,P4
43	Penetrasyon Testi Raporu Okuyabilme	P2,P3,P4
44	Protege	P3,P4
45	Redmine	P2,P3,P4
46	Regression Test	P2,P3,P4
47	REST Web Servis Kullanımı	P3,P4
48	Satınalımın Teknik İçeriği	P2,P3,P4
49	Servis İzleme	P3,P4
50	Sistem Mühendisliği	P2,P3,P4
51	SOA	P2,P3,P4
52	SOA Governance	P2,P3,P4
53	SOAP	P2,P3,P4
54	SOAP / UI	P2,P3,P4
55	SPARQL	P3,P4
56	Süreç Analizi	P2,P3,P4
57	Süreç Değerlendirme	P2,P3,P4
58	Süreç Modelleme	P2,P3,P4
59	Süreç Modelleme	P2,P3,P4
60	Test Raporu Okuyabilme	P2,P3,P4
61	Tripple Store	P3,P4
62	Ulusal Sağlık Veri Sözlüğü	P2,P3,P4
63	Unit Test	P2,P3,P4
64	Usability Test	P2,P3,P4
65	Veri Sanallaştırma	P3,P4
66	Web Servis Uygulama Sunucusu Yönetimi	P3,P4
67	WSDL	P2,P3,P4
68	WSO2	P2,P3,P4
69	WS-Standartları	P2,P3,P4

APPENDIX B3: Case Study B – Interview Records of Project Managers and Sub-Group Leaders

Project Manager of METU-CC:

Toplantı tutanakları ile ilgili yeni bir yapılanma yapabiliriz. Birincisi gerçek toplantı tutanakları ile beraber çalışmaları (çalıştayları) birbirinden ayırmalıyız. Toplantı tutanaklarını metaveriler ile kodlayıp, tutanaklar içinde arama yapmayı ve tutanaktan bilgi çıkarmayı kolay hale getirmeliyiz. Toplantı tutanaklarının standart bir tutanak yapısında tutulmasını biz de istiyoruz. Toplantı tutanaklarının farklı kişiler tarafından kayıt altına alınması ortak bir kültürün oluşması ve beraber iş yapmayı öğrenmek açısından çok önemli. Dış eğitimler hakkında, eğitime gidenlerin bilgilerini dönüş sonrası paylaşmamalarına karşın, bu kişilerin dönüşleri sonrasında sunum yapmalarını zorunlu hale getirebiliriz. Bir şekilde insanların bu sunumları yapmalarını ve katılmalarını teşvik etmeliyiz. Feng-Office yüklenen dosyaların etiketlenmesinde eksiklikler oluyor, bunları engellememiz gerekecek. BBS grubu içinde süreç grubu konusuna çok hakim, ama diğer gruplar yeni yeni öğreniyorlar, o konuda bulgular doğru.

Project Manager of METU-CC BBS Project:

Bu projenin içinde bir Expertise Network oluşturabiliriz. Bir kalite ekibi olabilir, bunlar dokümanları değerlendirip eksikleri bulup düzeltmeden, düzeltmeleri yapmaları için dokümanları hazırlayanlara geri dönüş yapabilirler. Mekan sıkıntısı nedeniyle (ortak çalışma alanımızın olmamasından dolayı), bir araya gelip yaptığımız çalışmalara toplantı adını veriyoruz. Halbuki eğer "open office" gibi bir çalışma imkanımız olsaydı, toplantı bazında bir araya gelme ihtiyacımız olmayacaktı. Toplantı ve ortak çalışmaların birbirinden mutlaka ayrılması gerekmekte. Ben de modelin öğrenme yeteneklerini ölçebildiğini düşünüyorum. Ortaya çıkardığımız sonuçlar, benim sürekli gözlemlerimle uyuşuyor. Ölçülen öğrenme yeteneğinin direk olarak rekabet üstünlüğü sağlayacağını düşünmüyorum ancak elbette ki rekabet üstünlüğü sağlayacak iyileştirmelerde kullanılır. Yani dolaylı olarak üstünlük sağlar. Ayak izi ise, zaman içindeki değişimi gösterdiğinden anlamlı. İlk iki fazda bir altyapı kurulduğundan karşılaştırılabilirliği düşük ölçümlerin. Ancak 3 ve 4 ve sonraki fazlarda yapılacak (yapılırsa) ölçümlerle daha anlamlı ve karşılaştırılabilir

sonuçlar çıkacağını da düşünüyorum. Bu model SPI için kullanılabilir. Bahsettiğim gibi süreç iyileştirmenin ilk aşaması ölçüm yapmaktır. Eğer bu modeli bir ölçüm mekanizması olarak kabul ediyorsak bunu süreç iyileştirmenin bir parçası olarak da kabul etmeliyiz.

Sub-Group Team Leader 1:

Toplantılar birbirlerinden ayrılması gerekiyor. Toplantılarda genellikle gündem bilinmiyor, bu gündemin önceden tarafımıza iletilmesi gerekir. Toplantı esnasında konular çok sapıyor, hiçbir toplantı öngörülen sürede bitmiyor. Toplantılarda toplantı moderatörü olması lazım. Toplantılara zamanında gelen insan sayısı az. Harici eğitimlerle ilgili, eğitime giden kişiden bir rapor isteniyor ama diğer kişilerin hazırladığı herhangi bir raporu görmedim, bu raporlar sadece arşivleniyor. Kurum dışı alınmış eğitimler mutlaka o eğitimi alan kişi tarafından kurum içinde tekrarlanması lazım. Feng-Office'in arayüzü "rahatsız edici", daha kullanıcı dostu bir arayüzü olmalıydı. Feng-Office'i değiştirmek veya bir kullanım kılavuzu (guideline) yazmalıyız. Feng-Office'teki çoğu dokümanın ne olduğu ancak isminden anlaşılıyor, konuya hakim olmayan bir kişinin anlaması çok zor. Kılavuz (guideline) hazırlama konusunda hep başarısızız, insanlar bunları gözden geçirmiyor. Bu kılavuzların kalitesini artırmak için bir mekanizma olabilir ama bu da işgücünden çalmak olur. BBS projesinde çalışanların çoğu (2 kişi hariç) BBS'de tam zamanlı değil, dolayısıyla herkesin bir ikinci işi görevi daha var. Bu da işlerin aksamasına ve gecikmesine neden oluyor. Birincil ve ikincil işlerin karmaşıklığı var. İnsanların anlık (örneğin yılın ilk ayında) motivasyonu oluyor, bir sürü bilgi topluyor işi için ama daha sonra herhangi bir eser göremediğinde motivasyonu düşüyor. İnsanların motivasyonunu düşürmemek lazım. Bazen proje içinde çok boş bir işle uğraştığımız oluyor ve motivasyonumuzu kendi kendimize düşürmüş oluyoruz. Ayrıca insanları beraber çalıştırmada sorunlar yaşıyoruz, işi çok iyi bilen 5 adamımız var, ama 5'ini beraber çalıştıramıyoruz. İnsanların çalışma yöntemleri farklı oluyor ve biz çözüm üretemiyoruz. Projede çok iyi programlama ve planlama yapmak gerekiyor ama bunu çok iyi yapamıyoruz.

Sub-Group Team Leader 2:

İnsanlar eğitime gidiyor ama aldıkları eğitimi uygulamıyorlar, kurum içinde bunu diğer kişilerle paylaşmıyorlar. Eğitimin faydasını görmek için kişiler performans kriterlerine göre takip edilebilir ama bizde performans değerleme süreci yok. Performans sürecimizin olması gerekir. Performansları ekip veya proje yöneticileri değerlendirebilir, örneğin eğitimden önce yaptığı işe bakılır, eğitim sonrası yaptığı işe bakılır, proje yöneticisi bu ikisini karşılaştırır, ama burada önemli olan takibin yapılmasında. Eğitim sonrası kişinin neler yaptığına bakılmalı, kayıt altına alınmalı ve değerlenmeli. Örneğin Rektörlük bize "şu kadar insanı şu kadar eğitime gönderdiniz, bu eğitimlerin Bilgi İşleme katkısı nedir" diye sorsa, bir şey söyleyemeyiz. Bu model kanımca performans, toplantı ve eğitimler hakkında bilgi vermek için kullanılabilir.

Sub-Group Team Leader 3:

Kanımca efor gerekli ve önemli bir eksik, efor bilgisini daha sonraki projelerimizde kullanabiliriz, eski proje elemanları hakkında bilgi de verebilir bize. Katıldığım toplantılarda bir görev dağılımı yok, toplantı başlandığında tutanağı tutan birisi yok, toplantı bittikten sonra "hadi sen tutanağı hazırla" diye kişilere görev veriliyor. Bence bir kişi önceden seçilmeli ve bu görevini bilerek toplantı tutanağı tutmalı. Dönüşümlü olarak bu görev verilebilir kişilere.

Sub-Group Team Leader 4:

Ekipler farklı elemanlardan oluştuğu için bir araya gelmenin en kolay yolu toplantı düzenlemek. Bir toplantıdan diğerine sarkan açık maddeler toplantılar arasında takip edilmiyor, bir maddenin kapatılıp kapatılmadığı, durumunun ne olduğu bilinmiyor. Bence tutanakların tutulması için ayrı bir kişinin, bu işte uzman olan veya uzmanlaşacak bir kişinin ayrılması gerekir. KPub alanı tam netleşmemiş, elimizdeki bilgiler ham bilgi olduğu için bunları yayınlayamıyoruz. Ayrıca KPub için kendi iş yoğunluğumuz da engel oluyor. KEval bence azalmak yerine yükselmeliydi, çünkü proje ile ilgili çok fazla bilgi bizim için gri alandı, zaman içinde netleşti. Sayının artmasını beklerdim ama bu azalma anketin uygulanma şeklinden de kaynaklanmakta. Ürünün olmaması, ürünü aklımızda tam canlandıramamamız KUse alanını düşük kılıyor bence. Çoğu zaman bilgi aktarmak için çalışma yaptık, bilgiyi başarı ile aktardık ama bilgiyi projede birebir kullanmadığımız için bu bilgi kalmadı, kayboluyor. Bilgiyi elde etme kısmı ile ilgili olarak, tamamen yeni bir alan olduğu için kaynak bulmakta zorlandık ve bu bilgiler yeni olduğundan uygularken tam başarılı olamadık, zorluklar çektik. Hala öğrendiğimiz ama bu nasıl uygulanır dediğimiz noktalar var, Bu bilgileri projeye doğrudan uygulayabilir olsaydık daha net oturtabilirdik bazı şeyleri. Proje olarak yürüttüğümüz bazı araştırmalarımız var, bu araştırmalarımız etkinliği nasıl ölçülebilir? KUse2 haricinde ürün kalitesini tanımlamak için neler yapılabilir? KPub3 için ise, akademik bir birim olmadığımız için, farklı yöntemler uygulanmasını öneririm. Bilgi elde etme kısmının daha detaylı süreçlerle tanımlanması süreç iyileştirme için daha faydalı olabilir, bence daha fazla katkı sağlayabilir.

Sub-Group Team Leader 5:

Bu modelin ölçtükleri haricinde bence insanların motivasyonunu da ölçebilsek faydalı ve anlamlı olurdu. Bu motivasyon ölçümü bu modelin içinde bir süreç veya ayrı bir model olarak düşünülebilir. Alt gruplara bakarak motivasyonun neden düştüğünü, neden arttığına bakabiliriz, bu ayrıca bilgi edinme ve kullanma etkinliğimiz hakkında da bize bilgi vermiş olur.

APPENDIX C1: Case Study C – Questionnaires of Project Team Members and Project Managers

Açıklama: Aşağıdaki soruları, yukarıda belirtilen süreleri ve **X** projesini düşünerek cevaplamanız gerekmekte	
Sorular	Cevaplar
1a. Bu projede kaç farklı iş yapmaktasınız?	
1b. Yaptığınız işlerin kaçını yeni (sahip olmadığınız) bir bilgiyi/leri kullanarak yaptınız?	
2a. Bu projede kaç farklı doküman kısmı hazırlamaktasınız?	
2b. Hazırladığınız doküman kısımların kaçını yeni (sahip olmadığınız) bir bilgiyi/leri kullanarak hazırladınız?	
3a. Bu süre içinde takım elemanları haricinde diğer kişilere kaç soru sordunuz?	
3b. Bu süre içinde takım elemanları haricinde diğer kişilere sorduğunuz sorulardan kaçına faydalı cevap aldınız?	
4. Bu süre içinde faydalandığınız harici kaynaklar (web siteleri, forumlar, dokümanlar, kitaplar vs.) nelerdi?	
5. Bu süre içinde kaç tane fikir (problem çözücü veya orijinal) ürettiniz?	
6. Soru 5'te verdiğiniz sayıya dayanarak, bu fikirlerin kaçı uygulanabilir bulundu?	
7. Soru 6'da verdiğiniz sayıya dayanarak, bu fikirlerin kaçı gerçekten uygulandı?	
8. Bu süre içinde üst yönetimden (Proje Yöneticisi dahil) kaç tane bilgi içerikli mesaj aldınız?	
9.a. Bu süre içinde kaç tane takım içi (takımın bir başka üyesinden) eğitim aldınız?	
9.b. Bu süre içinde takım içi (takımın bir başka üyesinden) aldığınız eğitimlerin süresi nedir?	
9.c. Bu süre içinde takım içi (takımın bir başka üyesinden) aldığınız eğitim başlıkları nedir?	
10.a. Bu süre içinde kaç tane takım dışı (takıma ait olmayan kişilerden) eğitim aldınız?	
10.b. Bu süre içinde takım dışı (takıma ait olmayan kişilerden) aldığınız eğitimlerin süresi nedir?	
10.c. Bu süre içinde takım dışı (takıma ait olmayan kişilerden) aldığınız eğitim başlıkları nedir?	
11. Bu süre içinde proje takımı haricinde kaç tane eğitim verdiniz?	
12. Soru 11'e dayanarak, kaç konu hakkında eğitim verdiniz?	
13. Soru 11'e dayanarak, kaç saat eğitim verdiniz?	

Değerlendirme Başlangıç Tarihi:	
Değerlendirme Bitiş Tarihi:	
Açıklama: Aşağıdaki soruları, yukarıda belirtilen süreleri ve **X** projesini düşünerek cevaplamanız gerekmekte	
Sorular	Cevaplar
0.a Bu süre içindeki toplam proje eforu nedir? (adam ay)	
0.b Bu süre içinde projede çalışmış olan toplam eleman sayısı ne kadardır?	
1. Kaç toplantı (sayı olarak) yapıldı?	
2. Yapılan toplantıların toplam süresi (saat olarak) ne kadardı?	
3a. Bu süre içinde takım elemanları haricinde diğer kişilere (kurum içi veya dışı) kaç soru sordunuz?	
3b. Bu süre içinde takım elemanları haricinde diğer kişilere (kurum içi veya dışı) sorduğunuz sorulardan kaçına faydalı cevap aldınız? (Faydalı cevap/Sorulan soru)	
4. Bu süre içinde faydalandığınız harici kaynaklar (web siteleri, forumlar, dokümanlar, kitaplar vs.) nelerdi? (İsmen belirtiniz)	
5. Bu süre içinde kaç tane fikir (problem çözücü veya orijinal) ürettiniz?	
6. Soru 5'te verdiğiniz sayıya dayanarak, bu fikirlerin kaçı uygulanabilir bulundu?	
7. Soru 6'da verdiğiniz sayıya dayanarak, bu fikirlerin kaçı gerçekten uygulandı?	
8. Bu süre içinde üst yönetimden kaç tane bilgi içerikli mesaj aldınız?	
9. Bu süre içinde proje takımı haricinde kaç tane eğitim (sayı olarak) verdiniz?	
10. Soru 9'a dayanarak, kaç konu hakkında eğitim verdiniz?	
11. Soru 9'a dayanarak, kaç saat eğitim verdiniz?	
12a. Toplantılarda kaç konu gündeme geldi?	
12b. Toplantılarda gündeme gelen kaç konu, toplantılarda tartışıldı? (Tartışılan konu/Gündeme gelen konu)	
13. Toplantılarda tartışılan kaç konu çözüme kavuşturuldu? (Çözüme kavuşan konu/Tartışılan konu)	
14a. Proje başı ile sonu karşılaştırıldığında yapılan işler % kaç değişti? (Değişen iş/Toplam iş)	
15. Proje başı ile sonu karşılaştırıldığında üretilen ürünler (doküman, yazılım, prototip vs.) % kaç değişti? (Değişen doküman kısımları/Toplam doküman kısımları)	
16.a. Bu süre içinde dokümanlarda hata düzeltme oranı nedir? (Düzeltilmiş Hata/ Bulunmuş Hata)	
16.b. Bu süre içinde ürünlerde hata düzeltme oranı nedir? (Düzeltilmiş Hata/Bulunmuş Hata)	
17. Yapılan işlerin % kaçı "guideline"lardan farklı yapıldı? (Guideline'dan farklı yapılan iş / Tüm işler)	
18. Üretilen dokümanların % kaçı şablonlardan farklı üretildi?	
19. Bu projeden kaç patent, lisans, TM, Copyright vs. üretildi? (sayı olarak)	
20.a. Harici organizasyonlara verilen "guideline" sayısı nedir?	
20.b. Harici organizasyonlara verilen şablon sayısı nedir?	

21. Bu takımın uygulayacağı bir sonraki projede kullanılacak olan "guideline"ların % kaçı değişmelidir? (Değişecek guideline kısımları/Guideline kısımlarının tamamı)	
22. Bu takımın uygulayacağı bir sonraki projede kullanılacak olan doküman şablonlarının % kaçı değişmelidir? (Değişecek şablon kısımları/Şablon kısımlarının tamamı)	
23. Bu takımın uygulayacağı bir sonraki projede yapılacak olan işlerin % kaçı değişmelidir?	
24. Bu proje kapsamında üretilen dokümanlara bir kalite notu veriniz? (tüm dokümanlara ortalama bir not olarak)	
25. Bu proje kapsamında üretilen ürünlere (yazılım, prototip vs.) bir kalite notu veriniz? (tüm ürünlere ortalama bir not olarak)	
26. Takım içi ve takımın kullanımı için kaç guideline üretildi? (sayı olarak)	
27. Bu projeye dayanılarak bu süre içinde yapılan akademik yayın sayısı nedir?	
28.a. Bu süre içinde kaç tane takım içi (takımın bir başka üyesinden) eğitim aldınız?	
28.b. Bu süre içinde takım içi (takımın bir başka üyesinden) aldığınız eğitimlerin süresi nedir?	
28.c. Bu süre içinde takım içi (takımın bir başka üyesinden) aldığınız eğitim başlıkları nedir?	
29.a. Bu süre içinde kaç tane takım dışı (takıma ait olmayan kişilerden) eğitim aldınız?	
29.b. Bu süre içinde takım dışı (takıma ait olmayan kişilerden) aldığınız eğitimlerin süresi nedir?	
29.c. Bu süre içinde takım dışı (takıma ait olmayan kişilerden) aldığınız eğitim başlıkları nedir?	

APPENDIX C2: Case Study C – Interview Records of Project Managers

Project Manager Team 1:

Bu projenin en temel sorunu sahiplenmeydi. Takımımızın asıl görevi koordinasyonu ve denetimi (auditing) sağlamaktı, bu projenin sahibi biz değildik. Fakat üst yönetim projeyi gerektiği gibi üstlenmediği için bu projenin sahibi bizim takımmış gibi algılandı ve bu farklı sorunlara yol açtı. Eğer bu proje tekrar yapılıyor olsaydı, projeyi üst yönetimin üstlenmesini isterdik. Bu projede iterasyon tabanlı çalıştık, fakat çeşitli nedenlerden dolayı projedeki iterasyon planlaması düzgün yapılamadı. KDis ve KPub alanlarında yüksek değer elde etmiş olmamız çok anlamlı, temel görevimiz diğer takımlara uygulayacakları yöntem ve süreçler hakkında kılavuzlar üretmek, bilgi vermek. Üst yönetim projeye büyük ölçüde müdahale etti, ama standartların uygulanma şeklini değiştirme yönünde değil.

Project Manager Team 2:

Takım 2'de dış eğitimleri tamamen uzmanlaşma amacı ile tasarlamakta ve planlamaktayız. Her konuda bir kişiyi uzmanlaştırmayı planlıyoruz, o yüzden her eğitime birden fazla kişi göndermemeyi tercih ediyorum. Takım içi eğitimleri seminer bazında veya sunum şeklinde yapmıyoruz, ama peer-programming çalışmalarımız takım içi eğitim kabul edilebilir. Uzmanlaşmış veya konuyu bilen bir kişiyi bilmeyenin yanına oturtarak beraber kodlamalarını istiyorum. Fakat takım elemanları bunu eğitim gibi görmüyorlar, işi yapma olarak kabul ediyorlar. Takım olarak Hukuk alanına uzaktık ve bu alanla ilgili dış kaynaklar kullandık. Ama onun haricinde Java ile programladığımız için programlama için de sürekli dış kaynaklar kullandık, çünkü Java'ya takım olarak tam hakim olmamamızdan dolayı sık sık bilgi almamız gerekti harici dokümanlardan. Bu yüzden dış kaynak sayımız fazlaydı. Projemizde süreç olarak fikir toplama sürecimiz var. Takım elemanlarına sürekli "Fikirleriniz ne? Fikirlerinizi takımla ve benle paylaşın, buna açığız" mesajını veriyorum. Takım çalışanları projeyi bir ürün olarak görüyorlar, böyle olunca çok fazla fikir üretiyorlar. Kendi yapmış olduğu iş hakkında, kendisine yeni yük çıkarması pahasına takım elemanları "bunu böyle yaptım ama beğenmedim, böyle yapsak daha iyi olur" şeklinde düşünceler üretiyorlar. Sonuçları görünce, çalışan anketlerinde üretilen fikir sayısının bazı elemanlar tarafından çok yüksek yazılmasını, takım içindeki bu sürece bir tavır olarak da düşündüm, ama çalışanları sorgulamadım bu konuda. Takım olarak bu fikirleri hep destekliyoruz. Üst yönetim projemize sürekli müdahale ediyor, işin nasıl ve ne şekilde yapılması konusunda

yönlendirici oluyor, ayrıca bilgi de iletiyor. Incremental modeli kullanıyoruz ve fazlar arasında farklılaşmıyoruz, işleri ve dokümanları hep aynı şekilde yapıyoruz. Projenin en başında hazırlanmış olan kılavuzlar mevcuttu, ama proje ilerledikçe bu kılavuzlardan çok farklı şekilde yapmaya başladık işleri, kılavuzları da güncellemedik. Şimdi işler kılavuzdan çok farklı gerçekleşiyor.

Project Manager Team 3:

Takım 3 yeni kurulan bir takım. Ocak 2011'de kuruldu ve 2011'in ikinci yarısında takım üyelerinin çoğunluğu şirkete katıldı. Her ne kadar yazılım geliştirme ve programlama alanı hakkında bilgi sahibi olsak da, Sağlık alanı hepimiz için yeniydi, öğrenecek çok fazla alan bilgisi mevcuttu. Takım üyeleri, proje yöneticisi de dâhil olmak üzere, alan bilgisini yeni öğrendi ve hatta yeni öğreniyor. Bundan dolayı öğrenme süreci alan açısından zor oluyor. Yazılım açısından ise işler sadece yapılıyor. Takım içinde her üyenin temel (asil) görevi var ve bunlar çok net belirlenmiş durumda. Eğitimler ve görev dağıtımları bu temel görev doğrultusunda yapılmakta. O yüzden her takım elemanını her eğitime göndermemeyi tercih ediyorum. Eğitime gönderilecek olan kişi, kişinin yaptığı iş ve görev doğrultusunda seçiliyor. Uzmanlaşmaları için kişiler genellikle tek tek eğitime gönderiliyor. Ayrıca takım/proje bütçemiz herkese her eğitimi aldıracak kadar çok değil. Dışardan alınan eğitimlerden öğrenilen şeylerin takım içinde paylaşılması idealimiz var ama genelde bu yapılmıyor. Bunun yapılmasını istiyoruz. Dış kaynak dokümanı olarak sadece sağlık alanına ait dokümanları kullandık, projeyi .NET tabanlı geliştirdiğimiz ve bu konu hakkında takım üyelerinin geniş bilgisi olduğu için proje geliştirme ve kodlama konularında ek kaynaklara ihtiyaç duymadık. Takım çalışanlarından fikir toplama gibi ayrı bir sürecimiz yok. Projemiz henüz bir ürüne dönüşmediği için takım çalışanları bunu bir olarak görmüyor, göremiyorlar. Takım içinde 3-4 kişinin yeni fikirler ürettiklerini biliyorum ama değerlendirme esnasında ürettikleri şeyleri fikir olarak görmediler. Üst yönetim projemize ve takımın çalışmasına çok karışmıyor, müdahale etmiyor. Üst yönetim sadece riskli alanlara veya risk olarak gördükleri konulara müdahale ediyor. KInt ile ilgili olarak, her ne kadar waterfall yaşam döngüsü kullansak da fazlar iç içe geçti, müşterinin ihtiyacına göre faz ayrımı yaptık ama fazlar paralel gitti. KInt için ölçümleri projenin başından bu yana yapıyor olsaydık ölçebilirdik, hatta çok faydalı olurdu, ama geriye dönüp baktığımızda bunu ölçemiyoruz.