UNIVERSITY OF SOUTHAMPTON

ILO DIAGRAM: A NOVEL CONCEPTUAL MODEL OF INTENDED LEARNING OUTCOMES

by

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A thesis submitted for the degree of
Doctor of Philosophy

in the
Faculty of Physical Sciences and Engineering
Electronics and Computer Science

June, 2014

University of Southampton

ABSTRACT

FACULTY OF PHYSICAL SCIENCES AND ENGINEERING

ELECTRONICS AND COMPUTER SCIENCE

Doctor of Philosophy

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Achieving intended learning outcomes (ILOs) in education is an ongoing topic within distance learning and educational communities. The term "ILOs" has been introduced to indicate what learners will be able to do by the end of the course of study. Developing the ILO structure, in which the subject matter and their relationships are integrated with the capabilities to be learned, is a challenge to instructional designers. In this research, the ILO diagram – a novel conceptual model of intended learning outcomes – is proposed to support not only instructional designers in designing and developing courses of study, but also learners and instructors in performing the courses' learning and teaching activities.

The research covers three objectives. First, in order to pioneer courses of study which should consider all stakeholders in education, the research aims primarily to reconcile constructivist and instructivist theories in order to propose an equivalent architecture, using ILOs to support learning and teaching. Second, more significantly, the research aims to contribute a novel conceptual model of ILOs (called an ILO diagram) using a diagrammatic technique. In the ILO diagram, ILO nodes are represented as the two-dimensional classification of a performance/content matrix based on the component display theory proposed by Merrill. The ILO relationships have formulated the hierarchical structure using the cognitive hierarchy comprising six levels adopted the Bloom's taxonomy of the cognitive domain. Moreover, three types of the principal relationship, two types of the composite relationship, and three relationship constraints are proposed. Finally, the third objective of the research is to experimentally ascertain how the structured ILOs format conceptualised through the proposed ILO diagram can contribute to both teaching and learning.

Furthermore, the three experimental studies were conducted to explore whether providing the well-defined structure of ILOs, conceptualised through the ILO diagram, can facilitate teaching and learning. In the first experiment, the main aim was to investigate the instructors' satisfaction with using the ILO diagram in teaching. The results revealed that the proposed ILO diagram met the instructors' satisfactions with higher ratings for perceived usefulness, perceived ease of use, and attitude towards representing ILOs than the plain-text document. The second experiment was to investigate whether using the ILO diagram to facilitate learning can support learners to indicate the learning paths. The results revealed that the mean completeness of all learning paths was statistically significantly higher with the structured ILOs (ILO diagram), showing that the learners benefited from the ILO diagram in performing their self-regulated learning. Finally, the last experiment was to investigate how well the learners understand the conceptual representation of the ILO diagram. The results of the experiment revealed that the average mean of understandability for the conceptual representation of the ILO diagram was higher than for both the sentential and tabular representations. These findings indicate that the ILO diagram provides more understandability than the sentential and tabular representational styles of ILOs.

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Declaration of Authorship

I, Preecha Tangworakitthaworn, declare that the thesis entitled "*ILO Diagram: A Novel Conceptual Model of Intended Learning Outcomes*" and the work presented in this thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this university;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this university or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly acknowledged;
- where I have quoted from the work of others, the source is always given (With the exception of such quotations, this thesis is entirely my own work.);
- I have acknowledged all main sources of help;
- where the thesis is based on work done by me jointly with others, I have made clear exactly what was done by others and what I, myself, have contributed;
- parts of this work have been published as:

1. Tangworakitthaworn, P., Gilbert, L. and Wills, G. (2011). Towards a Matching Strategy of Constructivism and Instructionism. *The 19th International Conference on Computers in Education (ICCE 2011)*, 28 November - 2 December 2011, Chiang Mai, Thailand.
2. Tangworakitthaworn, P., Gilbert, L. and Wills, G. (2012). An Equivalent Architecture of Learners' and Instructors' Knowledge Through the Matching of Intended Learning Outcomes. *The 5th World Summit on the Knowledge Society (WSKS2012)*, 20-22 June 2012, Rome, Italy.
3. Tangworakitthaworn, P., Gilbert, L. and Wills, G. (2013). Facilitating Formative Assessment Through Learning Paths Extracted From a Logical Structure of Intended Learning Outcomes. *International*

Computer Assisted Assessment Conference Research into E-Assessment (CAA2013), 9-10 July 2013, Southampton, UK.

4. Tangworakitthaworn, P., Gilbert, L., and Wills, G. (2013). Designing and Diagramming an Intended Learning Outcome Structure: A Case Study from the Instructors' Perspective. *The 13th IEEE International Conference on Advanced Learning Technologies (ICALT2013)*, 15-18 July 2013, Beijing, China.
5. Tangworakitthaworn, P., Gilbert, L., and Wills, G. (2013). A Conceptual Model of Intended Learning Outcomes Supporting Curriculum Development. *The 32nd International Conference on Conceptual Modelling (ER2013)*, 11 - 13 November 2013, Hong Kong, China.
6. Tangworakitthaworn, P., Gilbert, L., and Wills, G. (2013). ILO Diagram: A Conceptual Model for Curriculum Development. *IEEE Technology and Engineering Education (ITEE), Vol.8 (No.3)*, 12-19.
7. Tangworakitthaworn, P., Gilbert, L., and Wills, G. (2013). Using Conceptualisation of Intended Learning Outcomes as Facilitators to Support Self-Regulated Learners in Indicating Learning Paths. *Journal of Computer Assisted Learning (JCAL)*, Vol.X(No.Y). *(Accepted and waiting for the publication process)*
8. Tangworakitthaworn, P., Gilbert, L., and Wills, G. (2013). Conceptual Representation of Intended Learning Outcomes: A Study of Learners' Understandability. *(Submitted to the British Journal of Educational Technology - BJET).*

Signed: ....

Date: ....

Acknowledgements

My sincere appreciation goes to all who provided me with encouragement and support in various ways towards the completion of my study; words are not enough to say, "Thank you. I am forever grateful".

First and foremost, I would like to express my utmost gratitude to Assoc. Prof. Lester Gilbert and Assoc. Prof. Dr. Gary B Wills, my first and second supervisors, for their continuous help, encouragement, and support during my study. They are always prepared to offer their time for frequent discussions and consultations despite their busy schedules. Their creative thinking and insightful guidance make our discussions fruitful and interesting. The production of this research work would not have been successful without their kind supervision.

My thanks also go to the many postgraduate students who make my days at the ESS lab enjoyable. To my colleagues and the staff at the ESS lab, "Thank you for providing a wonderful research atmosphere". I would also like to take this opportunity to thank all my friends in the University of Southampton for their generous help and kind support. To my best friends in Thailand, "Thank you for being there in good and bad times".

I am very grateful to my mother, who always energises me with her indispensable love, continuous support and encouragement, both before and during my PhD studies. I am also indebted to my brothers, my sisters, my nephews and entire family, for their everlasting understanding and encouragement; despite the distance, they are always near.

Finally, this thesis is dedicated to the memory of my father, who passed away in 1998. Although he is not here to see what I have achieved in my student life, I am sure he is somewhere out there always looking at me thoughtfully. Faith and love have bound us unceasingly.

Definitions and Abbreviations Used

ADDIE	Analysis, Design, Development, Implement and Evaluation
AT	Attitude Toward Representing ILOs
CDT	Component Display Theory
CH	Cognitive Hierarchy
CIMM	Constructivism and Instructivism Matching Model
DFD	Data Flow Diagram
eLCV	Enabling Learned Capability Verb
ERD	Entity-Relationship Diagram
EERD	Extended Entity-Relationship Diagram
ID	Instructional Design
IDT	Instructional Design Theory
ILO	Intended Learning Outcome
IM	Information Management
LCV	Learned Capabilities Verb
LP	Learning Path
PEOU	Perceived Ease of Use
PU	Perceived Usefulness
SMC	Subject Matter Content
UEffec	Understandability Effectiveness
UEffic	Understandability Efficiency
UML	Unified-Modelling Language
UT	Understandability Time
2D-PCM	Two-Dimensional Performance/Content Matrix

Instructor, *lecturer* and *teacher* as well as *learner* and *student*, are terms used throughout this thesis to have similar meaning. In relevant sections, they are mentioned interchangeably, depending on the surrounding context.

Nomenclature

ae	Adjacent edge
C^{e}	Completeness of edge
C^{lp}	Completeness of learning path
CE	Correct edge
CN	Correct node
e	Edge
n	Number of node
w	Weighted value

Chapter 1

Introduction

1.1 Overview of Research

Recent design of learner-centric educational activities is usually based on constructivism (Konings, Brand-Gruwel, and van Merrienboer, 2007), the theory that knowledge is actively constructed by learners based on their experiences (Bodner and Klobuchar, 2001; Johnson, 2009). Constructivists educate learners by providing learning activities and consequential feedback. In contrast to constructivism, instructivism is an instructor-focused approach, starting from the instructor's understanding of the subject matter to be taught (Hill, 2008; Niess, 2005; Shulman, 1987), and aiming to educate learners by providing subject matter and supporting learning information.

We argue that constructivism and instructivism are complementary. The primary aim of the research is to reconcile these two theories in order to conduct a matching strategy, using intended learning outcomes (ILOs) to support learning and teaching. An ILO states what learners can do by the end of a lesson, course, or programme (Dodridge, 1999; Gilbert and Gale, 2008). Practically speaking, designing the ILO structure, in which the subject matter and their relationships are integrated with the capabilities to be learned, is a challenge to instructional designers. The research contributes a novel conceptual model of intended learning outcomes for the design and development of courses of study, called an ILO diagram. The research has proposed a diagrammatic technique to model the logical structure of ILOs and the ILOs' components conceptualised through the ILO diagram. The two basic components of ILOs comprise the capability and associated subject matter content represented as the two-dimensional classification based on the component display theory proposed by Merrill (1994b). To assist conceptualisation, the ILO diagram, three types of principal relationship, two types of the composite relationship, three constraints, and the diagrammatic formalism and diagram notations are proposed.

The outstanding feature of the proposed conceptual model is that the six levels of the cognitive hierarchy of the cognitive domain adopted by Bloom's taxonomy (Bloom, Engelhart, Furst, Hill, and Krathwohl, 1956) are augmented with the logical structure of the ILOs, forming the ILO diagram.

Furthermore, the research aims to evaluate the proposed ILO diagram in teaching and learning. Instructors and learners can benefit from the conceptual information embodied in the logical structure of the ILOs, as envisioned through the ILO diagram. The three experimental studies of the research addressed the following three issues. First, facilitating teaching activities with the well-defined structured ILOs can support instructors in teaching and meet instructors' satisfactions. Second, performing the learning activities with the structural learning contents is a powerful method, and it is important to guide the learners to initiate and indicate the learning direction or learning paths (Steele, Medder, and Turner, 2000). Finally, if learners can understand the conceptual representation of the proposed ILO diagram, they can benefit from the conceptual information embedded within the ILO diagram.

1.2 Research Objectives

The objectives of the research are to:

1. reconcile the theoretical basis of constructivism and instructivism;
2. contribute a novel conceptual model of intended learning outcomes; and
3. evaluate the proposed ILO diagram in teaching and learning situations.

1.3 Structure of the Report

This report is divided into nine chapters.

In chapter two, the background and related work have been summarised to reveal the educational background and related theories of the research work. The pedagogical theories, the taxonomy of educational objectives, learning outcomes, competence in learning and teaching, instructional design theories, the ADDIE model, and review of conceptual background are discussed.

Chapter three deals exclusively with the proposed equivalent architecture for balancing the learners' and instructors' knowledge, which illustrates the three main components: constructivism, instructivism, and learning materials. The knowledge exchange model and the constructivism and instructivism matching model (CIMM) are introduced and discussed.

After completing the proposed framework, a novel conceptual model of intended learning outcomes has been introduced in chapter four. The ILO modelling, the conceptualisation of ILOs through the ILO diagram and the design of ILO relationships are introduced and discussed. At the end of this chapter, a case study of applying the ILO diagram is exemplified. Finally, there is a scenario demonstrating the proposed approach in education.

In chapter five, the experimental methodology of the research is introduced. The three experimental studies are described. The first experiment is a study of applying the ILO diagram in teaching. The second experiment is a study of using the ILO diagram as a facilitator in indicating learning paths. The third experiment is a study of the understanding of the ILO diagram.

The first, second, and third experimental studies are presented in chapters six, seven, and eight respectively. The details of each experimental study including the conjecture and research question, experimental design and variables, measurement, experiment results and statistical analysis, as well as the limitations of the study are summarised and reported.

Chapter nine discusses the experiment results and the findings of each experimental study.

Finally, the last chapter of this report provides the summary of the thesis. In addition, the contributions made by this research are listed, and the future work are summarised.

Chapter 2
Background and Related Work

In this chapter, the literature has been summarised to reveal the background and related work of the research. The chapter begins with an introduction and a discussion of the pedagogical theories of learning and teaching. In the next five sections (sections 2.3 - 2.7), the taxonomy of educational objectives, learning outcomes, the competence in learning and teaching, the instructional design theories, and the ADDIE model, have been summarised and discussed. The chapter concludes with the review of the conceptual modelling (section 2.8) that is the basis of the research contributing to the proposed conceptual model. Finally, the chapter is summarised in section 2.9.

2.1 Introduction

Pedagogy, *art or science of teaching* (Beetham and Sharpe, 2007), is the grounded theory that describes the skills and profession of teaching required to educate learners. According to this theory, the effective connection between teaching and learning can be initialised and education can arrive at the educational objectives. Considering the approach of this research, pedagogy is the essential background that links learners and instructors. Thus, the two pedagogical theories, namely constructivism (learner's perspective) and instructivism (instructor's perspective), are primarily related to this research. Consequently, the educational objectives including an approach of intended learning outcomes play the crucial role as the basis of the proposed approach. Instructional design is referred to be an engineering approach to the achievement of pedagogical intent. Entirely, and more importantly, the proposed approach has concentrated on the fundamental ideas of conceptual modelling and conceptual representation. The details of each related reference to the literature are summarised in the following sections.

2.2 Pedagogical Theories

In theory, the studies described in this research can be embedded in at least two important theories of learning and teaching, namely, constructivism and instructivism. The details of each theory are described as follows:

2.2.1 Constructivism

The constructivist approach is student focused, meaning based, process oriented, interactive, and responsive to student's personal interests and needs (Johnson, 2004; Johnson, 2009). The key idea of the constructivist learning is that, individually, learners actively construct their knowledge based on existing experiences (Bodner and Klobuchar, 2001; Johnson, 2009). Piaget's constructivist theory is a well-known developmental theory that states how children become progressively practised with reality, and are gradually able to understand symbolic objects (Ackermann, 2004; Piaget, 1955; Piaget and Inhelder, 1956). The learner's interactions with the environment and ability to understand reality are the core concept of constructivism (Piaget, 1955; Savery and Duffy, 1996). Learners understand the learning materials, the context, or the learning activities provided in the learning environment (e.g., classroom, or school). They use past experiences and prior knowledge to form an understanding of the subject matter. Initiated self-learning is realised and knowledge created. Consequently, knowledge is constructed by learners (called *active learning*) rather than received from instructors (Svinicki, 1998). An understanding of the subject matter is an individual construction; it cannot be shared (Savery and Duffy, 1996). Similarly, knowledge cannot be transmitted from the instructor to the learner directly, but it can be actively created in the mind of an individual (Geelan, 1997).

In constructivism, passive learning might not be appropriate for learners because they have their own knowledge construction process while they are studying in the learning environment and creating knowledge in a unique way (Ben-Ari, 1998). However, active learning is more suitable than passive learning in accordance with the construction of knowledge guided by instructors and realised from feedback provided by friends and instructors (Ben-Ari, 1998). In addition, Koohang, Riley, and Smith (2009) state that the constructivist learning approach is suitable for e-learning and distance education because it enables that the learning outcomes of learners are met.

Additional four approaches associated with constructivism are: social constructivism, constructionism, constructive alignment, and minimally guided instruction which are summarised as follows:

2.2.1.1 Social Constructivism

Vygotsky's social developmental theory (1978) is a well-known theory that is the foundation of the social constructivist approach. This theory focuses on the interaction between human and social context in order to interact with shared experiences (Crawford, 1996). Vygotsky states that learning materials have been used as tools to perform social activities. For example, children usually learn from books, and practise the development of speech as ways of communicating with others (Vygotsky, 1978). Hence, social constructivism entails knowledge constituted in individuals and constructed from self-understanding and participation in the surrounding social environment (Atwater, 1996; Vygotsky, 1978).

2.2.1.2 Constructionism

Papert asserts the distinction between constructivism and constructionism as follows:

> The word with the V expresses the theory that knowledge is built by the learner, not supplied by the teacher. The word with the N expresses the further idea that this happens especially felicitously when the learner is engaged in the construction of something external or at least sharable (Papert, 1990, p.3).

Papert's constructionism and situated learning (also known as situated knowledge, the fact that knowledge grows in context or situation) are more realistic than Piaget's constructivist approach (Ackerman, 2001). The differentiation arises from the discriminative characteristics of these two terminologies, since constructivism has been declared a generic concept and aimed at individuals, whilst constructionism deals with personal products that can be shared with others (Jonassen, Myers, and McKillop 1996). The personal products in this sense mean the meaningful personal representations of individual knowledge, such as the ability to communicate with others in the class, speaking and writing skills, et cetera. Specifically, constructionism arises particularly in the context where the learner has consciously engaged in constructing a public "being" (Papert and Harel, 1991).

Based on the above explanation, this research can be said to be built on the constructivist approach in which the concern is focused primarily on individual knowledge constructed by personal understanding.

2.2.1.3 Constructive Alignment

Biggs (2003) originally introduced the constructive alignment (CA) approach which comprises two aspects. The former is the constructive aspect, in which learners create an understanding of the learning contents by accomplishing the learning tasks until they form their own knowledge. The latter is the alignment, where instructors ensure that the learning tasks (and assessments) are suitable for the learning outcomes. Therefore, the crucial parts of the teaching cover both the teaching methods and the assessments which are aligned to the pedagogical activities included in the learning outcomes (Biggs, 2003). There are four steps which represent the main characteristics of the CA, illustrated in Figure 2-1.

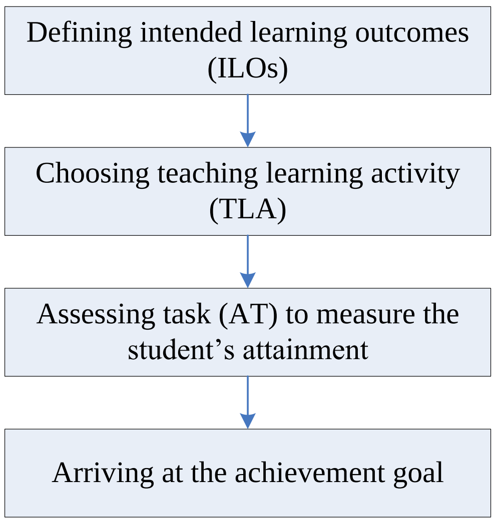


Figure 2-1 Four steps of constructive alignment summarised from Biggs (2003)

In addition, Ullah, Khattak, and Siddiqa (2011) state that the fundamentals of CA comprise three basic components, namely, intended learning outcomes (ILOs), teaching learning activity (TLA), and assessment task (AT). The CA approach is suitable for the curriculum design which administers the conditions for quality of learning; this means that CA provides the process of initiating learning standards and of operating on the learning objectives that conform to the standards (Ullah et al., 2011).

Normally, a course is described as being constructively aligned when it conforms to four stages: ILOs are clearly specified, ILOs are explicitly communicated to the students, the assessments match ILOs, and the teaching activities match ILOs

(Brabrand, 2008). However, our research does not cover the AT because the proposed approach deals with the conceptual modelling of intended learning outcomes which relates to the initial design of the courses or programme. Instead, the studies of both the ILO structure and the TLA have taken priority in order to provide learners with suitable learning tasks based on their background knowledge.

Based on the constructivist approach, consideration should be given to reducing the involvement of the instructors in the learning environment whilst, at the same time, increasing the independence of the learners. Thus, the instructor acts as a tutor or helper to provide minimal guidance to learners.

2.2.1.4 Minimally Guided Instruction

Constructivist learning aims at knowledge constructed by learners, and so "they need to have the opportunity to construct by being presented with goals and minimal information" (Kirschner, Sweller, and Clark, 2006, p.78). The term *minimal guidance* is identified to enable learners to understand the learning contents, and then, construct knowledge on their own with as little information as possible.

Brunstein, Betts, and Anderson (2009) demonstrate the experiments of contrasting a minimally guided discovery condition with a variety of instructional conditions and they suggest that high levels of practice can lead the learners to become more efficient at knowledge construction, and also that circumstances with some minimal guidance can assist successful learning. In addition, Adams, Paulson, and Wieman (2009) explain that learners learn more through self-guided engaged exploration if they are given the learning contents with minimal to no guidance. There are two reasons for this: a) the structure and appearance of the learning materials provides considerable guidance, and b) innovation and efficiency training are used. In other words, innovation is the attempt to create the solution to an unfamiliar problem, while efficiency training refers to the rote learning (or learning by memorisation) and focuses on creating specific skills (Adams et al., 2009).

Consequently, learners who study in the constructivist learning environment can improve their learning capacities by perceiving the minimally guided instruction, through high levels of practice (or efficiency training) and innovation. The instructional guidance has been determined by a concern or motivation to transfer the subject matter to learners with as little guidance as possible.

2.2.2 Instructivism

Many researchers use the term *instructivism* to refer to the classic method of teaching in the classroom and formal education (Diaz and Bontenbal, 2000; Hustad and Olsen, 2011; Silverman, 1995; Quilling and Blewett, 2009) and identify it with the objectivist approach of epistemology (Kanuka and Anderson, 1999; Silverman, 1995). The idea of the instructivist approach is that learners have been educated by applying rote learning; this means that learners memorise the learning contents provided by instructors (Quilling and Blewett, 2009).

Instructivism relates to the term *instructionism* which is summarised as follows:

2.2.2.1 Instructionism

Instructionism has been referred to as being teacher focused, skill based, product oriented, non interactive, and highly prescribed as well as being highly structured (Johnson, 2009). This approach starts from the teacher's understanding of the learning contents to be taught and tends to formalise the ways in which it can be taught (Shulman, 1987).

In essence, instructionism is based on one-way communication (Gulati, 2004); learners are the receivers of information that instructors convey to them. Absorption and accumulation, which have been analogously acclaimed as the *sponge* method of teaching (Schank and Jona, 1991) and the *banking* approach of learning (Freire and Macedo, 1987), respectively, are the techniques used by learners to realise the learning contents that they are given until the examination (Jonassen et al., 1996).

In fact, although many researchers refer to the terms *instructivism* and *instructionism* separately, they point out that these two terminologies have the same meaning. Hence, in this research, the term *instructivism* is used to compare with *constructivism* which is discussed in the following section.

2.2.3 Comparing the Features of Constructivism and Instructivism

In order to compare the characteristics of constructivist and instructivist perspectives, Johnson (2009) investigated the comparative features as summarised in Table 2-1.

Table 2-1: Comparative features of instructivism and constructivism (Johnson, 2009)

Instructivism	Constructivism
Teacher focused	Student focused
Teacher controlled	Student controlled
Product oriented (Outcome driven)	Process oriented (Process driven)
Non interactive instructional practices	Highly interactive instructional practices
Highly structured	Loosely structured
Highly prescribed	Responsive to student personally

A comparison of the features of these two theories (listed in Table 2-1) indicates that they manifest a contradiction in terms of the nature of learning and teaching. It is worth noting that there are many aspects of teaching and learning relating to the difficulties of (and suggesting the practical solutions to) bridging the gap between instructivism and constructivism. Some aspects are discussed as follows:

1. The first aspect deals with the role of feedback that is a crucial part of the learning process and competency development cycle. Feedback and the instructor's response inform learners about how well they have done and how to improve their performance. According to the instructivist perspective, in order to effectively educate learners and develop their learning results, the instructor should act within the context of understanding individual learning in order to devise explicit teaching strategies and, more importantly, to provide learners with meaningful feedback. According to the constructivist perspective, learners interact socially, communicate and work with instructor and friends to realise learning problems and subject matter after receiving feedback, and then they draw their conclusions from their internal and cognitive processes. Laurillard's suggested solution is that the "goal-action-feedback-modified action" cycle should operate iteratively and interactively (Laurillard, 1993; 1999). In this cycle, after the goals have been set and the actions (learning and teaching activities) performed, the feedback could be communicated to individual learners to allow them to realise the learning problems and reflect the modified actions.
2. The next aspect deals with the evaluation to assess the learning results. Accordingly, in pursuit of the instructivist perspective, the aim of evaluating

learners' competencies entails determining both formative and summative assessments of the learners' performance after they have undertaken the learning activities. Instructors, in line with the instructivist perspective, usually perform frequent learner evaluation and assessment until course objectives are met. In terms of the constructivist perspective, learners retake the learning tasks and perform the assessment until the subject matter is mastered. Following the constructivist perspective, learners can organise and relate the assessment questions to their existing experiences and finally they can draw conclusions and construct new knowledge.

3. Another aspect relates to the types of roles both instructors and learners should perform in teaching and learning. In the constructivist perspective, the role of learners aims at constructing new knowledge which is actively built upon previous experiences, while, in the instructivist perspective, the role of instructors tends to educate learners by facilitating information and subject matter through the use of teaching strategies. Generally speaking, the highly passive instructivist way is not recommended. Learners participate directly in the construction of their knowledge and should not rely on passive teaching strategies. Instead, instructors should actively involve learners in practical and realistic exercises. For instance, an instructor stimulates learners to solve problems through interaction with others, so that learners establish their own understanding by comparing it with the understanding of other learners; this type of instructor then provides positive feedback to learners, so that they can decide how to improve their competencies. Alternatively, instructors understand learners' needs and background experiences, and this enables them to transfer the suitable information and subject matter to learners and allows them to apply their existing experiences and current understanding to constructing new knowledge.

The research proposes a balanced approach via a constructivism and instructivism matching model, using intended learning outcomes or ILOs (see section 3.4). Practically, the capability component of ILOs introduced in this research represents the action verbs called learned capability verbs. These verbs are the key to actively performing pedagogical activities. In a constructive learning environment, these action verbs suggest directions that aid learners to utilise their autonomy when learning:

learners can choose suitable ILOs that match their competencies in order to perform their learning activities. On the other hand, from an instructivist perspective, instructors may refer to these verbs in order to prepare their teaching activities as well as using these verbs to design the learner assessments (i.e., questions, quizzes, or tests).

2.2.4 Epistemological Orientation

Epistemology is a branch of philosophy that states the origin, nature, methods, and limits of human knowledge. Two principals of epistemological orientations are objectivism and subjectivism (Von Glasersfeld, 1995). The former, objectivism, is based on the premise that the world is structured and that structure can be learnt and taught (Johnson, 2009). Knowledge according to this principal presents the real world as occurring separately and independently from the learners. Johnson goes on the state that "knowledge is considered true only if it correctly reflects that independent external world" (Johnson, 2009, p.90). Objectivism is the major method of learning in institutions, so that instructors are the transmitters of reality while learners are the passive receptors of information. *Instructivism* is an educational application of objectivism.

In contrast, there is subjectivism, which refers to knowledge as part of the individual background. The construction and interpretation of reality are based on personal experiences and the interaction of individuals leads the learners to participate in the learning environment. Knowledge acquisition occurs through the learning processes under the constructivist environment; it is "active knowledge absorption" (Johnson, 2009). *Constructivism* is an educational application of subjectivism.

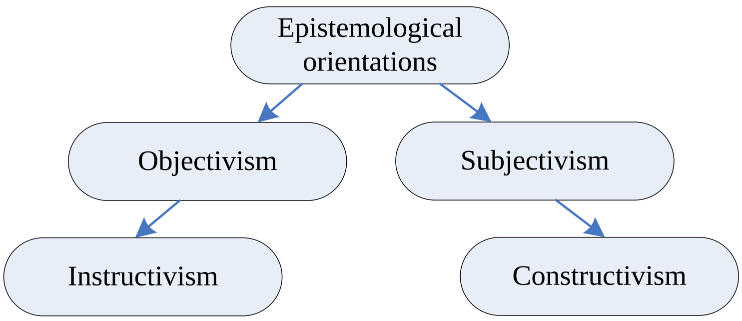


Figure 2-2 Instructivism and constructivism of epistemology

In order to conceptualise the epistemology described above, we demonstrate the hierarchical structure of the epistemological orientations as revealed in Figure 2-2.

2.2.5 The Exclusive Perspective on Objectivism and Subjectivism

There is a traditional conflict between objectivism and subjectivism because these two terms are mutually exclusive and practitioners will support either one approach or the other (Cronje, 2006; Vrasidas, 2000). Cronje (2006) states that they can be plotted at the opposite ends of a straight line as depicted in Figure 2-3. Similarly, Vrasidas (2000) points out that the major philosophical assumptions of two approaches can be placed on a continuum with objectivism on the left-hand side and subjectivism on the right-hand side. Thus, the mutually exclusive perspectives of these two approaches reveal that there are different aspects on the pedagogical goals of learners and instructors (Collins, Greeno, and Resnick, 2002; Shuell, 2002). Objectivism which focuses on the needs of the instructors, describes how the instructor tries to transmit the content knowledge to learners directly, whilst subjectivism expresses the motivational behaviour of a learner constructing knowledge individually. The more the content knowledge transfers to the learners, the fewer will be the opportunities for the learners to concentrate on the knowledge construction process.

Objectivism 5 4 3 2 1 0 1 2 3 4 5 Subjectivism

Figure 2-3 Objectivism is on the opposite side of subjectivism (Cronje, 2006)

Cronje (n.d.) raises the issue that when one side wins, the other side loses; this leads to a reduction in the amount of the other. These two approaches are simply at cross-purposes; the conflict between these two perspectives reveals that, if a learning event scores high on one, it does not necessarily score low on the other (Cronje and Burger, 2006). Although the theory of epistemology has stated the distinguishable relationship between objectivism and subjectivism, there has been an interest in the integrated issue of these two approaches. For instance, Cronje (2006) proposes the use of a *right-angled model* for plotting two approaches as both highly subjectivist and highly objectivist without any inherent contradiction. He suggests that the instructional designer should select both approaches to analyse and evaluate the goals of the learning activities and the objectives setting. In addition, McKenna and Laycock (2004) propose the *third-way approach* to introduce the third learning artefact that aims to combine instructivism and constructivism; this approach has deconstructed the content of the course into small units (called artefacts) and presented them in a controlled way through the verbal and graphical instructions.

The integrated issue sheds light on our research approach. In this research, we focus on how to balance between constructivism and instructivism by concentrating on learning outcomes, also known as educational objectives. In the next section, the study of the classification of the educational objectives defined in terms of taxonomy will be discussed.

2.3 The Taxonomy of Educational Objectives

There is a theoretical attempt to build a taxonomy of educational objectives which is used to classify the goals of the educational system (Bloom et al., 1956). Generally, it is intended to guide all educators, instructors, professional specialists, and research workers who are confronted with curricular and educational problems in order to consider these problems with greater precision (Bloom et al., 1956). Furthermore, specifically, it is meant to assist instructional designers to define the objectives so that it becomes easier to design learning activities and prepare the materials for assessment (Simpson, 1966).

Many approaches referring to the taxonomy of educational objectives as the theoretical basis used for defining educational plans have been cited. For instance, instructional designers have developed a course curriculum with a range of achievable learning outcomes (Harden, 2002), and researchers have invented a specific educational taxonomy for computer science education (Fuller, Johnson, Ahoniemi, Cukierman, Hernan-Losada, Jackova, Lahtinen, Lewis, Thompson, Riedesel, and Thompson, 2007), et cetera. This section features summaries of three principal theories of educational taxonomy which are widely used in the design and development of courses, namely, Bloom's taxonomy, Gagné's hierarchy of learned capabilities, and Merrill's level of performance. In addition, the comparative features of these three theories are discussed.

2.3.1 Bloom's Taxonomy

Bloom proposed a taxonomy of educational objectives which covers three domains: the cognitive domain (Bloom et al., 1956), the affective domain (Bloom, Krathwohl, and Masia, 1964), and the psychomotor domain. The cognitive domain is defined as covering the mental processes of learning activities, such as remembering and recalling knowledge, thinking, problem solving, or creating. The affective domain covers the learning objectives which explain the emotional expressions, such as attitude, feeling, or mental values. The psychomotor domain deals with the motor-skill area which emphasises the manipulation of learning materials and objects involving the learning context.

The main characteristic of Bloom's taxonomy (both the cognitive and affective domains) is that the accomplishment of levels is usually progressive because each level of the taxonomy relies upon the learner's capability to achieve at all levels below it (Ferris and Aziz, 2005). For example, in the case of a student wanting to apply knowledge in the cognitive domain (level 3), he or she is required to achieve both remembering the fundamental information (level 1) and understanding of this information (level 2).

2.3.1.1 Taxonomy of the cognitive domain

In 1956, Bloom and his colleagues proposed the taxonomy of the cognitive domain which comprises six categories, namely, knowledge, comprehension, application, analysis, synthesis, and evaluation (illustrated in Figure 2-4).

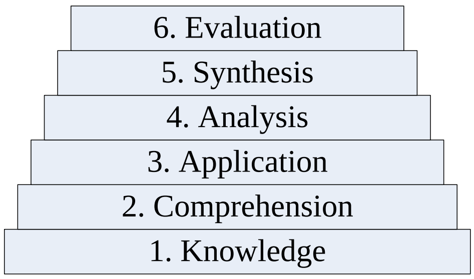


Figure 2-4 Bloom's taxonomy of cognitive domain

The definitions of the individual levels are summarised as follows:

"*Level 1 (Knowledge) defines the ability to remember, recognise, and recall the relevant knowledge from long-term memory.*

Level 2 (Comprehension) defines the ability to understand and construct the meaning through interpreting, exemplifying, classifying, and explaining.

Level 3 (Application) defines the ability to apply and carry out the procedure (or process) through executing, or implementing.

Level 4 (Analysis) defines the ability to analyse and break down information into its components through differentiating, organising, and attributing.

Level 5 (Synthesis) defines the ability to put elements together to form a functional whole through generating, planning, and producing.

Level 6 (Evaluation) defines the ability to evaluate and make judgement based on criteria or a given purpose." (Bloom et al., 1956).

2.3.1.2 Taxonomy of affective domain

In order to describe the way in which learners deal with things emotionally, Bloom et al. (1964) proposed five major levels of affective domain: 1) *Receiving* is a willingness to receive essential information; 2) *Responding* refers to individuals participating in an active learning environment; 3) *Valuing* refers to a simple acceptance of the values, which means a thing, phenomenon, or behaviour that has worth; 4) *Organisation* refers to the ability to systematise the values in which the individual learners encounter a situation presenting more than one relevant value, requiring them to arrange the list of values to incorporate the target values; 5) *Characterisation by value complex* refers to the individual's value hierarchy which has been completely organised into some kind of internally consistent system (or inner control system) (Bloom et al., 1964; Bloom, Madaus, and Hastings, 1981).

2.3.1.3 Taxonomy of psychomotor domain

The psychomotor domain puts the main emphasis on the physical skills involving co-ordination of the brain and muscular activity. This domain deals with the manipulation of material and objects (Bloom et al., 1956; Bloom et al., 1964). Although the psychomotor domain has been identified in literature, relatively little has been done about the development of this classification in institutions (Bloom et al., 1956). In addition, Ferris and Aziz (2005) suggest that the psychomotor domain is the absent domain because it has been rarely developed in academia. Instead, the use of the taxonomy in cognitive and affective domains features prominently in the field of higher education.

Most educators are familiar with the cognitive domain because they have largely ignored the affective (and the psychomotor) domain by choosing instead to concentrate on the attainment of cognitive objectives (Bloom et al., 1981; Bolin, Khramtsova, and David, 2005). Hence, it is sufficient to conclude that the cognitive domain is the most widely recognised when referring to Bloom's taxonomy.

2.3.2 Gagné's Varieties of Learned Capabilities

Gagné proposed that human performances can be simplified by categorising the types of learning outcomes (or educational objectives) into one of five main categories, called varieties of learned capabilities (Gagné, 1985). In his classical work, *The Conditions of Learning*, Gagné also stated that "learning conditions are not the same for different varieties of what is learned" (Gagné, 1965, p.47). This means that each different kind of learning outcome requires different conditions of learning.

The following are summaries of the five main categories of learned capabilities (Gagné, 1985) and their examples:

Category 1: Intellectual skills

The intellectual skills refer to the ability to use *symbols* describing things in learning situations. Learners interact with the environment symbolically. Being able to utilise the symbol is called "knowing how", the so-called procedural knowledge. For instance, a learner counts the books by using numeric values, the international student learns how to read and write the grammatical structure of the English language, and so on. There are three subcategories of the intellectual skills: rule, concept, and discrimination. Basically, the nature of intellectual skills is clarified in terms of the relation between two or more things in a specific domain; it is called a *rule*. A thing (or thing-concept) is the instance of this domain which is analysed as a new category of intellectual skill called a *concept*, for instance, "a gallon of liquid consists of four quarts" is an example of a rule which represents a relationship between gallon, liquid, and quart. In this case, there are three concepts, namely, gallon, liquid, and quart (Gagné, 1985, p.53). Furthermore, the ability to tell the difference (distinguish) between characteristics of the object properties (and rules) is called *discrimination*.

Category 2: Verbal information

Verbal information refers to the ability to *state*. The learner learns to state (or *tell* a fact) by using oral speech (or by using writing, typewriting, or drawing a diagram). Being able to state the idea demonstrates the learner's "knowing that", the so-called declarative knowledge. For instance, a novice programmer who tries to develop a web application can sketch the web-page hierarchy by using a diagram.

Category 3: Cognitive strategies

The cognitive strategies have controlled the learner's own *internal processes* which cover the individual's own learning, remembering, and thinking behaviour. For example, when individual learners have been asked to read an unfamiliar article, they can handle the motivation to read different parts of the text, as well as being able to approach the task by searching for relationships amongst the unrelated names and other familiar names. Traditionally, learners normally deal with the question (or problem) needing to be solved. When they practise solving new problems, presumably they can learn both the rules appertaining to each problem and the ways of achieving problem solving (Gagné, 1985). Gagné (1985, p.143) also states that "these capabilities of self-control are the cognitive strategies of thinking".

Category 4: Motor skills

It is in the manipulative area that a learner can learn to interpret and execute movements in various ways to interact with tools or equipment. For instance, the learner learns how to ride a bicycle, how to steer an automobile, how to use a can opener, or how to jump a rope (Gagné, Wager, Golas, and Keller, 2004).

Category 5: Attitudes

Petry, Mouton, and Reigeluth (1987, p.15) explained that "attitudes are complex mental states of human beings that affect their choices of personal action towards people, things, and events". The mental states acquired by learners have been influenced by the *choices of personal actions*. Individually, in any situation, each person may have many alternatives to choose from when selecting the optimum way of obtaining the best outcome. For example, the learner selects to enrol for mathematics rather than physics as an elective course because he or she might not be interested in physics.

When differentiated characteristics of Gagné's and Bloom's approaches are considered, Gagné's classification scheme differs slightly from Bloom's taxonomy in two ways (Gagné et al., 2004). Firstly, Gagné determines verbal information as a disconnected domain of learning, and not as a part of the skills. Secondly, Gagné cites comprehension, application, analysis, synthesis, and evaluation as the processes used to demonstrate learning. These processes especially cover the intellectual skills assigned in terms of the ability to define concepts (concrete concepts and discriminations), rule using, problem solving, and cognitive strategy.

Table 2-2 The comparison of Bloom and Gagné (Gagné et al., 2004, p.61)

Bloom	Gagné
Evaluation	Cognitive strategy, problem solving, rule using
Synthesis	Problem solving
Analysis	Rule using
Application	Rule using
Comprehension	Defined concepts, concrete concepts, and discriminations
Knowledge	Verbal information

In its illustration of how Gagné's learned capabilities can be compared with Bloom's taxonomy, Table 2-2 shows that the cognitive domain of Bloom's taxonomy equates to only three categories of Gagné's learned capabilities, namely, verbal information, intellectual skills (including rule and concept), and cognitive strategy (including problem solving).

2.3.3 Merrill's Level of Performance

Merrill proposed a classification scheme comprising *performance* and *content*, through the component display theory (CDT). Performance covers three major categories: find, use, and remember (or know), whilst content (called subject matter content) is depicted in four types: fact, concept, procedure (or process), and principle. The primary dimension of Merrill's theory (performance dimension) originated from similar work in Gagné's *varieties of learned capabilities* (Gagné's only dimension). It means that the performance dimension has attempted to represent the learner's capabilities to perform the learning activities with the particular subject matter content (the secondary dimension). Thus, Merrill's approach is an extended classification of the learned capabilities originally proposed by Gagné (Merrill, 1994a).

Firstly, *find* is the performance that challenges learners to acquire information in order to generate a new abstraction. The abstraction here is the state of being creative; this usually occurs in each individual when the cognitive strategies are performed. Secondly, *use* is the performance that the learner applies to the abstraction dealing with problem solving in a particular situation. Lastly, *remember* is the performance when the learner remembers the idea by searching memory in order to recognise some related information previously known (Merrill, 1994b).

Three levels of performance correspond to three categories of Gagné's approach, namely, intellectual skills (including concepts and rules), verbal information, and cognitive strategy (Merrill, 1994a). We illustrate the comparative components of Merrill’s and Gagné’s approaches as depicted in Figure 2-5.

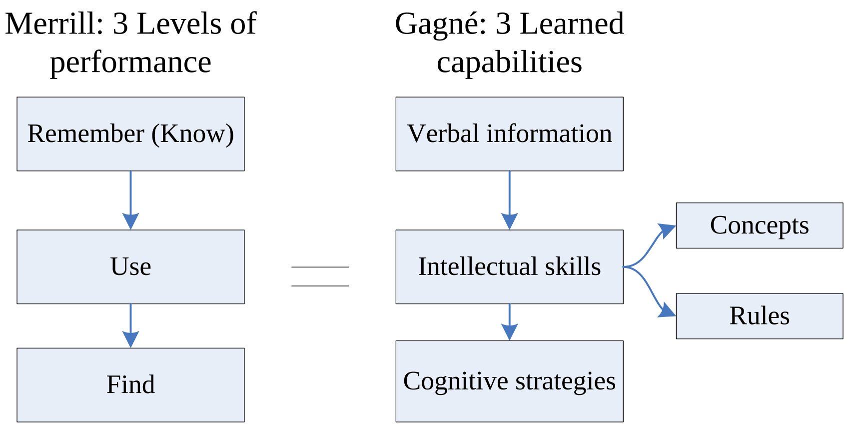


Figure 2-5 The comparison of Merrill and Gagné

For an expanded study of the comparable components of the three main theories, we introduce a comparison of Bloom’s taxonomy, Merrill's level of performance, and Gagné's hierarchy of learned capabilities as illustrated in Table 2-3.

Table 2-3 The comparison of Bloom's taxonomy, Merrill's (level of performance) and Gagné's (hierarchy of learned capabilities)

<table>
<tr><th colspan="2">Bloom's taxonomy
(Bloom et al., 1956)</th><th>Gagné's
hierarchy of learned capabilities
(Gagné, 1965, Gagné, 1985)</th><th>Merrill's
level of performance
(Merrill, 1994b)</th></tr>
<tr><td rowspan="6">Cognitive domain</td><td>Synthesis</td><td>Problem solving</td><td>Find</td></tr>
<tr><td>Evaluation</td><td>Cognitive strategy</td><td rowspan="4">Use</td></tr>
<tr><td>Analysis</td><td rowspan="2">Rule using</td></tr>
<tr><td>Application</td></tr>
<tr><td>Comprehension</td><td>Defined concepts, concrete concepts, and discriminations</td></tr>
<tr><td>Knowledge</td><td>Verbal information</td><td>Know (Remember)</td></tr>
<tr><td rowspan="5">Affective domain</td><td>Receiving</td><td rowspan="5">Attitude</td><td rowspan="6"></td></tr>
<tr><td>Responding</td></tr>
<tr><td>Valuing</td></tr>
<tr><td>Organisation</td></tr>
<tr><td>Value complex</td></tr>
<tr><td>Psychomotor domain</td><td></td><td>Motor skills</td></tr>
</table>

To summarise, Bloom's taxonomy is widely used in the construction of learning outcomes (Mayes and Freitas, 2004). Although taxonomies have been developed to cover the affective and psychomotor domains of learning, educators use the cognitive domain to define their desired outcomes. Similarly, Gagné and Merrill have also focused on the mental (or cognitive) aspect. Gagné contended that different kinds of learning outcomes require different conditions of learning, which can be divided into five main categories of learned capabilities, namely, intellectual skills, verbal information, cognitive strategies, attitudes, and motor skills; subsequently Merrill extended the classification of the learned capabilities originally proposed by Gagné by adding the content dimension. Merrill proposed a two-dimensional classification scheme comprising performance and content through the CDT theory. The performance dimension compared with Bloom and Gagné, covers three types of capabilities in particular, namely, find, use, and remember (or know).

In this research, the proposed approach has confined itself to two taxonomies of educational objectives, namely, the cognitive domain of Bloom's taxonomy referring to the fundamental part of the proposed ILO modelling, and Merrill's level of performance in designing the ILO components, and its structure. Firstly, the cognitive domain of Bloom's taxonomy represents the classification of educational goals and objectives according to six cognitive levels of complexity. The mental processes and cognitive behaviours are clearly shown by the learning performance in which the learned capabilities can be classified into six categories: knowledge, comprehension, application, analysis, evaluation, and synthesis. Secondly, owing to the extended classification of Gagné's hierarchy of learned capabilities, the two-dimensional classification scheme proposed by Merrill enhances the performance dimension (originally proposed by Gagné) by broadening the content dimension to cover fact, concept, procedure, and principle. This extended classification provides the clearly defined mechanism to describe the relationship between performance and content, supporting the instructional design process. Thus, in this research, Merrill's taxonomy instead of Gagné's taxonomy has been adopted.

2.4 Learning Outcomes

A learning outcome emphasises the achievement in learning and states that the curriculum should start with what learners will be able to achieve after gaining the learning experience (Allan, 1996). There are various meanings attributed to learning outcomes. The following are some examples:

> Learning outcomes are broad statements of what is achieved and assessed at the end of a course of study (Harden, 2002, p.151).
>
> Learning outcomes are statements of what is expected that a student will be able to DO as a result of a learning activity (Jenkins and Unwin, 2005, p.1).

Focusing on the learning goals for learners is the main characteristic of learning outcomes and leads to the powerful design of an educational programme and curriculum; in addition, using the learning outcomes in higher education encourages instructors to care about learners (McDaniel, Felder, and Gordon, 2000). In the classroom, an instructor may set a prior intention about the results of the pedagogical activities and attempt to organise the classroom (or learning environment) to persuade learners to interact and form an understanding until they finally reach the learning outcomes (Hussey and Smith, 2003). There are two main categories of learning outcomes: the intended learning outcome and the actual (or emergent) learning outcome (Alexander, 1999; Anderson, Moore, Anaya, and Bird, 2005). The intended learning outcome (ILO) is desired (and planned) before involving the learners in the learning environment (Anderson et al., 2005; Harden, 2002; Hussey and Smith, 2003; Jenkins and Unwin, 2005), whilst the actual learning outcome is that which is achieved after assessing the learning activities (Anderson et al., 2005; Hussey and Smith, 2003).

The following sections discuss the issues of the learning outcomes related to this research, namely, intended learning outcome, outcome-based education, the importance of learning outcomes, learning outcomes as goal orientation in self-regulated learning, and top-level objective of learning.

2.4.1 Intended Learning Outcome

An intended learning outcome (ILO) is a planned learning outcome which expresses the learner’s ability by the end of the course module (Kennedy, Hyland, and Ryan, 2007). All ILOs of a specific course of study are commonly planned and desired before providing the learners with learning activities (Anderson et al., 2005).

There are many related terms for an ILO; Harden (2002) uses the term *expected learning outcome* to express an idea of the emphasis being on the education processes to consider the results of the students' studies; Hussey and Smith (2003) explain the term *desired learning outcome* as the attempt to encourage, contribute and engage the processes of learning in the classroom. In addition, according to the AMEE Guide No.14 (Harden, Crosby, Davis, and Friedman, 1999b), a number of criteria used to determine a statement of intended learning outcome should be expressed in such a way that the ILO:

- reflects the vision and mission of institutions,
- addresses a specific area of competence,
- is manageable in terms of the number of outcomes,
- is defined at an appropriate level of generality,
- assists with the development of "enabling outcomes" (see section 2.4.5),
- indicates the relationship between different outcomes.

2.4.2 Outcome-Based Education

Outcome-based education (OBE) is an educational approach that concerns the results of pedagogical activities defined in terms of what learners should achieve by the end of the course module or programme (Anderson et al., 2005; Bouslama, Lansari, Al-Rawi, and Abonamah, 2003; Spady and Marshall, 1991). This approach starts from the abstraction of what essential subject matter learners will be able to learn, then organises the curriculum, instruction and assessment to ensure that the learning activities conform to the learning outcomes (Adedoyin and Shangogoyin, 2010). The term *outcome* in this sense is a clear and observable demonstration of learning that exists after the learners gain the learning experience (Spady and Marshall, 1994). It can guide instructional designers not only to plan the learning goals for the course modules but also to initiate the intended learning outcomes which will be officially declared to standardise the curriculum (Bouslama et al., 2003). Furthermore, OBE can encourage educators to pay attention to initiating the complete contents of the curriculum and content structures (e.g., lessons, units, courses and programmes) in order to determine what lessons are essential for learners to gain a high level of performance (Spady and Marshall, 1991).

2.4.3 The Importance of Learning Outcomes

Harden et al. (1999b) state that the concept of learning outcomes presents an effective and attractive approach for reforming and managing education. Focusing on learning outcomes is increasingly recognised in curriculum planning (Otter, 1995). There are many key benefits to applying the learning outcomes in higher education which are summarised as follows (Harden, Crosby, and Davis, 1999a):

- Learning outcomes lead to focus on the relationship between curriculum and practice (learning and teaching) in the learning environment.
- They constitute the acceptable and intuitive approach of most instructors.
- They assist in unifying the curriculum by providing a powerful framework for courses of study.
- They articulate the accountability and quality assurance.
- They encourage learners to relate to their responsibility of learning (self-directed learning).
- They contribute to initiating the collaboration of learning and teaching.

- They can be a tool for curriculum evaluation (e.g., performance-based assessment).

2.4.4 Learning Outcomes as Goal Orientation in Self-Regulated Learning

According to the work of Gagné and Merrill (1990), instructional design begins with the identification of the learning goals which are considered as learning outcomes defining the required capabilities for improving learners' performance. Learning outcomes form the common part of the goal orientation in which this approach can support self-regulated learning (Harden et al., 1999b; Ismail and Sharma, 2012). In order to achieve learning outcomes, self-regulated learners apply a mastery goal orientation by focusing on mastering the task, developing new skills and improving competence and comprehension (Ismail and Sharma, 2012). Zimmerman (1990) states that self-regulated learners use systematic and controllable strategies and own their responsibility for achieving the learning outcomes.

2.4.5 Top-Level Objective of Learning

Top-level objective of learning has been referred to as identifying the topmost (or principal) objective of learning. This approach has been referred to a "designing-down" approach that allows the development of *enabling outcome* (Harden et al., 1999b); for instance, a progressive study forms the enabling outcomes at the end of year 4 to the exit outcomes at the end of year 5. The exit outcome in this sense is pivotal to all the outcomes achieved by learners at the time of graduation. Gilbert and Gale (2008) refer to the term *enabling objective* to describe the same meaning which illustrates the hierarchy as depicted in Figure 2-6.

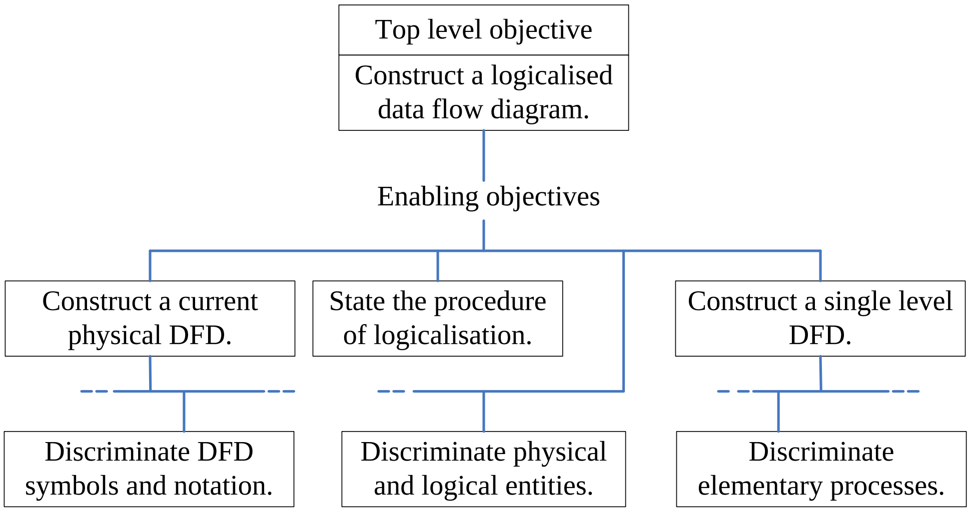


Figure 2-6 An example of enabling objective hierarchy (Gilbert and Gale, 2008)

The terms *learning objective* and *learning outcome* can be used interchangeably (Gilbert and Gale, 2008). Gilbert and Gale (2008) also state that the learning objective is specified by the standard phrase: "By the end of the course, the student will be able to X ", where X is a performance. In addition, the essence of a performance X is denoted by the learned capability verb (Gagné et al., 2004) in which it demonstrates the outcome. Table 2-4 shows the example of the components of a basic learning objective.

Table 2-4 Components of a basic learning objective (Gilbert and Gale, 2008, p.87)

Component	Example
Objective	The student will be able to analyse target audience characteristics by listing those characteristics pertinent to the e-learning under consideration
Performance	…to analyse target audience characteristics by listing…
Ability	…analyse target audience characteristics…
Learned capability verb	…analyse…
Learned capability object	…target audience characteristics…
Assessable behaviour	…listing those characteristics pertinent to the e-learning under consideration

In order to design the courses of study effectively, Gagné (1985) suggests that it is essential to clarify the varieties of learned capabilities as plainly as possible. These capabilities have been observed as human performances; and these performances are the results of learning which are reflected in what the learner has learned (Gagné and Driscoll, 1988). Gagné points out an example as below:

> If what has been learned is a capability of stating the sense of a set of propositions, then "telling" is the performance that shows learning has occurred. If a motor skill such as "writing" with a pen has been acquired, then this performance may be exhibited, and its occurrence verified (to an external observer) that the capability has been learned (Gagné, 1985, p.75).

To summarise, this section has concentrated on discussing learning outcomes and their benefits in learning and teaching. In this research, an approach of intended learning outcomes has been decided on as the basis of the design of the courses of study that pertain primarily to the learners' achievement. Generally speaking, the term that is closely related to learning outcomes is *competence*. The next section will describe *competence* and its structure.

2.5 Competence in Learning and Teaching

There are many widely accepted definitions of the term *competence* in the literature (Strebler, Robinson, and Heron, 1997). One is given by Athey and Orth: they define the meaning of competence as "a set of observable performance dimensions, including individual knowledge, skills, attitudes, and behaviours..." (Athey and Orth, 1999, p.216). The American Academy of Physician Assistants (AAPA, 1996) asserts that the term competence entails "the totality of knowledge, skills, and abilities required for professional practice". In addition, McClelland (1973, p.9) also states that competence can be "knowledge, skills, traits, attitudes, self-concepts, values, or motives related to job performance or important life outcomes".

The competence approach to pedagogical activities has been widely applied, established and used in organisations and institutions (Garavan and Mcguire, 2001; Hoffmann, 1999). Developing competence assists individuals to improve the performance of all stakeholders in education (Kalz, Specht, Nadolski, Bastiaens, Leirs, and Pawlowski, 2010). This approach is applicable to pedagogical activities in order to relate the learning, teaching, and assessment of learners to the learning outcomes with a review to enhancing their performance (Hoffmann, 1999). The following sections will deal with the competence structure and the beneficial use of competence.

2.5.1 Competence Structure

Structurally, competence consists of two main components: intended learning outcome, and context (Sitthisak, Gilbert, and Davis, 2008). The former, the intended learning outcome (ILO), is the sub-category of the learning outcome which is assigned as the planned goal of the course of study. An ILO consists of two components: capability and subject matter content. The latter is the context which represents the conditions, situation, environment, tool, times, or place accompanying the pedagogical activities. In addition, a special property is a prerequisite of competence, a property which is characterised by a prior competence occurring in the learning structure. Thus, the learning structure shows the prerequisite learning relations between the competences (Reigeluth, Merrill, Wilson, and Spiller, 1980). Furthermore, teaching and learning activities are the two supporting components of competence which have a direct influence on the achievement goals in education; both learning and teaching activities can be formally described in the pedagogical tasks in order to accomplish the common goals in teaching and learning. The conceptual model of the competence structure in learning and teaching is shown in Figure 2-7.

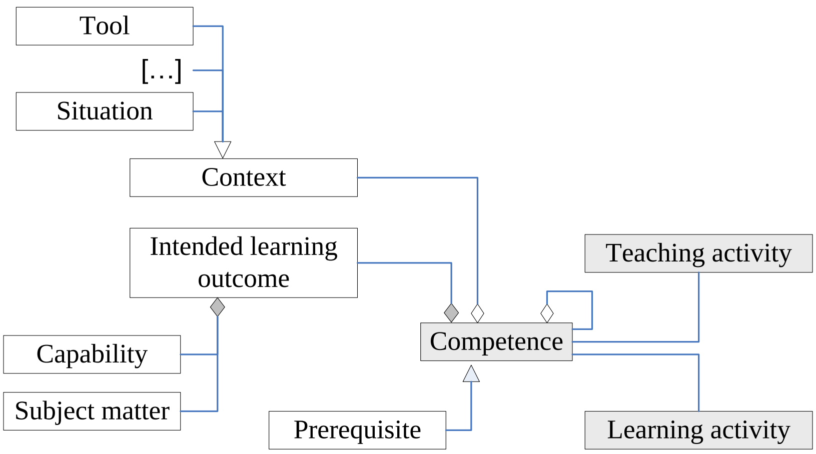


Figure 2-7 The conceptual model of competence in learning and teaching (Nitchot et al., 2011; Sitthisak, Gilbert, and Davis, 2008)

2.5.2 The Beneficial Use of Competence

The improvement of individual performance is a key benefit of applying competence in education (Hoffmann, 1999). Edwards, Sanchez-Ruiz, and Sanchez-Diaz (2009) discuss five major advantages of using competence in higher education which are summarised as follows:

- Competence has satisfied the needs of all stakeholders (e.g., learners, instructors, researchers, or educators) to improve human performance.
- Competence empowers personal traits (e.g., ability, characteristic, or idiosyncrasy).
- Competence makes learners the focus of attention.
- Competence provides the methods of designing learning, teaching, and assessments.
- Competence and learning outcomes provide flexibility and autonomy in the curriculum design.

In this research, according to the benefits of competence as discussed above, competence and its structure have been adopted as the basic structure of the proposed ILO modelling that will be described in section 4.2. The next section will discuss the instructional design theories that reflect the design of the proposed approach of this research.

2.6 Instructional Design Theories

Merrill (2001) defines an instructional design (ID) and an instructional design theory (IDT) as follows:

> Instructional design is an engineering activity for which the artifact created is an instructional product designed to help a learner acquire some knowledge and skill. An instructional design theory is a set of prescriptions for designing this instructional product (Merrill, 2001, p.294).

Furthermore, instructional design theory is referred to simply as the *instructional theory* (Reigeluth, 1983) which provides explicit guidelines to support human development through the instructional products (Reigeluth, 1999). The instructional products in this sense mean the materials (or artefacts) which are utilised in learning and teaching, such as online courses, training programs, tutorials, instructional modules, course management systems, or web-based study resources (Montilva, Barrios, and Sandia, 2002).

Reigeluth (1999) also states that all instructional design theories share the following three main characteristics in common:

- Instructional design theories have been described as design oriented, focusing on the achievement of educational goals and course development, rather than description oriented, focusing on how to describe the results of given events. So, they offer guidance as to what methods should be used to yield the best results for a given goal.
- Instructional design theories have described the *methods* of instruction which identify the ways to support and facilitate learning, and the *situations* in which those methods have been used.
- Instructional design theories have provided ways to deconstruct the methods of instruction into more *detailed component methods* that give additional information and guidelines to both educators and instructors.

There are many theories in the field of instructional design. Each of the original theorists has invented and developed unique contributions to academia. In the following sections, two instructional design theories which are the most comprehensive and widely known as the influential theories, have been summarised. First, Gagné and Briggs proposed the Gagné-Briggs theory of instruction which is known as the *granddaddy* of instructional theories (Petry et al., 1987). Second, Merrill contributed the component display theory (CDT) to lead the design and development of learning and teaching activities (Merrill, 1994b; Merrill, 1998).

2.6.1 Gagné-Briggs Theory

The Gagné-Briggs theory was originally developed and put together based on the works of Robert Gagné and Leslie Briggs in the 1960s. Gagné proposed the theory of how learning occurs, whilst Briggs proposed the instructional development procedures; consequently, the Gagné-Briggs theory illustrates the *instructional prescriptions* that describe the different methods of instruction for any given learning situation (Petry et al., 1987). Also, the Gagné-Briggs theory comprises three main sets of prescriptions, namely, the prescription of five categories of learned capabilities, the prescription of nine events of instruction and the prescription of sequence instruction (Petry et al., 1987). These three sets of prescriptions have been discussed as follows:

2.6.1.1 The Categories of Learned Capabilities

You will recall that, in section 2.3.2, Gagné describes five categories of human learned capabilities. These five categories are the intellectual skills comprising three subcategories (i.e., discriminations, concepts, and rules), verbal information, cognitive strategies, attitudes, and motor skills. The instructional prescriptions of each category are summarised as shown in the following table.

Table 2-5 Five categories of learned capabilities and their prescriptions (Petry et al., 1987)

Category	Instructional Prescription
Verbal information	Learners recall verbal information when they learn. For instance, they write, or state such information as names, words, sentences, or arguments of related details.
Intellectual skills	Learners use intellectual skills when they show competence by using symbols or language in the following ways:
- Discriminations	- They discriminate when things are required to be differentiated.
- Concepts	- They acquire a concept when they define a previously unencountered item into a class.
- Rules	- They acquire a rule when they address a question in any unfamiliar situation.
Cognitive strategies	Learners acquire cognitive strategies when they develop ways to improve their intellectual or problem-solving strategies.
Attitudes	Learners have attitudes when they make a choice in any situation.
Motor skills	Learners develop motor skills when they do a physical activity by using materials or equipment.

Petry et al. (1987) suggests that each category of learned capability is needed to identify the instructional prescriptions before the instruction is designed and developed, because each category requires a different instructional method.

2.6.1.2 The Events of Instruction

The events of instruction form the specific *order of instructional methods* that establishes "the conditions of the learning essential for the various types of learned capability to be learned" (Petry et al., 1987). There are nine events of instruction which have been identified to support the learning activities. These nine events and their prescriptions are summarised as shown in Table 2-6.

Table 2-6 Nine events of instruction and their prescriptions (Petry et al., 1987)

Order	Events	Instructional prescription
1	Gaining attention	The learners' attention is gained when they are presented with immediate stimulus changes which can apply to all learned capabilities.
2	Informing the learner of the Lesson objectives	Introducing learners to the lesson objectives helps them to realise the expectations of the course. Different instructional techniques are suitable for different categories of learned capabilities: - *Verbal information*: states what learners will be able to do by the end of the lesson. - *Intellectual skill*: describes and demonstrates the learning activity. - *Cognitive strategy*: clarifies the expected solution. - *Attitude*: informs them after the appropriate behaviour is demonstrated. - *Motor skill*: explains the desired performance.
3	Stimulating recall of prior learning	Learners are asked to recall some "facts" already learned. Different techniques are suitable for each category of learned capabilities: - *Verbal information*: stimulates recall of prior knowledge by summarisation and outlines. - *Intellectual skill*: stimulates recall concepts and prerequisite rules that need to be applied in learning. - *Cognitive strategy*: stimulates recall of the strategy of learning tasks. - *Attitude*: stimulates recall of the learning situation and activities affected by individual choices. - *Motor skill*: stimulates recall of how to operate and execute the learning materials.
4	Presenting the stimulus material with distinctive features	Learners should be presented with the unique features of incentive material to stimulate their attention, such as diagrams or charts, bold or italic text, or volume in speech. - *Verbal information*: shows printed or transferred verbal statements in an organised way. - *Intellectual skill*: explains objects and symbols as features used in rules and concepts. - *Cognitive strategy*: explains the problem and states the strategy for solving it. - *Attitude*: describes and demonstrates the nature of choices of personal action. - *Motor skill*: shows the learning situation and demonstrates how to operate learning materials.

5	Providing learning guidance	Learning guidance needs to be given to learners as clearly as possible. - *Verbal information*: relates to the content by giving an example. - *Intellectual skill*: provides clear understandable instances of concept or rule. - *Cognitive strategy*: provides verbal explanation of strategy. - *Attitude*: explains the action of choice. - *Motor skill*: supports and administers the feedback of performance.
6	Eliciting the performance	Learners need to show their learned capabilities. - *Verbal information*: asks for information, or allows learners to paraphrase or state their own explanation. - *Intellectual skill*: applies the concept and rule. - *Cognitive strategy*: allows learners to solve unfamiliar problems. - *Attitude*: allows learners to choose the most suitable alternative provided in a previously unencountered situation. - *Motor skill*: allows learners to perform the whole learning procedure.
7	Providing informative feedback	Feedback can be used to communicate the correctness of performance in a variety of ways, such as, computer-assisted instruction, individualised instruction, etc. - *Verbal information*: conveys the correctness of a statement of information. - *Intellectual skill*: conveys the correctness of applying concept and rule. - *Cognitive strategy*: imparts the solution to a specific problem. - *Attitude*: provides information on the choice of action. - *Motor skill*: provides feedback on the degree of accuracy and timing.
8	Assessing performance	Assessing performance is needed to measure the degree of gain of the learners' new capability. - *Verbal information*: evaluates the learner's paraphrasing of specific information. - *Intellectual skill*: evaluates the learner's ability to apply concept and rule to a new situation. - *Cognitive strategy*: evaluates the learner's ability to solve numerous forms of problems. - *Attitude*: evaluates the learner's ability to make decisions in real or simulated situations.

		- *Motor skill*: evaluates the learner's ability to perform the total number of skills.
9	Enhancing retention and transfer	Encouraging learners to study numerous examples or case studies enables them to increase retention of all learned capabilities.

2.6.1.3 The Sequencing Prescription

The sequencing prescription has been represented through the hierarchical task analysis which has been analysed as a hierarchical sequence of instruction. In order to design the hierarchical sequence of instruction, the first process is to identify the general goals (and objectives), and then, the next step is to deconstruct the goals into the specific sub-goals (Petry et al., 1987). These processes form the learning hierarchy and the sequence is then organised. However, the learning hierarchy and sequence are suitable solely for intellectual skills, because these processes are carried out on the performance objectives which are based on the intellectual skills (Petry et al., 1987).

To summarise, the Gagné-Briggs theory is comprehensive in a broad area of instructional strategies, because this theory prescribes all three domains of Bloom’s taxonomy: cognitive, affective, and psychomotor through five categories of learned capabilities. In addition, the nine events of instruction are prescribed: the learner’s attention, lesson objectives, stimulating recall, stimulus material, learning guidance, performance, feedback, assessment of performance, and enhancement of retention. Moreover, this theory also provides the prescriptions for the sequencing of contents through the hierarchical task analysis.

2.6.2 Component Display Theory

The component display theory (CDT) is proposed by Merrill. He extended the work of Gagné (1965) through the development of the CDT. Originally, Gagné proposed that different types of learning outcomes (classified on a performance dimension) require different types of learning conditions (Gagné, 1965; Gagné, 1985). Based on this assumption, Merrill broadened the classification scheme by adding a *content dimension* (Li and Merrill, 1991), producing the CDT. Consequently, the CDT is based on a two-dimensional classification scheme comprising performance and content (Merrill, 1994b).

As mentioned in section 2.3.3, the performance dimension covers three categories, namely, *find*, *use*, and *remember*. This dimension represents the learner's capabilities with respect to particular subject matter content and is a condensed version of Bloom's cognitive taxonomy. The content dimension (also called subject matter content) involves four types, namely, *fact*, *concept*, *procedure*, and *principle*. A fact has two associated parts of information, such as, a specific name and a date, an event and the particular name of a place, et cetera. A concept is a concrete or abstract item with certain characteristics, such as, a human being, and so on. A procedure (or process) is a set of steps for accomplishing an objective, such as a computer program, a recipe for cooking Thai food, et cetera. Finally, a principle is a cause-and-effect relationship which predicts outcomes, such as that road accidents occur because of slippery roads, apples fall because of gravity, and so on.

The CDT can be used to design and develop instructional products (i.e., learning activities, learning materials) (Merrill, 1994b). In order to specify the instructional products systematically, the CDT covers the important topic called the *performance-content matrix* that is summarised as follows:

2.6.2.1 Performance-Content Matrix

Merrill's classification system can be represented by the performance-content matrix which has been proposed to identify the relationship between the performance dimension and content dimension. All learning objectives can be said to be categorised into one or more cells of the performance-content matrix (Merrill, 1994b). Figure 2-8 shows the classification that conceptualises the relationship between these two dimensions.

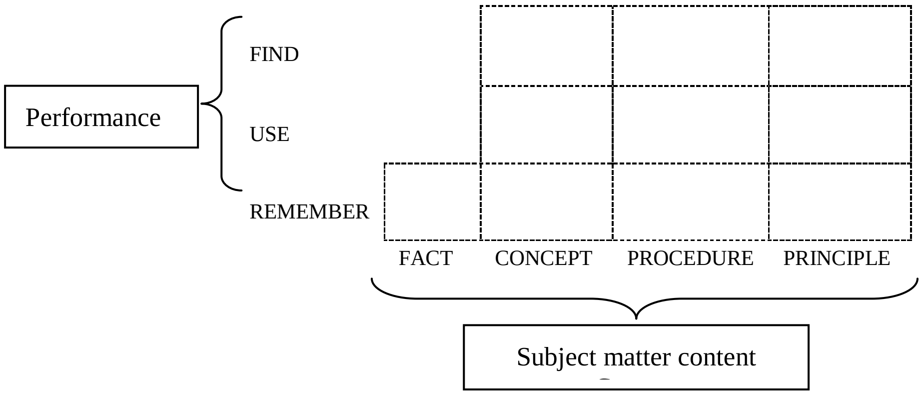


Figure 2-8 The performance-content matrix (Merrill, 1994b)

In summary, Merrill's classification provides ten relationships between performance and subject matter content. Table 2-7 represents these ten relationships and their examples.

Table 2-7 Merrill's classification with examples, summarised from (Merrill, 1994b)

Classification	Examples
Remember-Fact	1. On a topographic map, what is the symbol for a church?
Remember-Concept	1. What are the characteristics of a conifer? 2. Define positive reinforcement.
Remember-Procedure	1. What are the steps entailed in balancing a cheque book? 2. Describe the steps in making a black-and-white print in the darkroom.
Remember-Principle	1. What happens when water evaporates? Explain in terms of molecular movement and heat.
Use-Concept	1. Is the mountain pictured in this photograph an example of a folded mountain? 2. Read the following story and identify that paragraph which best portrays the story's climax.
Use-Procedure	1. Demonstrate how to clean a clarinet. 2. Make a whip or tongue graft in a fruit tree.
Use-Principle	1. Read the following case study of an ecological system. In this system the rodents are increasing in number. Predict some possible hypotheses based on your knowledge of life cycles and the interdependence of species in this ecological system.
Find-Concept	1. Sort the rocks on this table into several different piles. 2. Figure out a way to group students in a classroom that assures a range of ability and diversity in gender.
Find-Procedure	1. Write a computer program that will index and retrieve recipes. 2. Devise a technique for randomly assigning students to experimental treatments as they enter the laboratory.
Find-Principle	1. Set up an experiment to assess the effect of tobacco smoke on plant growth. Report your findings.

In addition, Merrill provided a methodology to identify the learning objective for the performance-content matrix as illustrated in Table 2-8.

Table 2-8 Specification of objectives for the performance-content matrix (Merrill, 1994b, p.117)

	CONDITIONS		BEHAVIOUR		CRITERION	
	Variable1	Fixed	Fixed	Variable2	Fixed	Variable3
	Given:	Of/for:	Will:	By:	With:	Shown by:
Use-Concept	Drawings Pictures Descriptions Diagrams	New examples	Classify	Writing Selecting Pointing Sorting	Some errors Short delay	
Use-Procedure	Word Materials Equipment Device	Name new task	Demonstrate	Manipulating Calculating Measuring Removing	Some errors timed or untimed	Check list
Use-Principle	Word Descriptions Drawings Figures	Name new problem	Explain or predict	Predicting Calculating Drawing Graphing	Some errors untimed	
Find-Concept	Drawings Pictures Descriptions Diagrams Objects	Reference from unspecified categories	Invent categories	Sorting and observing attributes Specifying attributes	Untimed High correlation when others use concept	
Find-Procedure	Description Demonstration Illustration Specification	Desired product or event	Derive steps	Experiment Analysis Trial & error	Untimed demo of utility	
Find-Principle	Description Illustration Observation	Event	Discover relationship	Experiment Analysis Observation Demonstration	Untimed Appropriate research Design or scholarship	
Remember-Fact	Drawing Pictures Diagrams Objects	A In any order	Recall B	Writing Drawing Pointing Circling	No errors No delay	1 point for each correct symbol in 10 sec.
Remember-Concept	Word Symbol	Name	State definition	Writing Selecting Circling Checking	Few errors Short delay	1 error for each characteristic
Remember-Procedure	Word Symbol Directions	Name	State relationship	Writing Drawing Formula Graph	Few errors Short delay	1 error each step
Remember-Principle	Word Symbol	Name	State relationship	Writing Drawing Formula Graph	Few errors Short delay	1 error each relationship

In order to interpret this table, Merrill provided an example of how to specify the learning objective for *remember-fact* as follows:

> Given a drawing (column 1) of an eye (A) with the parts numbered in random order (column 2), the student will be able to recall the name of each part(B) (column 3), by writing the name opposite the number corresponding to that part (column 4) with no errors and no delay (column 5), as shown by one point for each part named correctly and one point subtracted from the score for each 10 seconds over 1 minute required to complete the exercise (column 6) (Merrill, 1994b, p.116).

The methodology reviewed above suggests the way to form the expression of the learning objective by providing the template that represents three components: condition, behaviour, and criterion.

To summarise, Merrill proposed the CDT theory that classifies the learning objectives into two dimensions, namely, performance and content. The performance dimension consists of *find*, *use*, and *remember,* whilst the content dimension (called subject matter content) comprises *fact*, *concept*, *procedure*, and *principle*. In addition, the performance-content matrix has been introduced to identify the ten relationships of the learning objectives in order to represent the classification system of the performance and subject matter content (see Table 2-7 and Table 2-8).

2.6.3 Summary of Theory Selection

The CDT theory plays a crucial role as the fundamental theory adopted in the design and development of the proposed ILO's structure. The reasons are based on the outstanding contributions of the CDT theory summarised as follows:

1. The CDT classification of performance levels and contents accurately prescribes the learning components and their relationship through the performance/content matrix (see Figure 2-8). All learning objectives can be categorised into one or more cells of the performance/content matrix.
2. The CDT provides an explicit methodology that incorporates the prescriptions of learned capabilities and subject matter contents to be taught.
3. The CDT deals with the micro-levels (or fine-grained levels) of instruction design in which the subject matter is broken down into small parts, lower level, or individual tasks. This leads to the delivery of all details of instructional products to learners.

According to the above literature reviews, it is important to note that the instructional design is the core theory for educational development. The following section will discuss how the instructional process can be initiated through the generic mechanism called the ADDIE model.

2.7 The ADDIE Model

ADDIE is an acronym for the "Analysis, Design, Development, Implementation and Evaluation" phases of instructional design (Lohr, 1998). These five phases represent the fundamental model (called ADDIE model) that describes the generic process of instructional design. Although there was no original reference for the ADDIE model in any histories of instructional design (Molenda, 2003), many instructional designers and professionals refer to the ADDIE model as the basis for the instructional development process (Bichelmeyer, 2005).

The explanations of the individual processes are summarised as follows (Gustafson and Branch, 2002):

- Analysis entails examining the learning situations, learning tasks, and learning materials as well as determining the assessment.
- Design covers identifying the learning objectives in measurable terms, categorising the subject matter into types or subtypes, and identifying learning activities and the media used to represent the learning materials.
- Development means creating learning materials as specified during the design process.
- Implementation involves performing the teaching and learning as well as delivering the learning materials to learners.
- Evaluation covers three processes: formative evaluation, summative evaluations, and revision. The formative evaluation is the collection of data during the course to identify needed revisions to the instruction, whilst summative evaluation is the collection of data to measure the whole instruction. The revision includes ensuring that the changes are in agreement with the formative evaluation data.

The ADDIE processes are not determined in a linear development (or step-by-step process), because they need revising when each process is performed (Gustafson and Branch, 2002). Figure 2-9 illustrates the relationship between the five core processes of ADDIE model.

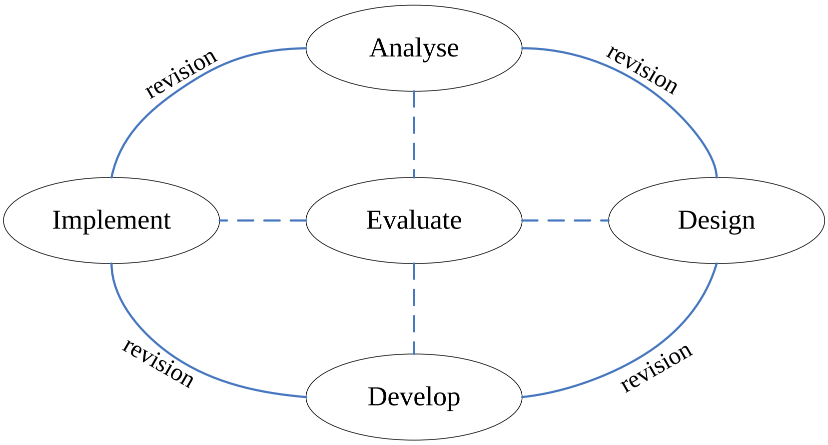


Figure 2-9 Core processes of ADDIE (Gustafson and Branch, 2002)

Practically, the ADDIE model can be applied to every instructional design theory (discussed in section 2.6). This is because the ADDIE model provides the core processes of instructional design to ensure that goals, strategies, and instructional results (or instructional products) are satisfied when the ADDIE model is adopted. In this research, the proposed approach can facilitate all processes of the ADDIE and the summary of the research contribution is discussed through the ADDIE model (see section 10.2.4).

2.8 Conceptual Modelling

This section discusses the discipline of conceptual modelling which is the fundamental issue of the proposed conceptual model featured in the second objective of the research (see section 1.2). The following sub-sections introduce the conceptual background, followed by the three examples of conceptual models (i.e., concept map, entity-relationship diagram, and unified modelling language). Additionally, conceptual understanding through graphical representation and quality metrics and measurement for conceptual models will be discussed.

2.8.1 Introduction to Conceptual Background

It should be noted that conceptualisation, using graphical or diagrammatic techniques, is the crucial way to improve humans' capacity to construct knowledge (Carney and Levin, 2002). In order to introduce this idea, Levin and Mayer (1993) proposed the seven "C" principles for introducing the basic understanding of why conceptual representation can improve learners' learning. This is because graphical representation makes the learning content more:

- concentrated (focused with respect to directing reader's attention),
- compact/concise ("A picture is worth a thousand words"),
- concrete (representation function),
- coherent (organisation function),
- comprehensible (interpretation function),
- correspondent (relating unfamiliar text to reader's prior knowledge), and
- codable (mnemonic transformation function).

Many research studies focus on how to conceptualise the real-world problems and situations in ways that support humans with problem solving and decision making. For instance, Keogh and Naylor (1999) introduced the "concept cartoons" as a tool for teaching and learning; this approach proposed the development of an innovative teaching strategy to capture the learners' attention in order to promote learning and stimulate them to focus their attention on creating meaningful explanations and constructing knowledge. Additionally, Cheng (1999) applied "law encoding diagrams (LEDs)" as tools in the representational analysis of conceptual learning in complex scientific and mathematical domains. Major contributions of these two examples (i.e., concept cartoons and LEDs) are that they benefit conceptual representation as the tool which can facilitate mental processes. This entails describing the internal representation (or mental representation) of human knowledge of the real world (Greca and Moreira, 2000).

The term *representation* has many connotations, depending on the context; the representation can be defined as the process or the product (the outcome of the process) (Scaife and Rogers, 1996). In this research, we determine the definition of the *conceptual representation* as the product which can refer to the *conceptual model*. The term *conceptual model* has been defined as "any collection of specification statements relevant to some problem" (Lindland, Sindre, and Solvberg, 1994, p.42). At the same time, conceptual modelling has been described as "the process of formally documenting a problem domain for the purpose of understanding and communication among stakeholders" (Siau, 2004, p.73). The outstanding challenge of the conceptual model and conceptual modelling is to help every stakeholder in the development process such as software development in the information system and software engineering, or curriculum development in education, to realise the complex problems and the possible solutions through *abstraction*. The term *abstraction* refers specifically to the simplification that occurs when moving from real-world problems (or situations) to the conceptual model (Kotiadis and Robinson, 2008).

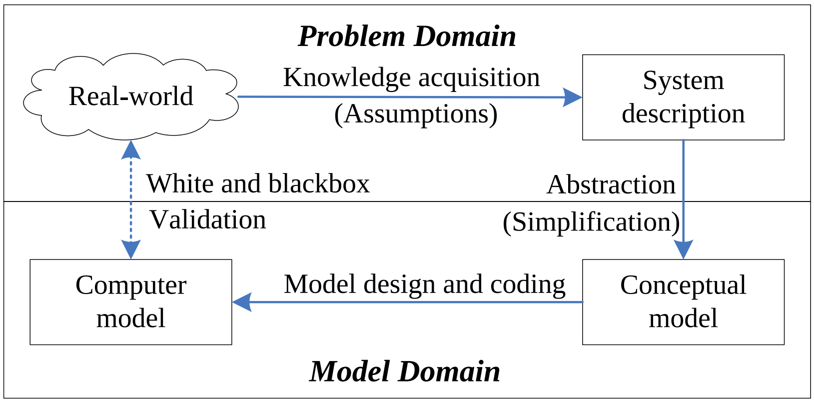


Figure 2-10 Artefacts of conceptual modelling (Kotiadis and Robinson, 2008)

In order to illustrate the interaction within the problem situation and conceptual model as a scenario, Figure 2-10 shows the key artefact of the conceptual modelling discussed in Kotiadis and Robinson (2008); the *cloud* represents the real-world problem; the *system description* represents the declaration of the problem situation; the *conceptual model* represents the conceptual abstraction of non-software specific description; and the *computer model* represents a software specific design and software representation of the conceptual model. According to the interaction within this scenario, the conceptual model simplifies the problem domain through the representation of the conceptual abstraction.

Nowadays, the methods and techniques of many hundreds of conceptual models have been introduced but few have enjoyed widespread use (Parsons and Cole, 2005). The following three sections (sections 2.8.2 – 2.8.4) introduce the three conceptual models that are widely accepted as the famous models in the conceptual modelling communities and they are closely related to this research approach. They are the concept map, the entity-relationship diagram (ERD), and unified-modelling language (UML).

2.8.2 Concept Map

A concept map is the graphical tool that visualises the *concepts* and the hierarchical relationships between them. It was first introduced by Novak and Gowin (1984, p.4) when they defined *concept* as "a regularity in events or objects designated by some label". For example, a chair is the label designating an object with legs, a seat, and a back that is used for sitting on. The concepts are enclosed in circles or boxes containing some meaningful words. The relationship between the two concepts is indicated by a line; the words on a line, referred to as linking words or linking phrases, express the relationship between the two concepts (Novak and Canas, 2006).

The main characteristic of the concept map is that the hierarchical structure represents the generalisation of the concepts. This means that the most general concepts are at the top of the concept map and the specific concepts (or less general concepts) are hierarchically below (Novak and Canas, 2006). For instance, an example of the concept map representing the individuals' understanding of art (Novak and Gowin, 1984, p.I82), is illustrated in Figure 2-11.

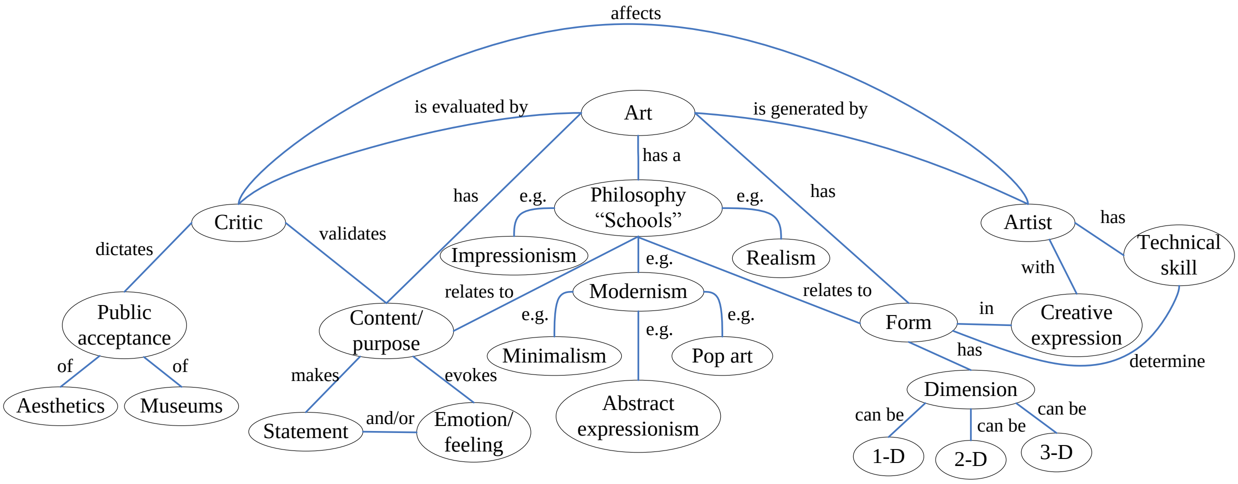


Figure 2-11 Example of concept map (Novak and Gowin, 1984, p.I82)

Another important characteristic of the concept map is that it includes the *cross-links* or relationships between concepts in different domains (Novak and Canas, 2006). The cross-links identify how a concept in one knowledge domain is linked to a concept in another domain. As illustrated in Figure 2-12, the cross-links' relationships can be represented by using the solid arrowhead.

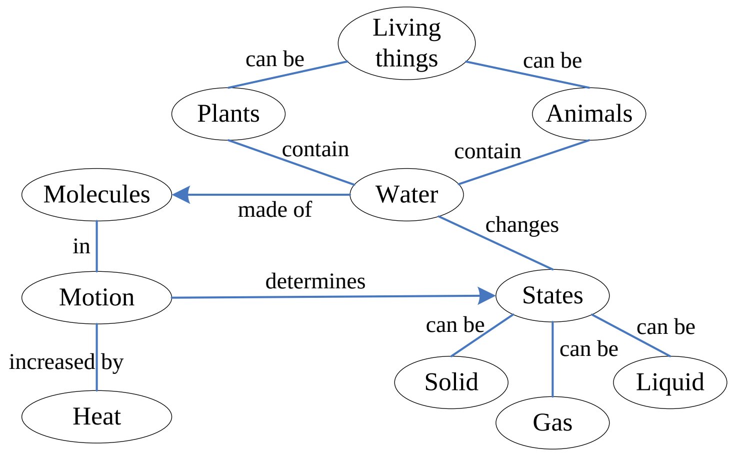


Figure 2-12 Example of concept map for living things (Novak and Gowin, 1984, p.18)

Research on concept maps has been done in several disciplines. Although Novak and Gowin were the first to propose the concept map to help students and educators to understand the meanings of the learning materials (Novak and Gowin, 1984), a number of research studies reveal that the concept map has been used in many research directions, for instance, using concept maps as the graphical tools for organising and representing knowledge in the knowledge management area (e.g., Kinchin, Hay, and Adams, 2000; Slotte and Lonka, 1999; Torre, Stark-Schweitzer, Siddartha, Pelkova, and Ziebert, 2007); using the concept maps as assessment tools to evaluate the learners' understanding in learning (e.g., Roberts, 1999; Ruiz-Primo and Shavelson, 1996; Schau and Mattern, 1997; Turns, Atman, and Adams, 2000); or using the concept maps as the interview tools in the interview-based research where they enhance learners' recall and elicitation of knowledge (e.g., Rye and Rubba, 1998).

In addition, the concept maps can be useful in curriculum planning and development. As Novak and Canas state:

> The concept maps present in a highly concise manner the key concepts and principles to be taught. The hierarchical organisation of concept maps suggests more optimal sequencing of instructional materials (Novak and Canas, 2006, p.26).

The above authors also suggest that concept maps can be used to construct either the global "macro map" in order to draw the main ideas of what instructional designers plan to develop in the entire curriculum, or the specific "micro map" to represent the knowledge structure for a specific lesson or learning module (Novak and Canas, 2006, p.27).

2.8.3 Entity-Relationship Diagram

An entity-relationship diagram (or ERD) is a renowned conceptual model that embodies some semantic information about the business requirements and real-world information. The ERD was first introduced by Chen (1976) using a diagrammatic technique as a tool for database design and development. Chen (1976) gives the definitions of an entity and a relationship as follows:

> An *entity* is a "thing" which can be distinctly identified. A specific person, company, or event is an example of an entity. A *relationship* is an association among entities. For instance, "father-son" is a relationship between two "person" entities (Chen, 1976, p.10).

Each entity in the ERD is represented by a rectangular box, and each relationship is represented by a diamond-shaped box (as depicted in Figure 2-13). For instance, the relationship "Dept-Emp" is defined on the entities "Department" and "Employee".

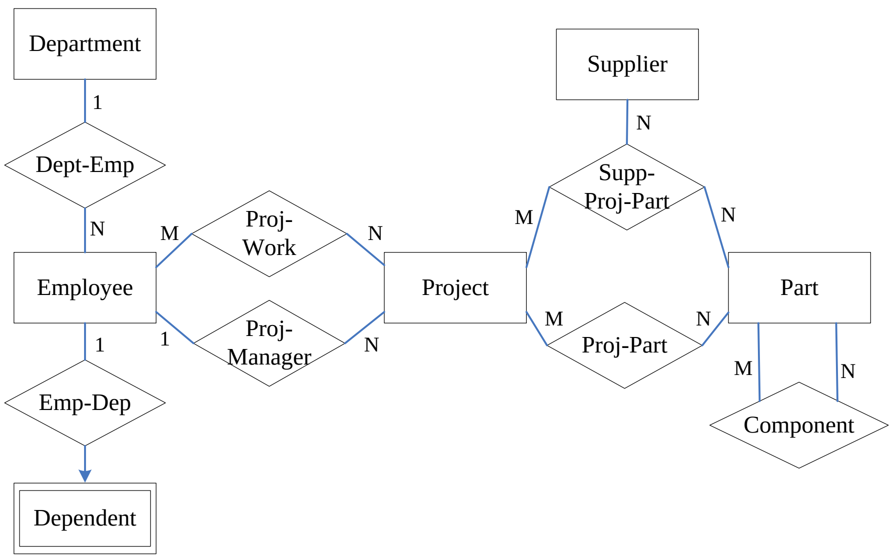


Figure 2-13 An ERD for analysis of information in a manufacturing firm (Chen, 1976, p.19)

The main characteristics of the ERD are as follows (Chen, 1976):

- A relationship with one entity may be defined as a *Unary* relationship (e.g., a relationship "Component" is defined in terms of an entity "Part"), a relationship with two entities is called a *Binary* relationship (e.g., a relationship "Dept-Emp" is defined in terms of two entities "Department" and "Employee"), or in terms of more than two entities, in which case it is called an *N-ary* relationship (e.g., a relationship "Supp-Proj-Part" is defined in terms of three entities "Supplier", "Project", and "Part") (Chen, 1983).

- There may be more than one relationship defined in terms of any given two entities. For instance, two relationships "Proj-Work" and "Proj-Manger" are defined in terms of the entities "Employee" and "Project".
- There are 1:1 (called one-to-one), 1:n (called one-to-many), and m:n (called many-to-many) mappings between the relationship of two entities. For instance, a relationship "Dept-Emp" is a 1:n mapping, that is, one department may have many (n=0, 1, 2,...) employees and each employee works for only one department.
- There may be an *existence dependency* of one entity on another. For instance, the arrow in the relationship "Emp-Dep" identifies the existence of the entity "Dependent" that depends on the corresponding entity "Employee". It means that if an employee leaves the company, his or her dependents may no longer be of interest. This entity is called the *Weak* entity and the ERD notation is the special rectangular box.

Traditionally, the ERD plays a crucial role in logical database design and there have been extensive research contributions to ERD. Thus, the various extensions and enhancements of the traditional ERD have been proposed for some specific approaches. For example, Tryfona, Busborg, and Christiansen (1999) extended the traditional ERD to produce the starER as a conceptual model for the Data Warehouse design and development. In their work, the starER model combines the semantically rich construct of the ERD with the star schema that conducts the data structure in the Data Warehouse; Lumineau, Laforest, Gripay, and Petit (2012) applied the traditional ERD to produce the eXtended Dynamic Entity-Relationship (called XD-ER) model that exhibits dynamic data entities and dynamic relationships to design and develop pervasive applications.

In addition, a number of extended ER (called EER) models have emerged in much of the literature. For instance, in Teorey, Yang, and Fry (1986) the EER has been developed for representing the two additional types of objects: the subset hierarchy which specifies the overlapping subsets and the generalisation hierarchy which specifies the non-overlapping subsets; in Markowitz and Shoshani (1992), an EER has been introduced which is similar to that of Teorey et al. (1986) but covers more definitions for the generalisation. Markowitz and Shoshani propose that the generalisation is a set of entity sets, for example, "Secretary", "Faculty" that can be generalised as a single generic entity, for example, "Employee" (Markowitz and Shoshani, 1992).

2.8.4 Unified Modelling Language

The unified modelling language (UML) is a family of design notations that is approaching a de facto standard for software development language (Medvidovic and Robbins, 2002). The formal evolution of UML was controlled and placed by the Object Management Group (www.omg.org) and the language has been accepted to be the standard for object-oriented software development (Dobing and Parsons, 2006).

The UML covers various types of diagrams that can be utilised to model the behaviour of the system. Although many revisions of the UML specification have been launched since 1995, and the current version, at the time of writing, is the UML 2.5 (OMG, 2013), the UML 1.0 and 1.1 are acceptably documented in a huge number of books (Cook, 2012). The UML 1.0 standardises the notations for eight diagrams, namely, class, use case, state, activity, sequence, collaboration, component and deployment diagrams (Cook, 2012), as illustrated in Figure 2-14.

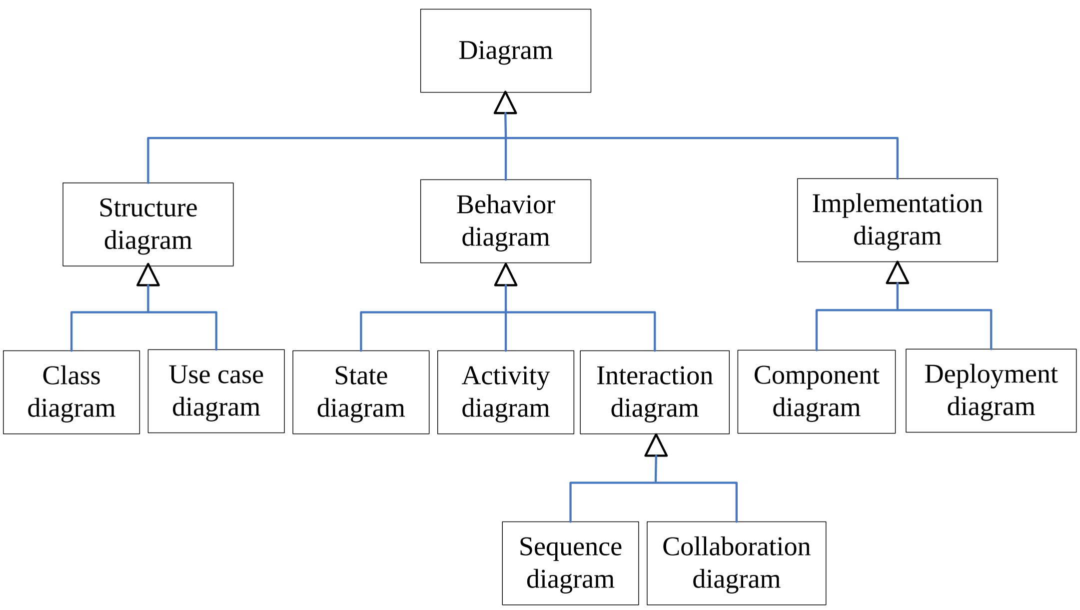
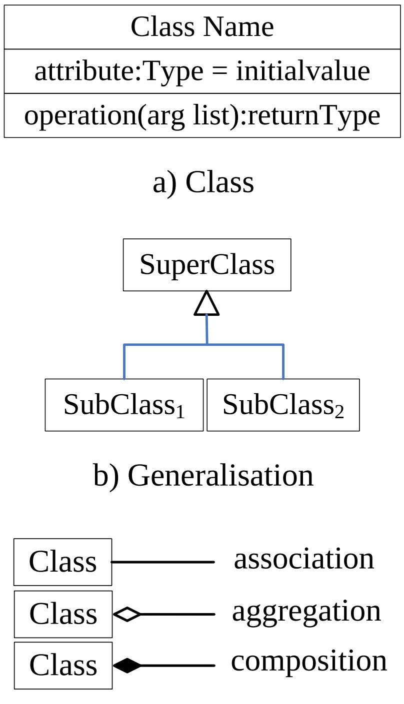


Figure 2-14 UML 1.1 Diagram type (Cook, 2012)

In this section, the three diagrams which are class, use case, and activity diagrams are summarised in terms of the related diagram used in this research. The core characteristics of each diagram are described as follows:

2.8.4.1 Class Diagram

A class diagram is the structure diagram that shows the types of objects and the various kinds of static relationships existing among them (Fowler and Scott, 1999). The class covers its attributes and operations as illustrated in Figure 2-15(a), showing that attributes describe the data contained in an object of the class and operations define the way in which objects may interact; for instance, a *Book* class comprises *title*, *ISBN*, or *publisher* as the attributes and contains *borrow(c:Copy)*, *return(c:Copy)* as the operations. The two basic types of the static relationships that express the relationship between classes are generalisation and association. First, the generalisation represents the superclass/subclass of the objects as illustrated in Figure 2-15(b), for example, a general *customer* class (superclass) initiates a *personal* customer and a *corporate* customer as subclasses. It has to be noted that the *personal* customer is a subclass if all instances of *personal* customer are all instances of *customer* class. Second, the association that represents the relationship between classes consists of three basic types: basic association, aggregation, and composition, as illustrated in Figure 2-15(c).



a) Class

b) Generalisation

c) Associations

Figure 2-15 Class diagram notations (Stevens and Pooley, 2006)

2.8.4.2 Use Case Diagram

A use case diagram is the structure diagram that reveals the interaction between *users* and *tasks*; the UML identifies *actors* and *use cases* as technical terms for users and tasks respectively (Stevens and Pooley, 2006). An actor can also be someone or something external to the system, such as, the output from some other system, or the product from another type of merchandise, et cetera. The links between actors and use cases show the relationships of the diagram (i.e., include, or extend). The *include* relationship occurs when there is a chunk of behaviour that duplicates more than one use case and there is no need to keep copying that behaviour; whilst the *extend* relationship occurs when the extending use case adds behaviour to the base use case (called *extension point*) (Fowler and Scott, 1999). Additionally, the use case generalisation provides the different levels of use case as the same manner of superclass/subclass of the class diagram. The UML notations for the use case diagram are illustrated in Figure 2-16.

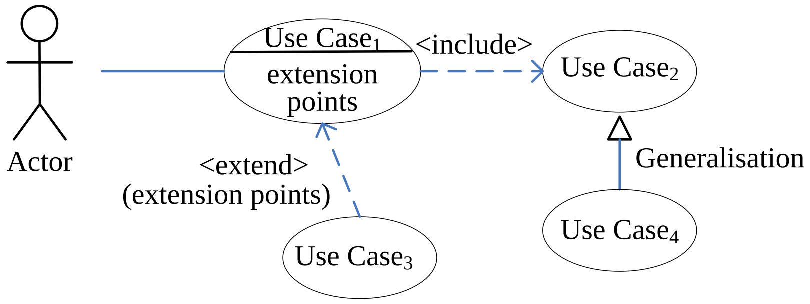


Figure 2-16 Use case diagram notations (Fowler and Scott, 1999)

2.8.4.3 Activity Diagram

An activity diagram is the behaviour diagram that describes the sequencing of activities. There are four behaviours in the activity diagram, namely, *fork*, *join*, *branch*, and *merge*. The fork occurs with a single incoming transition and many outgoing transitions, whilst the join that occurs with an outgoing transition is taken only when all incoming transitions have completed their activities. The branch has a single incoming transition and several outgoing transitions; actually, the branch represents the alternative direction in which only one of the outgoing transitions can be taken. The merge has many incoming transitions and a single outgoing transition; the merge marks the end of conditional behaviour started by a branch (Fowler and Scott, 1999). The UML notations for the activity diagram are illustrated in Figure 2-17.

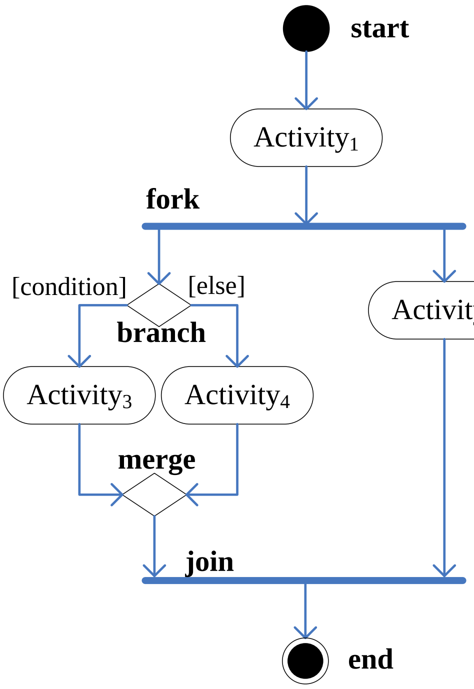


Figure 2-17 Activity diagram notations (Fowler and Scott, 1999)

2.8.5 Conceptual Understanding through Graphical Representation

A number of research studies show that graphical (or external) representations (such as diagrams) support conceptual understanding in learning (Artique, 2002; Cox, 1999; Linder, 1996; Nokes and Ross, 2007; Postigo and Pozo, 2004). Vekiri (2002, p.261) claims that "graphics are effective learning tools when they allow learners to interpret and integrate information with minimum cognitive processing". Learners construct their own realisation by internalising information captured from pre-constructed representations, and then they formulate their own representation (self-regulated external representation) by understanding the concepts that they have learnt previously (Vekiri, 2002). In addition, Berlanga, Kalz, Stoyanov, and Rosmalen (2009) suggest that graphical representations play a crucial role in supporting learners' conceptual development.

Many studies refer to conceptual understanding as the main outcome in specific courses of study. For instance, in Linder's work (Linder, 1996), a conceptual exploration has been employed to enhance student understanding in introductory Physics; in Nokes and Ross (2007), the authors discuss the conceptual learning through analogy in Mathematics; in Postigo and Pozo (2004), the authors explore learners' performance by using different types of graphical representation with different levels of education and knowledge background.

Due to the benefits of graphical representation in demonstrating conceptualisation, there is a need to judge how well the conceptual representation can support humans when they apply this approach in real situations. The following section will discuss the way to evaluate conceptual models.

2.8.6 Quality Metrics and Measurement for Conceptual Models

In the course of developing a conceptual model, there has been much investigation of evaluation techniques that focus on how to measure the completeness, usability, or understandability of conceptual models (Cruz-Lemus, Genero, Manso, Morasca, and Piattini, 2009; Genero, Poels, and Piattini, 2008; Moody, 1996; Moody, 2005). Improving the quality of the models is currently considered as the major topic for research and practice in the conceptual modelling (Houy, Fettke, and Loos, 2012). Table 2-9 provides a summary of the quality metrics and measurement of conceptual models.

Table 2-9 Summary of quality metrics and measurement for conceptual models

Authors	Approach	Quality measurement	Focus models
(Genero et al., 2008)	Understandability *(performance-based measurement)*	• Understandability time (UT) • Understandability effectiveness (UEffec) • Understandability efficiency (UEffic)	ER
(Parsons and Cole, 2005)	Suitability *(for expressing domain semantics)*	• Internal validity • External validity	UML
(Cherfi et al., 2002)	Three dimensions of quality *(usage, specification, implementation)*	• Legibility: clarity • Legibility: minimality • Expressiveness • Simplicity • Correctness	EER, UML
(Patig, 2004)	Expressiveness	• Extensional expressiveness • Intentional expressiveness	ER
(Shanks, 1997)	Quality factors	• Correctness • Completeness • Innovation • Flexibility	ER

	• Understandability • Overall quality

In this research, it can be expected that developing the graphical representation of intended learning outcomes by using a diagrammatic technique to conceptualise the learning objectives would result in a better understanding of the knowledge structure embedded in the content being taught. Thus, this research contributes a conceptual model that enables instructional designers to model a logical structure of learning content and learning materials in which the subject matter and its relationships are integrated with the capabilities to be learned. Furthermore, according to the literature on how to evaluate the conceptual models, these techniques shed some light on how the proposed conceptual model could be evaluated. Throughout the three experimental studies of the research (see chapter 5), the intention is to evaluate the satisfaction, completeness, and understandability of the proposed conceptual model (ILO diagram).

2.9 Summary

In this chapter, seven principal topics relating to the research are discussed, namely, pedagogical theories, taxonomy of educational objectives, learning outcomes, competence in learning and teaching, instructional design theory, the ADDIE model, and the review of conceptual modelling.

First, there is a summary of the two basic pedagogical theories: constructivism and instructivism. Constructivism is representative of the student-centred approach which, in relation to educational activities, works on the premise that knowledge is constructed in the mind of the learners. The key idea of constructivist learning is that, individually, learners actively construct their knowledge, based on existing experiences. Next, social constructivism, constructionism, and constructive alignment are summarised to clarify a variety of constructivist approaches. The discussion moves on to minimally guided instruction in teaching with a view to casting light on instructional guidance that transfers the instructor's knowledge to the learner. In contrast, the instructivist approach is referred to as being teacher focused, starting from the teacher's understanding of the learning contents to be taught and tending to formalise the ways in which it can be taught. Instructionism is also discussed and the comparative features of constructivism and instructivism are summarised. Furthermore, the two principal epistemological orientations, objectivism and subjectivism, are introduced in order to give an understanding of the conflict between the issues of teaching and learning. The exclusive perspective (or contradiction of the practitioner's perspective) in these two approaches is discussed as well as proposing the integrating approach.

Second, three theoretical backgrounds of the taxonomy of educational objectives are discussed, namely, Bloom's taxonomy, Gagné's varieties of learned capabilities and Merrill's level of performance. Bloom's taxonomy has become widely used as the generic classification of learning outcomes. The cognitive domain is categorised as follows: knowledge, comprehension, application, analysis, synthesis, and evaluation. Although the affective and psychomotor domains are also identified in the literature, most educators are familiar with the cognitive domain when defining learning outcomes. Similarly, Gagné and Merrill have also focused on the mental (or cognitive) aspect. Gagné's varieties of learned capabilities can be classified into five categories, namely, intellectual skills, verbal information, cognitive strategies, motor skills and attitudes. Merrill's level of performance covers three levels: find, use, and know (remember). In addition, this section has also summarised the comparison of these three theories.

Third, learning outcomes are discussed. There are two main categories of learning outcomes: intended learning outcome (called ILO) and actual (or emergent) learning outcome. The ILO is desired or planned before involving the learners in the course of study, whilst the actual learning outcome is indicated by what learners have achieved after taking the course assessment. In addition, outcome-based education (OBE) is summarised to indicate an approach to teaching which is concerned with the results of the educational activities that are defined in terms of what the learner should achieve by the end of the course of study. Moreover, the importance of learning outcomes, learning outcomes as goal orientation in self-regulated learning and top-level objectives of learning are also discussed.

Fourth, competence in learning and teaching is discussed and the definitions of competence summarised. In addition, the competence structure which covers the two main components (i.e., intended learning outcome and context) is also explained by means of the conceptual model of competence in learning and teaching. And then, the benefits of using competence in higher education are summarised.

Fifth, the two instructional design theories are introduced. The former, the Gagné-Briggs theory, describes the instructional prescriptions for stating the different methods of instruction in any given learning situation; this theory comprises three main sets of prescriptions: the prescription of five categories of learned capabilities, the prescription of nine events of instruction and the prescription of sequence instruction. The latter, the component display theory (CDT) proposed by Merrill, describes a two-dimensional classification scheme. The first dimension is the learner performance, which is divided into three categories: find, use, and remember. The second dimension is the subject matter content comprising four major types: fact, concept, procedure (or process), and principle. The performance-content matrix has been proposed to identify the relationship between these two dimensions.

Sixth, the ADDIE model covers five phases of instructional design which are analysis, design, development, implementation, and evaluation. This model is the generic process that can be applied with every instructional design because, when the ADDIE is applied, it can ensure that goals, strategies, and instructional results are satisfied.

Finally, the conceptual background is reviewed. The definitions of the conceptual model and conceptual modelling are discussed. The three conceptual models, namely, the concept map, the entity-relationship diagram (ERD), and the unified-modelling language (UML) are introduced and the notations for each model are illustrated. Additionally, conceptual understanding through graphical representation is also discussed and the quality metrics and measurement of the conceptual models are reviewed.

Chapter 3
An Equivalent Architecture of Intended Learning Outcomes

In this chapter, an equivalent architecture of learners’ and instructors’ knowledge is introduced via a matching strategy using the intended learning outcomes. The balanced approach, the knowledge exchange model, and the constructivism and instructivism matching model are introduced and discussed. Finally, the matching of learners' and instructors' ILOs is discussed and exemplified.

3.1 Introduction

In the preceding chapter, it was noted that constructivism and instructivism – two grounded theories of learning and teaching – are contradictions in terms of the perspective of practitioners. This leads to an attempt to bridge the gap between these two theories. The philosophies of constructivism and instructivism shed some light on the balance between learners' knowledge and instructors' knowledge by way of the intended learning outcomes (or learning objectives). Thus, the research introduces an equivalent architecture of intended learning outcomes as described in the following sections.

3.2 The Balanced Approach

The research methodology has originated from the assumption that, based on the learners' experiences, learners who perceive the subject matter content as suitable, can reach the learning goals. This gives rise to the proposed balanced approach that reveals the primary idea of an equivalent architecture of learners’ and instructors’ knowledge. Thus, the research introduces an equivalent architecture illustrated in Figure 3-1.

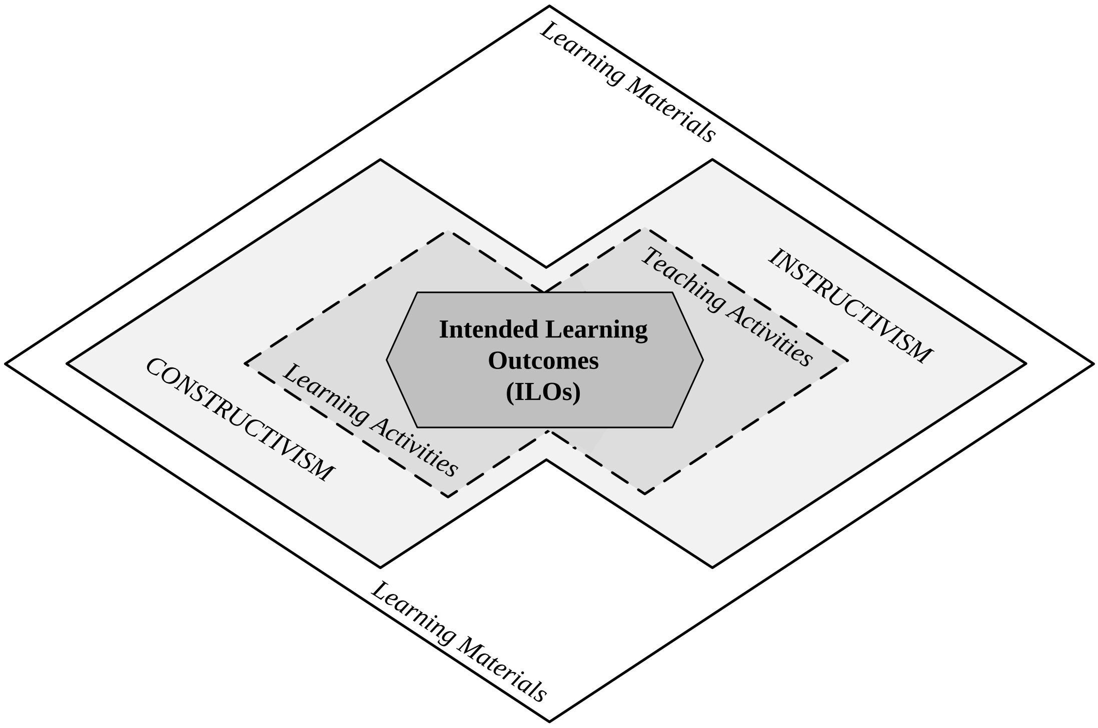


Figure 3-1 An equivalent architecture

An equivalent architecture conceptualises the relationship between the three main components, namely, constructivism, instructivism, and learning materials.

First, constructivism reveals the representative component of the learners whose knowledge can be constituted by their own understanding based on existing experiences. To reflect the radical orientation of this approach, an equivalent architecture has been conceived as the collaborative learning practice which provides learners with suitable learning activities. As stated by Mvududu (2005) and Hammond and Gibbons (2001), the clarification of pedagogical activities which focuses on teaching and learning, contributes to the scaffold of education. The term *scaffolding* originally coined by Wood, Bruner, and Ross (1976) permits learners to solve the problem and carry out the learning process to the point of achieving a goal with coaching and training; it starts from the tutoring in which a tutor (or an instructor) "knows the answer", but the novice does not (Wood et al., 1976). An understanding of the subject matter is initiated while learners perform the learning activities. Individually, learners come to the learning situation with what they already know, as the prior memorisable knowledge that can trigger the realisation of what they really want to learn rather than what the instructor passively provides in the learning environment. Thus, the learning is an active task rather than a passive activity.

Second, instructivism refers to the teacher-led approach that provides the content knowledge (defined in terms of subject matter content) to learners. In order to educate learners in establishing an understanding of the subject matter content, the framework has considered the instructivist component as the theoretical basis for supporting the knowledge construction.

Additionally, the learning materials represent the resources that serve the needs of pedagogical activities. This means that all resources used in teaching and learning are delivered to both learners and instructors as they perform the learning and teaching activities simultaneously. The supportive learning materials can be referred to as the instructional products. The instructional products in this sense encompass the learning modules, tutorials, learning systems (e.g., course management system, or e-learning system) and other resources (e.g., texts, video, graphics, or presentations) (Montilva et al., 2002) that facilitate the accomplishment of the learning goals.

3.2.1 Determining the Matching Relationship

According to Figure 3-1, the matching relationship between instructivism and constructivism refers to the pedagogical activities; these two grounded theories of learning and teaching share the learning and teaching activities. The need to consider this relationship arises from the fact that learners may attempt to perform their learning that requires some background knowledge (constructivist perspective) to construct their understanding; whilst instructors provide the instructional products including teaching activities to learners in order to educate them at the best achievement (instructivist perspective). Fundamentally, the instructors, learners, and supportive learning materials are necessary to harmonise the balance between the accessibility and availability. The terms *accessibility* and *availability* in this sense arise when both learners and instructors focus on the completion of the educational goals, and they need to be able to communicate and interact to each other in order to exchange their ideas. In addition, if they acquire any resources to facilitate their pedagogical activities, they need to be able to access the learning materials simultaneously. This concern has not been to diminish the subject matter content provided by instructors since it can allow learners to promote their understanding by themselves with the suitable amount of learning materials. In the learning situation, this relationship between the three components (i.e., instructivism, constructivism, and learning materials) can be initiated, which can potentially optimise the learning experience.

During the learning activities, the learners who accurately perform the learning activities can construct their own understanding of the subject matter. The learning materials should be provided to facilitate learning activities as well as to maximise the capability to understand the subject matter manipulated in the learning environment. As a result, new knowledge has been determined to represent the new finding or understanding after performing the learning activities and providing the appropriate learning materials to learners. Finally, when instructivism and learning materials have been determined, this interaction deals with what learning materials are needed to teach and what learning contents are required to support the learners. The instructors have constituted the learning materials which are delivered to learners accordingly.

3.2.2 The Integration of All Components

The integration of all components is through the intended learning outcomes (ILOs) that represent the learning objectives of the study. The framework identifies an outcome-based learning expression of what learners should be able to do by the end of the course of study. The ILOs have expressed the desire to achieve the educational goals that demonstrate the completion of the study. In order to perform lifelong learning successfully, learners who can pursue their study through the course of study with accurate learning activities will be able to obtain the highest achievement goals.

3.2.3 Intended Learning Outcome

In section 2.3.1, an intended learning outcome (ILO) statement is the planned learning outcome that expresses the learners' ability to be able to perform learning activities by the end of the course modules (Dodridge, 1999; Harden et al., 1999a; Kennedy et al., 2007). The ILO has commonly been planned and desired before providing the learners with learning tasks (Anderson et al., 2005). Traditionally, an ILO begins, "By the end of the course, the learner will be able to X and Y", where X is capability and Y is subject matter content (Gilbert and Gale, 2008). An ILO is normally expressed in terms of the plain text that defines the learning objectives of the course of study (Gilbert and Gale, 2008; Kennedy et al., 2007).

3.3 Knowledge Exchange Model

To assist understanding of the relationship between the three components of an equivalent architecture, the knowledge exchange model is proposed as shown in Figure 3-2.

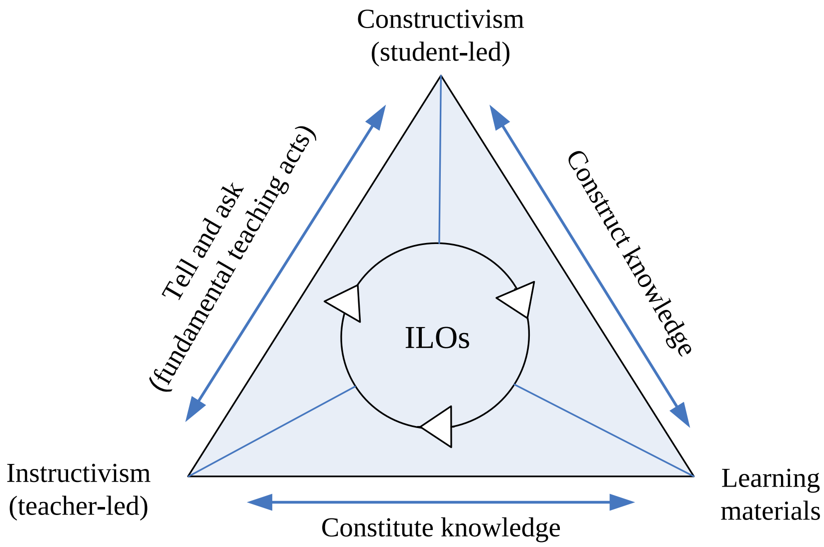


Figure 3-2 Knowledge exchange model

Initially, from the instructivist viewpoint, the instructors' perspective which is referred to as "teacher-led", aims to utilise the fundamental teaching acts, *tell* and *ask* (Gilbert and Gale, 2008) to transmit to and exchange the subject matter content with the learners and to constitute knowledge in terms of the learning materials simultaneously. Secondly, constructivism, which is known as "student-led", refers to the learners who construct new knowledge realised from the subject matter content based on prior experiences, as well as gaining information from the learning materials provided by the instructor. Finally, the learning materials provided by the instructor have been employed to present the model in order to impart the learning contents to learners.

At the mid-point of the model, circularly, these three components can be interacted through the ILOs. The ILOs play a crucial role as the infrastructure of the research which represents the hierarchical structure of the courses or programme. Technically, the sketch of ILO structure has been based on the learning objectives of the course and it can be used as the blue-print to guide and generate suggested learning activities.

The following section introduces an equivalent architecture via the constructivism and instructivism matching model.

3.4 The Constructivism and Instructivism Matching Model (CIMM)

The primary objective of the research is to reconcile constructivism and instructivism in developing an equivalent architecture by illustrating through the proposed matching model. The constructivism and instructivism matching model, called the CIMM model, has been proposed as the pedagogical layer defined to conceptualise the hierarchical structure of the relationship between constructivism and instructivism. The main idea of the CIMM model is the matching layer of the ILO which can be categorised into four different layers, namely, goal, knowledge, activity and ILO (illustrated in Figure 3-3).

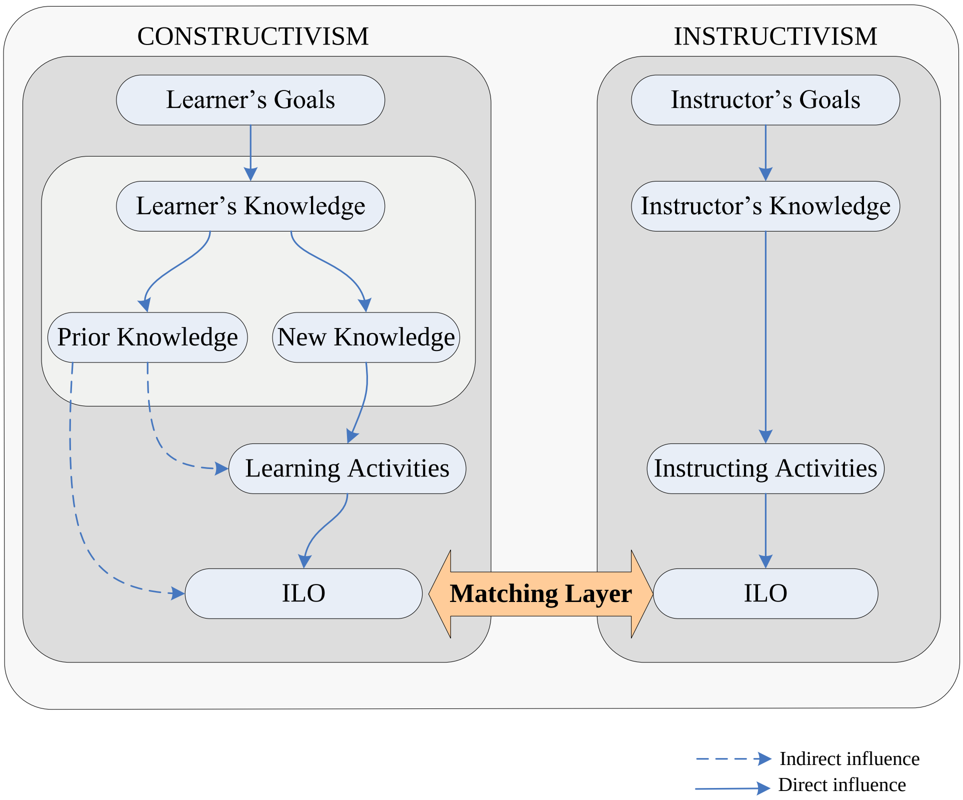


Figure 3-3 The constructivism and instructivism matching model (CIMM)

The two pedagogical approaches of constructivism and instructivism are shown in CIMM as two different layered perspectives. The constructivist perspective comprises learning goals which lead to the consideration of learner's knowledge, conceived as prior knowledge and new knowledge. Learning the new knowledge involves learning activities, which are included in ILOs. On the other hand, the instructivist perspective comprises teaching goals which lead to the consideration of the instructor's knowledge and then to appropriate teaching activities which are incorporated into ILOs. The connection between these two otherwise separate perspectives is at the ILO layer, hence the model's name of "matching model". This leads to the analysis of the ILO in following section.

3.5 Matching Learner and Instructor ILOs

The instructors and the learners share the pedagogical content of the instructors' goals and the learners' goals, instructors' knowledge and learners' knowledge, and the instructing activities and learning activities.

Figure 3-4 illustrates the matching perspective of the ILOs.

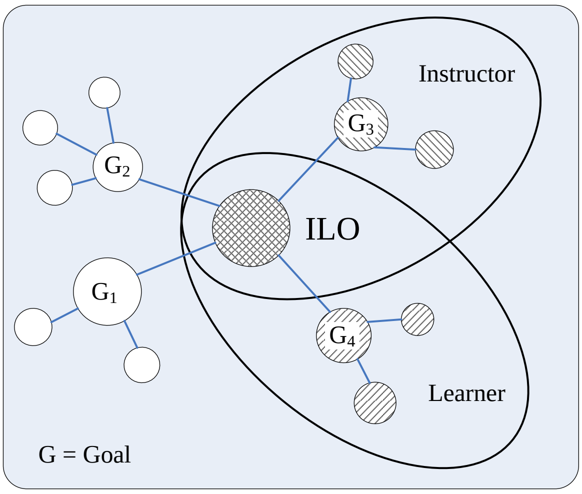


Figure 3-4 Matching perspective of ILO

Besides the instructors' and the learners' views, there is a matching perspective that normally occurs during the course of study. This is because the teacher and the learner share similar goals for the pedagogical activities: the teaching activities and the learning activities. It is their joint intention to gain an understanding of the subject matter (also called learning material) which is the ideal of the pedagogical activities. Hence, the shared goals are the indication of the improvement of the learned capabilities.

Figure 3-5 illustrates an ILO which matches the instructor and learner perspectives through an example ILO: "draw a data flow diagram (DFD)".

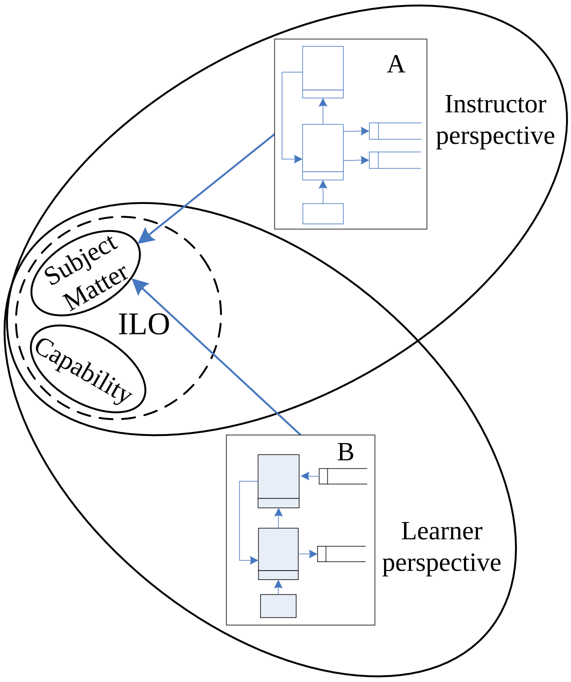


Figure 3-5 An example of the ILO matching

The ILO expresses an ILO to "draw a DFD". The example capability expresses the ability to "draw" and the subject matter is "DFD". The goal of this example is to educate learner about how to draw a DFD. Thus, both learner and instructor share the same educational goal.

In particular, the instructor might present DFD "A", whilst the learner may understand (and draw) DFD "B". Although the instructor may explain the way to draw a DFD, the learner may understand only some part of the lesson. The DFDs sketched by the instructor and the learner might be different if the learner is a novice practitioner with limited ability to understand the subject matter (which is referred to as the DFD elements, i.e., the processes, the data flows, the inbound elements, or the outbound elements). Owing to the limitation of individuals, the level of achievement or proficiency (Lantolf and Frawley, 1988) can distinguish the learner's ability based on the heterogeneous perspectives of an understanding of the subject matter. However, the capability and proficiency are established on the basis of the surrounding contexts. For example, the learning environment may encompass any kinds of tools used during the course of study, and the restricted period of time, or the place (or classroom).

3.6 Summary

In this chapter, the concept of the matching methodology of constructivism and instructivism that balances learners' and instructors' knowledge has been introduced. The proposed methodology originates from an equivalent architecture that conceptualises the relationship between the three main components, namely, constructivism, instructivism, and learning materials. The core relationship of these components has determined the achievement goal defined in terms of the learning objectives or intended learning outcomes (ILOs). The ILOs have been denoted as representing the purposes of the courses of study which were planned before taking the course modules. The framework identifies an outcome-based learning expression of what learners will be able to do by the end of the course of study.

Furthermore, in order to facilitate learning and teaching, the constructivism and instructivism matching model (CIMM) was proposed to conceptualise the hierarchy of the relationship between constructivism and instructivism. Four layers of the model (i.e., goal, knowledge, activity, and ILO) were introduced to epitomise the educational objectives. Moreover, the matching of the ILOs for instructors' and learners' perspectives was illustrated. The matching of ILOs normally occurs during the course of study that is because the instructor and learner share similar goals of teaching and learning activities.

Chapter 4
ILO Diagram: A Novel Conceptual Model of Intended Learning Outcomes

Designing and developing a logical structure of intended learning outcomes (ILOs) by using a diagrammatic technique, is a challenge to instructional designers in their systematic design and development of lessons, courses, programmes, or curriculums. In this chapter, an ILO diagram – a novel conceptual model of intended learning outcomes supporting curriculum development – is proposed. This chapter begins with introductory part; then the following five sections discuss five aspects of the proposed conceptual model. Section 4.2 introduces the ILO modelling which represents fundamental structure of ILOs and its components. In section 4.3, the proposed approach of a novel conceptual model of intended learning outcomes through the design and development of the ILO diagram is introduced. In section 4.4, the designed ILO relationships and relationship constraints are introduced and exemplified. In section 4.5, a case study applying the ILO diagram is demonstrated whilst section 4.6 elaborates on a scenario for introducing the ILO diagram in education. Finally, the comparison of the ILO diagram and course sequencing approach and the current approaches in learning design is discussed in section 4.7.

4.1 Introduction

Recently, distance learning and e-learning have played the crucial role as the application domains of software engineering (Caeiro-Rodriguez, Llmas-Nistal, and Anido-Rifon, 2005). In a general software development process, a data model called an entity-relationship diagram (or ERD) (Chen, 1976) is a renowned conceptual model for database design and development (discussed in section 2.8.3). Although an ERD embodies some semantic information about the business requirements, a conceptual model used by instructional designers in their systematic design of curriculum development should incorporate specific information about educational contexts and facilitate every stakeholder in educational domain.

In order to design a lesson, course, or programme that serves both learners and instructors, an outcome-based education approach (Allan, 1996; Jessup, 1995; Otter, 1995) is required with a view to focusing on what learners will be able to achieve after they are taught (Allan, 1996). Moreover, focusing on the learning goals is the main characteristic of intended learning outcomes that leads to the powerful design of an educational programme and curriculum (Bouslama et al., 2003).

This chapter presents a novel conceptual model of intended learning outcomes for supporting curriculum development that allows instructional designers to model a logical structure of learning content and learning materials in which the subject matter and their relationships are integrated with the capabilities to be learned. The diagrammatic formalism of ILOs is proposed to support not only instructional designers to design and develop courses of study systematically, but also instructors and learners to undertake teaching and learning activities.

4.2 ILO Modelling

In order to develop the proposed conceptual model, the framework identifies an outcome-based learning expression through intended learning outcomes (discussed in sections 2.4.1 and 3.2.3). The idea of using intended learning outcomes can guide the instructional designers to plan the educational goals for the course modules as well as to initiate the learning objectives which will be officially declared to support the curriculum development.

4.2.1 ILOs' Structure and Its Components

The ILOs introduced in this research are defined for both instructors’ and learners’ perspectives. The focus is on how to form and represent the ILOs' structure and their components. In this research, the two main components of an ILO (i.e., capability and subject matter content) are depicted in Figure 4-1 using a concept map.

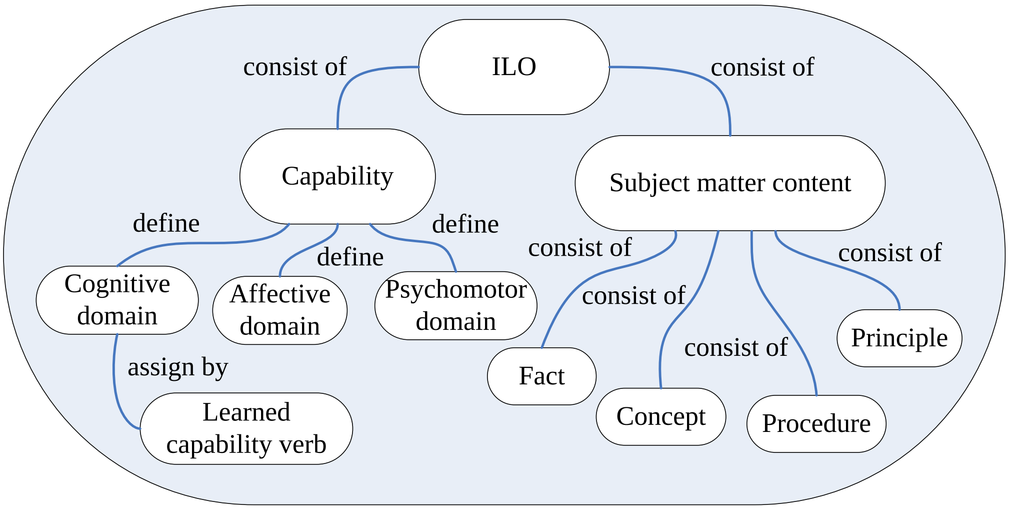


Figure 4-1 A concept map for components of an ILO

The ILOs structure introduced in this research is based on the competence structure (introduced in section 2.5.1) proposed by Sitthisak, Gilbert, and Davis (2008), where the ILO comprises a capability and associated subject matter content. The details of these two components are discussed as follows:

4.2.2 Capability

The capability component deals with the learner's ability to perform the learning activities. The capability of an ILO refers to a verb designating the learned capability in which it can define the taxonomy of educational objectives (i.e., cognitive domain, affective domain, or psychomotor domain of Bloom's taxonomy). In this research, the *learned capability verb* (LCV) has been assigned as the action word which expresses the linguistic element of ILOs. In addition, cognitive domain in Bloom's taxonomy (Bloom et al., 1956) has been adopted to represent the capability component of ILOs. For instance, an ILO may state, "By the end of the course, the student will be able to design the entity relationship diagram". The learned capability verb of this example is "design".

The six levels of Bloom's cognitive domain (Bloom et al., 1956) form the basis of the *cognitive hierarchy*. Table 4-1 shows the examples of LCVs classified for each level of the revised cognitive taxonomy proposed by Anderson and Krathwohl (2001).

Table 4-1: Examples of LCVs for each level of the cognitive hierarchy (Anderson and Krathwohl, 2001; Biggs and Tang, 2007; Bloom et al., 1956; Bloom et al., 1981)

Revised cognitive hierarchy	**LCVs**
Create	assemble, categorise, compose, construct, create, design, develop, establish, formulate, generalise, generate, hypothesise, integrate, invent, make, perform, plan, produce, organise
Evaluate	appraise, argue, assess, conclude, contrast, criticise, critique, decide, evaluate, judge, justify, measure, predict, prioritise, prove, rank, rate, resolve
Analyse	analyse, break down, categorise, characterise, classify, compare, discriminate, examine, differentiate, distinguish, examine, relate, separate, test
Apply	apply, assess, change, choose, compute, construct, demonstrate, develop, experiment, operate, prepare, produce, select, show, transfer, use
Understand	associate, change, clarify, classify, describe, explain, express, exemplify, identify, indicate, report
Remember	collect, define, describe, draw, enumerate, find, identify, label, list, match, name, order, present, recall, recognise, state, tell, write

In this research, the cognitive hierarchy represents the cumulative and usually progressive accomplishments of learning. Remember that, in section 2.3.1, each level of the cognitive hierarchy relies upon the learner's performance at the lower levels (Ferris and Aziz, 2005). For example, a learner wanting to apply knowledge (application level), usually needs to both remember the fundamental information (knowledge level) and understand this information (comprehension level).

Although Anderson and Krathwohl have proposed an updated version (Anderson and Krathwohl, 2001), this research has adopted Bloom's original taxonomy as the fundamental part of the proposed conceptual model of ILOs and the ILOs' logical structure (see Figure 4-3).

4.2.3 Subject Matter Content

The subject matter content (SMC) identifies the learning content or learning materials of the course of study. In this research, based on the component display theory (Merrill, 1973; Merrill, 1994b), there are four categories of SMC, namely, *fact*, *concept*, *procedure*, and *principle*. The details and examples are summarised as follows:

4.2.3.1 Fact

Fact consists of two associated parts of information, such as, a specific name and a date, an event and the particular name of a place, et cetera. The following table shows examples:

Table 4-2 Examples of fact

Fact ID	Examples
Ft01	The Current KING of Thailand is King Bhumibol Adulyadej.
Ft02	The colour of gold is yellow.
Ft03	The official URL of the University of Southampton is http://www.southampton.ac.uk.

4.2.3.2 Concept

Concept is a concrete or abstract item with certain characteristics, such as, a human being is a primate with a bipedal gait, et cetera. The examples are as follows:

Table 4-3 Examples of concept

Concept ID	Examples
Ct01	Identify characteristics of human error.
Ct02	List the main properties of a hybrid car.
Ct03	A student record comprises Std_Name, B_Date, Age, etc.

4.2.3.3 Procedure

Procedure (or process) is a set of steps for accomplishing some objectives, such as, a computer program, a recipe for cooking Thai food, et cetera. The examples of a procedure are listed as follows:

Table 4-4 Examples of procedure

Procedure ID	Examples
Pc01	Specify the steps required to prepare the data for Data Mining.
Pc02	Please explain how to cook Thai green curry.
Pc03	Develop the web application by using Java.

4.2.3.4 Principle

Principle is a cause-and-effect relationship which predicts outcomes. For example, road accidents occur because of slippery roads, apples fall because of gravity, et cetera. The following table shows examples of principle:

Table 4-5 Examples of principle

Principle ID	**Examples**
Pr01	Identify the causal evidence of the road accident.
Pr02	Given a basic equation A; solve the problem B.
Pr03	State the reason why we need to regularly change the password of an internet account.

Following Merrill (1973), we define the two-dimensional performance content matrix (2D-PCM) using Merrill's classification scheme (Merrill, 1994b; Reigeluth, Merrill, and Bunderson, 1978). The first dimension is performance, which comprises three types: *find*, *use*, and *remember*. The second dimension is the subject matter content which, as before, comprises *fact*, *concept*, *procedure*, and *principle*. There are ten relationships instantiated in 2D-PCM, as shown in Table 4-6 with examples. Any ILO can be assigned to one of the 2D-PCM relationships.

Table 4-6: Ten relationships of 2D-PCM and their examples

2D-PCM	**Examples**
Remember-Fact	1. Identify the value of π(Pi). 2. Name the prime minister of England.
Remember-Concept	1. Identify the physical properties of rainbow. 2. Define the characteristics of gravity.
Remember-Procedure	1. State the steps in making cookies. 2. Rehearse the methods of pay online.
Remember-Principle	1. Explain the cause and effect of the Euro Collapse.
Use-Concept	1. Classify the features of hand-written styles.
Use-Procedure	1. Demonstrate how to draw an ER diagram. 2. Demonstrate how to solve an equation by using the Laplace transform.
Use-Principle	1. If there is a road accident in the morning, give the possible reasons for a traffic jam.
Find-Concept	1. Predict the climate information for Isle of Wight. 2. Categorise learners into groups of five; determine that all learners in each group share the same hobby.
Find-Procedure	1. Devise an online auction algorithm in ASP.Net.
Find-Principle	1. Discover the result of testing the chemical reaction of burning a candle if the oxygen is limited.

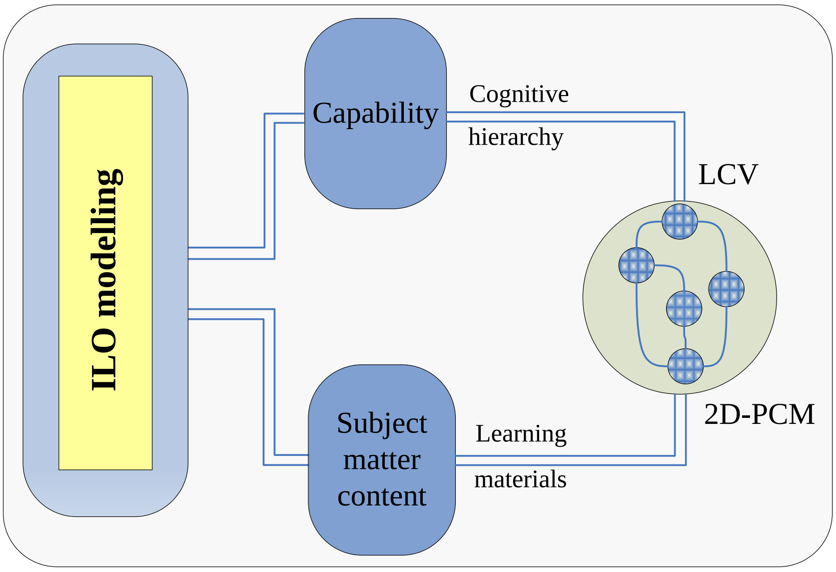
To conclude, this section discusses the design of ILO modelling and its structure. According to the proposed approach discussed in chapter three, this research scrutinises the design of the ILO structure composing the capability and subject matter content. The capability has been adopted from the Bloom's taxonomy of the cognitive domain to classify the learned capability verbs into one of the six levels of the cognitive hierarchy, whilst the subject matter content has been adopted from the component display theory proposed by Merrill through the 2D-PCM.

4.3 Conceptualising ILOs through an ILO Diagram

The research contributes the conceptualisation of traditional ILOs that are usually expressed as a plain-text document using a diagrammatic technique, called an ILO diagram. This section will introduce the diagrammatic formalism of ILOs and the mechanism to map the traditional ILOs into the proposed ILO diagram.

4.3.1 Fundamental Diagrammatic Formalism of ILOs

In order to conceptualise all the ILOs of a specific lesson, course, or programme using a diagrammatic formalism through the proposed ILO diagram, the two main components of ILOs play a crucial role as illustrated in Figure 4-2.



2D-PCM: 2 Dimensions performance-content matrix
LCV: Learned capability verb

Figure 4-2 The ILO modelling

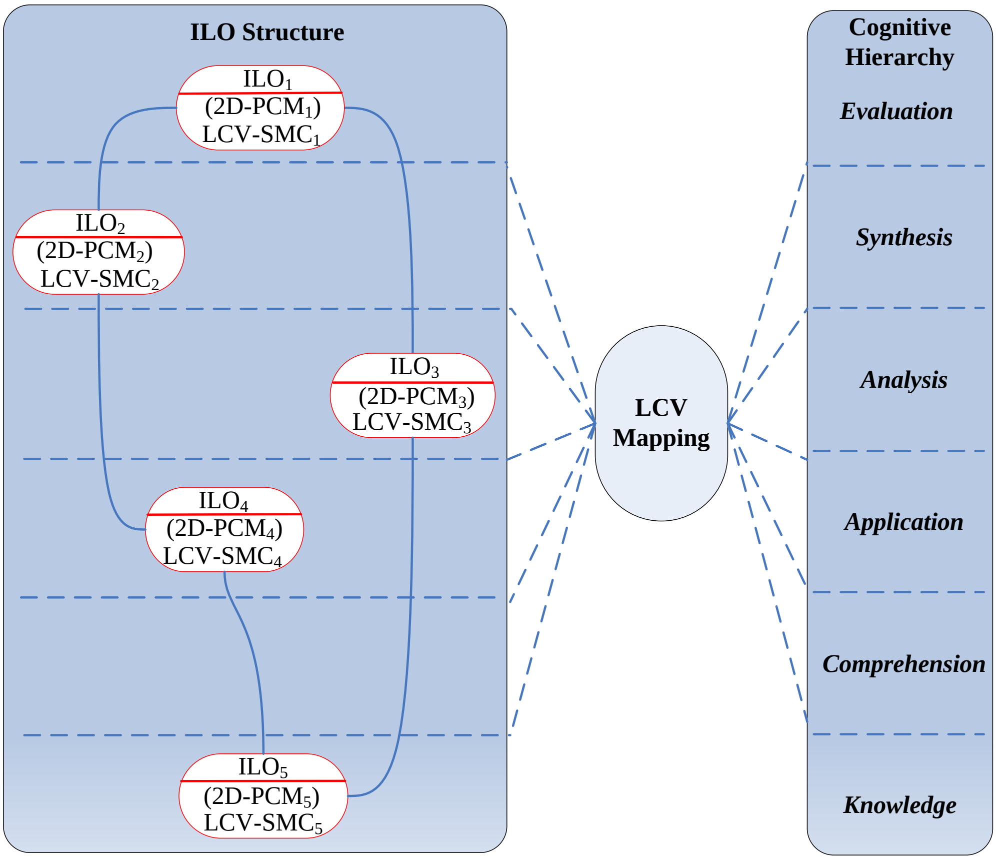
First, the capability component refers to the action or activity of learners in performing learning tasks. Six categories of Bloom's cognitive taxonomy forming the cognitive hierarchy are adopted to express the capability of ILO by using the learned capability verb, LCV. Second, the subject matter component refers to the learning material which is represented by using the 2D-PCM. Figure 4-2 illustrates the process of the ILO modelling contributed in this research. The diagrammatic formalism used to construct the proposed ILO diagram is discussed in the next section.

4.3.2 Mapping ILOs into a Diagram

In general, a diagram is the representation of nodes (boxes) and relationships (links). In this research, a diagram is used to visualise the logical structure of ILOs and their relationships. The diagram is named an *ILO diagram*. The nodes called *ILO nodes* represent the specific ILOs of the course, whilst the links called *ILO relationships* signify the direction from one node to the next, and their characteristics. The relationships are designed with constraints according to the educational purposes of instructional design (see section 4.4). Thus, the relationship constraints indicate that the ILO diagram is a directed acyclic graph (DAG) for three reasons:

1. The ILO diagram provides the relationships without loops or directed cycles.
2. There is no root node.
3. All ILO nodes can connect to each other.

The entire set of the ILO nodes and relationships forms the logical structure of the ILOs and is called the ILO structure (see Figure 4-3) which identifies the sequences and prerequisites of learning objectives.



2D-PCM: 2 Dimensions performance-content matrix
LCV: Learned capability verb
SMC: Subject matter content

Figure 4-3 The LCV mapping scheme

Any traditional ILO statement expressed in plain text can be formed as an ILO node of an ILO diagram. Structurally, each ILO node consists of four elements, namely, ILO number, 2D-PCM, LCV, and SMC. The ILO number identifies the node in an ILO diagram. The 2D-PCM represents the classification of the node within the performance/content matrix. The SMC represents the subject matter content of the ILO, and it is used to show relationships between ILOs with matching or similar SMCs. The LCV of each node is used in two ways. Firstly, it is mapped to the cognitive hierarchy as illustrated in Figure 4-3. Secondly, and more significantly, an enabling ILO is related to higher-level ILOs through consideration of the LCV (called LCV mapping).

In principle, the ILO diagram can initially be designed by augmenting the ILO structure with the cognitive hierarchy based on Bloom's taxonomy, but later on the design and development of the ILO diagram can be applied to other taxonomies, such as, Gagné's hierarchy of learned capabilities (Gagné, 1965), or Merrill's level of performance (Merrill, 1994b) (discussed in section 2.3).

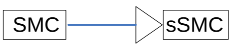
4.4 Design of ILO Relationships

In this research, a relationship of one ILO to another represents either a partial or a whole part that shares some elements (i.e., LCV, SMC, or both LCV and SMC) in common. It is important to note that two basic elements of the ILO node, the LCV and the SMC, play important roles in relationship design, because these two elements are the representative units of the basic component of the ILO. Thus, there are two types of ILO relationships, namely, partial part and whole part. The partial part represents the fundamental structure of the basic component that holds either the LCV or the SMC – hence the name *principal relationship* for this relationship. Whilst, the whole part is determined by both LCV and SMC elements, the name of the relationship is *composite relationship*. The following sections discuss these two relationships in detail.

4.4.1 Principal Relationship

The principal relationship connects two ILO nodes that have a relationship with either the learned capability verb or the subject matter content. There are three types of the principal relationships (as shown in Table 4-7).

Table 4-7: Three principal relationships of the ILO diagram

Type	Notation	Description
Capability relationship		when learned capability verb (LCV) relates to enabling verb (eLCV)
Topic relationship		when subject matter content (SMC) is in common
Inheritance relationship		when subject matter content (SMC) relates to superclass SMC (sSMC)

4.4.1.1 Capability Relationship

A capability relationship exists when a learned capability verb is an enabler of the other verb (called enabling learned capability verbs or eLCV). The value of an ILO diagram is given when ILOs which enable higher-level ILOs are identified. The result supports learning paths and learner positioning within a learning domain. In constructing the ILO diagram, enabling ILOs are identified by their LCVs being enablers of other LCVs, hence being enabling LCVs or "eLCVs". For example, "create" is an enabling LCV of "modify". This is because "create" is the prerequisite capability of "modify" in the intellectual skill domain. The ILO diagram notation for the capability relationship is a solid arrowhead placed near the centre of relationship line.

4.4.1.2 Topic Relationship

A topic relationship exists when a pair of ILOs shares common subject matter content. A group of ILOs share a common topic if they have common subject matter content, resulting in a topic relationship. For example, "describe DFD" shares a common SMC with "change DFD". The ILO diagram notation for the topic relationship is a simple line.

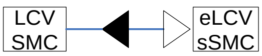
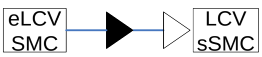
4.4.1.3 Inheritance Relationship

An inheritance relationship exists when the subject matter content of one ILO is the superclass subject matter content (sSMC) of the other. This relationship is based on the class hierarchy of an object-oriented UML class diagram (UML_Revision_ Taskforce, 2010). For instance, a data warehouse is identified as the superclass SMC of a data mart. The ILO diagram notation for the inheritance relationship is a line with an open arrowhead placed at the superclass.

4.4.2 Composite Relationship

The composite relationship connects two ILO nodes that have relationships between both elements (i.e., learned capability verb and subject matter content). Thus, the composite relationship holds two principal relationships. There are two different directions of the composite relationship, namely, the opposite and the same orientation. The ILO diagram notations are shown in Table 4-8.

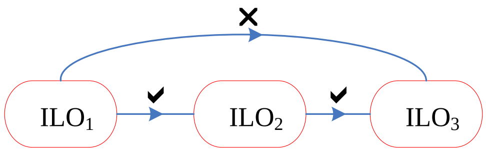
Table 4-8: Two types of the composite relationship

Type	Notation	Description
Opposite orientation		when capability and inheritance relationships occur with the opposite orientation
Same orientation		when capability and inheritance relationships occur with the same orientation

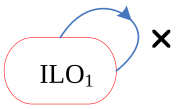
The composite relationship provides the whole-part relationship of the ILO nodes. This means that a relationship occurs when a LCV (or eLCV) is linked to a LCV (or eLCV) and a SMC (or sSMC) is related to a SMC (or sSMC). For instance, a composite relationship connects "design simple ERD" with "evaluate logical model", when "design" is an enabling LCV of "evaluate" and "logical model" is a superclass SMC of "ERD".

4.4.3 Relationship Constraints

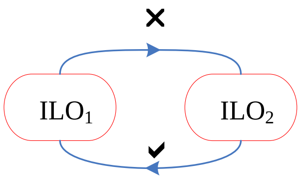
Although, apparently, it can be useful to design the relationship of the hierarchical structure of the ILO, the conceptual model of the ILO should contribute modelling construction for explicitly supporting the pedagogical activities.



(a) No transitive relationship



(b) No recursive relationship



(c) No circular relationship

Figure 4-4 Three constraints on the ILO relationship

Based on the educational purposes of the course design (Gilbert and Gale, 2008), we propose that there are three constraints on the ILO relationship which are illustrated in Figure 4-4.

4.4.3.1 No Transitive Relationship

Whenever ILO_1 is related to ILO_2 and ILO_2 is related to ILO_3, then the relationship of ILO_1 is not obviously transferred to ILO_3. This is because not only can the capability part of the ILO not be conveyed, but also the subject matter content part cannot be transmitted from ILO_1 to ILO_3. For example, a learner can evaluate the ER model if he or she can previously identify the business rules and then draw the basic

ER model, but he or she cannot evaluate it without making a complete drawing of the ER model.

4.4.3.2 No Recursive Relationship

The ILO conceptual model should not construct a recursive structure, when a single ILO node is related to itself. Referring to the inheritance relationship of the ILO, each ILO node is instantiated from the competency class. This means that, when the ILO has been referred to the instance level of the class, it cannot hold the recursive relationship. The reason is that, when the prerequisite behaviour has been furnished to the ILO, it is not a self-contained behaviour.

4.4.3.3 No Circular Relationship

The principle of educational objective abstractly reveals that, if ILO_1 is a prerequisite of ILO_2, then ILO_2 cannot simultaneously be the prerequisite of ILO_1. This leads to preventing the recursive relationship of the ILO diagram.

In this section, the two types of the ILO relationship, which are the principal and composite relationships described above, show that the ILO diagram has been designed to explicitly express the logical structure of the ILOs. The former is the principal relationship that connects either the LCV or SMC element to another node, whilst the latter is the composite relationship which enables both LCV and SMC elements to form the combination of two principal relationships.

4.5 A Case Study of Applying the ILO Diagram

In order to demonstrate how to apply the conceptual model of intended learning outcomes (the ILO diagram), in designing the course of study, we consider the available published course document of the IT curriculum that conforms to the emerging accreditation standards for IT programmes (Ekstrom, Gorka, Kamali, Lawszon, Lunt, Miller, and Reichgelt, 2006). In this study, the chosen course is the Information Management (IM4) Data Modelling unit which consists of 11 core learning outcomes and 12 elective learning outcomes (see Appendix A.1). We consider all learning outcomes and form 23 intended learning outcomes (listed in Table 4-9) to be represented as 23 ILO nodes.

Table 4-9 List of 23 ILOs of the IM4 data modelling course

Intended learning outcomes	
ILO_1	Interpret an Entity Relationship diagram (ERD).
ILO_2	Design a simple Entity Relationship diagram (ERD).
ILO_3	Interpret an Enhanced Entity Relationship diagram (EERD).
ILO_4	Identify business rules.
ILO_5	Describe a logical model.
ILO_6	Describe a physical model.
ILO_7	Identify UML standard models.
ILO_8	Demonstrate an understanding of CASE tools, their usage and application.
ILO_9	Describe data integration.
ILO_{10}	Describe meta-modelling.
ILO_{11}	Describe a data warehouse, its basic structure, etc.
ILO_{12}	Create an Entity Relationship diagram (ERD).
ILO_{13}	Create an Enhanced Entity Relationship diagram (EERD).
ILO_{14}	Formulate identification of business rules.
ILO_{15}	Evaluate a logical model.
ILO_{16}	Evaluate a physical model.
ILO_{17}	Demonstrate how to reengineer databases.
ILO_{18}	Compare patterns and standard models.
ILO_{19}	Use given CASE tools.
ILO_{20}	Evaluate meta-models.
ILO_{21}	Evaluate data integration and its use in the creation of a data warehouse and data marts.
ILO_{22}	Develop data warehouse.
ILO_{23}	Change an existing data mart.

We analyse and assign the suitable level of a cognitive hierarchy by referring to the LCV mapping mechanism as well as to the ILO relationships which have been assigned to each pair of ILO nodes. Then we can obtain the ILO diagram as in Figure 4-5.

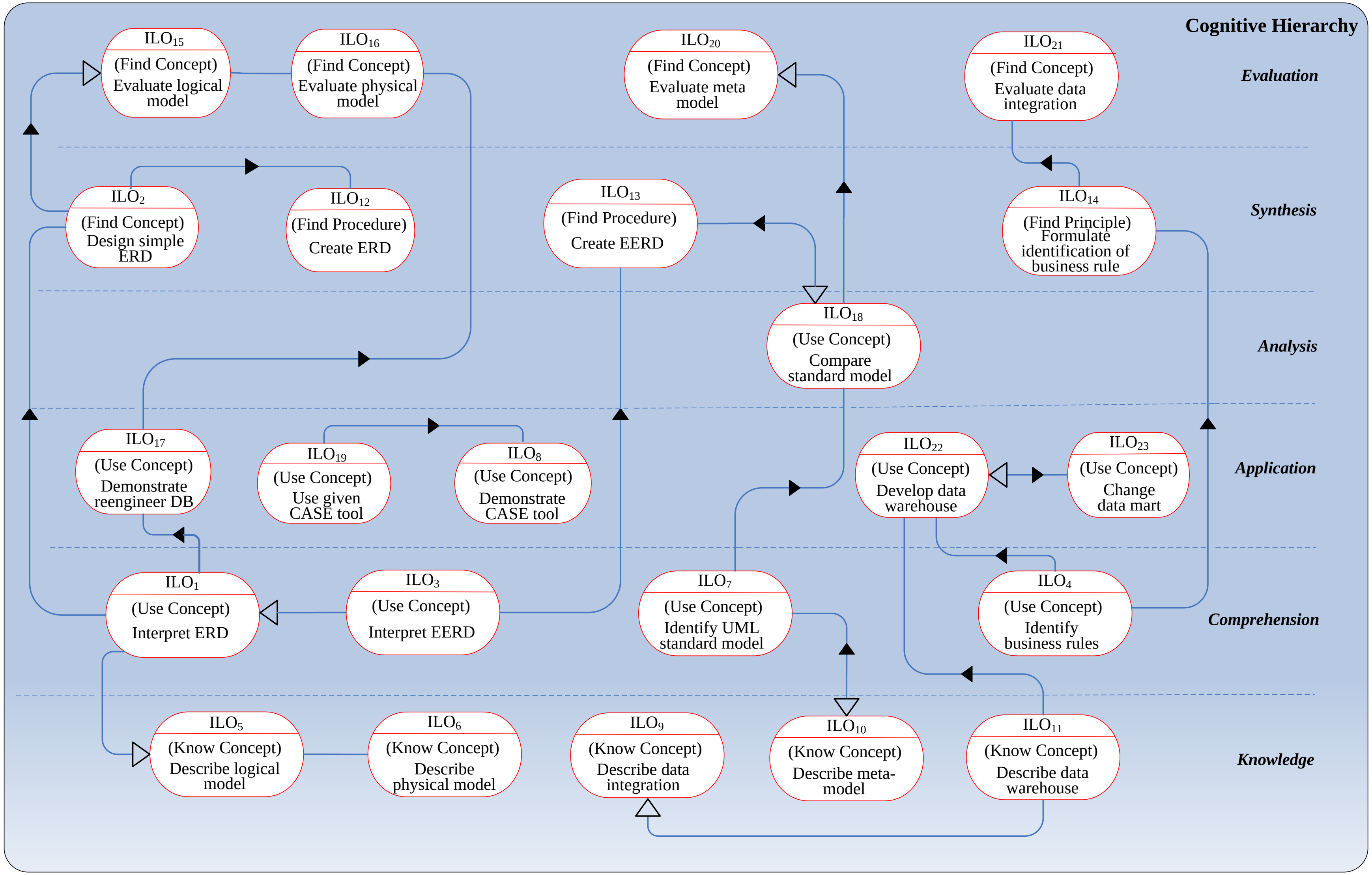


Figure 4-5 The ILO diagram of the IM4 data modelling course

A case study demonstrated in Figure 4-5 shows that the proposed conceptual model of ILOs has been introduced to give a complete conceptualisation of the course structure of the data modelling unit in the IT curriculum. Moreover, an example of detailed ILO structures for this case study has been specified in Table 4-10.

Table 4-10 An example of detailed structure of ILO_1

<table>
<tr><th colspan="2">ILO1: Interpret an ERD</th></tr>
<tr><td colspan="2">Curriculum: Information Management (IM4) Course</td></tr>
<tr><td colspan="2">Course module: Data Modelling Unit</td></tr>
<tr><td colspan="2">Prerequisites: None</td></tr>
<tr><td colspan="2">Learning objective: Given a basic definition of an entity relationship diagram (ERD), by the end of the course, a student will be able to interpret an ERD.</td></tr>
<tr><th colspan="2">PART 1: INTENDED LEARNING OUTCOME</th></tr>
<tr><th>Section 1
Capability</th><th>Section 2
Subject matter content</th></tr>
<tr><td>Performance:
... to interpret ERD</td><td>SMC category:
Concept</td></tr>
<tr><td>Level of performance:
Use</td><td>2D-PCM type:
Use-Concept</td></tr>
<tr><td>Learned capability verb:
Interpret</td><td>Subject matter items:
1) Entity refers to the object which is the basic structure of the ERD (concept).
2) Relationship represents the link between entities (concept).</td></tr>
<tr><td>Learned capability object:
Entity relationship diagram</td><td>Enabling objectives:
1) Identify ERD components: entity and relationship (use-concept),
2) Describe ERD components (use-concept).</td></tr>
<tr><td>Cognitive level (Bloom taxonomy):
Comprehension</td><td>Performance-content matrix:
<table>
<tr><th></th><th>Fact</th><th>Concept</th><th>Procedure</th><th>Principle</th></tr>
<tr><td>Find</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Use</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>Know</td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><th colspan="2">PART 2: CONTEXT</th></tr>
<tr><td colspan="2">This course module introduces the basis of an entity relationship diagram (ERD) which covers two major components: entity and relationship. Students will receive the hand-out of the course module prepared by MS-Powerpoint. The minimum core coverage time of this course module is 6 hours.</td></tr>
<tr><td colspan="2">Proficiency:
- Excellent: a student can describe and interpret ERD with greater than 80 % of correctness
- Average: a student can describe and interpret ERD with greater than 50 % of correctness
- Poor: a student can describe and interpret ERD with less than 50 % of correctness</td></tr>
</table>

4.6 A Scenario for Introducing the Proposed Approach in Education

We elaborate on the initialisation steps, in which the proposed approach can promote the state-of-the-art conceptual model in education. In order to systematise the processes of course design, course development and course delivery, we show the system interaction in Figure 4-6 and Figure 4-8 as the UML use case diagrams.

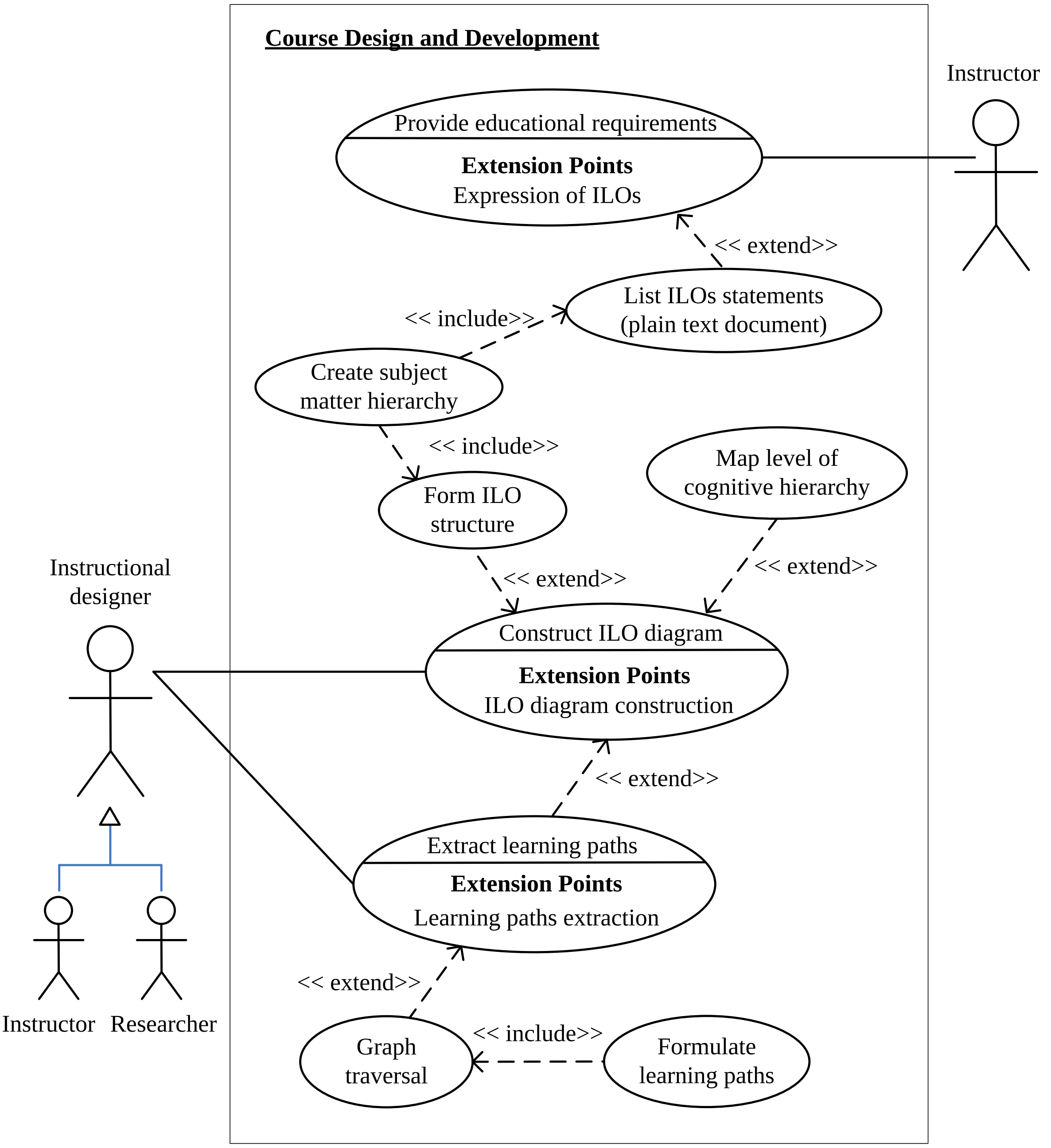
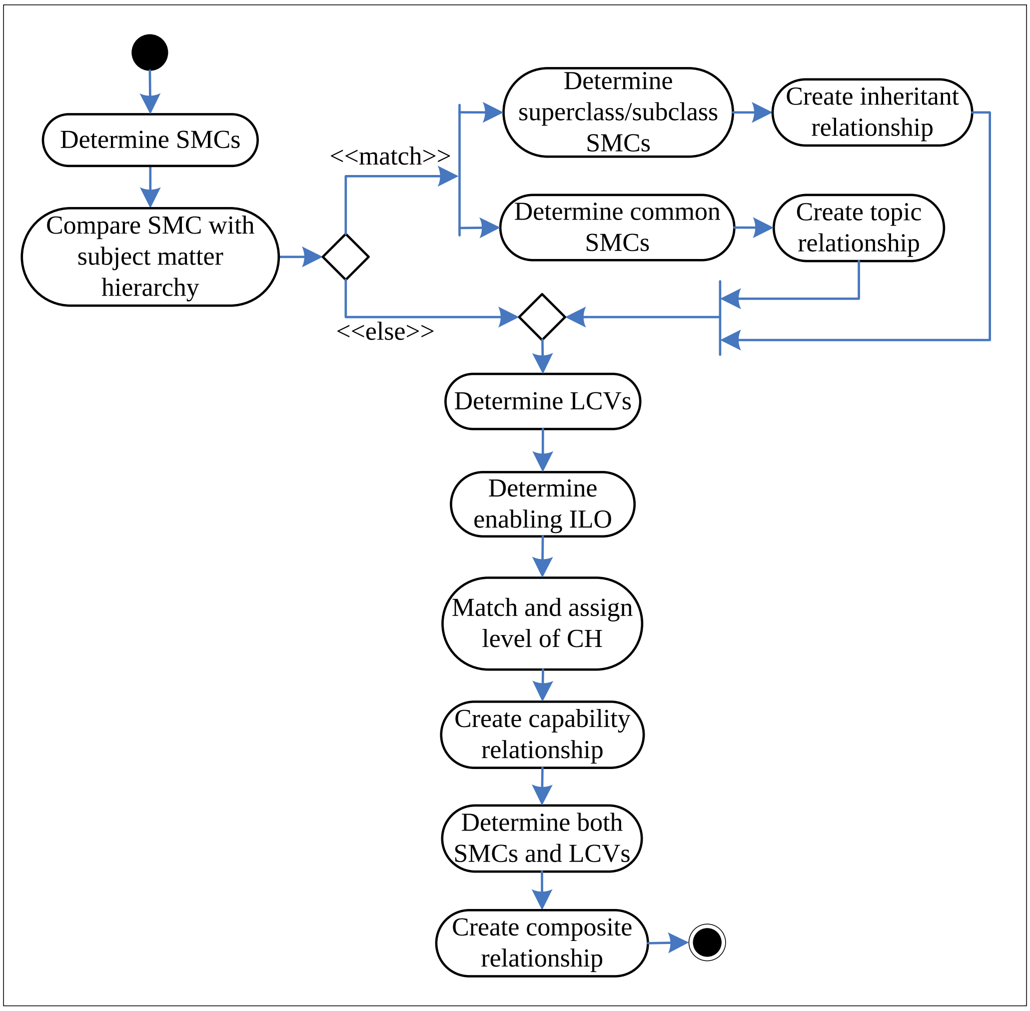


Figure 4-6 Use case diagram for course design and development

In the first phase which is the course design and development, the first step is to identify all the ILOs of a course of study. An instructor provides the educational requirements by declaring the pedagogical goals expressed in plain-text document (unstructured ILOs format). In order to construct the conceptualisation for all the ILOs, the instructional designer, including the instructor (or lecturer) and researcher, comes up with the ILO diagram construction. This covers the forming of the ILO structure by assigning four elements for each ILO (i.e., ILO ID, 2D-PCM, LCV, and SMC) and mapping the ILO nodes to the suitable level of the cognitive hierarchy. In addition, the subject matter hierarchy has been designed and created in order to construct the superclass/subclass SMCs. Practically, the detailed algorithm to construct the ILO diagram is illustrated by using the activity diagram depicted in Figure 4-7.



LCV: Learned capability verb
SMC: Subject matter content
CH: Cognitive hierarchy

Figure 4-7 Activity diagram for constructing an ILO diagram

All activities of the ILO diagram construction illustrated in Figure 4-7 show that the modelling construction can be achieved by 1) determining and comparing SMCs with the subject matter hierarchy and formulating the inheritance and topic relationships; 2) determining LCVs, enabling ILO nodes, matching LCVs and assigning the suitable level of cognitive hierarchy to each ILO node, and then formulating the capability relationship; 3) determining both SMCs and LCVs to formulate the composite relationship.

Furthermore, in the final process of the course design and development phase (see Figure 4-6), we propose the learning paths extraction that generates the sequences of pedagogical activities. Instructional designers can extract the learning paths (extracted from the ILO diagram) via the graph traversal through all ILO nodes and formulating the learning paths. Consequently, the learning paths can be utilised to suggest the appropriate direction to learners so that they can perform the suitable learning activities to achieve their learning goals.

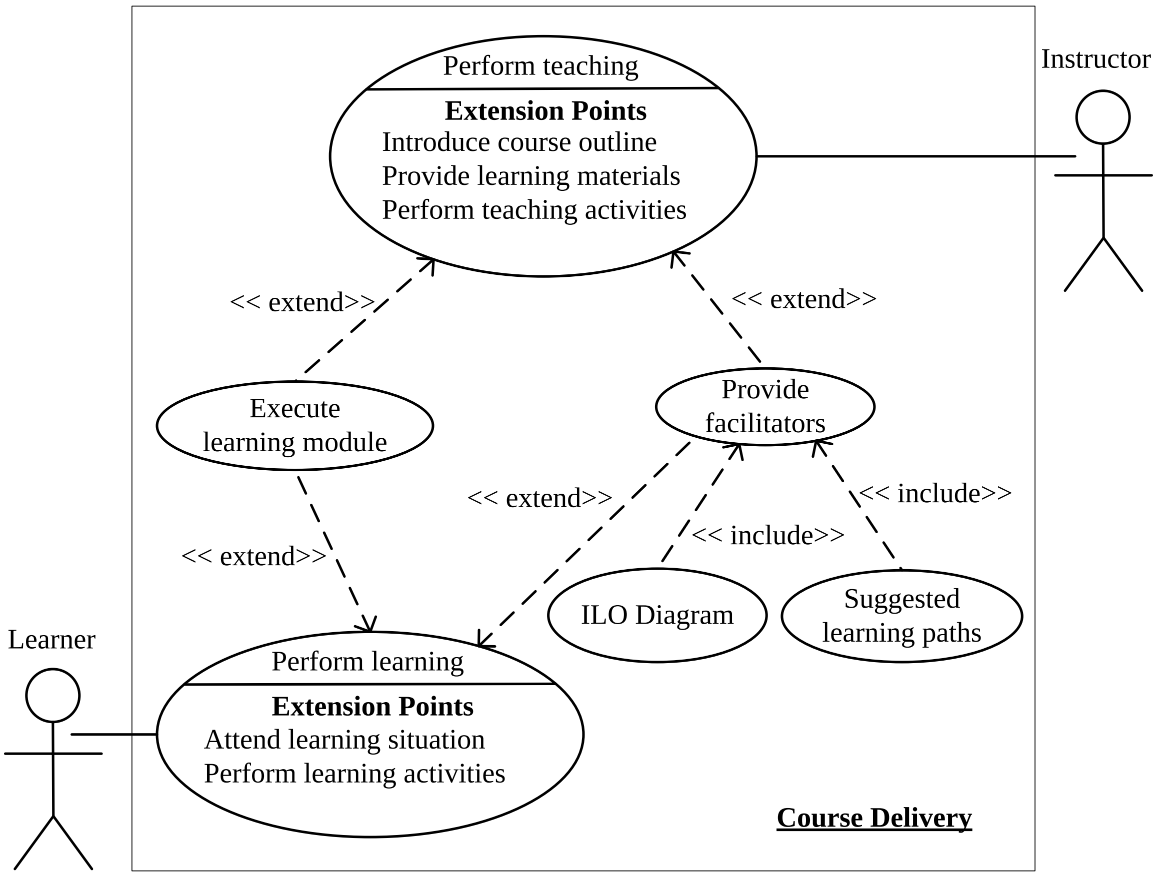


Figure 4-8 Use Case diagram for course delivery

In the second phase, the course delivery is illustrated in Figure 4-8. The proposed ILO diagram and the suggested learning paths have been introduced to be the additional facilitators for teaching and learning. The ILO diagram can be utilised as the facilitators perform the pedagogical activities whilst instructor and learner execute the learning module (or course of study). Additionally, the learning paths extracted from the ILO diagram can be introduced to the classroom (or learning environment) in order to guide the learners and instructors in executing the learning materials with a view to achieving the desired pedagogical goals.

4.7 ILO Diagram vs. Course Sequencing and Current Approach in Learning Design

This section discusses the comparison of the proposed ILO diagram and the two research directions: 1) course sequencing approach and 2) the current approaches in learning design.

Firstly, the comparative approach to the ILO diagram relates to a course sequencing approach. According to the literature review conducted at the time of writing, although it is likely that there is no corresponding approach in the current literature that represents the sequencing of ILOs, an approach that is closely related to the present research is that of course sequencing. Based on the work of Brusilovsky and Vassileva (2003), course sequencing is devised to generate an individualised course for each learner. This approach represents the network of concepts where each concept is a small piece of subject knowledge and teaching operations; the sequencing mechanism then devises an individual learner model by traversing through this course sequencing network and deciding which one of teaching operations is the best for learner, given his or her level of knowledge (Brusilovsky and Vassileva, 2003). However, various researches contribute many kinds of sequencing systems, for example, an approach called task sequencing proposed by Brusilovsky (1993), or a sequencing of lessons proposed by Capell and Dannenberg (1993), et cetera. It might be noted that the proposed approach can do the sequencing of ILOs extracted from an ILO diagram. The sequencing ILOs introduced in this research represent the list of ILOs aiming to achieve a specific learning goal. Thus, this research could be said to introduce an alternative research direction that suggests how to extract the sequencing ILOs from the ILO diagram (see section 7.5).

Secondly, with regard to the current research in learning design, different approach initiatives have introduced valuable contributions for the development of instructional and educational outcomes. As suggested by Koper (2005), the three themes of current works in the field of learning design are: 1) learning design and ontologies, 2) developing learning designs with other standards, and 3) learning design engines.

First, the specification of learning design covers the conceptual model and ontology used in the learning and teaching process (Koper, 2005). This theme contains two aspects of current research work: the former is the use of conceptualisation to design the learning activities, and the latter is the development of learning objects to increase the level of reusability by using ontology. It should be noted that the present research covers only the first aspect of this theme, that is the application of a conceptual model in learning design. Many researches focus on this aspect. For instance, in Paquette's work (Paquette, Leonard, Lundgren-Cayrol, Mihaila, and Gareau, 2006), the authors propose a general graphical language that supports the construction of learning design process; or, in Yang, Li, and Lau (2010), the authors introduce an open model to construct learning paths, that is a generic model to support learning design for any subject disciplines. Although these two studies (i.e., Paquette et al., 2006; and Yang et al., 2010) propose a graphical language and a generic model in the learning design process, the present research introduces an alternative approach to systematically design the courses of study in different way. An important issue of the proposed approach to learning design embodied in this research is that using a conceptual model in curriculum development contributes a diagrammatic formalism and notations to conceptualise the logical structure of ILOs. At present, according to the literature review conducted at the time of writing, there is no corresponding approach that incorporates ILOs to construct the formal representation and conceptual model of learning outcomes.

Second, the next theme is to support learning designers in their development process by using formal pedagogical standards, for example, an IMS content package, an IMS learning design specification, et cetera. The research trend in this theme is to develop the physical level of implementation that covers the physical storage considerations. It is worth noting that the proposed ILO diagram introduced in this research has had important implications for learning design, while learning designers design the logical structure of learning contents. Thus, the implementation of pedagogical standards is not the main consideration of this research. However, the mapping of an ILO diagram into physical storage (called ILOs machine processable format or ILOs schema) is discussed in the future work (see section 10.3.5).

Third, the last theme is to address the use of learning design run-time engines (Koper, 2005). The research trend in this theme focuses on how to implement the IMS learning design of a specified unit of learning in *run-time*. For instance, the run-time services and components (e.g., test, forum, or quiz) integrate learning design into an e-learning system (Weller et al., 2005), or the implementation of Moodle run-time engines is incorporated in the university context (Dougiamas and Taylor, 2002). It is noted that the ILO diagram is mainly utilised at the *design-time* and not in *run-time*. Thus, this theme is out of the scope of the present research.

By and large, the use of a conceptual model in systematic design and development of courses of study enables instructional designers to clearly define the logical structure of subject matter. This research advances the current approaches in learning design in which the proposed conceptual model can be referred to as the facilitator in all conventional development processes of courses of study, such as using an ILO diagram as a facilitator when applying the ADDIE model in the instructional design process (as discussed in section 10.2.4).

4.8 Summary

An approach of intended learning outcomes (ILOs) has been introduced to indicate what learners will be able to do by the end of the course of study. Traditionally, an ILO statement expresses as plain text or unstructured document. The research contributes the design of a logical structure of ILOs by introducing a diagrammatic technique that incorporates information about educational contexts and learners' capabilities.

In this chapter, a novel conceptual model of intended learning outcomes called an ILO diagram was introduced to conceptualise a logical structure of ILOs through the design of ILO relationships and constraints. The ILO structure and its components have been proposed to represent both the instructor's and the learner's perspectives. The core characteristic of the ILO structure that is described as being the matching relationship between the learners' and instructors' perspective, was introduced.

In order to model the ILO, the component display theory was adopted to identify the two main ILO components, namely, capability and subject matter content. First, the capability deals with the learners’ ability to perform the learning activities. The capability is composed of the verb that designates the learned capability (called the learned capability verb or LCV). The LCV is denoted by defining the action word represented by the linguistically designated element of the ILO. Second, the subject matter content (called the SMC) identifies the learning content of the pedagogical activities that comprise four types, namely, *fact*, *concept*, *procedure*, and *principle*.

To facilitate conceptualising the ILOs of a specific course of study by way of a diagrammatic formalism, we propose the LCV mapping mechanism that maps LCVs to the six levels of cognitive hierarchy. Moreover, the three principal relationships (i.e., *capability*, *topic*, and *inheritance*) and the two composite relationships were proposed to represent the linkage between the ILO nodes. In addition, the research introduced the three constraints of the ILO relationship, namely, *no transitive*, *no recursive*, and *no circular*, to construct the conceptual model for explicitly supporting the pedagogical activities.

Additionally, a case study of applying the ILO diagram in education was illustrated through the information management (IM4) data modelling course. There are 11 core learning outcomes and 12 elective learning outcomes forming the 23 ILO nodes of the ILO diagram. This case study demonstrated that the proposed ILO diagram provided a complete conceptualisation of all the ILOs of the data modelling course. Finally, the research introduced a scenario that systematises the ILO diagram and suggested learning paths in course design, course development, and course delivery, by using the UML use case diagrams. In this scenario, the first phase is the course design and course development identifying all ILOs of a course of study and constructing the ILO diagram. Whilst the second phase which is the course delivery facilitates learning and teaching activities by providing ILO diagram and suggested learning paths to learners and instructors.

Chapter 5

Experiment Methodology

In the preceding chapter, the design and development of the proposed ILO diagram were introduced and discussed. In this chapter, the experiment methodology of the research will be described with a view to investigating how the structured ILOs illustrated through the proposed ILO diagram can contribute to teaching and learning.

In order to evaluate the proposed approach, the three experimental studies were conducted to investigate the satisfaction, completeness, and understandability of the proposed ILO diagram. These three experimental studies explored the possibility that providing conceptualisation of the structured ILOs formats through the proposed ILO diagram could facilitate both teaching and learning. In the first study (experiment I), the main aim was to investigate the instructors' satisfaction with using the ILO diagram as facilitators of teaching. In the second and the third experiments, the objectives were to explore the application of the ILO diagram to learning; so that the learners could benefit from the conceptual information embodied in the ILO diagram which indicates the learning paths (experiment II) and enables them to understand the conceptual representation of the ILO diagram (experiment III).

All experimental studies conducted pilot studies before the participants were recruited to perform the real experiments. The number of participants for each study was different due to the objective of each experimental study which was estimated and obtained from the G*Power tool (Faul, Erdfelder, Lang, and Bruchner, 2007). The following three sections explain the detailed design of each experiment.

5.1 Experiment I: A Study of Applying ILO Diagram to Teaching

The first experiment was to investigate the instructors' satisfaction with using the ILOs as facilitators of teaching. The aim of this study was to compare the two representational styles of the ILOs, namely, the unstructured ILOs format expressed as plain-text document and the structured ILOs format conceptualised through the proposed ILO diagram. The instructors' satisfaction was measured under the three categories: perceived usefulness, perceived ease of use, and attitude toward representing ILOs. The following is an informative summary of this study:

Table 5-1 Summary of the experimental study I

Purpose	To investigate whether using the ILOs to facilitate teaching meets the instructors' satisfactions.
Research method	Quantitative study by means of a survey questionnaire
Number of participants	17 lecturers in Computer Science and ICT
Independent variables	1. Structured ILOs illustrated via the ILO diagram 2. Unstructured ILOs expressed in plain text
Dependent variables	1. Perceived usefulness (PU) 2. Perceived ease of use (PEOU) 3. Attitude toward representing ILOs (AT)
Research question	Does the ILO diagram conceptualising the structured ILOs meet instructors' satisfactions?
Hypothesis setting	Using the structured ILOs format through ILO diagram to support instructors and satisfy their teaching performance needs (defined in terms of usefulness, ease of use and attitude toward representing ILOs)

According to the above information, the expectation was that the use of the ILO diagram by teaching facilitators should be more satisfying to lecturers than the use of the plain-text document. Hence, the following hypothesis is posited:

H_0: Structured ILOs format (ILO diagram) will not meet instructors' satisfactions with higher ratings of PU, PEOU, and AT than an unstructured ILOs format.

H_1: Structured ILOs format (ILO diagram) will meet instructors' satisfactions with higher ratings of PU, PEOU, and AT than an unstructured ILOs format.

In order to test this hypothesis, the first experimental study was conducted and it received the approval of Ethics Committee under the reference number ERGO/FoPSE/ 3824. The number of participants for this study was estimated by using the G*Power tool with 5% of level of significance (critical P-Value), 0.65 of the effect size, and 0.95 of the statistical power. As a result, the seventeen participants (N=17) were required to take part in this study.

The online survey questionnaire (see Appendix B.1) that contains instructions asking the instructors' satisfaction with using the list of ILOs expressed as plain text and an ILO diagram to support them in teaching, was distributed to 17 lecturers at the department of Electronics and Computer Science (ECS) at the University of Southampton in the UK and the faculty of Information and Communication Technology (ICT) at the Mahidol University in Thailand. All participants were lecturers who are the domain experts and who are familiar with the topic used in this study which was the data modelling module in IT education (Ekstrom et al., 2006). All participants were recruited by e-mail from the mailing list provided by the university.

In order to participate in this study, participants were required to perform the following task protocol:

1. Visit the online questionnaire website.
2. Initial the box in the consent form to indicate consent to participate in this study.
3. Read the details of the case study and the supporting information in order to have a clear understanding of the terms and definitions used in the study.
4. Follow the instructions of the questionnaire.
5. Select the option that most closely reflects their satisfaction.
6. After completing all questions, they were asked to save and submit the questionnaire.

All data collected from this study were analysed by using the multivariate test of significance (MANOVA) between the mean ratings of instructors' satisfaction. The multivariate test has analysed the significant differences between the average means of all dependent variables (i.e., PU, PEOU, and AT). There are four types of the test statistics, namely, Pillai's Trace, Wilks' Lamda, Hotelling's Trace, and Roy's largest root. In this study, Pillai's Trace was the main one used to signify the statistically significant differences between the results of the experiments. The details of this experimental study and the analysis of the results are described and reported in chapter 6.

5.2 Experiment II: A Study of Using ILO Diagram as Facilitator in Indicating Learning Paths

The second experimental study investigated whether providing the ILOs as facilitators in learning can support learners to indicate the learning paths. This study was intended to compare the two representational styles of the ILOs, namely, the well-defined structured ILOs format as conceptualised through the ILO diagram, and the unstructured ILOs format expressed as plain-text document. The following table shows the information gained from this experiment:

Table 5-2 Summary of the experimental study II

Purpose	To investigate that whether the ILOs illustrated through an ILO diagram or expressed as plain text can facilitate learners in indicating the learning paths
Research method	Quantitative study by means of a survey questionnaire
Number of participants	21 students in Electronics and Computer Science
Independent variables	1. Structured ILOs illustrated via ILO diagram 2. Unstructured ILOs expressed in plain text
Dependent variables	Completeness of six learning paths (LP1-LP6)
Research question	Does the ILO diagram conceptualising the structured ILOs facilitate learners' ability to identify their learning paths?
Hypothesis setting	Using the structured ILOs format through the ILO diagram to support learners to perform the learning tasks leads them to indicate the complete learning paths which are more complete than the learning paths indicated by learners who referred to the unstructured ILOs format expressed as plain text.

It was expected that using the proposed ILO diagram to support learners in performing the learning tasks would lead them to indicate the complete learning paths. Consequently, the learning paths identified by learners who referred to the structured ILOs format (ILO diagram) should be more complete than the learning paths indicated by learners who referred to the unstructured ILOs format (plain text). Hence the following hypothesis of this experimental study is posited:

H_0: Structured ILOs format (ILO diagram) will not support learners in indicating learning paths with a higher completeness score than an unstructured ILOs format.

H_1: Structured ILOs format (ILO diagram) will support learners in indicating the learning paths with a higher completeness score than an unstructured ILOs format.

This experimental study received the Ethics Committee's approval under the reference number ERGO/FoPSE/5406. The experiment was conducted to test the hypothesis using the online survey questionnaire (see Appendix B.2). The total number of participants for this study was twenty one (N=21) estimated by using the G*Power tool with 5% of level of significance (critical P-Value), 0.6 of the effect size, and 0.95 of the statistical power.

Thus, the questionnaire was distributed to 21 postgraduate students who are studying Electronics and Computer Science (ECS) at the University of Southampton in the UK. All participants were recruited by e-mail from the mailing list provided by the university and their participation was executed by using the following protocols:

1. Visit the online questionnaire website.
2. Initial the box in the consent form to indicate consent to participate in this study.
3. Read the supporting information to have a clear understanding of the terms and definitions used in the study and the details of the case study.
4. Follow the instructions of the questionnaire.
5. Select the ILO number that addresses the question or relates most closely to the question.
6. After completing all questions, please provide the demographic information.
7. Save and submit the questionnaire.

After all participants completed the questionnaire, the six learning paths were formulated and the completeness scores of the learning paths were calculated, based on the proposed formation of the learning paths and the completeness metrics (see section 7.5). The experiment results were analysed by using the multivariate test of significance (MANOVA). In this study, the Pillai's Trace was mainly considered to test the statistically significant differences between the average mean scores of all six learning paths completeness. Moreover, Tukey's HSD (Honest Significant Difference) Post-Hoc test was used to analyse the interaction between the six learning paths. This statistical technique was to test the multiple comparison of the average means completeness that is significantly different in each case; the test compared all possible pairs of the average means completeness. The details of this experimental study and the analysis of the results are described and reported in Chapter 7.

5.3 Experiment III: A Study of Understandability of ILO Diagram

The third experimental study was to investigate how well the learners understand the representational styles of the ILOs when the three different styles are compared – in other word, the conceptual representation gave the ILOs conceptualisation through the ILO diagram, the tabular representation represented the row and column of the ILOs, and the sentential representation expressed the ILOs as the list of a plain-text document. The following details describe information of this study:

Table 5-3 Summary of the experimental study III

Purpose	To investigate whether the learners are better able to understand the conceptual representation of the ILOs than the tabular and sentential representations.
Research method	Quantitative study by means of a survey questionnaire
Number of participants	48 students in Computer Science (ECS), Education Science, and Financial and Management, University of Southampton, UK.
Independent variables	1. Conceptual representation (ILO diagram) 2. Tabular representation (rows and columns of ILOs) 3. Sentential representation (list of ILOs)
Dependent variables	1. Understandability efficiency (UEffic) 2. Perceived understandability (PU)
Research question	Do learners understand the conceptual representation in an ILO diagram?
Hypothesis setting	The conceptual representation of the ILOs is better understood by learners than the sentential and tabular representations.

Based on the above information, it was expected that the proposed ILO diagram would be more readily understood by learners than would representing the ILOs as rows and columns (tabular representation) and expressing them as plain text (sentential representation). Hence the following hypothesis is posited:

H_0: Learners will not understand the conceptual representation of ILOs (ILO diagram) with the higher understandability of UEffic and PU than with the sentential and tabular representations.

H_1 : Learners will understand the conceptual representation of ILOs (ILO diagram) with the higher understandability of UEffic and PU than with the sentential and tabular representations.

This experimental study received the Ethics Committee's approval under the reference number ERGO/FoPSE/7956. The experiment was conducted to test the hypothesis using the online survey questionnaires (see Appendix B.3). The total number of participants for this study was forty eight (N=48) estimated by using the G*Power tool with 5% of level of significance (critical P-Value), 0.45 of the effect size, and 0.95 of the statistical power.

The thirty-six online survey questionnaires were distributed to forty eight postgraduate students at the University of Southampton in the UK. All participants were divided into four different groups according to their educational background:

1. The *CS group*: To this group were assigned twelve postgraduate students (N=12) who are studying at the department of Electronics and Computer Science (ECS).
2. The *MS group*: To this group were assigned twelve clinical and medical students (N=12) who are the current students at the Health Science.
3. The *FS group*: To this group were assigned twelve postgraduate students (N=12) in Financial and Management.
4. The *O group*: To this group were assigned the other twelve postgraduate students (N=12) who are studying in the other departments and who are not familiar with the three subject domains (i.e., Computer Science and Information Technology, Health Science, and Financial and Management).

The survey questionnaires covered the three representational styles of the ILOs: the sentential representation expressed the list of ILOs as plain text, the tabular representation represented the ILOs as rows and columns, and the conceptual representation visualised the ILOs through the proposed ILO diagram. Each representational style comprised the three questions asking the participants to take a look at the ILOs of each representation and choose the ILO number that can suitably address the questions.

All participants were recruited by e-mail from the mailing list provided by the university and their participation was executed by using the following protocols:

1. Visit the online questionnaire website.
2. Initiate the box in the consent form to indicate their consent to participate in this study.
3. Read the supporting information to have a clear understanding of the terms and definitions used in the study and the details of the case study.
4. Follow the instructions of the questionnaire.
5. For each ILO's representational style, indicate the starting time to begin.
6. Read the three survey questions of each representation.
7. Take a look at the ILOs of each representation, and choose the ILO number that addresses the questions.
8. After finishing the three questions of each representation, indicate the stopping time.
9. For each ILO's representational style, choose the rating scale that reflects its understanding of the ILO's representational style.
10. After completing all the questions of three representational styles, provide your demographic information.
11. Save and submit the questionnaire.

The experiment results obtained from 48 participants were calculated the understandability scores based on the understandability metrics (see section 8.5). The results were analysed by using the repeated measure MANOVA which was to test the statistical results covering many dependent variables. This was to analyse the statistically significant differences between the understandability metrics (i.e., the understandability efficiency scores and the rating scales of the perceived understandability) based on the three representational styles of ILOs (i.e., sentential, tabular, and conceptual representations). In this study, the Pillai's Trace and Roy's Largest Root were mainly considered to test the statistically significant differences between the average means of understandability metrics. The details of this experimental study and the analysis of the results are described and reported in Chapter 8.

Chapter 6
A Study of Applying ILO Diagram in Teaching

As discussed in section 3.4, the core characteristic of the ILOs introduced in this research is proposed as being the matching of instructors' and learners' perspectives. Although the conceptual model of ILOs has been proposed to support both the instructors' and the learners' views, the main focus of this chapter is on teaching rather than learning. Thus, the first experimental study was intended to investigate the instructors' satisfaction with teaching. In this chapter, the conjecture and research questions are discussed. The experimental design of the study is described and the experiment results are reported. The chapter ends with a summary.

6.1 Introduction

This chapter reports on and summarises the first experimental study that investigated the instructors' satisfaction with using the ILOs to facilitate teaching. The aim of this study was to compare whether the ILOs visualised through the ILO diagram met the instructors' satisfactions better than the ILOs listed as plain-text document. The instructors' satisfaction was measured in three categories: perceived usefulness (PU), 3 questions; perceived ease of use (PEOU), 3 questions; and attitude toward representing ILOs (AT), 2 questions. The results revealed that the mean ratings of perceived usefulness, perceived ease of use, and attitude towards representing ILOs, were significantly higher with the ILO diagram.

6.2 Conjecture and Research Question

The ILOs of a specific course of study represent the learning objectives in which the planned outcomes are introduced and which summarise the entire learning contents embodied in the learning module. Thus, we expect the instructors to be able to utilise them to perform the teaching activities (e.g., introducing the objectives of the course to the learners, representing the structure of the course content, or explaining what the learners are expected to achieve after they are taught, etc). In addition, we expect the instructors to find it easier to undertake their teaching activities, if ILOs could be conceptualised using a diagrammatic formalism through the ILO diagram. We then make the following conjecture:

> *If traditional ILOs can be conceptualised as the structured ILOs through the ILO diagram, then instructors can utilise them in performing the teaching activities.*

This conjecture is an unproven claim, because nowadays there is no clearly defined conceptual model for facilitating the pedagogical activities and there is no formal representation of the learning objectives that systematically applies the ILOs. Consequently, the following research question is initiated:

> *Does the ILO diagram conceptualising the structured ILOs meet the instructors' satisfactions in performing the teaching activities?*

6.3 Experimental Design

A survey questionnaire was distributed to each of 17 lecturers at the department of Electronics and Computer Science (ECS) at the University of Southampton in UK and the faculty of Information and Communication Technology (ICT) at the Mahidol University in Thailand. The selected learning course was an Information Management (IM4) Data Modelling module conforming to the curriculum proposed by the ACM Special Interest Group on IT education (Ekstrom et al., 2006), as illustrated in Appendix A.1.

The participants were divided into two groups. Eight participants (N=8) in the first (control) group were asked to indicate their satisfaction with ILOs expressed in plain text (see Table 6-1). So, the control group participated with unstructured ILOs.

Table 6-1 Eight unstructured ILOs represented as plain text

ILO Number	Description
ILO_1	Describe and interpret an ERD.
ILO_2	Design a simple ERD.
ILO_3	Create a simple ERD.
ILO_4	Describe and interpret an EERD.
ILO_5	Create and design an EERD.
ILO_6	Describe a logical model.
ILO_7	Evaluate a logical model.
ILO_8	Demonstrate reengineer DB.

Nine participants (N=9) in the second (experimental) group indicated their satisfaction with ILOs expressed in plain text as well as illustrated through an ILO diagram (depicted in Figure 6-1); hence, the experimental group participated with structured ILOs.

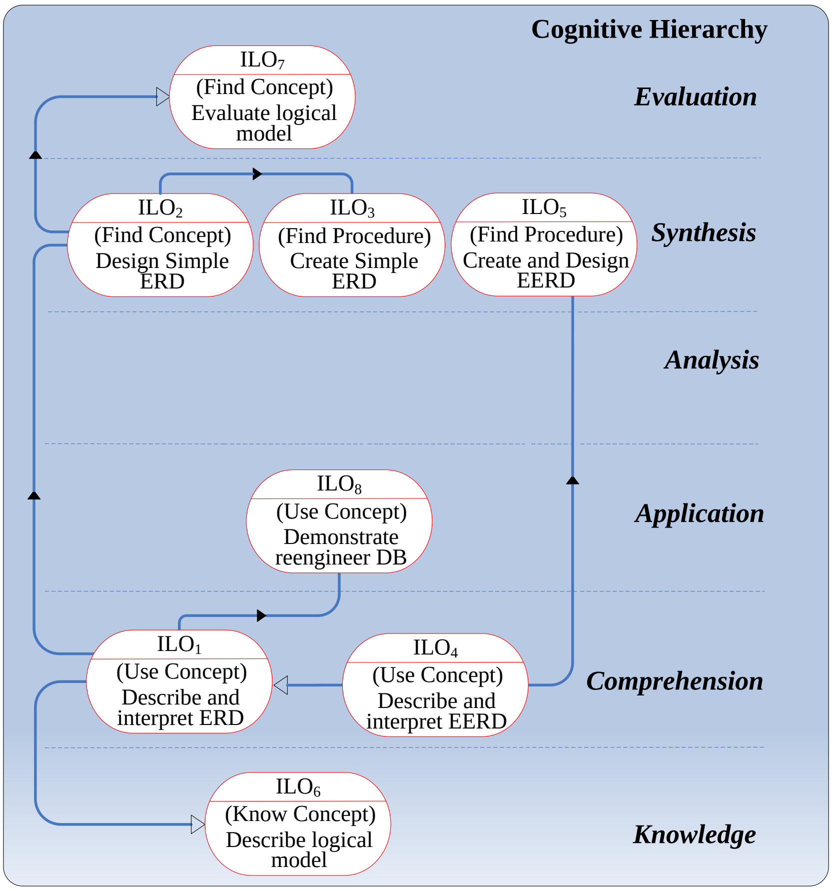


Figure 6-1 An ILO diagram of the IM4 data modelling module

6.4 Experimental Variables

The independent variables were the two ILOs formats: unstructured and structured ILOs. Participants in the control group used the list of eight unstructured ILOs expressed in plain-text format, whilst participants in the experimental group referred to ILOs expressed in plain text and conceptualised through the ILO diagram as structured ILOs format. They were required to indicate their satisfaction with using the ILOs to facilitate teaching. The instructors’ satisfaction was classified in three metrics (i.e., PU, PEOU, and AT). Hence, the dependent variables of this study were the three metrics of instructors’ satisfaction.

6.5 Measurement

The instructors’ satisfaction defined in this experiment was measured by using a 5-point Likert-type scale ("strongly agree" to "strongly disagree") under 3 categories of criteria: PU, PEOU, and AT. There were eight questions which were mapped to these three categories and listed in the following table.

Table 6-2 Experimental criteria and questions

Perceived usefulness (PU)	**Variable**
• Using the ILOs allows instructors to explain the learning objectives to learners more clearly.	PU1
• Using the ILOs to facilitate teaching is helpful.	PU2
• Using the ILOs allows instructors to track the level of learners' performance in learning.	PU3
Perceived ease of use (PEOU)	**Variable**
• The ILOs are understandable to instructors.	PEOU1
• The ILOs provide an easy way to plan the teaching activities for the specific subject matter content.	PEOU2
• The ILOs provide an easy way to envision the entire range of relationships of all learning outcomes.	PEOU3
Attitude toward representing ILOs (AT)	**Variable**
• Representing all ILOs is a good idea.	AT1
• Representing all ILOs makes course contents more interesting.	AT2

Thus, the overall ratings of three metrics of subjective criteria (i.e., PU, PEOU, and AT) rated by participants were used to measure the instructors' satisfaction with how they experience the usefulness, ease of use, and representing of ILOs, comparing the ILO diagram with the plain-text document.

6.6 Experiment Results

The multivariate test of significance (MANOVA) between the mean ratings of satisfaction was used to analyse the data obtained from 17 participants. Table 6-3 shows the results of mean and standard deviation of all dependent variables. Table 6-4 shows the results of multivariate tests of significant difference between the mean ratings for all dependent variables.

Table 6-3 Mean and standard deviation of all dependent variables

	Group	N	Mean	Std. Deviation	Std. Error Mean
PU1	Unstructured ILOs	8	3.62	0.518	0.183
	Structured ILOs	9	4.00	0.500	0.167
PU2	Unstructured ILOs	8	3.00	0.525	0.189
	Structured ILOs	9	3.89	0.601	0.200
PU3	Unstructured ILOs	8	2.63	1.061	0.375
	Structured ILOs	9	4.11	0.601	0.200
PEOU1	Unstructured ILOs	8	3.75	0.463	0.164
	Structured ILOs	9	3.33	0.866	0.289
PEOU2	Unstructured ILOs	8	3.25	0.886	0.313
	Structured ILOs	9	4.11	0.333	0.111
PEOU3	Unstructured ILOs	8	2.75	1.165	0.412
	Structured ILOs	9	3.89	0.782	0.261
AT1	Unstructured ILOs	8	3.50	0.535	0.189
	Structured ILOs	9	4.11	0.601	0.200
AT2	Unstructured ILOs	8	2.88	0.354	0.125
	Structured ILOs	9	3.56	0.726	0.242

Table 6-4 Multivariate tests (MANOVA) for all dependent variables

Effect		Value	F	Hypothesis df	Error df	Sig.
Group	Pillai's Trace	0.767	3.290	8	8	0.056
	Roy's Largest Root	3.290	3.290	8	8	0.056

All dependent variables: PU1, PU2, PU3, PEOU1, PEOU2, PEOU3, AT1, and AT2

The results indicated that the mean ratings of all dependent variables for structured ILOs were higher than for unstructured ILO, except the PEOU1 (see Table 6-3). Table 6-4 shows the results of multivariate tests of significant differences between the mean ratings for all dependent variables. The results indicated that the two groups were significantly different in their mean ratings over all questions (Pillai's trace = 0.767, F = 3.29, df = 8, 8, p = 0.056).

While the p value of this result was 0.056 and hence was not statistically significant, the effect was considered highly suggestive.

In addition, we analysed multiple comparisons of the two groups (i.e., structured ILO and unstructured ILO) using the Tukey's HSD Post-hoc test as illustrated in Table 6-5.

Table 6-5 Post-hoc test (TUKEY'S HSD) of multiple comparisons of groups

Dependent Variable	**(I) Group**	**(J) Group**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**
PU1	Structured ILO	Unstructured ILO	0.375	0.247	0.150
PU2	Structured ILO	Unstructured ILO	0.889	0.277	0.006
PU3	Structured ILO	Unstructured ILO	1.486	0.412	0.003
PEOU1	Structured ILO	Unstructured ILO	-0.417	0.344	0.244
PEOU2	Structured ILO	Unstructured ILO	0.861	0.317	0.016
PEOU3	Structured ILO	Unstructured ILO	1.139	0.476	0.030
AT1	Structured ILO	Unstructured ILO	0.611	0.277	0.044
AT2	Structured ILO	Unstructured ILO	0.681	0.283	0.030

From Table 6-5, the results revealed that there was no statistically significant difference between the mean ratings of "using the ILOs allows instructors to explain the learning objectives to learners more clearly" (PU1) for structured and unstructured ILO groups (p=0.15 > 0.05) and there was no statistically significant difference between the mean ratings of "the ILOs are understandable to instructors" (PEOU1) for structured ILO and unstructured ILO groups (p=0.244 > 0.05). Otherwise, there were significant differences in the mean ratings for other six pairs of structured and unstructured ILO groups (i.e., PU2, PU3, PEOU2, PEOU3, AT1, and AT2).

Figure 6-2, Figure 6-3, and Figure 6-4 provide the profile graphs for the mean ratings of PU, PEOU, and AT questions.

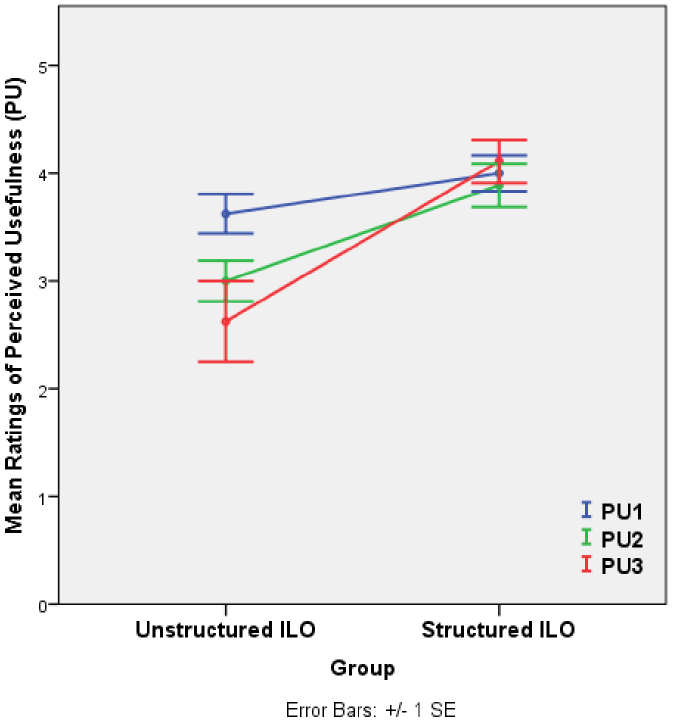


Figure 6-2 Mean ratings of PU for unstructured and structured ILO

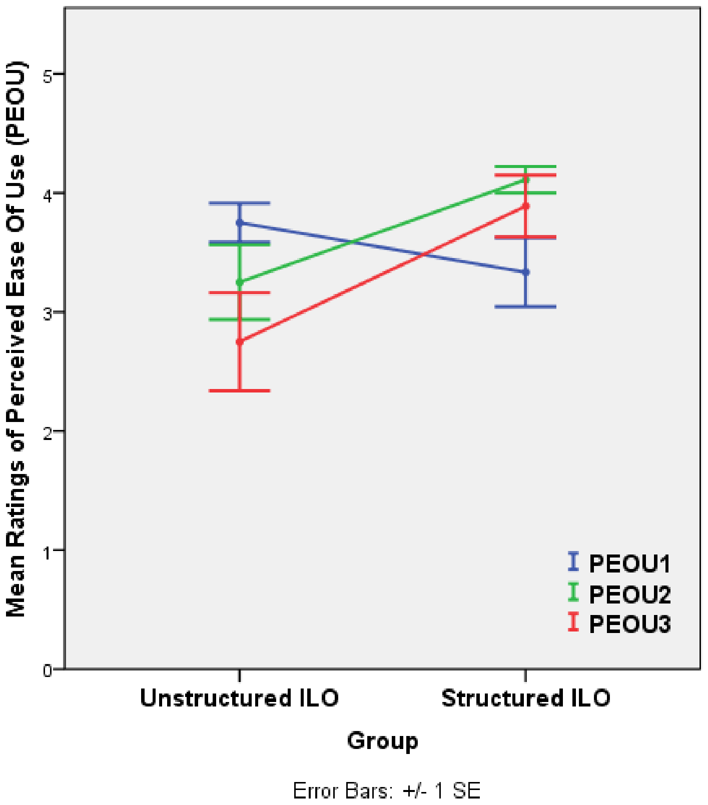


Figure 6-3 Mean ratings of PEOU for unstructured and structured ILO

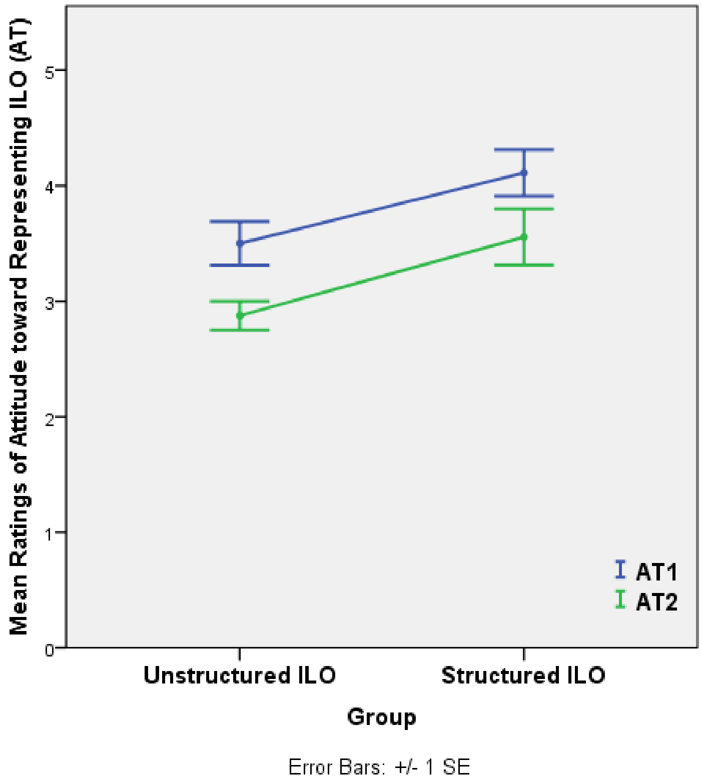


Figure 6-4 Mean ratings of AT for unstructured and structured ILO

Figure 6-2 illustrates the mean ratings for the three perceived usefulness (PU) questions which were higher for structured ILOs, such that "using the ILOs allows instructors to explain the learning objectives to learners more clearly", "using the ILOs to facilitate teaching is helpful", and "using the ILOs allows instructors to track the level of learners' performance in learning". Although the profile graph shows that the mean ratings for PU1 was higher for structured ILOs, there was no statistically significant difference in the mean ratings of PU1 (see Table 6-5).

Figure 6-3 illustrates the mean ratings of the three perceived ease of use (PEOU) questions. Two were higher for structured ILOs, such that "the ILOs provide an easy way to plan the teaching activities for the specific subject matter content", and "the ILOs provide an easy way to envision the entire range of relationships of all learning outcomes". However, the mean rating of "the ILOs are understandable to instructors" (PEOU1) was lower for structured ILOs.

Finally, Figure 6-4 illustrates the mean ratings for the two attitudes toward representing ILOs (AT) questions. The results indicated that the mean ratings of structured ILOs were higher than the mean ratings of unstructured ILOs, such that the notion of structured ILOs "is a good idea" and "makes course contents more interesting".

6.7 Analysis of Qualitative Results

Participants given the structured ILOs rated significantly more satisfaction than those given the unstructured ILOs. The data collected from 17 participants revealed that the ILO diagram satisfied the instructors' needs with higher ratings than expressing ILOs as a plain-text document. For further analysis of the qualitative evaluation of the 5-point Likert-type scales data ("Strongly agree" to "Strongly disagree") in 3 categories of criteria, namely, perceived usefulness (PU), perceived ease of use (PEOU), and attitude toward representing ILOs (AT), the total rating scores were summarised as illustrated in Table 6-6.

Table 6-6 Summary of total rating scores for PU, PEOU, and AT

	Strongly agree (5)	**Agree (4)**	**Neither agree nor disagree (3)**	**Disagree (2)**	**Strongly disagree (1)**
PU1 *(Using the ILOs allows instructors to explain the learning objectives to learners more clearly.)*					
Unstructured ILOs	-	5	3	-	-
Structured ILOs	1	7	1	-	-
PU2 *(Using the ILOs to facilitate teaching is helpful.)*					
Unstructured ILOs	-	4	4	-	-
Structured ILOs	1	6	1	1	-
PU3 *(Using the ILOs allows instructors to track the level of learners' performance in learning.)*					
Unstructured ILOs	-	3	1	3	1
Structured ILOs	2	6	1	-	-
PEOU1 *(The ILOs are understandable to instructors.)*					
Unstructured ILOs	-	6	2	-	-
Structured ILOs	1	2	4	2	-
PEOU2 *(The ILOs provide an easy way to plan the teaching activities for the specific subject matter content.)*					
Unstructured ILOs	1	2	5	-	-
Structured ILOs	1	8	-	-	-
PEOU3 *(The ILOs provide an easy way to envision the entire range of relationships of all learning outcomes.)*					
Unstructured ILOs	1	1	2	4	-
Structured ILOs	2	5	2	-	-
AT1 *(Representing all ILOs is a good idea.)*					
Unstructured ILOs	-	4	4	-	-
Structured ILOs	1	2	6	-	-

AT2 *(Representing all ILOs makes course contents more interesting.)*					
Unstructured ILOs	-	-	7	1	-
Structured ILOs	-	6	2	1	-

Note: The numeric data indicated the total number of participants (out of N=17).

In the perceived usefulness (PU) category, the 17 lecturers completing the 5-point Likert-type scales rated their satisfaction with the structured ILOs at 5, 4, and 3, whilst they rated the unstructured ILOs at 4, 3, 2, and 1. The highest rating on the scale ("Strongly agree") was allocated to the structured ILOs for all questions (N=1 for both PU1 and PU2, and N=2 for PU3) which are: "Using the ILOs allows instructors to explain the learning objectives to learners more clearly", "Using the ILOs to facilitate teaching is helpful", and "Using the ILOs allows instructors to track the level of learners' performance in learning". There were two lecturers (N=2) who were satisfied with the ILO diagram which can allow them to track the level of learners' performance in learning (PU3). It is likely that 19 lecturers (N=7 for PU1, N=6 for PU2 and PU3) allocated the rating "Agree" to structured ILOs, while only 12 lecturers (N=5 for PU1, N=4 for PU2, and N=3 for PU3) allocated the rating "Agree" to unstructured ILOs. These results revealed that most lecturers were satisfied that the structured ILOs are more useful than unstructured ILOs. As confirmed by participants who provided their opinion for the suggested question (Q12: Do you have any suggestions for improvement and modification of the ILOs?), three lecturers stated their opinion about using the structured ILOs as follows:

> "I found the mapping of the ILOs to the cognitive hierarchy is useful and would make me think about the structure and content of the course," said lecturer A.
>
> "It seems to me more useful as a good planning aid," said lecturer B.
>
> "An explanation of each of the cognitive hierarchical levels would be useful," said lecturer C.

However, the unstructured ILOs did not receive the highest rating on the scale for all questions in PU category. In fact, expressing ILOs as a plain-text document received the lowest rating on the scale ("Strongly disagree") for PU3 (N=1). This meant as one lecturer observed, that, when using the unstructured ILOs, it is difficult to track the level of learners' learning performance.

For the perceived ease of use (PEOU) category, the lecturers rated their satisfaction with the structured ILOs at 5, 4, 3, and 2, whilst they rated the unstructured ILOs at 4, 3, 2, and 1. The "Strongly agree" rating on the scale went to the structured ILOs for all questions of PEOU category (N=1 for PEOU1, N=1 for PEOU2, and N=2 for PEOU3). Thirteen lecturers (N=8 for PEOU2 and N=5 for PEOU3) allocated the "Agree" rating on the scale to structured ILOs while only 3 lecturers (N=2 for PEOU2 and N=1 for PEOU3) allocated the "Agree" rating to the unstructured ILOs. This meant that many lecturers were satisfied with the ILO diagram as providing an easy way to plan the teaching activities for the specific subject matter content (PEOU2) since it can provide an easy way to envision the entire range of relationships of all learning outcomes (PEOU3). However, the results presented an unexpected rating for the PEOU1 ("The ILOs are understandable to instructors") since 6 lecturers allocated the "Agree" rating on the scale to the unstructured ILOs while only 2 lecturers allocated the "Agree" scale rating to the structured ILOs. It is likely that only some lecturers were satisfied that visualising all ILOs through the ILO diagram is understandable.

Finally, in the attitude toward representing ILOs (AT) category, the lecturers rated their satisfaction with the structured ILOs at 5, 4, 3, and 2 whilst, for unstructured ILOs, they gave ratings of 4, 3, 2, and 1. The "Strongly agree" rating on the scale was allocated to the structured ILOs for AT1 (N=1), which indicates that using the ILO diagram to represent all ILOs is a good idea. However, 4 lecturers allocated the "Agree" rating to the unstructured ILOs for AT1 whilst only 2 lecturers allocated the "Agree" rating to the structured ILOs. Six lecturers (N=6) allocated the "Agree" rating, which is "Representing all ILOs makes course contents more interesting", to the structured ILOs for AT2.

6.8 Limitations of the Study

This study adopted the existing published course documents for IT education (Ekstrom et al., 2006) to be used as the standard set of intended learning outcomes. The selected course, which was the information management (IM4) data modelling module, might be not suitable for some specific institutions. Thus, the selection of ILOs is an inherent limitation. This limitation was minimised by either determining the existing course that is currently provided in the institutions where participants work as instructors, or examining the new course that will be initiated in the institution.

Furthermore, the generality of the participants is limited. The small number of participants should be considered because this limitation restricts diversity in population. Future studies would be advised to increase the number of lecturers.

6.9 Summary

This chapter reports on and summarises the first experimental study of the research. The main objective was to investigate whether the ILOs conceptualised through the ILO diagram (structured ILOs format) met instructors' satisfactions which was better than the ILOs listed as plain text (unstructured ILOs format). The instructors' satisfaction was measured under the three categories of subjective criteria, namely, perceived usefulness, perceived ease of use, and attitude towards representing ILOs. The experiment results show that the structured ILOs format gave greater rates of satisfaction than the unstructured ILOs format. Thus, the findings of this study claim that the ILO diagram met the instructors' satisfactions with higher ratings of all three dependent variables (i.e., perceived usefulness, perceived ease of use, and attitude towards representing ILOs) than the plain-text document.

Chapter 7
A Study of Using ILO Diagram as Facilitator in Indicating Learning Paths

7.1 Introduction

This chapter presents the second experimental study, the main theme of which was to investigate whether providing ILOs as facilitators of learning can assist learners to initiate and identify the learning paths. In the light of self-regulated learning in which a learner performs learning activities by self-regulated thoughts, attitudes, and actions (Ismail and Sharma, 2012), does a self-regulated learner utilise the ILOs of a specific course of study to guide self-learning? The present study addresses this question. The completeness metrics have been proposed as the measurement to evaluate the complete learning paths. The results revealed that the mean completeness of all learning paths was statistically significantly higher with the structured ILOs.

7.2 Conjecture and Research Question

Traditionally, all the ILOs of a specific course of study are formulated before undertaking the learning and teaching tasks by defining them as plain-text or unstructured documents. We expect that learners will find it easier to perform the learning tasks in self-regulated learning and that, if ILOs could be represented as a well-defined structure, learners will achieve levels that they could not accomplish before. Further consideration strengthens our belief that the proposed conceptual model of ILOs supports self-regulated learners to identify the learning paths to the learning goals. In this study, we concentrate on learning rather than teaching; thus, we state a conjecture as follows:

> *If traditional ILOs can be conceptualised as structured ILOs through an ILO diagram, then learners can better identify their learning paths.*

The point of the above conjecture is to seek the answer to the following research question:

> *Does an ILO diagram conceptualising the structured ILOs facilitate learners' identification of their learning paths?*

7.3 Experimental Design

An online survey questionnaire, including learning content, supporting learning information, learning tips, and six survey questions, was distributed to each of 21 postgraduate students in the department of Electronics and Computer Science (ECS) at the University of Southampton in the UK. All participants were voluntary postgraduate students (aged from 21 to 30 years; 14 females, 7 males) studying computer science. Their profiles are similar and they are familiar with the mathematics and the topic used in this study. The topic used in this study was "Pascal's triangle" which is a topic about number patterns in mathematics. We considered two curriculums in mathematics published by the national curriculum for England (HMSO-QCA, 1999) and the Michigan curriculum framework (Michigan-GOV, n.d.), illustrated in Appendix A.2. Fourteen intended learning outcomes which covered the introduction to Pascal's triangle calculation and Pascal's triangle patterns, were selected and listed as unstructured ILOs format (see Table 7-1). Then, the ILOs were put into conceptualisation through ILO diagrams as illustrated in Figure 7-1 and Figure 7-2.

Table 7-1 Fourteen unstructured ILOs represented as plain text

ILO number	Description
ILO_1	Define numbers and position.
ILO_2	Select appropriate numbers.
ILO_3	Compare numbers and position.
ILO_4	Formulate Pascal triangle value.
ILO_5	Classify numbers as even or odd.
ILO_6	Compute integers by adding.
ILO_7	Describe numbers, and number relationship.
ILO_8	Analyse patterns including sequences and series.
ILO_9	Use patterns to solve problem.
ILO_{10}	Indicate numerical patterns.
ILO_{11}	Draw triangle patterns in 2D.
ILO_{12}	Explain numerical patterns.
ILO_{13}	Combine patterns.
ILO_{14}	Compare patterns.

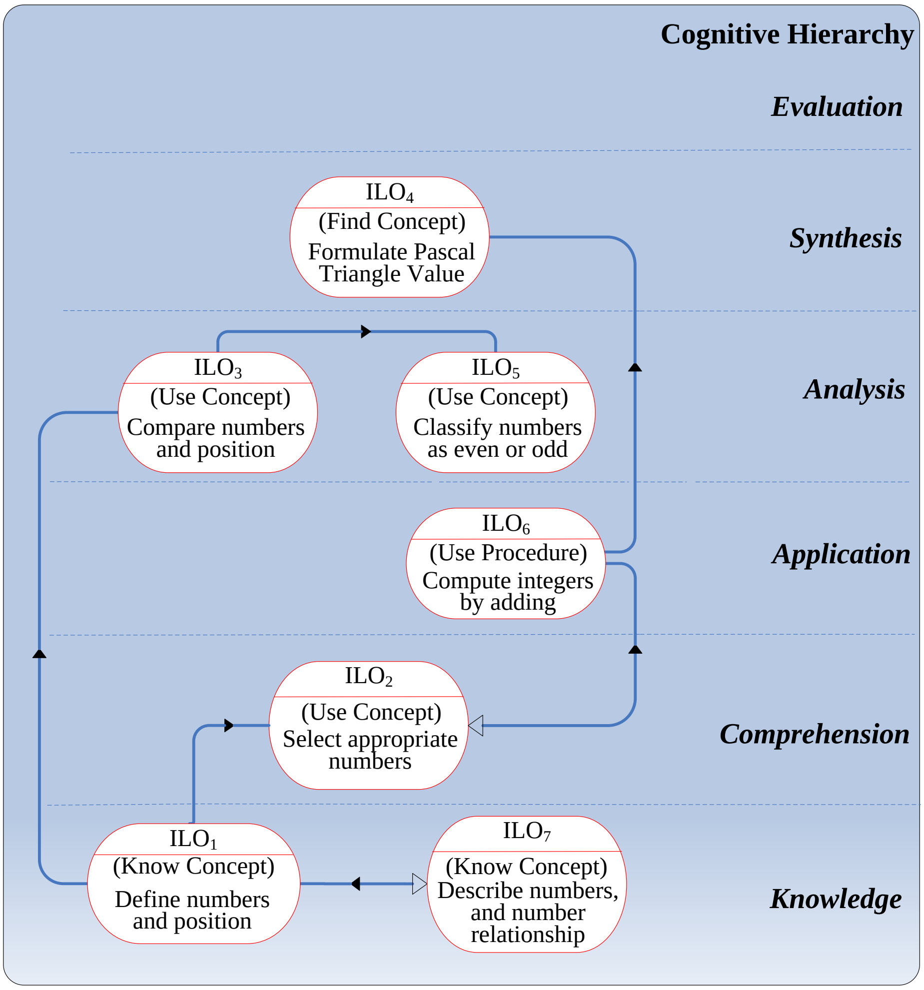


Figure 7-1 An ILO diagram of Pascal's triangle calculation

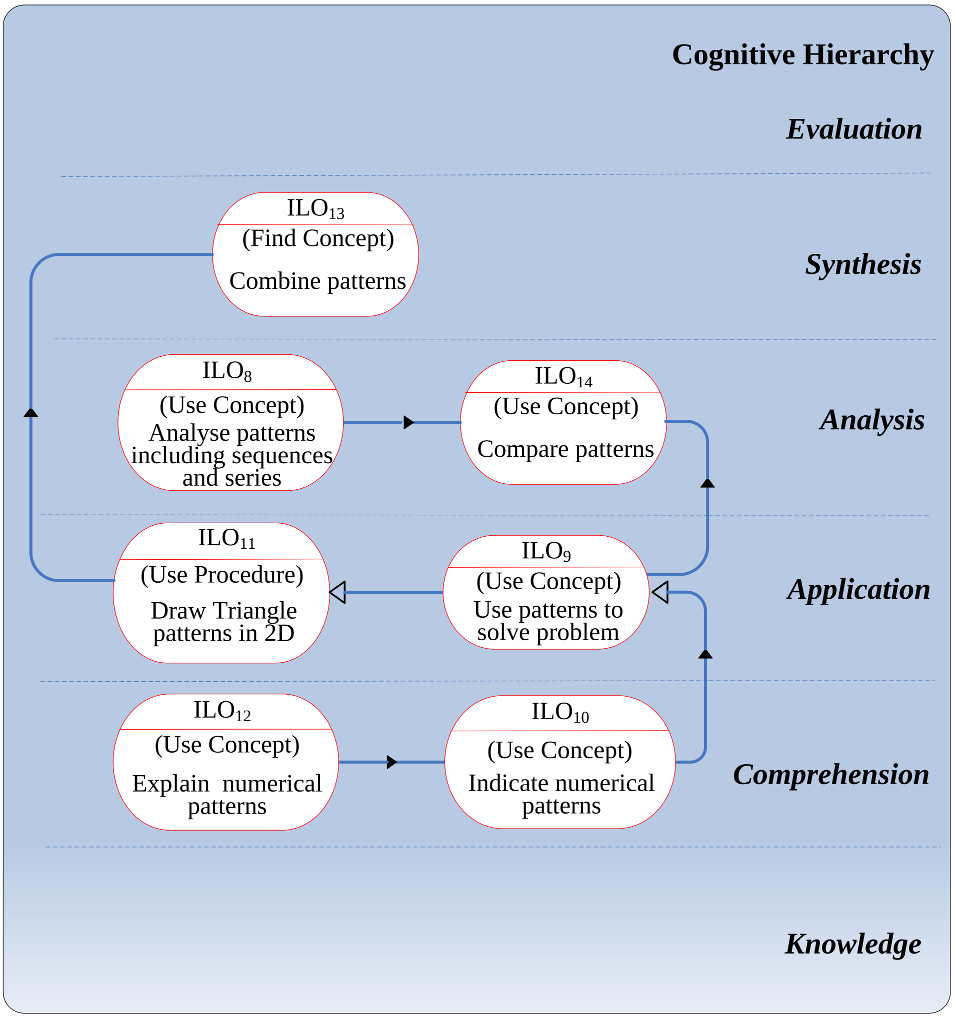


Figure 7-2 An ILO diagram of Pascal's triangle patterns

All participants were given the consent information. Although they had previously learnt about the numerical analysis in mathematics, they also received supporting information in order to have a clear understanding of the terms and definitions used in this study (e.g., intended learning outcomes, ILO, learning objectives, learning paths, Pascal’s triangle, numerical patterns, etc.) and the use of ILOs and learning paths. In addition, participants were asked to read the scenario and the instructions on performing self-learning and completing the questionnaire. After that, they were required to undertake self-learning. They practised calculating Pascal's triangle and defining Pascal's triangle patterns by themselves without any interaction from instructors. After that, they were asked to answer three questions indicating three learning paths (i.e., LP1, LP2, and LP3) for Pascal's triangle calculation and three questions indicating three learning paths (i.e., LP4, LP5, and LP6) for Pascal's triangle patterns.

All participants were randomly divided into two groups. Ten participants (N = 10) in the first (control) group were asked to indicate the six learning paths (see Table 7-2) by answering the survey questions. They were required to refer to the list of fourteen ILOs expressed in plain text as facilitators. Thus, this control group participated with *unstructured ILOs*. Eleven participants (N = 11) in the second (experimental) group answered the same survey questions to indicate the same six learning paths by referring to both the list of ILOs expressed in plain text and the ILO diagrams. Hence, the experimental group participated with *structured ILOs*.

7.4 Experimental Variables

The independent variables were the two ILOs formats: unstructured and structured ILOs. Participants in the control group used the list of fourteen unstructured ILOs expressed in plain text, whilst participants in the experimental group referred to ILOs expressed in plain text and illustrated through the ILO diagrams as structured ILOs format. All participants were asked to provide the answers to the survey questions in order to formulate six learning paths (illustrated in Table 7-2). Thus, the dependent variables were the completeness of the six learning paths, namely, LP1, LP2, LP3, LP4, LP5, and LP6.

Table 7-2 Six learning paths

LP	Learning path	Description	Survey question
LP1	$ILO_1 \rightarrow ILO_2$	In order to select appropriate Pascal's triangle numbers (ILO_2), student should be able to define numbers and position (ILO_1) previously.	Q1
LP2	$ILO_7 \rightarrow ILO_1 \rightarrow ILO_2 \rightarrow ILO_6$	In order to compute integers by adding (ILO_6), student should be able to firstly describe numbers and number relationship (ILO_7) and then define numbers and positions (ILO_1) and finally select appropriate numbers (ILO_2).	Q2
LP3	$ILO_7 \rightarrow ILO_1 \rightarrow ILO_2 \rightarrow ILO_6 \rightarrow ILO_4$	In order to formulate Pascal's triangle value (ILO_4), student should be able to firstly describe numbers and number relationship (ILO_7) and then define numbers and position (ILO_1) and select appropriate numbers (ILO_2) and finally compute integers by adding (ILO_6).	Q3

LP4	$ILO_{12} \rightarrow ILO_{10}$	In order to indicate numerical patterns (ILO_{10}), student should be able to explain numerical patterns (ILO_{12}) previously.	Q5
LP5	$ILO_{12} \rightarrow ILO_{10} \rightarrow ILO_9 \rightarrow ILO_{11}$	In order to draw triangle patterns (ILO_{11}), student should be able to firstly explain numerical patterns (ILO_{12}) and then indicate numerical patterns (ILO_{10}) and finally use patterns to solve problem (ILO_9).	Q6
LP6	$ILO_{12} \rightarrow ILO_{10} \rightarrow ILO_9 \rightarrow ILO_{14} \rightarrow ILO_8$	In order to analyse patterns including sequences and series (ILO_8), student should be able to firstly explain numerical patterns (ILO_{12}) and then indicate numerical patterns (ILO_{10}) and then use patterns to solve problem (ILO_9) and finally compare patterns (ILO_{14}).	Q7

7.5 Measurements

The learning paths identified by participants were measured according to their completeness. After a participant completed the survey questions, six learning paths were formulated and the completeness score of each learning path was calculated. In this study, the formulation and definitions of learning paths and the completeness metrics used to measure the learning paths have been proposed and described as follows:

Definition 1: Learning path

A learning path (*LP*) is a sequence of ILOs $\{ILO_1, ILO_2, ..., ILO_n\}$ in such a way that $\{(ILO_1, ILO_2), (ILO_2, ILO_3), ... (ILO_{n-1}, ILO_n)\}$ are relations on all ILOs called the *edges*. Two ILOs are connected if there is a path (or edge) leading from one to the other. Thus, an edge is an order pair (ILO_i, ILO_j); i is the starting position and j is the end position of an edge.

If ILO_i and ILO_j are two ILO nodes, and an order pair (ILO_i, ILO_j) is an edge between these two ILOs, we say that a learning path *LP* goes from ILO_i to ILO_j that is

$$LP = ILO_i \rightarrow ILO_j \tag{1}$$

For example, the survey question No.1 was "In order to select appropriate Pascal's triangle numbers, what is a previous ILO needed to be performed?". This question was to formulate the learning path to achieve "ILO2: Select appropriate number". The participant's answer to this question might be "ILO1: Define numbers and positions". Thus, the learning path was "ILO1→ ILO2".

There are two major properties concerned in formulating the learning path *LP*:

- Correct Node (CN) – each ILO node of an order pair is correct.
- Correct Edge (CE) – an edge is correct.

Consider these two properties CN and CE, given a set of all ILO nodes N and a set of relations on N called edges E. When an ILO node exists in N and an edge exists in E, we say that CN and CE is correct, otherwise it is incorrect.

Definition 2: Completeness of edge

A completeness of edge (C^e) is an accuracy index of a given edge for an order pair (ILO_i, ILO_j).

The proposed completeness C^e can be defined as follows:

$$C^e_{(ij)} = CN_i * CN_j * \frac{(CE_{ij} * w)}{ae} \tag{2}$$

Where i and j are the starting and end positions of an order pair, *CN* and *CE* are the "Correct Node" and "Correct Edge" values of an order pair, note that the *CN* (and *CE*) value is set to 1 if the ILO node (and edge) is correct, otherwise it is set to 0, *ae* is an "Adjacent Edge" which represents the number of edges leading from i to j, and w is the weighted value of a given *Edge* which has two possible cases:

$$w = \begin{cases} 2 & \text{if } Edge \text{ is direct relationship} \\ 1 & \text{if } Edge \text{ is indirect relationship} \end{cases}$$

Definition 3: Completeness score of learning path

A learning path *LP* is said to connect from ILO_i to ILO_j through a sequence of ILOs $ILO_i = ILO_i, ILO_{i+1},..., ILO_{j-1} = ILO_j$. A *completeness score of learning path LP* (C^{lp}) is an accuracy index which summarises the total value of C^e for a sequence of ILOs from ILO_i to ILO_j.

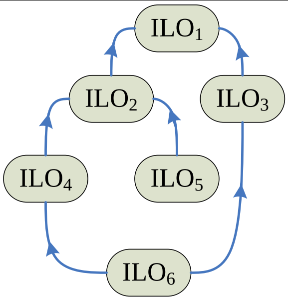
The proposed completeness score of learning path C^{lp} can be defined as follows:

$$C^{lp} = \frac{\sum_{i \neq j} C^e_{(ij)}}{n} \tag{3}$$

Where C^{lp} is the completeness score index of a given learning path *lp*, C^e is a completeness of an order pair of edge *(ILO_i, ILO_j)*, and n stands for the total number of

ILOs in a given learning path *lp*. Note that, *i* is not equal to *j* in order to prevent the recursive relationship of ILOs.

Figure 7-3 illustrates the examples of how to calculate the completeness score of the learning paths.



Learning path 1	Learning path 2
$LP_1 = ILO_4 \rightarrow ILO_6 \rightarrow ILO_3$	$LP_2 = ILO_6 \rightarrow ILO_3 \rightarrow ILO_1$
$C^e_{(4,6)} = (1*1*(1*1)/1)$ $C^e_{(6,3)} = (1*1*(1*2)/1)$	$C^e_{(6,3)} = (1*1*(1*2)/1)$ $C^e_{(3,1)} = (1*1*(1*2)/1)$
$C^{lp} = (1+2) / 3$ $= 1.00$	$C^{lp} = (2+2) / 3$ $= 1.33$

Figure 7-3 Examples of the completeness calculation

Thus, the completeness score has been assigned to be the accuracy index of the participants' performance in indicating the learning paths.

7.6 Experiment Results

The experiment results obtained from 21 participants were formulated as the completeness scores of six learning paths. Thus, the six dependent variables (i.e., completeness of LP1, LP2, LP3, LP4, LP5, and LP6) were analysed and summarised. The statistical analysis of this study can be summarised in two main parts, namely, the analysis of learning paths and the analysis of interaction between learning paths. The details are described as follows.

7.6.1 Analysis of Learning Paths

Repeated measures MANOVA was used to analyse the data collected. Table 7-3 shows the results of mean and standard deviation of all learning paths' completeness. Table 7-4 shows the results of repeated measures MANOVA for tests of within-subjects effects, whilst Table 7-5 presents the results for tests of between-subjects effects.

Table 7-3 Mean and standard deviation of All dependent variables

	Group	N	Mean	Std. Deviation	Std. Error Mean
LP1	Unstructured ILOs	10	0.79	0.341	0.109
	Structured ILOs	11	0.82	0.252	0.076
LP2	Unstructured ILOs	10	0.67	0.358	0.113
	Structured ILOs	11	0.91	0.440	0.133
LP3	Unstructured ILOs	10	0.72	0.189	0.059
	Structured ILOs	11	1.03	0.445	0.134
LP4	Unstructured ILOs	10	0.23	0.141	0.045
	Structured ILOs	11	0.74	0.311	0.094
LP5	Unstructured ILOs	10	0.51	0.122	0.039
	Structured ILOs	11	0.85	0.439	0.133
LP6	Unstructured ILOs	10	0.57	0.178	0.056
	Structured ILOs	11	1.02	0.305	0.092

Table 7-4 Repeated measure MANOVA for all LPs - tests of within-subject effects

Effect		Value	F	Hypothesis df	Error df	Sig.
LP	Pillai's Trace	0.631	5.126	5	15	0.006
LP* Group	Pillai's Trace	0.411	2.094	5	15	0.123

Table 7-5 Repeated measure MANOVA for all LPs - tests of between-subjects effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group	3.018	1	3.018	10.506	0.004
Error	5.457	19	0.287		

The results indicated that the mean completeness of all paths for structured ILOs was higher than for unstructured ILOs (see Table 7-3). Table 7-4 shows the multivariate tests for the repeated measure MANOVA for all learning path completeness. The results reveal that the interaction of learning paths and groups was not significant ($p = 0.123 > 0.05$). However, there were significant differences in the mean completeness score for the learning paths ($p = 0.006 < 0.05$) and the tests of group effects (as illustrated in Table 7-5) were significant ($p = 0.004 < 0.05$), which showed that the mean completeness score of the paths for unstructured ILOs was lower than for structured ILOs. Figure 7-4 illustrates the profile graph of the average mean of completeness score for learning paths.

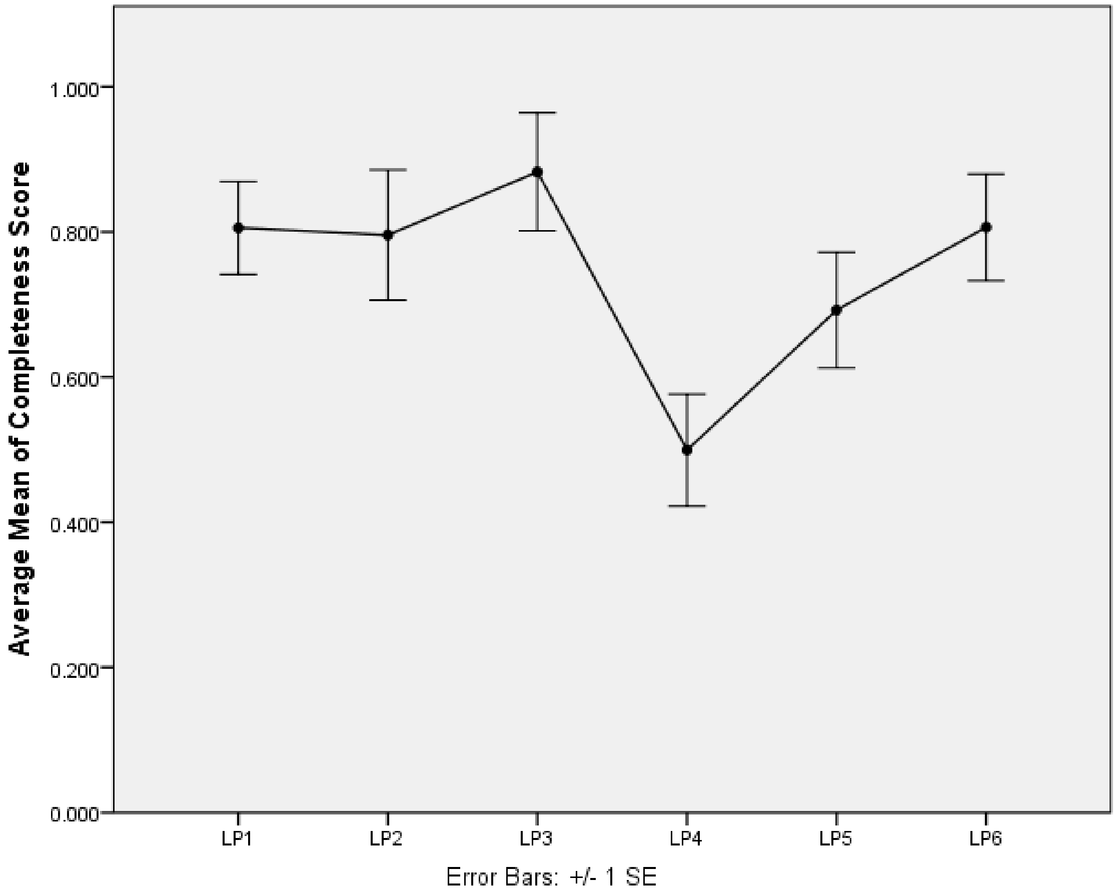


Figure 7-4 Profile graph of average mean of completeness score for all LPs

7.6.2 Analysis of Interaction between Learning Paths

We then analysed the results by comparing all learning paths with each other using Tukey's HSD Post-Hoc tests as depicted in Table 7-6.

Table 7-6 Post-Hoc Test (TUKEY'S HSD) of Multiple Comparisons of all LPs

Source	LPs	Average Mean		Mean Square	F	Sig.
		Source	LPs			
LP1	LP2	0.805	0.790	0.005	0.030	0.865
	LP3		0.155	0.104	0.650	0.430
	LP4		0.485	2.115	19.053	0.001
	LP5		0.680	0.305	2.395	0.138
	LP6		0.795	0.002	0.018	0.896
LP2	LP3	0.790	0.155	0.152	2.051	0.168
	LP4		0.485	1.923	10.899	0.004
	LP5		0.680	0.305	2.395	0.138
	LP6		0.795	0.001	0.005	0.946

LP3	LP4	0.155	0.485	3.159	20.192	0.001
	LP5		0.680	0.766	4.688	0.043
	LP6		0.795	0.134	1.441	0.245
LP4	LP5	0.485	0.680	0.814	7.775	0.012
	LP6		0.795	1.993	23.519	0.001
LP5	LP6	0.680	0.795	0.260	3.061	0.096

The results were as follows:

1. There was a significant difference between the average mean of completeness score of learning path 1 (0.805) for "In order to select appropriate Pascal's Triangle numbers (ILO_2), student should be able to define numbers and position (ILO_1) previously" and the average mean of completeness score of learning path 4 (0.485) for "In order to indicate numerical patterns (ILO_{10}), student should be able to explain numerical patterns (ILO_{12}) previously", $p = 0.001 < 0.05$.

2. There was a significant difference between the average mean of completeness score of learning path 2 (0.790) for "In order to compute integers by adding (ILO_6), student should be able to firstly describe numbers and number relationship (ILO_7) and then define numbers and positions (ILO_1) and finally select appropriate numbers (ILO_2)" and the average mean of completeness score of learning path 4 (0.485) for "In order to indicate numerical patterns (ILO_{10}), student should be able to explain numerical patterns (ILO_{12}) previously", $p = 0.004 < 0.05$.

3. There were significant difference between the average mean of completeness score of learning path 3 (0.155) for "In order to formulate Pascal's triangle value (ILO_4), student should be able to firstly describe numbers and number relationship (ILO_7) and then define numbers and position (ILO_1) and select appropriate numbers (ILO_2) and finally compute integers by adding (ILO_6)" and the average mean of completeness score of learning path 4 (0.485) for "In order to indicate numerical patterns (ILO_{10}), student should be able to explain numerical patterns (ILO_{12}) previously", $p = 0.001 < 0.05$, as well as the average mean of completeness score of learning path 5 (0.680) for "In order to draw Triangle patterns (ILO_{11}), student should be able to firstly explain numerical patterns (ILO_{12}) and then indicate numerical patterns (ILO_{10}) and finally use patterns to solve problem (ILO_9)", $p = 0.043 < 0.05$.

4. There were significant difference between the average mean of completeness score of learning path 4 (0.485) for "In order to indicate numerical patterns (ILO_{10}),

student should be able to explain numerical patterns (ILO_{12}) previously" and the average mean of completeness score of learning path 5 (0.680) for "In order to draw Triangle patterns (ILO_{11}), student should be able to firstly explain numerical patterns (ILO_{12}) and then indicate numerical patterns (ILO_{10}) and finally use patterns to solve problem (ILO_9)", $p=0.012 < 0.05$, as well as the average mean of completeness score of learning path 6 (0.795) for "In order to analyse patterns including sequences and series (ILO_8), student should be able to firstly explain numerical patterns (ILO_{12}) and then indicate numerical patterns (ILO_{10}) and then use patterns to solve problem (ILO_9) and finally compare patterns (ILO_{14})", $p=0.001 < 0.05$.

Surprisingly, the results showed a low completeness score for LP4 (see Figure 7-4). It should be noted that the LP4 indicated the change of the topics used in the study. When the participants in the control group referred to the list of unstructured ILOs items to answer the question 5 of the questionnaire ("In order to indicate numerical patterns, what previous ILO needs to be performed?"), only 2 participants (out of 10) provided the correct answer to this question. The reason might be that the different topics used in the survey questionnaire were at different levels of difficulty. For example, "The ILOs items are difficult to understand and I have no idea how they can connect to each other", said one of participants in the control group.

7.7 Analysis of Qualitative Results

The questionnaire also covered the four questions asking participants how well they performed their self-learning. These four questions were Q4, Q8, Q9, and Q10 (see Appendix B.2). The question, Q4, was intended to measure the participants' understanding of the calculation of the Pascal's triangle values (i.e., the values of two variables n^1 and n^2). The questions Q8, Q9, and Q10 were intended to measure the ability to distinguish the three patterns of Pascal's triangle (i.e., linear pattern, multiple-of-three pattern, and odd pattern). The results obtained from 21 participants revealed the following:

1) All participants in the experimental group who participated in the structured ILOs (N=11) provided the correct answers to all questions (i.e., Q4, Q8, Q9, and Q10). The proportion of the correct and incorrect answers to the structured ILOs revealed that 100 per cent of the total number of participants within the experimental group

identified the correct answers for calculating the Pascal's triangle values (Q4) and defining the three patterns of Pascal's triangle (Q8–Q10).

2) All participants in the control group who participated in the unstructured ILOs (N=10) provided the correct answer to only two questions (i.e., Q4 and Q8). This meant that 90 per cent of the total number of participants within the control group identified the correct answers for calculating Pascal's triangle values (Q4) and defining the linear pattern of Pascal's triangle (Q8). However, there were two participants who provided the incorrect answers for defining the multiple-of-three pattern (N=1 for Q9) and for defining the odd pattern (N=1 for Q10). The proportion of the correct and incorrect answers to the unstructured ILOs revealed that 10 per cent of the total number of participants within the control group provided the incorrect answers for defining these two patterns of Pascal's triangle (i.e., the multiple-of-three pattern and odd pattern). Table 7-7 shows the summary of this analysis.

Table 7-7 Summary of correct/incorrect answers for qualitative evaluation

			Group		
			Unstructured ILOs	**Structured ILOs**	**Total**
Q4	Correct answer	Count	10	11	21
		% within Q4	47.6%	52.4%	100.0%
		% within Group	100.0%	100.0%	100.0%
		% of total	47.6%	52.4%	100.0%
Q8	Correct answer	Count	10	11	21
		% within Q8	47.6%	52.4%	100.0%
		% within Group	100.0%	100.0%	100.0%
		% of total	47.6%	52.4%	100.0%
Q9	Correct answer	Count	9	11	20
		% within Q9	45.0%	55.0%	100.0%
		% within Group	90.0%	100.0%	95.2%
		% of total	42.9%	52.4%	95.2%
	Incorrect answer	Count	1	0	1
		% within Q9	100.0%	0%	100.0%
		% within Group	10.0%	0%	4.8%
		% of total	4.8%	0%	4.8%
Q10	Correct answer	Count	9	11	20
		% within Q10	45.0%	55.0%	100.0%
		% within Group	90.0%	100.0%	95.2%
		% of total	42.9%	52.4%	95.2%

Incorrect answer	Count	1	0	1
	% within Q10	100.0%	0%	100.0%
	% within Group	10.0%	0%	4.8%
	% of total	4.8%	0%	4.8%

7.8 Limitations of the Study

With regard to the main objective of this study, we focused on the learning of learning materials according to the different types of representation of ILOs (i.e., plain text and structured ILO diagram). This was to investigate the influence of completeness on indicating learning paths expecting differences between groups: structured and unstructured ILOs. We concentrated on the quantitative results in which the participants could perform learning by themselves to initiate and indicate the learning paths. Thus, time spent on participation in the experiment was discarded. However, the educational background of participants was primary concern since they should be studying Computer Science.

Furthermore, various courses of study are needed to validate the reliability and usability of the application of ILOs as educational tools across the variety of subject domains. In this study, although a selected learning module was a topic about the number patterns in mathematics, further studies that cover the additional subjects in other educational programmes should be determined.

7.9 Summary

An objective of this experimental study was to investigate whether the ILOs of a specific course of study illustrated through the proposed ILO diagram (structured ILOs format) or expressed as traditional plain text (unstructured ILOs format) can facilitate learners' indication of learning paths. Six learning paths identified by participants were formulated and measured according to their completeness. The formulations of learning paths and the completeness metrics were proposed as the accuracy index used in this study. The results revealed that visualising the ILOs through the ILO diagrams yielded better learning paths. The finding of this study shows that learners benefited from the conceptualisation of the ILO diagram (structured ILOs format) in performing their self-regulated learning.

Chapter 8
A Study of the Understandability of an ILO Diagram

This chapter examines the understanding of different representational styles of ILOs by learners. Three types of ILO representations were distinguished (i.e., sentential, tabular, and conceptual representations) and the last experimental study was conducted to investigate that how well the learners can understand the representations of ILOs. In this chapter, the conjecture and research question for this experimental study are introduced. The experimental designs and the results are reported and summarised.

8.1 Introduction

Analogously, "A picture is worth a thousand words", is the notion that the complex information can be delivered with a single picture (Mayer and Gallini, 1990). In a learning situation, a graphical representation (e.g., picture, graph, or diagram) is an effective learning tool that supports learners (Nokes and Ross, 2007) to perform better learning activities if they can understand the content explicitly. This chapter presents the final experimental study of this research. The main purpose was to investigate whether learners can understand the conceptualisation of the ILOs through the proposed ILO diagram (called *conceptual representation*) which is better than the tabular and sentential representations. In order to determine how students can benefit from the well-defined structure of information embedded in the ILOs' conceptual representation, a specially structured ILO diagram, the present study addresses this issue. The understandability of the ILOs' representational styles was measured by means of objective and subjective criteria. The objective measurement adopted the performance-based measurement (Genero et al., 2008) comprising three metrics:

Understandability Time (UT), Understandability Effectiveness (UEffec), and Understandability Efficiency (UEffic). The subjective measurement was measured by overall ratings of Perceived Understandability (PU). For two metrics (i.e., UEffic and PU), statistical significant differences in the understandability of the ILOs' representations were found. The experiment results indicate that the average mean of understandability were statistically significantly higher when the conceptual representation was given conceptualisation through the ILO diagram.

8.2 Conjecture and Research Question

With reference to section 4.4.1, enabling ILOs enables higher level ILOs through six levels of the cognitive hierarchy representing the hierarchical structure of the learned capabilities. We hypothesised that learners can achieve better learning levels if they can understand the conceptualisation of intended learning outcomes (through the ILO diagram). We then express a conjecture as follows:

> *If an ILO diagram conceptualises enabling ILOs by means of the cognitive hierarchy, then learners can understand the conceptual representation in an ILO diagram.*

Consequently, the research question is as follows:

> *Do the learners understand the conceptual representation in an ILO diagram?*

8.3 Experimental Design

Online survey questionnaires were distributed to forty-eight postgraduate students (N=48) at the University of Southampton in the UK. All participants were voluntary postgraduate students (16 participants aged from 21 to 25 years, 18 participants aged from 26 to 30 years, and 14 participants aged more than 30 years; 29 females, and 19 males). Participants were separated into four main groups. First, the "CS group" were twelve postgraduate students (N=12) who were studying in the department of Electronics and Computer Science. Second, the "MS group" were twelve clinical and medical students (N=12) who were current students of Health Sciences. Third, the "FS group" were twelve postgraduate students in Financial and Management (N=12) who were studying at the Southampton Management School. Finally, the "O group" were twelve postgraduate students (N=12) who were studying in other departments and who were not familiar with the three learning modules used in this experiment.

The three subject domains were: 1) web development in Information Technology named "IT domain" (IT); 2) clinical and medical training about doctors as professionals in Medical Education named "Medical domain" (Med); and 3) financial and accountancy training in accountancy skills in Financial Management named "Financial domain" (Fin). It should be noted that the participants' familiarity with the subject domains used in this study was balanced. This meant that none of the participants had experiences in all subject domains (as shown in Table 8-1). According to the demographic information provided by participants, 10 participants in the MS group, 9 participants in the FS group, and 10 participants in the O group had no experience in IT domain; 11 participants in the CS group, 11 participants in the FS group, and 12 participants in the O group had no experience in Medical domain; and 10 participants in the CS group, 11 participants in the MS group, and 6 participants in the O group had no experience in Financial domain.

Table 8-1 Number of participants with no experience (out of 12)

Subject domains	**Participants' groups**			
	Electronics and Computer Science (CS)	**Medical and Health Science (MS)**	**Financial Management (FS)**	**Other (O)**
Information Technology (IT domain)	0	10	9	10
Medical Education (Med domain)	11	0	11	12
Financial Management (Fin domain)	10	11	0	6

In addition, published curriculum guidelines for each of the three subject domains were referred to as the standard sets of ILOs, namely, the 9 ILOs of web development based on Lunt, Ekstrom, Gorka, Hislop, Kamali, Lawson, LeBlanc, Miller, and Reichgelt (2008) (see Appendix A.3), the 12 ILOs of "doctors as professionals" training based on AMEE guide No.25 (Harden, Crosby, and Davis, 1999; Shumway and Harden, 2003) (see Appendix A.4), and the 9 ILOs of the accountancy skills training based on Hartwell, Herring, and Jan (2000) (see Appendix A.5). Table 8-2 shows the chosen ILOs for each subject domain and the source of standard documents.

Table 8-2 Chosen ILOs for three subject domains

Subject domains	Learning module	Number of ILOs	Source
Information Technology (IT domain)	Web Development	5 Core ILOs 4 Advanced ILOs	Curriculum guidelines for degree programmes in Information Technology (Lunt et al., 2008)
Medical Education (Med domain)	Clinical and Medical Training	7 ILOs for what the doctor is able to do 3 ILOs for how doctors approach their practice 2 ILOs for the doctors as a professional	AMEE Guide No.25 for medical training programme (Harden et al., 1999b; Shumway and Harden, 2003)
Financial Management (Fin domain)	Financial and Accountancy Training	9 ILOs for Accounting and Financial programme	Curriculum structure for mastering the accountancy programme (Hartwell et al., 2000)

The ILOs of each subject domain were prepared in three representational styles. First, the sentential representation (S) expressed the ILOs as sentences (see Table 8-3, Table 8-4, and Table 8-5). Second, the tabular representation (T) represented the ILOs as rows and columns (see Table 8-6, Table 8-7, and Table 8-8). Third, the conceptual representation (C) visualised the ILOs through an ILO diagrams (see Figure 8-1, Figure 8-2, and Figure 8-3).

There were nine combinations of subject domain and ILOs representation, namely, IT_S, IT_T, IT_C, Med_S, Med_T, Med_C, Fin_S, Fin_T, and Fin_C. A participant in each group (i.e., CS, MS, FS, or O) was randomly assigned a set of three combinations, which provided one of each kind of representations. For instance, a participant in MS group assigned IT_S, Med_T, and Fin_C, meaning IT domain with sentential representation (IT_S), Medical domain with tabular representation (Med_T), and Financial domain with conceptual representation (Fin_C). In total, there were 36 sets which were prepared as the 36 questionnaires (illustrated in Table 8-9).

Table 8-3 The ILOs' sentential representation for IT domain (IT_S)

ILO_1: Describe the issues involved in developing a web interface. ILO_2: Summarise the need and issues involved in website implementation and integration. ILO_3: Explain the importance of interfacing websites with underlying databases. ILO_4: Explain why accessibility issues are an important consideration in web page development. ILO_5: List some of the organisations that have developed standards for web accessibility. ILO_6: Change a web interface. ILO_7: Integrate a website with another IT application. ILO_8: Create a web front-end to an underlying database. ILO_9: Design a website that meets the standards set.

Table 8-4 The ILOs' sentential representation for Medical domain (MED_S)

ILO_1: Formulate action plan to characterise the problem to reach a diagnosis. ILO_2: Undertake a range of procedures on a patient for diagnostic or therapeutic purposes. ILO_3: Arrange appropriate investigations for a patient. ILO_4: Identify appropriate treatment for the patient and to deliver this personally or to refer patient to the appropriate colleague for treatment. ILO_5: Recognize threats to the health of individuals or communities at risk. ILO_6: Communicate effectively with patients, relatives of patients, the public and colleagues. ILO_7: Analyse information using a range of methods including computers. ILO_8: Justify the basic, clinical and social sciences that underpin the practice of medicine. ILO_9: Adopt appropriate attitudes, ethical behaviour and legal approaches to the practice of medicine. ILO_{10}: Apply clinical judgement and evidence-based medicine to the practice. ILO_{11}: Recognise the healthcare system and the roles of other professionals within the system. ILO_{12}: Improve personal and professional development including personal health and career development.

Table 8-5 The ILOs' sentential representation for Financial domain (FIN_S)

ILO_1: Describe the role of information technology in solving business problems. ILO_2: Apply fundamental programming skills to typical business problems. ILO_3: Solve diverse and unstructured problems in unfamiliar settings. ILO_4: Work effectively with diverse groups of people. ILO_5: Possess a knowledge of the purpose and elements of financial statements. ILO_6: Recognise the fundamentals of accounting, auditing, and tax. ILO_7: Know methods of gathering, summarizing, and analyzing financial data. ILO_8: Clarify the economic, social, and cultural forces in the world. ILO_9: Examine how typical business organisations work and are managed.

Table 8-6 The ILOs' tabular representation for IT domain (IT_T)

ILO No.	Expression
ILO_1	Describe the issues involved in developing a web interface.
ILO_2	Summarise the need and issues involved in website implementation and integration.
ILO_3	Explain the importance of interfacing websites with underlying databases.
ILO_4	Explain why accessibility issues are an important consideration in web page development.
ILO_5	List some of the organisations that have developed standards for web accessibility.
ILO_6	Change a web interface.
ILO_7	Integrate a website with another IT application.
ILO_8	Create a web front-end to an underlying database.
ILO_9	Design a website that meets the standards set.

Table 8-7 The ILOs' tabular representation for Medical domain (MED_T)

ILO No.	Expression
ILO_1	Formulate action plan to characterise the problem to reach a diagnosis.
ILO_2	Undertake a range of procedures on a patient for diagnostic or therapeutic purposes.
ILO_3	Arrange appropriate investigations for a patient and interpret these.
ILO_4	Identify appropriate treatment for the patient and to deliver this personally or to refer the patient to the appropriate colleague for treatment.
ILO_5	Recognize threats to the health of individuals or communities at risk.

ILO_6	Communicate effectively with patients, relatives of patients, the public and colleagues.
ILO_7	Analyse information using a range of methods including computers.
ILO_8	Justify the basic, clinical and social sciences that underpin the practice of medicine.
ILO_9	Adopt appropriate attitudes, ethical behaviour and legal approaches to the practice of medicine.
ILO_{10}	Apply clinical judgment and evidence-based medicine to the practice.
ILO_{11}	Recognise the healthcare system and the roles of other professionals within the system.
ILO_{12}	Improve personal and professional development including personal health and career development.

Table 8-8 The ILOs' tabular representation for Financial domain (FIN_T)

ILO No.	**Expression**
ILO_1	Describe the role of information technology in solving business problems.
ILO_2	Apply fundamental programming skills to typical business problems.
ILO_3	Solve diverse and unstructured problems in unfamiliar settings.
ILO_4	Work effectively with diverse groups of people.
ILO_5	Possess a knowledge of the purpose and elements of financial statements.
ILO_6	Recognise the fundamentals of accounting, auditing, and tax.
ILO_7	Know methods of gathering, summarising, and analysing financial data.
ILO_8	Clarify the economic, social, and cultural forces in the world.
ILO_9	Examine how typical business organisations work and are managed.

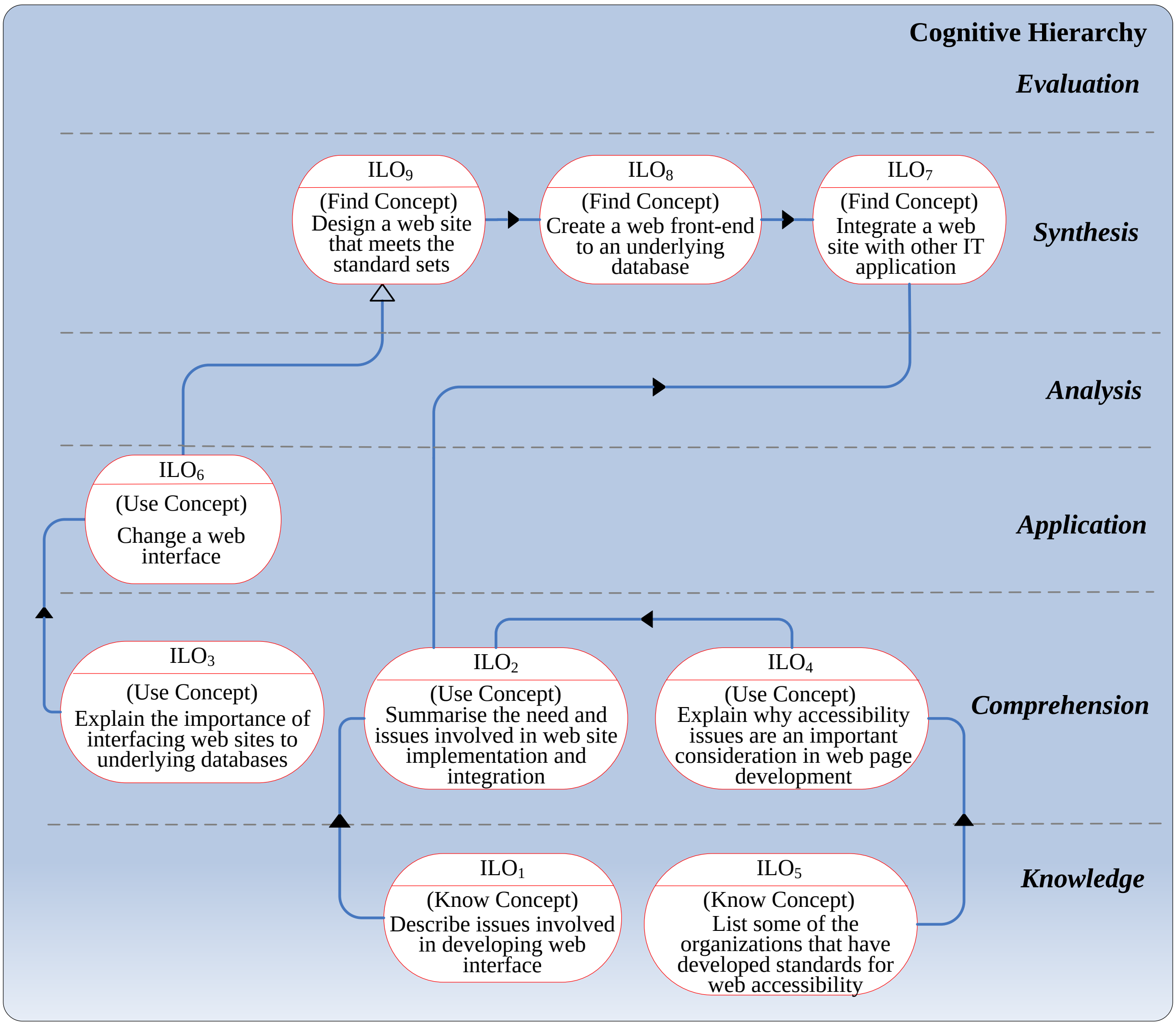


Figure 8-1 The ILOs' conceptual representation for IT domain (IT_C)

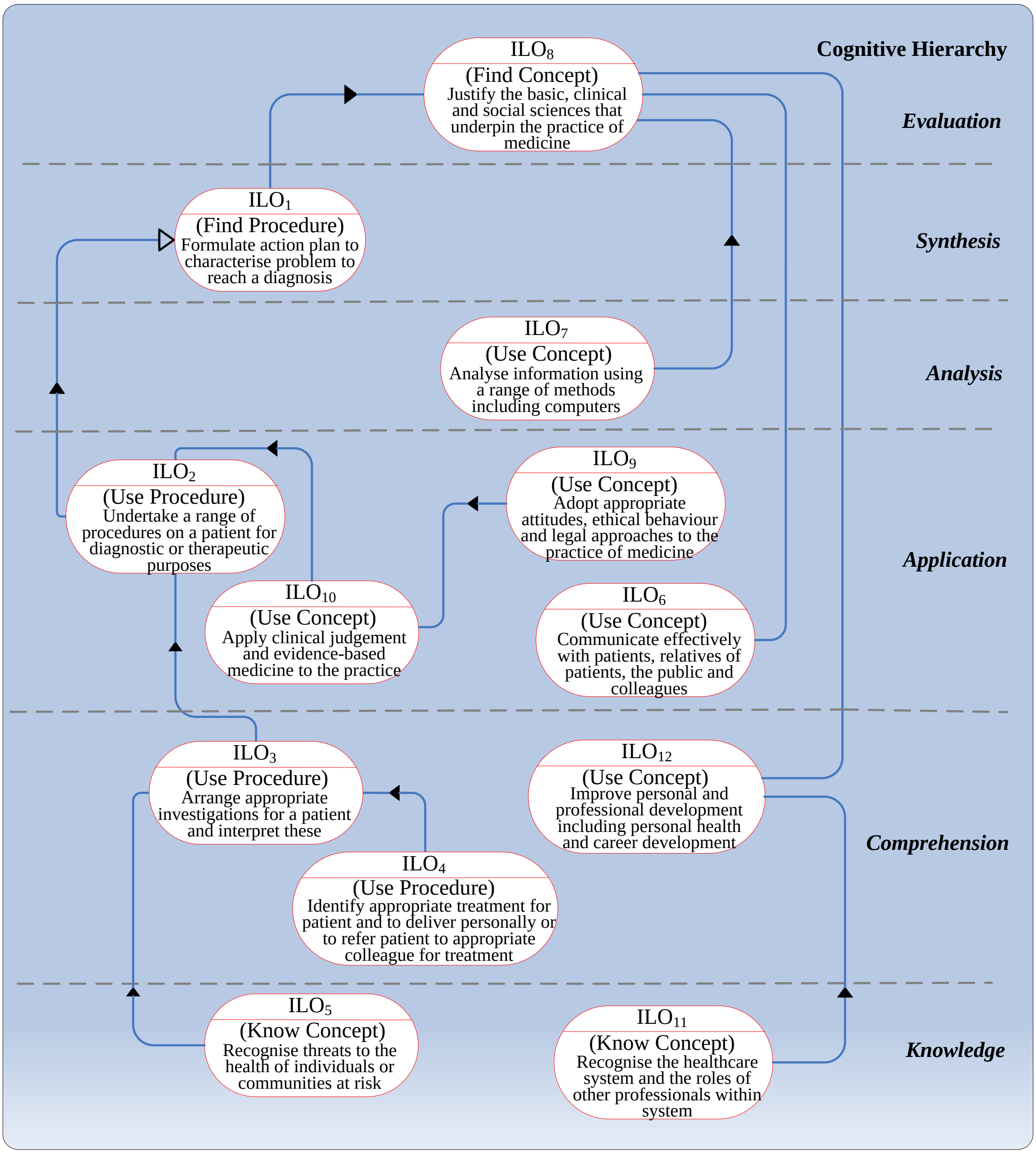


Figure 8-2 The ILOs' conceptual representation for Medical domain (MED_C)

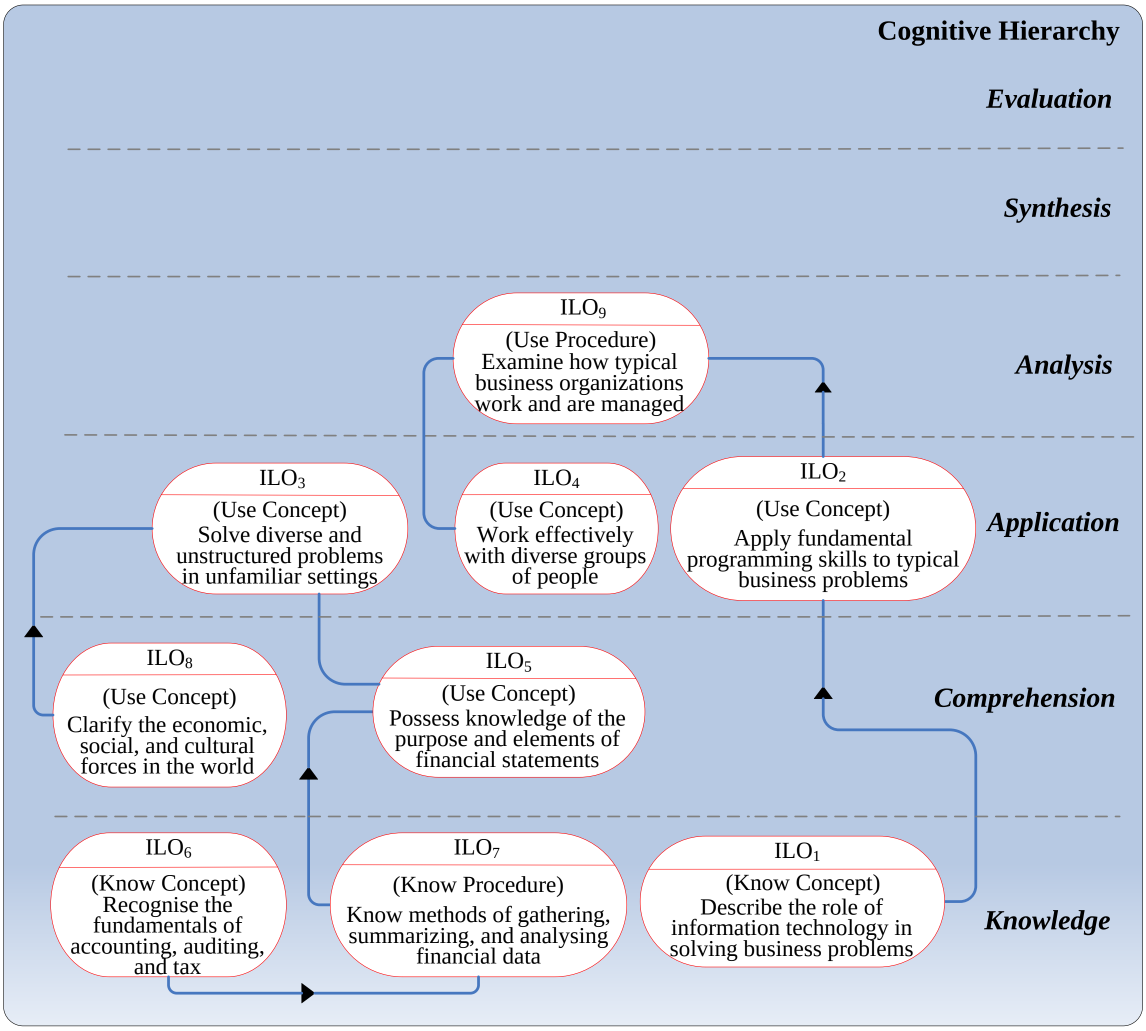


Figure 8-3 The ILOs' conceptual representation for Financial domain (FIN_C)

Table 8-9 Combinations of the ILOs representations

Pattern No.	**Combinations**		
1.	IT_S	Med_C	Fin_T
2.	IT_T	Med_S	Fin_C
3.	IT_C	Med_T	Fin_S
4.	IT_S	Med_T	Fin_C
5.	IT_T	Med_C	Fin_S
6.	IT_C	Med_S	Fin_T
7.	IT_S	Fin_C	Med_T
8.	IT _T	Fin _S	Med _C
9.	IT_C	Fin _T	Med _S
10.	IT_S	Fin _T	Med _C
11.	IT _T	Fin _C	Med _S
12.	IT_C	Fin _S	Med _T
13.	Med_S	Fin_C	IT_T
14.	Med _T	Fin _S	IT_C

15.	Med _C	Fin _T	IT_S
16.	Med _S	Fin _T	IT_C
17.	Med _T	Fin _C	IT_S
18.	Med _C	Fin _S	IT_T
19.	Med_S	IT_C	Fin_T
20.	Med _T	IT _S	Fin _C
21.	Med _C	IT _T	Fin _S
22.	Med _S	IT _T	Fin_C
23.	Med _T	IT _C	Fin_S
24.	Med _C	IT _S	Fin _T
25.	Fin_S	Med_C	IT_T
26.	Fin_T	Med_S	IT_C
27.	Fin_C	Med_T	IT_S
28.	Fin_S	Med_T	IT_C
29.	Fin_T	Med_C	IT_S
30.	Fin_C	Med_S	IT_T
31.	Fin_S	IT_C	Med_T
32.	Fin_T	IT _S	Med_C
33.	Fin_C	IT _T	Med_S
34.	Fin_S	IT _T	Med_C
35.	Fin_T	IT _C	Med_S
36.	Fin_C	IT _S	Med_T

In each set, each ILO representation has the tests enclosed with three questions (overall nine questions for each set shown in Table 8-10) and the questions for all 36 questionnaires were similar. The questions focused on how participants can understand and choose the suitable ILO that addresses the problem or relates to the question. Additionally, an example of the full survey questionnaire for the combination number 1 (IT_S, Med_C, Fin_T) was illustrated in the Appendix B.3.

Table 8-10 Nine questions for a combination of three ILO representations

ILO representation	**Questions**
IT_S, IT_T, IT_C (Information Technology)	1. In order to merge the web with other applications, which ILO do you need to be able to achieve? 2. While you are engaged in designing the website, which ILO do you need to be able to achieve in order to relate to the standard sets of organisation? 3. If you want to know the issues of web development, which ILO do you need to be able to achieve?
Med_S, Med_T, Med_C (Medical and Health	4. In order to remember the threats or risk to individuals' health, which ILO do you need to be able to achieve? 5. While you are in the stage of diagnosing the medical condition, which ILO do you need to achieve in order to inform the patient about the treatment methods to be used?

Science)	6. Which ILO can be the prerequisite competency for ILO2 (undertake a range of procedures on patient for diagnostic or therapeutic purposes)?
Fin_S, Fin_T, Fin_C (Financial and Accounting)	7. In order to deal with many people in an organisation, which ILO do you have to achieve? 8. Which ILO do you have to be able to achieve before solving diverse and unstructured problems in unfamiliar settings (ILO3)? 9. If you are a new financial student, which ILO is the most difficult to achieve?

All participants were given information to clarify their understanding of the terms and definitions used in the study. They were required to read the instructions on completing the questionnaire. After that, for each subject domain (i.e., IT domain, Medical domain, or Financial domain) participants were required to indicate the time spent in answering the questions, by recording the starting time. After that they were asked to answer the three survey questions for each ILO representation (shown in Table 8-10). In order to answer these questions, they had to refer to the ILOs of each representational style and they could choose an ILO number that suitably addressed the questions. After completing three questions of each subject domain, they were asked to indicate the stopping time. This time spent on each domain was used to indicate the understandability time (described in the section 8.5.1). Finally, when the three subject domains were completely answered, participants were required to rate their degree of understandability for the ILOs' representational style and provided the demographic information. An example of the full survey questionnaire of the combination no.1 (IT_S, Med_C, Fin_T) is shown in Appendix B.3.

8.4 Experimental Variables

The independent variables were the three ILOs representational styles, namely, sentential representation (list of ILOs), tabular representation (rows and columns of ILOs), and conceptual representation (ILO diagram). The dependent variables were the understandability of the ILOs representations which are the understandability efficiency (UEffic), and the overall ratings of perceived understandability (PU). These two variables will be discussed in the next section.

8.5 Measurement

The measurement used in this study was the understandability of the ILOs' representations covering two main categories: objective and subjective measurements. The details of each category can be described as follows:

8.5.1 Objective Measurement

The objective measurement of understandability was measured by assessing the participants' performance in addressing the experiment questions. After a participant completed the survey questions, the three variables of objective measurement, namely, understandability time (UT), understandability effectiveness (UEffec), and understandability efficiency (UEffic), were calculated. These three variables were defined by using the performance-based measurement adopted from Genero et al. (2008). Table 8-11 shows these three variables with the definitions.

Table 8-11 Three variables of objective criteria (Genero et al., 2008)

Variables	Definition
Understandability Time (UT)	The time needed to understand the ILO representations (expressed in minutes).
Understandability Effectiveness (UEffec)	The number of correct answers reflects how well the participants performed the required understandability tasks.
Understandability Efficiency (UEffic)	The number of correct answers (UEffec) divided by time (UT) relates the understanding performance of the participants to their effort (in terms of time spent).

For example, the survey questions of IT domain with the conceptual representation (IT_C) were "Q1) In order to merge the website to other applications, which ILO do you need to be able to achieve?", "Q2) While you are engaged in designing the website, which ILO do you need to achieve in order to relate to the standard sets of organisation?", and "Q3) If you want to know the issues of web development, which ILO do you need to achieve?". As the results, after a participant completed these three questions, the time spent was 4.32 minutes (UT=4.32) and the number of correct answers was 2 (UEffec=2). Thus, the understandability efficiency was 0.46 (UEffic=0.46).

Although there were three variables of the objective measurement, the main dependent variable used in this study was the understandability efficiency (UEffic) calculated as UEffec divided by UT.

8.5.2 Subjective Measurement

The second dependent variable was the perceived understandability (PU) which measured the subjective satisfaction rated by participants in order to understand the ILO representational styles. Overall ratings of perceived understandability were used to measure the participants' understanding of how difficult or easy they rate their understanding of the ILOs representations according to five rating scales ("very difficult to understand" to "very easy to understand"), illustrated in Table 8-12.

Table 8-12 Five rating scale for perceived understandability (PU)

Very difficult to understand	A bit difficult to understand	Neither difficult nor easy to understand	Quite easy to understand	Very easy to understand
Value=1	Value=2	Value=3	Value=4	Value=5

To conclude, the three ILOs' representational styles (i.e., sentential, tabular, and conceptual representations) were evaluated using the two understandability metrics (i.e., UEffic and PU).

8.6 Experiment Results

In the previous section, although there were three variables of the objective measurement (i.e., UT, UEffec, and UEffic), the main dependent variable used in this study was the UEffic calculated as UEffec divided by UT. Thus, the two main understandability metrics used to analyse the experiment results were the UEffic and PU. First, the UEffic variable was used to analyse the results as the objective measurement. Second, the PU was the subjective measurement rated by participants in order to understand the ILOs' representational styles. The statistical analysis of this study is presented and summarised as follows:

8.6.1 Analysis of Understandability

Table 8-13 presents the descriptive statistics of all variables.

Table 8-13 Mean and standard deviation of all variables

Representation		**Objective**			**Subjective**
		UT	**UEffec**	**UEffic**	**PU**
Sentential	Mean	3.142	1.060	0.386	2.46
	N	48	48	48	48
	Std. Deviation	1.325	0.836	0.391	0.944
	Std. Error of Mean	0.191	0.121	0.056	0.136
Tabular	Mean	3.680	1.270	0.440	3.27
	N	48	48	48	48
	Std. Deviation	1.525	0.818	0.389	1.067
	Std. Error of Mean	0.220	0.118	0.056	0.154
Conceptual	Mean	3.341	1.540	0.601	3.96
	N	48	48	48	48
	Std. Deviation	1.955	0.849	0.529	1.051
	Std. Error of Mean	0.282	0.123	0.076	0.152

Repeated measures MANOVA was used to analyse the data obtained from 48 participants. The two understandability metrics, namely, understandability efficiency (UEffic) and perceived understandability (PU) were analysed. Table 8-14 and Table 8-15 show the results.

Table 8-14 Repeated measure MANOVA - multivariate tests

Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Representation	Pillai's Trace	0.275	10.741	4	270	0.001
	Roy's Largest Root	0.374	25.252	2	135	0.001
Domain	Pillai's Trace	0.046	1.586	4	270	0.178
	Roy's Largest Root	0.048	3.247	2	135	0.042
Representation * Domain	Pillai's Trace	0.016	0.265	8	270	0.977
	Roy's Largest Root	0.012	0.412	4	135	0.800

From Table 8-14, the results revealed that the interaction of ILOs' representation and subject domain was not significant (Pillai's Trace=0.016, F=0.265, df=8, 270, p=0.977; Roy's Largest Root=0.012, F=0.412, df=4, 135, p=0.8). There was a significant difference in the mean understandability for the representation (Pillai's Trace=0.275, F=10.741, df=4, 270, p=0.001).

Table 8-15 Univariate tests of effects

Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.
Representation	UEffic	1.229	2	0.615	3.193	0.044
	PU	53.857	2	26.929	24.892	0.001
Domain	UEffic	1.238	2	0.619	3.216	0.043
	PU	0.131	2	0.066	0.061	0.941
Representation * Domain	UEffic	0.256	4	0.064	0.333	0.856
	PU	1.146	4	0.287	0.265	0.900
Error	UEffic	25.986	135	0.192		
	PU	146.047	135	1.082		

From Table 8-15, the results suggested that there were significant differences in the mean understandability for representation for both UEffic ($p=0.044 < 0.05$) and PU ($p=0.001 < 0.05$).

8.6.2 Analysis of Multiple Comparisons of ILOs Representations

We analysed multiple comparisons of the three ILOs representation styles (i.e., sentential, tabular, and conceptual representations) using the Tukey's HSD Post-Hoc tests as depicted in Table 8-16.

Table 8-16 Post-hoc test (TUKEY'S HSD) of multiple comparisons of representations

Dependent variable	(I) Representation	(J) Representation	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
						Lower bound	Upper bound
UEffic	Tabular	Sentential	0.054	0.089	0.819	-0.158	0.266
	Conceptual	Sentential	0.214	0.089	0.047	0.002	0.426
	Conceptual	Tabular	0.160	0.089	0.176	-0.051	0.372
PU	Tabular	Sentential	0.810	0.212	0.001	0.310	1.320
	Conceptual	Sentential	1.500	0.212	0.001	1.000	2.000
	Conceptual	Tabular	0.690	0.212	0.004	0.180	1.190

The results were as follows:

1. There was a significant difference between the mean score of Understandability Efficiency (UEffic) for the conceptual representation and the sentential representation ($p=0.047 < 0.05$).

2. There was a significant difference between the mean ratings of Perceived Understandability (PU) for the tabular representation and the sentential representation ($p=0.001 < 0.05$)

3. There was a significant difference between the mean ratings of Perceived Understandability (PU) for the conceptual representation and the sentential representation ($p=0.001 < 0.05$).

4. There was a significant difference between the mean ratings of Perceived Understandability (PU) for the conceptual representation and the tabular representation ($p=0.004 < 0.05$).

These results are illustrated in Figure 8-4 and Figure 8-5.

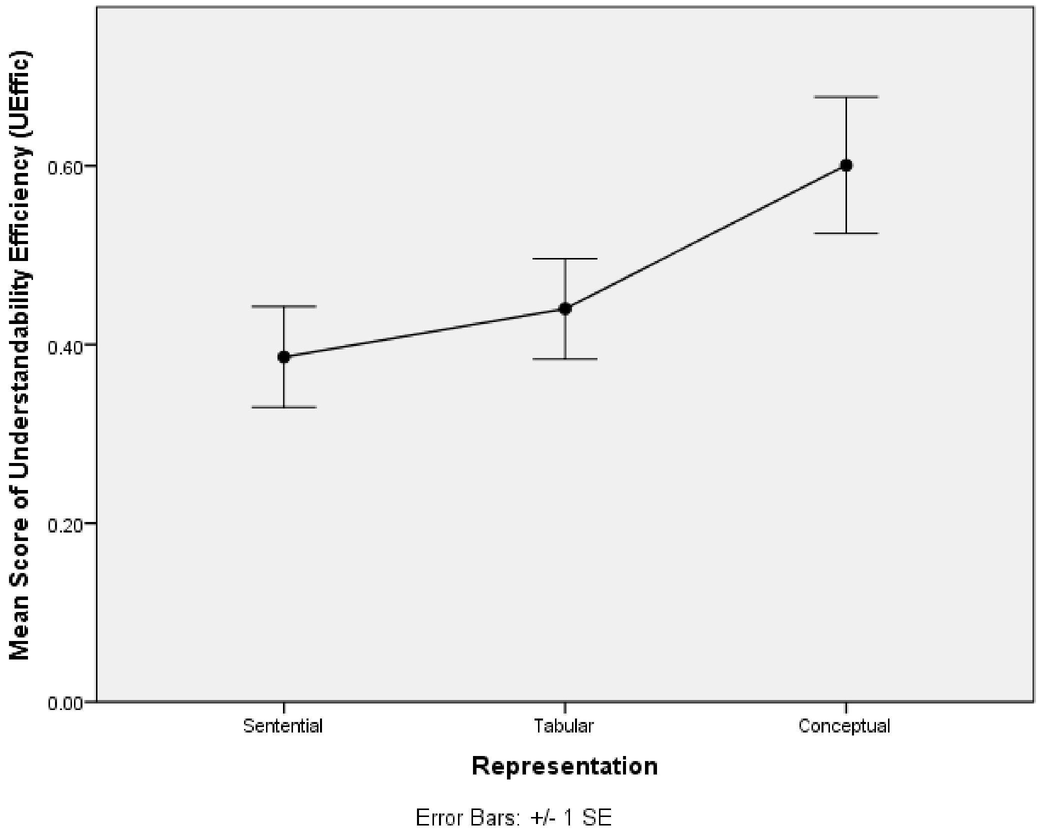


Figure 8-4 Profile graph for mean score of Understandability Efficiency (UEffic) across representational styles

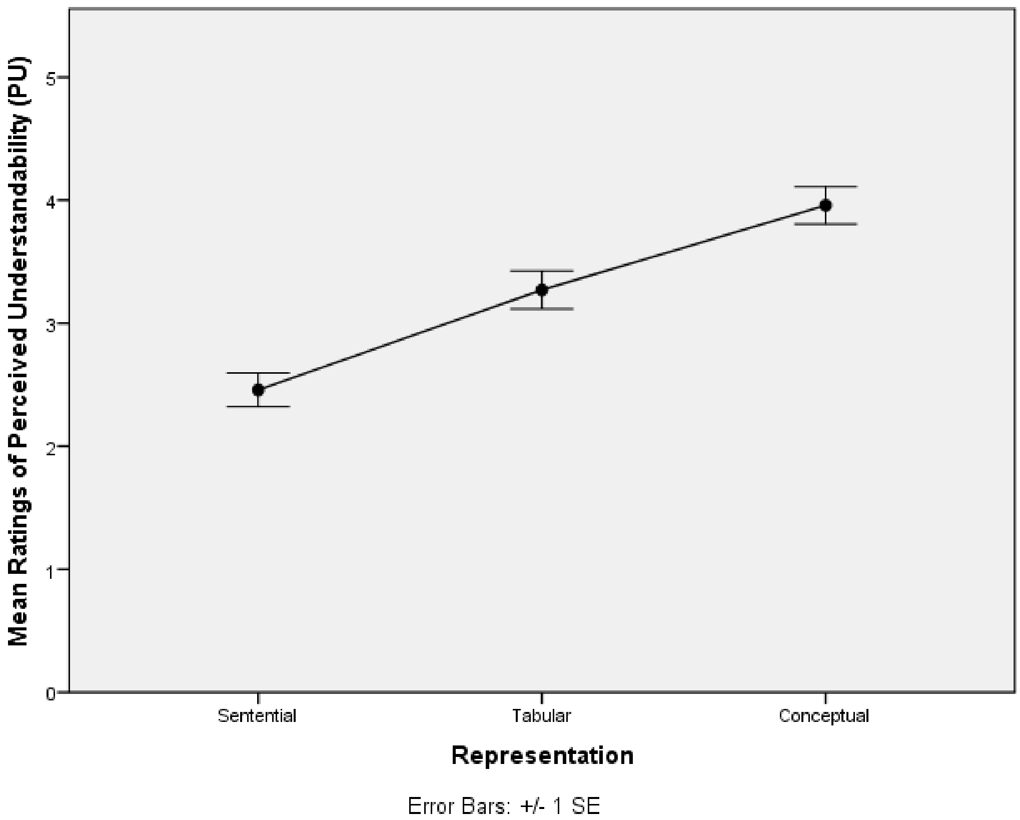


Figure 8-5 Profile graph for mean ratings of Perceived Understandability (PU) across representational styles

8.6.3 Analysis of Multiple Comparisons of Subject Domains

From Table 8-14, there was no significant difference in the mean understandability for the subject domain (Pillai's Trace=0.046, F=1.586, df=4, 270, p=0.178). The Tukey's HSD post-hoc tests of the multiple comparisons of all subject domains have been analysed and illustrated in Table 8-17.

Table 8-17 Post-hoc test (TUKEY'S HSD) of multiple comparisons of subject domains

Dependent variable	(I) Domain	(J) Domain	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
						Lower bound	Upper bound
UEffic	IT	Medical	0.214	0.089	0.047	0.001	0.426
	IT	Financial	0.161	0.089	0.174	-0.051	0.373
	Financial	Medical	0.053	0.089	0.824	-0.159	0.265
PU	IT	Medical	0.020	0.212	0.995	-0.480	0.520
	IT	Financial	0.040	0.212	0.979	-0.460	0.540
	Financial	Medical	-0.020	0.212	0.995	-0.520	0.480

The results revealed that there was a statistically significantly difference between the mean score of understandability efficiency (UEffic) for solely one pair of the Information Technology (IT domain) and the Medical Education (Medical domain) ($p=0.047 < 0.05$). There were no significant differences in the mean score of understandability efficiency (UEffic) for other two pairs (i.e., IT domain and Financial domain, and Financial domain and Medical domain). In addition, there were no significant differences in the mean ratings of perceived understandability (PU) for all pairs of subject domains (i.e., IT domain and Medical domain, IT domain and Financial domain, and Financial domain and Medical domain).

These results are illustrated in Figure 8-6 and Figure 8-7.

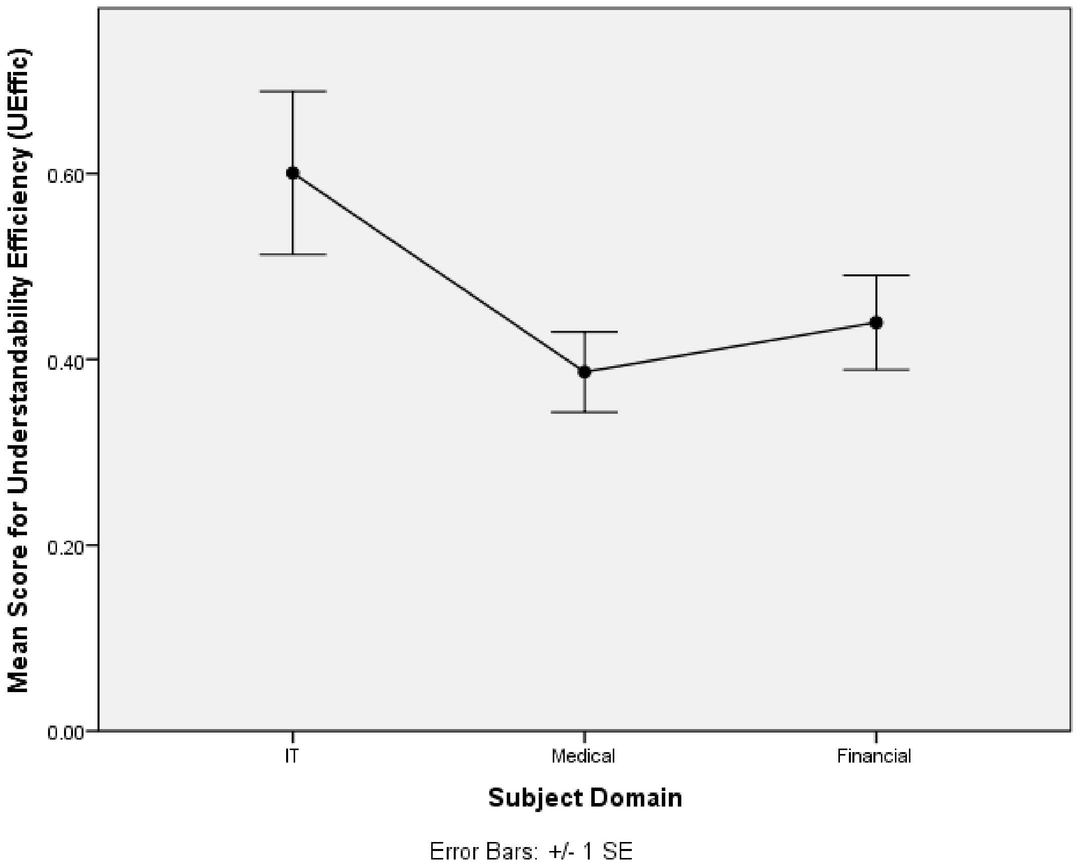


Figure 8-6 Profile graph for mean score of Understandability Efficiency (UEffic) for all subject domains

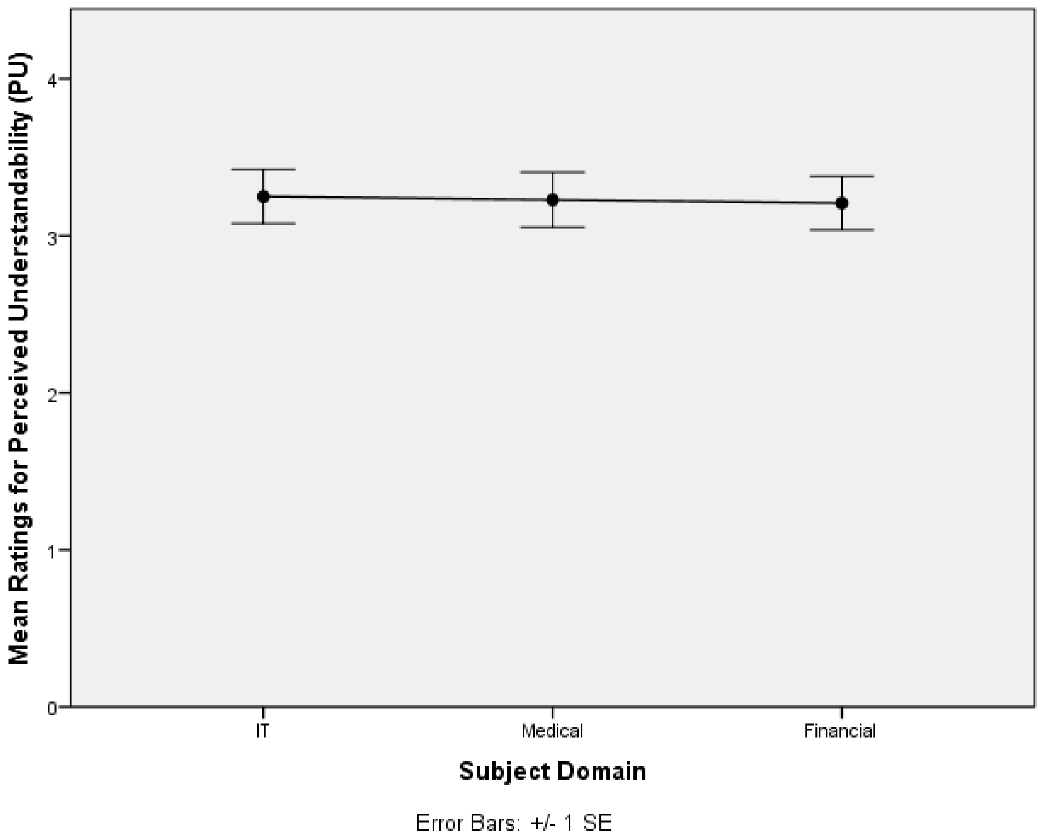


Figure 8-7 Profile graph for mean ratings of Perceived Understandability (PU) for all subject domains

8.7 Limitations of the Study

The complexity of ILO diagram defined in terms of the total number of ILO nodes should be taken into consideration. Although this study illustrated the ILOs' conceptual representation based on a standard sets of ILOs published by the three curriculum guidelines (Harden et al., 1999; Hartwell et al., 2000; Lunt et al., 2008) with limited number of ILOs, further studies that cover more ILOs should investigate how complicated diagrams can be demonstrated. In addition, this study investigated solely the understandability of the learners. Participants could be extended to other groups, such as, lecturers, researchers, instructional designers, and so on.

8.8 Summary

In this research, we proposed a novel conceptual model of intended learning outcomes called an ILO diagram. In this study, we investigated the conceptual understanding of an ILO diagram (called conceptual representation style) compared to the sentential and tabular representation styles. We showed how, from the learners' perspective, the conceptual information embodied in the ILO diagram can be better understood than the other two representation styles (i.e., sentential and tabular representations). The ILOs used in this study were prepared in three subject domains (i.e., information technology, medical education, and financial and management). The measurement was the understandability that is featured in both the objective and subjective criteria. The performance-based measurement was adopted to measure the objective understandability, whilst the learners' understandability rated by the participants in order to understand the ILOs representations was the subjective measurement. The experiment results revealed that the average mean of understandability for the conceptual representation was higher than for both sentential and tabular representations. These findings contend that the ILO diagram provides more understandability than the sentential and tabular representation styles of ILOs.

Chapter 9
Discussion

9.1 Introduction

The three experimental studies were conducted to investigate the instructors' satisfaction with using the ILOs as facilitators in teaching, the learners' ability to identify learning paths when referring to ILOs in self-regulated learning, and the learners' understandability of the ILOs' representational styles. The experimental results of these three studies are discussed and the general discussion is provided.

9.2 Experiment I

9.2.1 Discussion of Quantitative Results

The instructors' satisfaction under three categories (i.e., perceived usefulness, perceived ease of use, and attitude toward representing ILOs) was tested. The results showed that, in general, the structured ILO (conceptualised through the ILO diagram) met instructors' satisfaction with higher ratings of perceived usefulness, perceived ease of use, and attitude toward representing ILOs than the unstructured ILOs (expressed as plain-text document)

In particular, the Tukey HSD tests of multiple comparisons between groups (i.e., structured ILO and unstructured ILO) showed that the mean ratings for PU1 and PEOU1 which are "using the ILOs allows instructors to explain the learning objectives to learners more clearly" and "the ILOs are understandable to instructors", were not significantly different between the structured and unstructured ILOs. The reason might be that the notations of the ILO diagram were not precisely explained in the questionnaire. For example, "An ILO diagram needs a legend explaining what all boxes and arrows mean", said one of participants.

9.2.2 Discussion of Qualitative Results

The qualitative evaluation on the 5-point Likert-type scales revealed that the highest rating on the scale ("Strongly agree") was allocated to the structured ILOs for all questions in the three categories of criteria: PU, PEOU, and AT. On the other hand, there were only two lecturers who allocated the rating "Strongly agree" to unstructured ILOs. This meant that the needs of most lecturers who participated in this study were satisfied by the structured ILOs visualised though the proposed ILO diagram with higher rating scales for all three categories than by the plain-text document.

Taken as a whole, the study findings suggest that the diagrammatic formalism of ILOs can reasonably be used as the facilitator in performing teaching activities. For instance, instructors can refer to the ILO diagram while they plan the teaching activities for the specific subject matter content or, if instructors want to track the learners' ability to learn, they can match the current competency of the learner with the cognitive level of the ILO diagram and choose the suitable teaching activity to be performed, and so on.

9.3 Experiment II

9.3.1 Discussion of Quantitative Results

The learners' ability to identify the learning paths was tested. The experimental results revealed that the interaction of learning paths and groups (structured and unstructured ILOs) was not statistically significant. Therefore, the main effects were examined, where significant differences between learning paths and groups were found. The Tukey HSD tests of multiple comparisons of learning paths showed that the learning path 4 (LP4) represented a change of the learning topics and was therefore less complete than the other learning paths.

It should be noted that the LP4 was the first question of the new topic which was the change of the topics used in the study. The continuity in learning might be interrupted by the change of the first topic (Pascal's triangle calculation) to the second topic (Pascal's triangle patterns). It is likely that the discontinuity of learning topics was a reason why the learners' ability to become familiar with the subject matter was dropped when they participated in the different learning topics.

The findings show that expressing the ILOs of a specific course as plain text and visualising them through the ILO diagram yielded better (more complete) learning paths than unstructured ILO expressions. This suggests that learners benefit from the conceptual information in the ILO diagram in performing their self-regulated learning.

The findings of this study can have some important implications for instructional designers, instructors, or researchers who are interested in applying the conceptualisation of learning outcomes in academia. The findings confirm that the results are consistent with previous studies relating to the learning strategies in performing self-regulated learning, e.g., Ismail and Sharma (2012). However, the present study related to the direct influence of achievement goals by visualising the learning objectives through a novel conceptual model of intended learning outcomes (ILO diagram). The findings suggest that the conceptual information in the ILO diagram supports learners to initiate and indicate their learning paths in order to perform learning activities by themselves, because such learning paths were more complete when the ILO diagram was used.

Studies have found that graphical representation is an effective learning tool supporting learners' visual perception (Nokes and Ross, 2007; Postigo and Pozo, 2004; Vekiri, 2002). In this study, a graphical representation provided a well-defined structure of learning content augmented with a cognitive hierarchy. The results of this experimental study show that self-regulated learners can benefit from the proposed ILO diagram.

9.3.2 Discussion of Qualitative Results

For further analysis of the qualitative evaluation, the results of the four questions probing participants' understanding of the calculation of Pascal's triangle values and participants' ability to distinguish the three patterns of Pascal's triangle, were tested. The results revealed that 100 per cent of the total number of participants within the experimental group (participating in the structured ILOs) identified the correct answers to all four questions. However, only 10 per cent of the total number of participants in the control group (participating in the unstructured ILOs) could not provide the correct answers. This small proportion of incorrect responses (10 per cent) in the control group provided incorrect answers to two questions defining the two Pascal's triangle patterns, that is, the multiple-of-three pattern and the odd pattern. These results may be due to the different difficulties with Pascal's triangle patterns.

9.4 Experiment III

The learners' understandability of the three representational styles of ILOs was investigated. Across three subject domains, there was no significant difference between representational styles and subject domains. The findings of this study confirm that the understandability of conceptual representation visualised through the proposed ILO diagram was statistically significantly higher than the understandability of the tabular and sentential representations. The findings also show that there was no significant difference between the tabular and sentential representations. The results are consistent with many previous studies concerned with the learners' visual perception (Cheng, 1999; Keogh and Naylor, 1999; Nokes and Ross, 2007).

The Tukey HSD tests of multiple comparisons between three subject domains, namely, IT, medical, and financial, showed no significant differences in terms of the mean ratings of perceived understandability and understandability efficiency. Thus, the conceptual representation through the ILO diagram could be implemented for any domains, whose learning objectives (or learning outcomes) are traditionally expressed in the form of plain-text documents. Additionally, the design of conceptual representation using the proposed ILO diagram can facilitate instructional design (Gagné, 1985; Gustafson and Branch, 2002; Merrill, 1994), by allowing instructional designers to devise a logical structure of ILOs for any educational domains.

9.5 General Discussion

In this research, the logical structure of an ILO diagram was compared with the unordered list of plain-text ILOs that was prioritised, based on the original standard documents (see Appendix A). Although the ordered list of items may indicate some meaningful guidance, the present research focuses mainly on the structural representation and conceptualisation of ILOs. The comparative evaluation of the ordered and unordered lists was not the main consideration of the research. Thus, there was no experimental evidence to claim that the ILO diagram was superior to the unordered list of ILOs. However, further study on the ordered list of ILOs can be carried out in future work.

Overall, the three experimental studies were conducted to investigate satisfaction with, completeness, and understandability of the proposed ILO diagram. The findings of three experiments answer the research questions which are noted in sections 6.2, 7.2, and 8.2. The findings indicate that the proposed ILO diagram satisfied instructors' needs, visualising ILOs through the ILO diagram yielded better learning paths completeness than unstructured ILOs expressions, and the understandability of conceptual representation of the ILO diagram outperformed the traditional ILOs' representations for both sentential and tabular styles.

9.6 Summary

The present research contributes a conceptual model of intended learning outcomes using the diagrammatic technique of ILO diagram. The conceptualisation and conceptual information embodied in the ILO diagram were investigated in both instructors' and learners' perspectives. In teaching, using the ILO diagrams as facilitators meets instructors' satisfaction. In learning, providing ILO diagrams supports self-regulated learners to indicate their learning paths and visualising ILOs through the ILO diagrams is readily understandable.

Chapter 10

Summary, Contributions, and Future Work

This chapter summarises the report, reflecting the research objectives and the research questions. The research contributions are summarised and the research directions for the future work are discussed.

10.1 Summary

This report begins by introducing the overview of this research (in Chapter 1), followed by the theoretical background and related work (in Chapter 2). An equivalent architecture, knowledge exchange model, and matching model called CIMM (Constructivism and Instructivism Matching Model), are then introduced (in Chapter 3) to reflect the primary objective of this thesis that attempts to reconcile the theoretical basis of constructivism and instructivism. According to the conjecture introduced in this research, there is no clearly defined conceptual model for facilitating the instructional design process; nor is there any formal representation of the learning objectives that systematically illustrates the ILOs. Thus, the second objective of the research is to contribute a novel conceptual model of intended learning outcomes, called an *ILO diagram* (in Chapter 4). As part of the evaluation to reflect the third objective of the research, the methodology of the three experimental studies has been described (in Chapter 5) to investigate how the structured ILOs conceptualised through the proposed ILO diagram can contribute to both teaching and learning.

In the first experimental study (Chapter 6), the research aims to address the question: *Does the ILO diagram conceptualising the structured ILOs meet the instructors' satisfactions in performing the teaching activities?* Seventeen lecturers rated their satisfaction when referring to unstructured ILOs (plain-text document) and structured ILOs (ILO diagram). The instructors' satisfaction was measured by using a 5-point Likert-type scale (*strongly agree* to *strongly disagree*) under three categories of subjective criteria, namely, perceived usefulness: 3 questions; perceived ease of use: 3 questions; and attitude towards representing ILOs: 2 questions. The experiment results revealed that the structured ILOs format visualised through the proposed ILO diagram was rated as providing more satisfaction than the unstructured ILOs format expressed as plain-text document. The findings of this study contend that the ILO diagram met the instructors' satisfaction with higher ratings for all the three dependent variables than the plain-text document.

Chapter 7 recounts how the second experimental study was carried out to address the research question: *Does the ILO diagram conceptualising the structured ILOs facilitate learners' identification of their learning paths?* In this study, it was hypothesised that learners can benefit from the conceptualisation, especially in terms of their self-regulated learning in indicating the learning paths. This study investigated whether the ILOs of a specific course of study illustrated through the proposed ILO diagram (structured ILOs format) or expressed as traditional plain text (unstructured ILOs format) can facilitate learners to indicate the learning paths. Twenty-one postgraduate students performed self-regulated learning and formulated six learning paths. The formulation of learning paths and the completeness metrics used to measure the learning paths were defined and introduced in this study. The experiment results showed that visualising the ILOs through the ILO diagram yielded better learning paths. These findings show that the learners benefited from the conceptualisation of the ILO diagram in performing self-regulated learning to indicate their learning paths.

Finally, the last experimental study (in Chapter 8), was conducted to address the research question: *Do the learners understand the conceptual representation in an ILO diagram?* This study aimed to investigate whether learners can understand the conceptualisation of the ILOs through the proposed ILO diagram (conceptual representation) which is better than representing them as sentences (sentential representation) and rows and columns (tabular representation). The results from forty-eight postgraduate students showed that the mean understandability of the conceptual representation was statistically significantly higher than the mean understandability of both the sentential and the tabular representations.

Overall, this research introduces a conceptual model of intended learning outcomes called an ILO diagram. A formalism and diagrammatic technique formulate the traditional intended learning outcomes as a conceptual representation. Instructors and learners can benefit from the conceptual information embedded in the proposed ILO diagram in performing their pedagogical activities. The evaluation of this research shows that the proposed ILO diagram outperforms the traditional ILOs' representations. Furthermore, the experimental studies show how an ILO diagram can be used to facilitate the teaching and learning of both instructors and learners.

10.2 Contributions

This research advances the state-of-the-art curriculum development by proposing a novel conceptual model called an ILO diagram. The contributions of this research can be summarised as follows:

10.2.1 A Novel Conceptual Model

Conceptualising a logical structure of ILOs as a facilitator for supporting pedagogical activities, is the key contribution of this research. The outstanding feature of the proposed conceptual model is that a logical structure of ILOs of the specific course of study is augmented with the six levels of the cognitive hierarchy based on Bloom's taxonomy, forming the ILO diagram.

According to the experiments conducted in this research, the three experimental studies investigated:

1) Instructors' satisfaction with using the ILOs as facilitators in teaching;
2) Learners' ability to identify learning paths when referring to ILOs in learning;
3) Learners' understandability of the ILOs' representational styles.

The results of these three experimental studies revealed that conceptualising ILOs of the specific course of study through the proposed ILO diagram is readily satisfied by instructors (Experiment I) and understandable by learners (Experiment II and III). In the first experiment, the finding shows that the proposed approach envisages the ILOs that support instructors in performing the teaching activities. In the second experiment, the conceptual information embodied in the ILO diagram supports learners in initiating and indicating their learning paths to perform learning activities by themselves. The research confirms that the conceptualisation of ILOs can be used as facilitators supporting learners' visual perception. Learners can benefit from the well-defined structure of ILOs that visualises the entire set of ILOs and learning content to perform their self-regulated learning. Finally, in the third experiment, the conceptual representation using the proposed ILO diagram outperforms the traditional representations of ILOs. The results of the third experimental study revealed that the ILO diagram was more understandable than either expressing the list of ILOs as plain text or using the rows and columns of ILOs. The research confirms that the ILO diagram is readily understood by means of learners' perspective.

10.2.2 Challenges to Conceptual Modelling

In this research, there are four main challenges to designing a conceptual model for curriculum development. The *first* challenge is the conceptualisation of intended learning outcomes. Traditionally, all the ILOs of a specific course of study are expressed as plain text or unstructured documents. Learning by referring to unstructured ILOs may lead to an inability to understand the whole structure of the course content and learning materials. Thus, this research proposes a logical structure of ILOs by using a diagrammatic technique as a tool for supporting curriculum development and for facilitating pedagogical activities.

The *second* challenge is the design and development of a logical structure of intended learning outcomes, in which the subject matter and their relationships are integrated with the capabilities to be learned. The state-of-the-art of the proposed conceptual model is that a logical structure of intended learning outcomes is augmented with the six levels of the cognitive hierarchy based on Bloom's taxonomy.

The *third* challenge is the novelty of a conceptual model in educational communities. Currently, in instructional design and curriculum development, there is no conceptual model that systematically supports instructional designers, instructors, and educators in designing and developing learning modules, courses of study, or curriculums. Thus, the research contributes a novel conceptual model for supporting curriculum development.

Finally, the *fourth* challenge deals primarily with the implementation of an outcomes-based learning approach to be established in higher education. The proposed approach could shed some light on the idea of how to initiate and design the learner-centric educational activities, as well as sparking some motivations to explicitly introduce and apply learning outcomes in academia.

10.2.3 Enabling ILOs as Prerequisite Skills

The outstanding feature of the proposed ILO diagram is that the value of the diagram is given when ILOs which enable a higher level ILOs are identified, called *enabling ILOs*. These higher (or lower) level ILOs have been organised into six levels of cognitive hierarchy. The ILO diagram breaks down the learners' learned capabilities into enabling ILOs through the LCV mapping mechanism (see Figure 4-3).

Furthermore, the enabling ILOs represent the prerequisite skills involved before the mastery of subject matter (or performance) can be achieved. Hence, both subject matter and learned capabilities are modelled and formulated explicitly in the logical structure of the ILOs.

10.2.4 Facilitator for Instructional Design Processes

While instructional designers typically follow the ADDIE model in the instructional design process (described in section 2.7), they can refer to the proposed ILO diagram to facilitate all processes, as summarised in the following table:

Table 10-1 The summary of the ILO diagram contributions for all processes of the ADDIE model

ADDIE process	ILO diagram contributions
Analysis	The ILO diagram facilitates the analysis of educational goals, educational strategies, learning materials, and assessment methods.
Design	• All SMC elements of the ILO diagram provide learning materials, so that instructional designers can refer to them when designing the instructional products. • All LCV elements of the ILO diagram provide the learned capabilities (or action verbs), so that instructional designers can refer to them when designing the learning activities. • All ILO relationships provide the hierarchical structure of the ILOs, so that instructional designers can refer to them when designing the learning paths. • Each type of ILO relationship provides the logical link between two ILO nodes, so that instructional designers can refer to it in order to improve their design of the example or case study. For example, the inheritance relationship is represented when Data Mart is a kind of Data Warehouse, so when Data Warehouse is taught, Data Mart should be explained as an example. • The ILO diagram represents all the ILOs of the course, so that instructional designers can refer to them when designing the learner assessments (i.e., questions, tests, quiz, or other assessment methods).

Development	During the development process, using the ILO diagram as the conceptual model facilitates the way instructional designers systematically create and initiate study courses.
Implementation	The ILO diagram provides the logical ILO structure which supports instructors and learners with executing the learning materials in the learning environment. This means that the ILO diagram can be used to assist both instructors and learners as a facilitator to envision the learning contents.
Evaluation	The ILO diagram illustrates all subject matters, together with the learned capabilities, to support instructional designers and instructors in evaluating both the formative and the summative assessment processes. This means that using the ILO diagram as a facilitator to determine the mastery of subject matter according to the learned capabilities leads to having better judgement and evaluation criteria.

10.2.5 Formulation of Learning Paths and Completeness Metrics

As discussed in section 7.5, the research contributes the learning paths (*LP*) that can be extracted from the ILO diagram using the proposed mathematical formulation. In addition, the learning paths can be measured according to the two completeness metrics. The former is the completeness of edge (C^e) which is an accuracy index of a given edge for an order pair of two ILO nodes. The later is the completeness of learning paths (C^{lp}) which is the accuracy index that summarises the total value of C^e for a given sequence of ILO nodes. These completeness metrics are to measure the learners' performance in indicating the learning paths. The mathematical formulation and the definitions introduced in this research contribute some important implications for educators, instructors, researchers, and instructional designers who are interested in developing the learning paths (or learning directions) in curriculum development.

10.2.6 An Equivalent Approach of Constructivism and Instructivism

The research contributes an equivalent architecture that bridges the gap between constructivist and instructivist perspectives using intended learning outcomes (as discussed in chapter 3). The balancing between these two different perspectives has been proposed through the matching model called the CIMM. Four layers of the CIMM model, namely, goal, knowledge, activity, and ILO, are introduced to epitomise the educational objectives. The ILO layer plays a crucial role in this research as the matching layer of the model. The research introduces an outcome-based learning expression through the ILO that represents the educational objective expressing what learners will be able to do by the end of the course of study. Besides the instructivist and constructivist perspectives, learners and instructors share the same educational objective and the research has proposed the ILO as mediator to balance between constructivism and instructivism.

10.3 Future Work

There are a number of research directions in which this work could be extended. We believe that the novel ILO diagram introduced in this research can contribute the state-of-the-art conceptual model in educational communities universally, if some issues could be explored further. Thus, the future research work could be extended in the following directions:

10.3.1 Applying the Proposed Approach in the Real Education System

According to some limitations of the research reported in this thesis (discussed in sections 6.8, 7.8, and 8.7), we believe that there is much research remaining to be done in the domain of conceptual modelling that addresses these limitations. In all the experimental studies of this research, the learning modules and the chosen ILOs were selected from the existing standard documents of the specific curriculum or the published curriculum guidelines. Successful deployment of the proposed approach in real education system would require the demonstration of how ILO diagram can be utilised as the facilitator in curriculum development process. The proposed approach could be investigated in future by instructional designers designing their logical model in the form of ILO diagram.

In practice this may be not applicable to some institutions that have their own strategies for developing courses of study. Even though the education missions of some institutions may not apply the learning outcomes in higher education yet, the proposed approach can be initiated in all areas of education where the improvement of learners' performance is the main consideration within the relevant master plans. An approach of learning outcomes could first propose to academia in order to introduce the fundamental concept of how to establish the outcomes-based education in institution. Then, the proposed ILO diagram could determine to build up as the blue-print in the curriculum development process within the institution.

10.3.2 Extending the Proposed Approach in Business Organisations

It should be noted that the proposed approach can be implemented not only in higher education, but also in all organisations or businesses that have the human resource management (HRM or HR) and provide the training courses (or HR practices) to increase the employees’ competency development. Thus, if the proposed approach can be extended for implementation in either the education system or the training modules in business organisations, then it can potentially support all stakeholders in both academia and business organisations who promote the improvement of human performance or competency development.

Future work would focus on application and integration of the proposed approach in the competency development within the business organisations, such as, applying the ILO diagram in the design of the training courses, or using the suggested learning paths in the HR planning process.

10.3.3 Considering Time Consumption in the Conceptual Modelling Process

In this research, the evaluation of the proposed approach was mainly concerned with how ILO diagram can contribute to both learning and teaching as a facilitating support to instructors and learners in their performance of the teaching and learning activities entailed in the courses. Although time consumption is a major factor in many systems (Bolloju, Purao, and Tan, 2012) (e.g., software development in Information System and Software Engineering, or curriculum development in education), the primary step whereby the proposed ILO diagram can promote the novelty of a new conceptual model in teaching and learning, is elaborated in this thesis.

In all the experimental studies conducted in this research, the time spent during the design and development process of the ILO diagrams (called design-time) was not a matter of concern. Thus, the future work could determine the design-time when the ILO diagrams will be applied in the real education system. Future work would then investigate further for the design-time when developing the ILO diagrams with different complexity level of the ILOs defined in terms of the total number of ILOs' nodes.

10.3.4 Considering the Assessment of Learners' Attainment

In section 2.2.1, in order to complete the constructive alignment (Biggs, 2003), the three processes had to be determined, namely, defining the complete set of intended learning outcomes, choosing the suitable teaching and learning activities, and performing the assessment tasks to measure the learners' attainment. In this research, the first two processes are primarily concerned with the proposed approach. However, this research does not cover the learners' attainment because the proposed approach deals with the initial design and development of the courses of study through the conceptual model of intended learning outcomes. Thus, the research direction that could be considered for extension of this work is that of assessing the learners' attainment after performing the learning tasks in both formative and summative assessment.

For example, lecturers use the ILO diagrams as facilitators to determine a logical structure of intended learning outcomes in course modules and to assess the learners' attainment, so that they will align with pedagogical activities and with assessment tasks.

10.3.5 Mapping the ILO Diagram into Machine Processable Format

The ILO diagram plays a crucial role as the conceptual model for the curriculum development in the same fashion as the entity relationship diagram (ERD) does for the software development (reviewed in section 2.8.3). This means that the ILO nodes are represented as the data entities of ERD and the ILO relationships are represented as the data relationships of ERD. Thus, the ILO diagram could be mapped into the physical model in order to exemplify that it can be implemented in the computer system.

The future work could investigate further that the physical model of the ILO diagram could be formulated through the mapping mechanism transforming the conceptual model (ILO diagram) into the physical level (called *ILO schema* or *ILO machine processable format)*. Specifically, the physical level represents the physical storage considerations. It needs to analyse the ILOs' representation format with the suitable database format that would be recorded in the ILO database through the database management system.

Thus, the educational system, especially e-learning system, would benefit from the generated ILOs' schema to build up the automatically generating learning paths and feedbacks. The effective learning paths suggested through the computer system can deliver learning directions that help self-regulated learners and the effective feedbacks provide learners with self-correction in assessment tasks.

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Appendix A
The List of Intended Learning Outcomes

This appendix details all intended learning outcomes (ILOs) that were used in the three experimental studies. The set of ILOs for each experimental study has referred to the existing standard documents. The first experiment used the 23 ILOs according to the ACM Computing Curriculum standardised by the ACM Special Interest Group on IT Education (SIGITE) (Ekstrom et al., 2006). The second experiment used 14 ILOs from the two curriculum documents, namely, the National Curriculum for England, Key Stages 1-4 (HMSO-QCA, 1999) and the Michigan Curriculum Framework (Michigan-GOV, n.d.). Finally, the last experiment used 9 ILOs from the Curriculum Guidelines for undergraduate degree programmes in Information Technology published by the ACM and IEEE computer society (Lunt et al., 2008), 12 ILOs from the AMEE Guide No.25 for Medical Training Programme (Shumway and Harden, 2003), and 9 ILOs from the Curriculum Structure for Accountancy and Financial Management (Hartwell et al., 2000). The details are listed as follows:

A.1: The ILOs of Data Modelling Module (IM4) for IT Programme (Ekstrom et al., 2006)

Topics:

- Conceptual models
    - Entity relationship diagrams
    - Enhanced entity relationship diagrams
    - Identification of business rules
- Logical models
- Physical models
- Reengineering of databases
- Standardised Modelling in IDEF1, UML
    - Patterns and standard models
- CASE tools

Meta-modelling

Data integration

Data warehouse

Data marts

Core intended learning outcomes:

1. Interpret entity-relationship diagrams.
2. Design a simple entity-relationship diagram.
3. Interpret enhanced entity-relationship diagrams.
4. Identify business rules.
5. Describe a logical model.
6. Describe a physical model.
7. Identify patterns and UML standard models.
8. Demonstrate an understanding of CASE tools, their usage and application.
9. Describe data integration.
10. Describe meta-modelling.
11. Describe a data warehouse, and its basic structure.

Elective intended learning outcomes:

1. Create entity-relationship diagrams.
2. Create enhanced entity-relationship diagrams.
3. Formulate identification of business rules.
4. Evaluate a logical model.
5. Evaluate a physical model.
6. Demonstrate how to reengineer databases.
7. Compare patterns and standard models.
8. Use a given CASE tool.
9. Evaluate meta-models.
10. Evaluate data integration and its use in the creation of data warehouse and data marts.
11. Develop data warehouse.
12. Change an existing data mart.

A.2: The ILOs of Number Patterns in Mathematics

(HMSO-QCA, 1999; Michigan-Gov, n.d.)

Topics:

Number and the number system

Calculations

Number operations and the relationships between them

Using and applying number and algebra

Solving numerical problems

Sequences, functions and graphs

Using and applying shape, space and measures

Problem solving and reasoning

Core intended learning outcomes:

1. Define numbers and position.
2. Select appropriate numbers.
3. Compare number and position.
4. Formulate Pascal triangle values.
5. Classify number as even or odd.
6. Compute integers by adding.
7. Describe numbers, and number relationships.
8. Analyse patterns including sequences and series.
9. Use patterns to solve a problem.
10. Indicate numerical patterns.
11. Draw triangle patterns in 2D.
12. Explain numerical patterns.
13. Combine patterns.
14. Compare patterns.

A.3: The ILOs of Web Development (WS4)

(Lunt et al., 2008)

Topics:

Web interfaces

Website implementation and integration

Database integration

Accessibility issues

Web accessibility initiative

Core intended learning outcomes:

1. Describe the issues involved in developing a web interface.
2. Summarise the need and issues involved in website implementation and integration.
3. Explain the importance of interfacing websites to an underlying database.
4. Explain why accessibility issues are an important consideration in web page development.
5. List some of the organisations that have developed standards for web accessibility.

Advanced intended learning outcomes:

1. Change a web interface.
2. Integrate a website with another IT application.
3. Create a web front-end to an underlying database.
4. Design a website that meets the standards set.

A.4: The ILOs of Clinical and Medical Training

(Shumway and Harden, 2003)

Topics:

What doctors are able to do.

How the doctors approach their practice.

Doctors as professionals.

What the doctors are able to do:

1. Formulate an action plan to characterise the problem of reaching a diagnosis (competence in clinical skills).
2. Undertake a range of procedures on a patient for diagnostic or therapeutic purposes (competence in practical procedures).
3. Arrange appropriate investigations for a patient and interpret these (competence in investigating a patient).
4. Identify appropriate treatment for the patient and deliver this personally or refer the patient to the appropriate colleague for treatment (competence in patient management).
5. Recognise threats to the health of individuals or communities at risk (competence in health promotion and disease prevention).
6. Communicate effectively with patients, relatives of patients, the public and colleagues (competence in communication).
7. Analyse information using a range of methods including computers (competence in handling and retrieval of information).

How doctors approach their practice:

1. Understand the basic, clinical and social sciences that underpin the practice of medicine (approach practice with an understanding of basic and clinical sciences).
2. Adopt appropriate attitudes, ethical behaviour and legal approaches to the practice of medicine (approach practice with appropriate attitudes, ethical stance and legal responsibilities).
3. Apply clinical judgement and evidence-based medicine to the practice (approach practice with appropriate decision making, clinical reasoning and judgement).

Doctors as professionals:

1. Understand the healthcare system and the roles of other professionals within the system.
2. Improve personal and professional development including personal health and career development.

A.5: The ILOs of Financial and Accountancy Training

(Hartwell et al., 2000)

Topics:

Information development and distribution skills

Knowledge of accounting auditing and tax

Knowledge of business and the environment

Decision-making skills

Leadership development

Core intended learning outcomes:

1. Describe the role of information technology in solving business problems.
2. Apply fundamental programming skills to typical business problems.
3. Solve diverse and unstructured problems in unfamiliar settings.
4. Work effectively with diverse groups of people.
5. Possess a degree of knowledge of the purpose and elements of financial statements.
6. Recognise the fundamentals of accounting, auditing, and tax.
7. Know methods of gathering, summarising, and analysing financial data.
8. Clarify the economic, social, and cultural forces in the world.
9. Examine how typical business organisations work and are managed.

Appendix B

The Survey Questionnaires for Experiments

In this appendix, the survey questionnaires used for the three experimental studies are shown. The details of each questionnaire are expressed as follows:

B.1: The Survey Questionnaire for Experiment I (structured ILO format)

Study title: Using intended learning outcomes to facilitate teaching

THE CONTENTS OF THIS SURVEY ARE ABSOLUTELY CONFIDENTIAL. INFORMATION IDENTIFYING THE RESPONDENT WILL NOT BE DISCLOSED UNDER ANY CIRCUMSTANCES.

There are three parts to this questionnaire:

Part I: A case study of applying ILOs in teaching

Part II: Questions on ILOs

Part III: Demographic questions asking the teaching experiences

Please read a case study and then indicate the extent of your satisfaction by ticking ☑ in the provided box.

PART I: A CASE STUDY (Applying ILOs in teaching)

The department of IT innovation of XYZ University was established in 2012. In the first semester (1/2012), there are 9 compulsory courses and 7 elective courses which will be initiated by applying the concept of intended learning outcomes (ILOs) in their design and development. The advanced database course is one of the compulsory courses and the data modelling module is a learning unit within this course. The main objectives of the data modelling module are to provide an overview of the logical data model and to introduce a way of designing the database by using an entity-relationship diagram (ERD). There are 8 intended learning outcomes of this module which are listed in Table 1 and depicted in Figure 1.

Table 1 Intended learning outcomes of the data modelling module

Course of Study: Advanced database course Course Module: Data modelling module
Minimum core coverage time: 6 hours Intended learning outcomes: 1. Describe and interpret the entity-relationship diagram. 2. Design a simple entity-relationship diagram. 3. Create a simple entity-relationship diagram. 4. Describe and interpret an enhanced entity-relationship diagram. 5. Create and design an enhanced entity-relationship diagram. 6. Describe a logical model. 7. Evaluate a logical model. 8. Demonstrate how to reengineer databases .

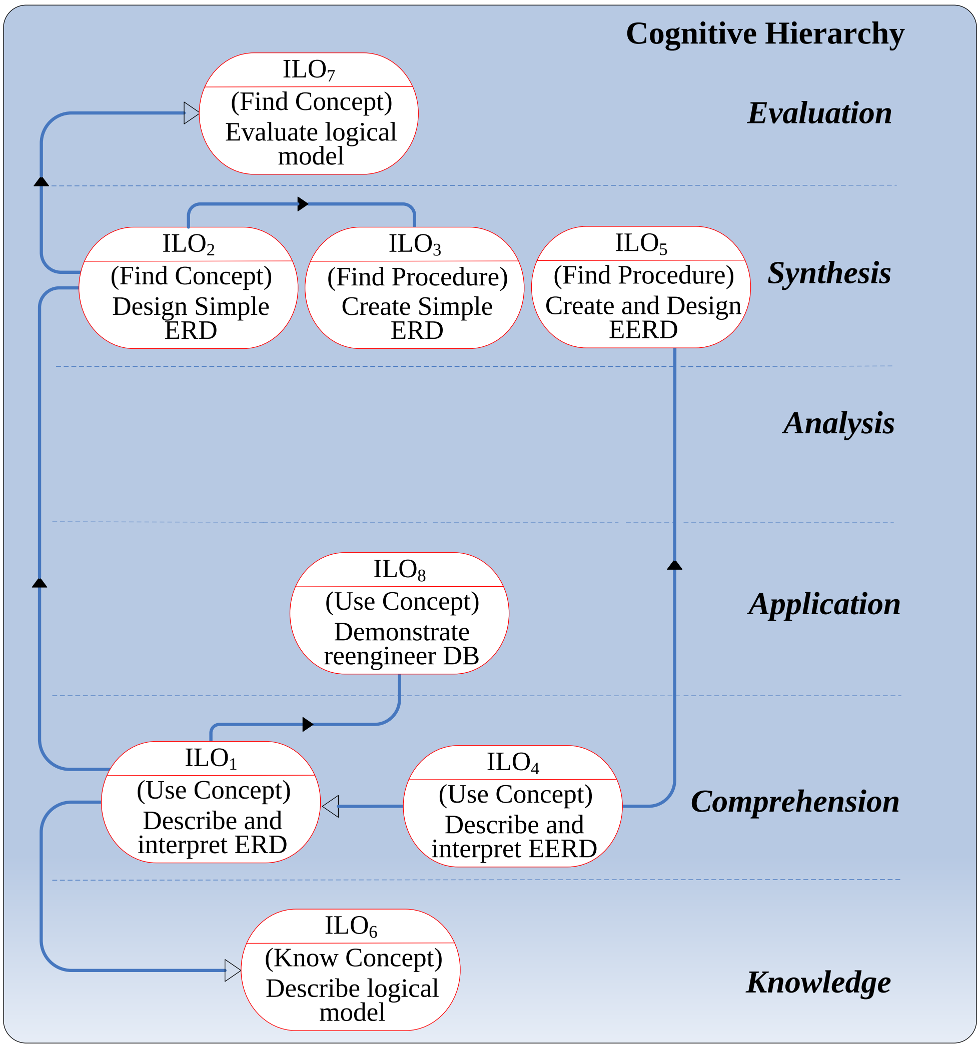

Figure 1. An ILO diagram of the IM4 data modelling module

Now, please use <u>Table 1 and Figure 1</u> to answer the questions 1-8

PART II: QUESTIONS On ILOs

Q1) Using the ILOs of Figure 1 and Table 1 when I introduce the course syllabus to my students, allows me to explain the learning objectives of the course more clearly.

Strongly disagree	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*
☐	☐	☐	☐	☐

Q2) Using the ILOs of Figure 1 and Table 1 to facilitate teaching is helpful to me.

Strongly disagree	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*
☐	☐	☐	☐	☐

Q3) Using the ILOs of Figure 1 and Table 1 allows me to track the level of learners' performance in learning.

Strongly disagree	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*
☐	☐	☐	☐	☐

Q4) The ILOs of Figure 1 and Table 1 are understandable to me.

Strongly disagree	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*
☐	☐	☐	☐	☐

Q5) The ILOs of Figure 1 and Table 1 provide an easy way to plan the teaching activities for the specific subject matter content.

Strongly disagree	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*
☐	☐	☐	☐	☐

Q6) The ILOs of Figure 1 and Table 1 provide an easy way to envision the entire range of relationships of all learning outcomes.

Strongly disagree	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*
☐	☐	☐	☐	☐

Q7) Representing ILOs as in Figure 1 and Table 1 is a good idea.

Strongly disagree	*Disagree*	*Neither agree nor disagree*	*Agree*	*Strongly agree*
☐	☐	☐	☐	☐

Q8) Representing ILOs as in Figure 1 and Table 1 makes course contents more interesting to me.

Strongly disagree	*Disagree*	*Neither agree Nor disagree*	*Agree*	*Strongly agree*
☐	☐	☐	☐	☐

PART III: Demographic questions regarding teaching experience

Now, to help us classify your answers and to make our statistical comparisons, could you please provide your personalised information as follows:

Q9) How long have you been teaching? (Please choose only one option.)	☐ 0 - 3 years ☐ 3 - 10 years ☐ more than 10 years
Q10) What subjects do you teach? (You can choose more than one option.)	☐ Computer Science ☐ Education ☐ Mathematics ☐ Psychology ☐ Other, please specify................. ....

Q11) Do you have any experience in designing (or initiating) a new course of study at your department?

☐ Yes ☐ No

If your answer to this question is "Yes", how many courses have you designed?

.... course(s).

Q12) Do you have any suggestions for improvement and modification of the ILOs of Figure 1 and Table 1?

....

....

....

....

Thank you very much for taking part in this study.

B.2: The Survey Questionnaire for Experiment II (structured ILO format)

Study title: Using the ILO diagram as facilitator in indicating learning paths

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Learning topic: PASCAL'S TRIANGLE
(Theme: Playing with Math)

There are many topics relating to the number patterns in mathematics that you used to learn in the past. One of the most interesting number patterns is Pascal's triangle. Can you answer the following questions?

- What is Pascal's triangle?
- What are the patterns of Pascal's triangle?

By the end of this learning topic, you will be able to address these two questions. Please read and follow the instruction of each section below.

SECTION I: An overview of the Pascal's triangle

<u>Supporting learning information:</u>

Pascal's triangle, developed by the French Mathematician Blaise Pascal, is an arithmetical triangle (see Figure1).

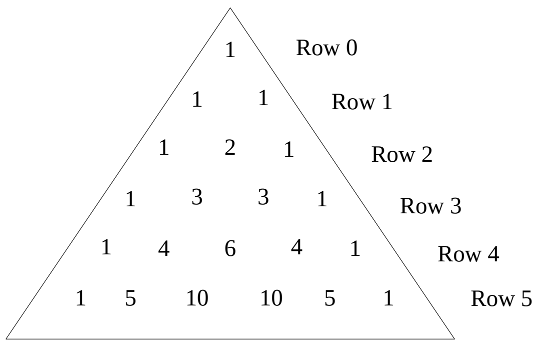


Figure 1 Pascal's Triangle

<u>Intended learning outcomes (ILOs):</u> In order to learn about the Pascal's triangle, by the end of this section, you will be able to:

ILO1 Define numbers and their position (e.g., left, right, over, or under).

ILO2 Select appropriate numbers.

ILO5 Classify numbers as even or odd.

ILO3 Compare numbers and position.

ILO6 Compute integers by adding.

ILO4 Formulate Pascal triangle values.

ILO7 Describe numbers and number relationship.

Figure 2 Seven ILOs of Pascal's triangle

These seven ILOs can be illustrated as an ILO diagram depicted in Figure 3:

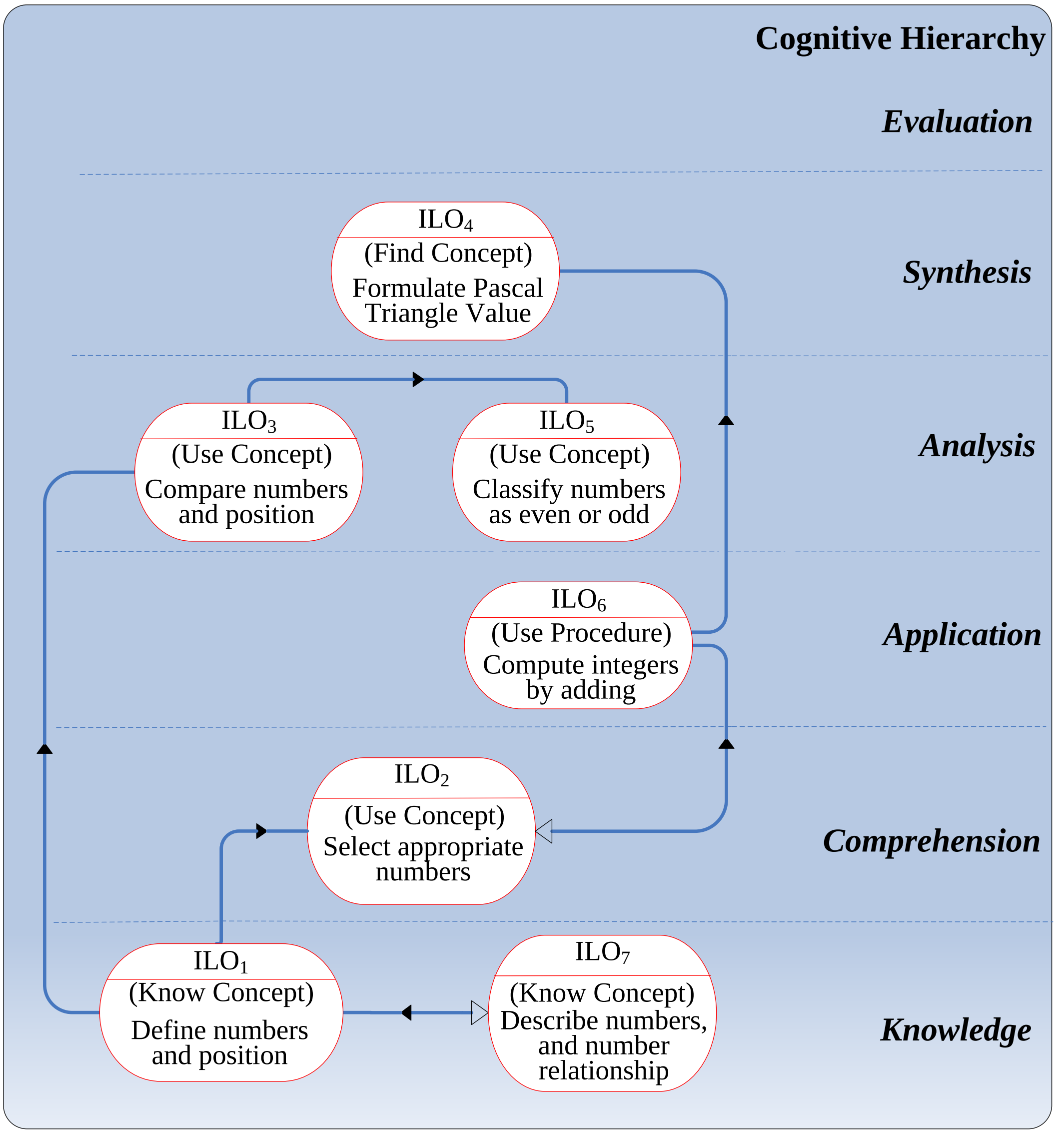
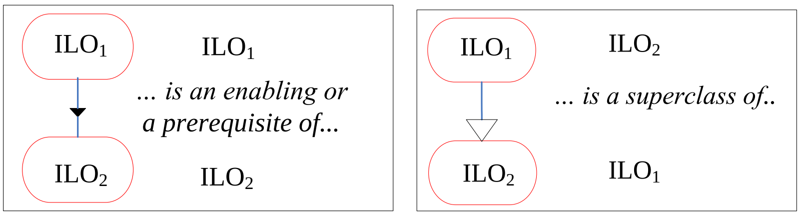


Figure 3 An ILO diagram of Pascal's triangle

Note that the notations are:



First of all, please recall your past experiences to answer the following questions by looking at an ILO diagram in Figure 3 and choosing ILOs from the list of provided ILOs in Figure 2.

Q1) In order to "select appropriate numbers", what previous ILO is needed to be performed? Please look at Figure3 and select one box of ILOs from Figure2.

Answer: previous ILO..

Learning tip: To be called "appropriate numbers", the numbers that you are looking at (in Figure 1) must have at least two numbers above them. For example, you may look at a number "3" of row 3 in Figure 1. In this case, two appropriate numbers above "3" are "2" and "1".

Q2) In order to "compute integers by adding", what previous ILOs are needed to be performed? Please look at Figure3 and select (up to three) boxes of the ILOs from Figure 2.

Answer: 1st ILO..

2nd ILO..

3rd ILO..

4th ILO..

5th ILO..

Now, you can learn how to construct Pascal's triangle from the following learning information.

<u>Supporting learning information:</u>

To build the Pascal's triangle, you start with the top two rows: 1, and 1 1. Then to construct each entry in the next row, you calculate by adding the two entries above it: the one above it on the right, and the one above it on the left. At the beginning and the end of each row, when there's only one number above, put a 1. Hence, the edges of the triangle are all 1.

For example, to create the 2nd row: 1; 1+1=2; 1. and the 3rd row: 1; 1+2=3; 2+1=3; 1. In this way, the rows of the triangle go on infinitely.

Learning tip: Read and study the examples above until you are sure you understand how to calculate them. Next, let's try to practise how to calculate all entries of the Pascal's triangle depicted in Figure4 and answer the following questions.

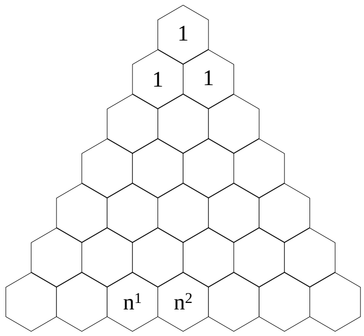


Figure 4

Q3) In order to "formulate Pascal's triangle values" (the value of n^1 and n^2 of Figure4), what previous ILOs need to be performed? Please look at Figure 3 and select (up to four) boxes of ILOs from Figure 2.

Answer: 1st ILO..

2nd ILO..

3rd ILO..

4th ILO..

5th ILO..

6th ILO..

Q4) What are the values of n^1 and n^2 of Figure 4? Please calculate and write down your answers.

Answer: n^1 = ... n^2 = ...

From this section, you would have gained some knowledge about Pascal's triangle.

Next, let's see how we can use Pascal’s triangle in Mathematics!!! Please read the following supporting learning information.

Supporting learning information: Binomial expression

The general form of the binomial expression is $(p+q)^n$.

We can write down the successive terms within the bracket i.e.

$$(p^5) + (p^4q) + (p^3q^2) + (p^2q^3) + (pq^4) + (q^5)$$

Next, the Pascal's triangle can be used to calculate the coefficient of each term of the binomial expression (i.e. the value in front of each bracket).

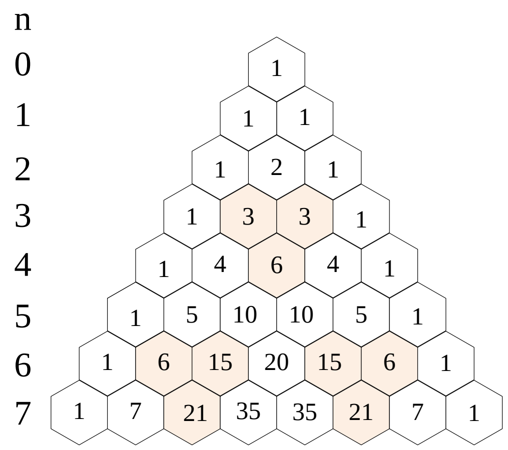


Figure 5

The coefficients in the expansion can be read directly from the Pascal's triangle against the value of n. For example, where n is 5, the coefficients are 1 5 10 10 5 1.

Thus, the expansion of $(p+q)^5$ is...

$$p^5 + 5(p^4q) + 10(p^3q^2) + 10(p^2q^3) + 5(pq^4) + q^5$$

End of section I

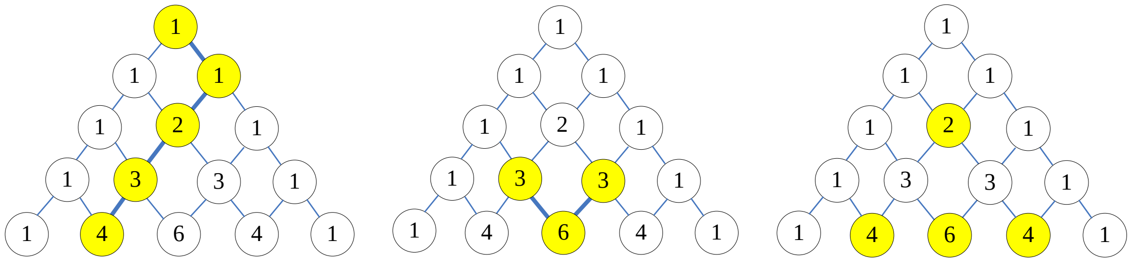
SECTION II: The magic of Pascal's triangle pattern

From the previous section, you have gained some knowledge about the Pascal's triangle. Let's see what can we do with Pascal's triangle in the following section.

Now, you can learn what Pascal's triangle pattern is from the following learning information:

<u>Supporting learning information: Pascal's triangle pattern</u>

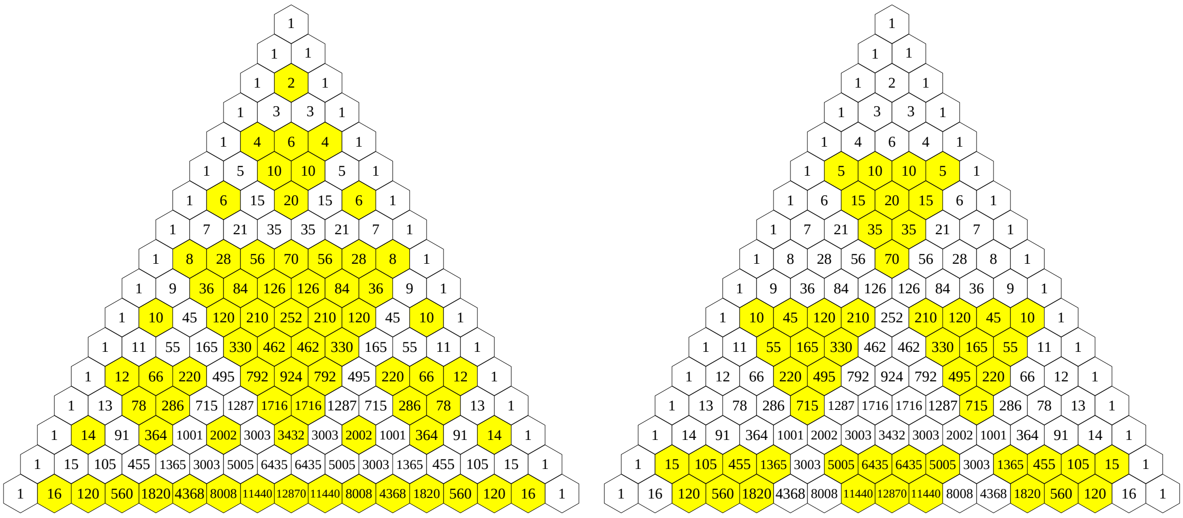
Imagine each number in the triangle is a node in a grid which is connected to the adjacent numbers above and below it. The Pascal's Triangle pattern can be created by determining the number of paths in the grid which connects this node to the adjacent nodes and rows (see Figure 6)



a) linear pattern b) multiples of 3 c) even pattern

Figure 6 Three patterns of Pascal's triangle

Now, let's see the following two examples of Pascal's triangle pattern.



a) Even pattern b) Multiples of 5

Figure 7 Two examples of the Pascal's triangle patterns

<u>Practice:</u> Try to highlight the patterns of multiples of 7.

Intended learning outcomes (ILOs): If you study Pascal's triangle patterns, by the end of this section you will be able to do the following:

ILO8 Analyse patterns including sequences and series.	
ILO9 Use patterns to solve problems.	ILO12 Explain numerical patterns.
ILO10 Indicate numerical patterns.	ILO13 Combine patterns.
ILO11 Draw triangle patterns in 2D.	ILO14 Compare patterns.

Figure 8 Seven ILOs of Pascal's triangle patterns

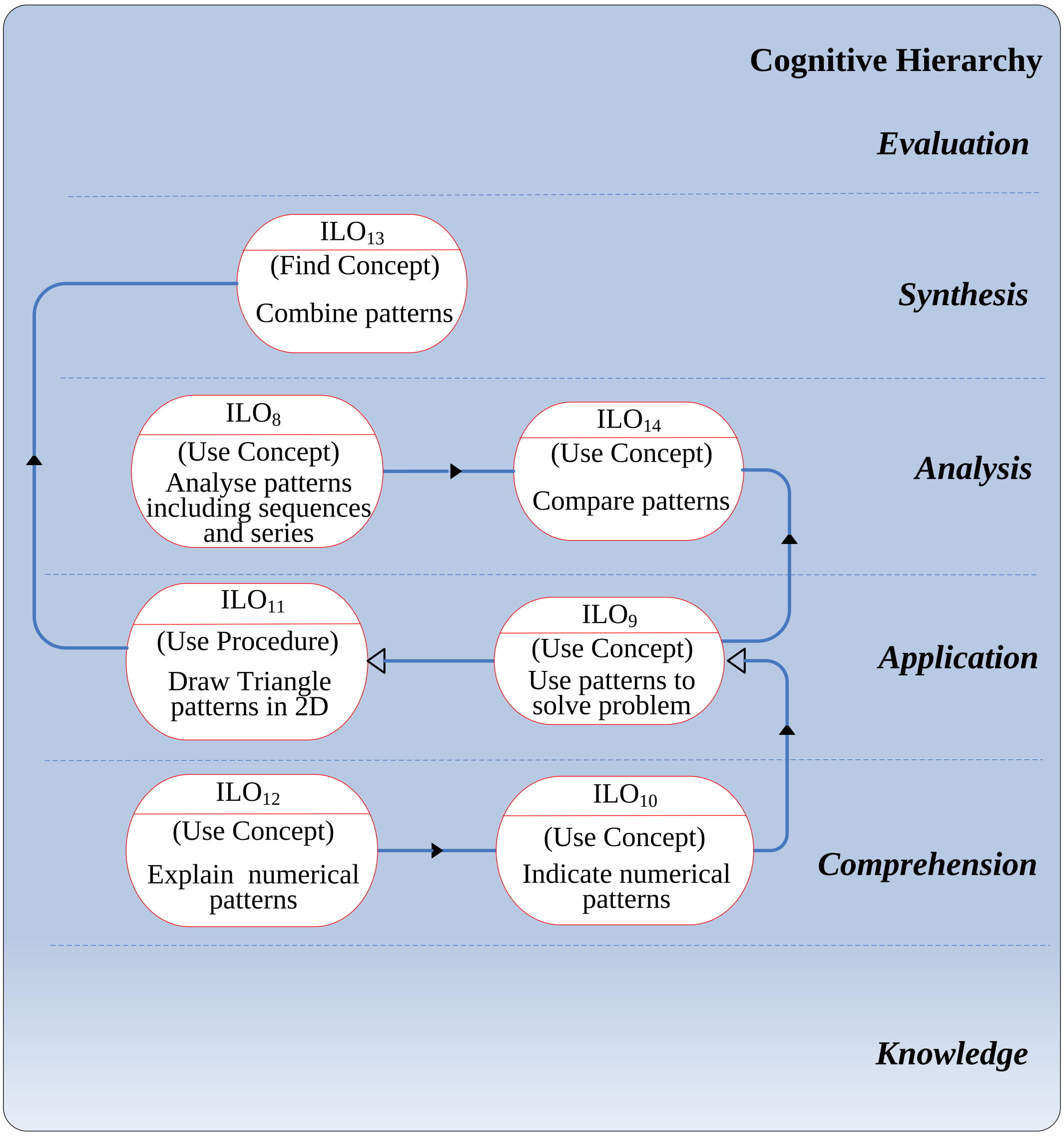


Figure 9 An ILO diagram of Pascal's triangle patterns

Next, study the examples until you are sure you can understand Pascal's triangle patterns, then answer the following questions by looking at an ILO diagram of Figure 9 and choosing the boxes of ILOs from Figure 8.

Q5) In order to "indicate numerical patterns", what previous ILO needs to be performed?
Please look at Figure 9 and select one box of ILOs (from Figure 8).

Answer: 1st ILO..

Q6) In order to "draw Triangle shapes", what previous ILOs need to be performed? Please look at Figure 9 and select (up to three) boxes of ILOs (from Figure 8).

Answer: 1st ILO..

2nd ILO..

3rd ILO..

4th ILO..

5th ILO..

6th ILO..

Q7) In order to "analyse patterns including sequences and series", what previous ILOs need to be performed? Please look at Figure 9 and select (up to three) boxes of ILOs (from Figure 8).

Answer: 1st ILO..

2nd ILO..

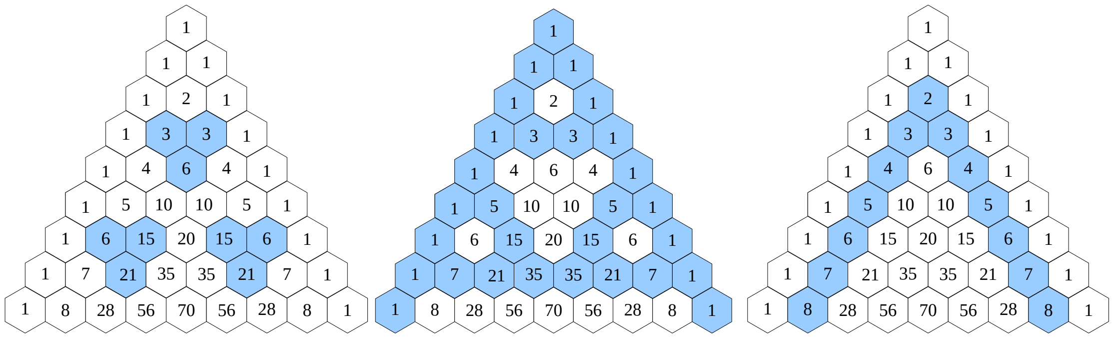
3rd ILO..

4th ILO..

5th ILO..

6th ILO..

Please use the following three Pascal's triangle patterns to answer Q8 to Q10.



a) b) c)

Figure 10 Three patterns of Pascal's triangle

Q8) Which of the three patterns is the "Linear pattern"?

Answer: ....

Q9) Which of the three patterns is the "Multiple-of-three pattern"?

Answer: ....

Q10) Which of the three patterns is the "Odd pattern"?

Answer: ....

Learning tip: All Pascal's triangle patterns can be graphically illustrated. Please study the following information:

Supporting learning information:

The pattern obtained by colouring only the odd (or even) numbers in Pascal's triangle is closely visualised as the "Fractal image" (see Figure 11).

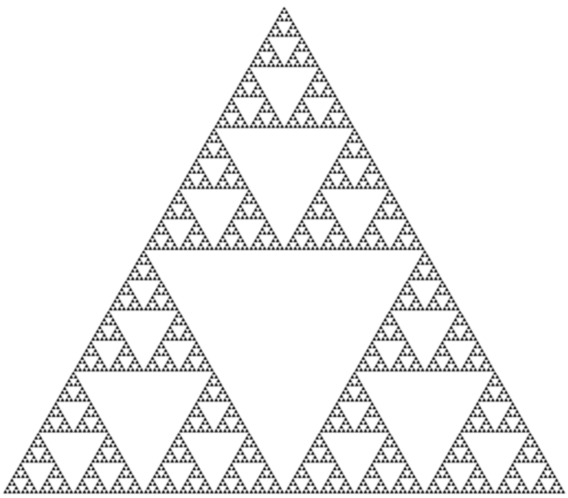


Figure 11 The Fractal of the Pascal's Triangle Pattern

End of section II

SECTION III: Demographic questions asking the participant's background

Now, to help us classify your answers and to make our statistical comparisons, kindly provide your personalised information as follows:

Q11) What is your gender?	☐ Male ☐ Female
Q12) What is your age range?	☐ < 15 ☐ 15 - 20 ☐ 21 - 25 ☐ 26 - 30 ☐ > 30
Q13) What is the subject area of your study?	☐ Electronics and Computer Science ☐ Other. Please specify..................... ....
Q14) Do you have any experience in number patterns in Mathematics? ☐ Yes ☐ No If your answer to this question is "Yes", are you familiar with the topic used in this study? ☐ Yes ☐ No	
Q15) Do you have any suggestions about the design of this learning course?	

Thank you very much for your participation in this study.

B.3: The Survey Questionnaire for Experiment III (Combination No.1: IT_S, MED_C, FIN_T)

Study title: A study of understandability of an ILO diagram

SECTION 1: Understandability of ILOs

Intended learning outcomes (ILOs) indicate what learners will be able to do by the end of the course of study. This survey questionnaire aims to investigate whether providing ILOs to students before involving them in the course module facilitates their understanding. There are three subject domains: Information Technology, Medical Education, and Financial and Accounting Education, providing different representational styles of ILOs. In each subject domain, please

1. indicate the STARTING time when you begin,
2. follow the instruction and answer the three questions, and
3. indicate the STOPPING time when you have finished.

Thank you very much. You may begin.

SUBJECT DOMAIN 1: Information Technology

LEARNING MODULE: Web Development

Developing a website for the Internet or World Wide Web (WWW) is intended to promote organisations' and businesses' information. What sort of web developer is the Information Technology programme aiming to produce? To elicit answers to this question, many intended learning outcomes are planned and desired for the Information Technology programme. Please read and follow the instructions below:

CHECK STARTING TIME (HH:MM:SS): ___________________ *(e.g., 12:49:37)*

By the end of the web development course, you will be able to do the following:

ILO_1: Describe the issues involved in developing a web interface. ILO_2: Summarise the need and issues involved in website implementation and integration. ILO_3: Explain the importance of interfacing websites with underlying databases. ILO_4: Explain why accessibility issues are an important consideration in web page development. ILO_5: List some of the organisations that have developed standards for web accessibility. ILO_6: Change a web interface. ILO_7: Integrate a website with another IT application. ILO_8: Create a web front-end to an underlying database. ILO_9: Design a website that meets the standards set.

Please refer to the nine <u>STATEMENTS</u> of intended learning outcomes (ILO_1 to ILO_9) to answer the following questions:

Q1) In order to merge the web to other applications, which ILO do you need to be able to achieve?

Answer: ILO No. ________________

How confident are you that this answer is correct?

Not at all confident	*Not too confident*	*Somewhat confident*	*Very confident*	*Extremely confident*
☐	☐	☐	☐	☐

Q2) While you are engaged in DESIGNING the website, which ILO do you need to achieve in order to relate to the standard sets of organisation?

Answer: ILO No. ________________

How confident are you that this answer is correct?

Not at all confident	*Not too confident*	*Somewhat confident*	*Very confident*	*Extremely confident*
☐	☐	☐	☐	☐

Q3) If you want to KNOW the issues of web development, which ILO do you need to achieve?

Answer: ILO No. _______________

How confident are you that this answer is correct?

Not at all confident	*Not too confident*	*Somewhat confident*	*Very confident*	*Extremely confident*
☐	☐	☐	☐	☐

CHECK STOPPING TIME (HH:MM:SS):____________________ *(e.g., 12:52:26)*

SUBJECT DOMAIN 2: Medical Education

LEARNING MODULE: Medical Training

Doctors have a unique blend of different kinds of abilities that are applied to the practice of medicine. What sort of doctor is Medical Education aiming to produce? To elicit answers to this question, many intended learning outcomes are planned and desired for the Medical Training programme. Please read and follow the instructions below:

CHECK STARTING TIME (HH:MM:SS): ________________ *(e.g., 12:55:09)*

By the end of the medical training module, you will be able to do the following:

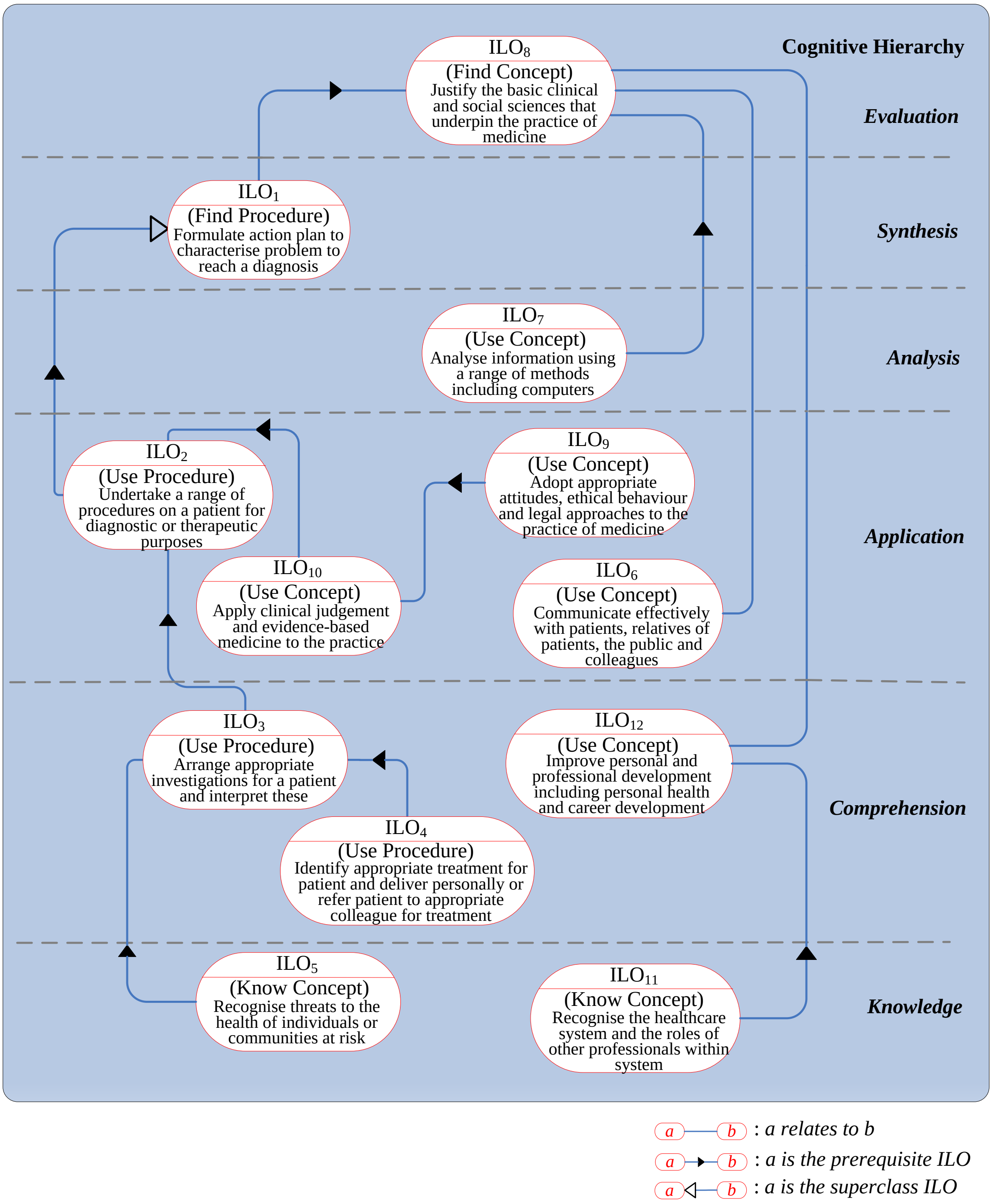


Figure 1 ILO diagram for Medical Training

Please refer to the twelve intended learning outcomes (ILO_1 to ILO_{12}) given conceptualisation through an ILO DIAGRAM illustrated in Figure 1 to answer the following questions:

Q4) In order to remember the threats or risk to individuals' health, which ILO do you need to achieve?

Answer: ILO No. _______________

How confident are you that this answer is correct?

Not at all confident	*Not too confident*	*Somewhat confident*	*Very confident*	*Extremely confident*
☐	☐	☐	☐	☐

Q5) While you are in the stage of DIAGNOSING the medical condition, which ILO do you need to achieve in order to inform the patient about the treatment methods to be used?

Answer: ILO No. _______________

How confident are you that this answer is correct?

Not at all confident	*Not too confident*	*Somewhat confident*	*Very confident*	*Extremely confident*
☐	☐	☐	☐	☐

Q6) Which ILO can be the prerequisite competency for ILO2 (undertake a range of procedures on a patient for diagnostic or therapeutic purposes)?

Answer: ILO No. ______________

How confident are you that this answer is correct?

Not at all confident	*Not too confident*	*Somewhat confident*	*Very confident*	*Extremely confident*
☐	☐	☐	☐	☐

CHECK STOPPING TIME (HH:MM:SS):____________________ *(e.g., 12:53:42)*

SUBJECT DOMAIN 3: Financial and Accounting Management

LEARNING MODULE: Financial Accountancy

Financial accountancy degree students should be able to master an integrated competency of marketing, finance, accounting, and management. Learning outcomes for the course comprise the business core objectives, financial and accounting objectives. In order to achieve these learning objectives, many intended learning outcomes are planned. Please read and follow the instructions below:

CHECK STARTING TIME (HH:MM:SS): ___________________ *(e.g., 12:55:14)*

In order to achieve the course module, you will be able to do the following:

ILO No.	Description
ILO_1	Describe the role of information technology in solving business problems.
ILO_2	Apply fundamental programming skills to typical business problems.
ILO_3	Solve diverse and unstructured problems in unfamiliar settings.
ILO_4	Work effectively with diverse groups of people.
ILO_5	Possess a degree of knowledge of the purpose and elements of financial statements.
ILO_6	Recognise the fundamentals of accounting, auditing, and tax.
ILO_7	Know methods of gathering, summarising, and analysing financial data.
ILO_8	Clarify the economic, social, and cultural forces in the world.
ILO_9	Examine how typical business organisations work and are managed.

Please refer to the nine <u>ROWS and COLUMNS</u> of intended learning outcomes (ILO_1 to ILO_9) to answer the following questions:

Q7) In order to deal with many people in an organisation, which ILO do you have to achieve?

Answer: ILO No. ________________

How confident are you that this answer is correct?

Not at all confident	*Not too confident*	*Somewhat confident*	*Very confident*	*Extremely confident*
☐	☐	☐	☐	☐

Q8) Which ILO is the most difficult to achieve?

Answer: ILO No. _______________

How confident are you that this answer is correct?

Not at all confident	***Not too confident***	***Somewhat confident***	***Very confident***	***Extremely confident***
☐	☐	☐	☐	☐

Q9) Which ILO do you have to be able to achieve before solving diverse and unstructured problems in unfamiliar settings (ILO3)?

Answer: ILO No. ______________

How confident are you that this answer is correct?

Not at all confident	***Not too confident***	***Somewhat confident***	***Very confident***	***Extremely confident***
☐	☐	☐	☐	☐

CHECK STOPPING TIME (HH:MM:SS):____________________ *(e.g., 12:59:08)*

SECTION II: Rating of understandability

Q10) Representing all the ILOs as the statements (sentential representation) as in subject domain I, allows me to understand the learning objectives.

Very difficult to understand	***A bit difficult to understand***	***Neither difficult nor easy to understand***	***Quite easy to understand***	***Very easy to understand***
☐	☐	☐	☐	☐

Q11) Graphical representation of all the ILOs as an ILO diagram (conceptual representation) in subject domain II, allows me to understand the learning objectives.

Very difficult to understand	***A bit difficult to understand***	***Neither difficult nor easy to understand***	***Quite easy to understand***	***Very easy to understand***
☐	☐	☐	☐	☐

Q12) Representing all the ILOs in rows and columns (tabular representation) as illustrated in subject domain III, allows me to understand the learning objectives.

Very difficult to understand	*A bit difficult to understand*	*Neither difficult nor easy to understand*	*Quite easy to understand*	*Very easy to understand*
☐	☐	☐	☐	☐

SECTION III: Demographic questions about the participant's background

Now, to help us classify your answers and to make our statistical comparisons, kindly provide your personalised information as follows:

Q13) How many years of experience in Web Development do you have? (Please choose only one option.)	☐ No experience ☐ Up to 1 year ☐ 2 - 3 years ☐ 4 - 6 years ☐ 7 - 10 years ☐ 11 years or more
Q14) How many years of experience in Medical Education do you have? (Please choose only one option.)	☐ No experience ☐ Up to 1 year ☐ 2 - 3 years ☐ 4 - 6 years ☐ 7 - 10 years ☐ 11 years or more
Q15) How many years of experience in Financial and Accounting do you have? (Please choose only one option.)	☐ No experience ☐ Up to 1 year ☐ 2 - 3 years ☐ 4 - 6 years ☐ 7 - 10 years ☐ 11 years or more
Q16) What is your gender?	☐ Male ☐ Female
Q17) What is your age range?	☐ < 15 ☐ 15 - 20 ☐ 21 - 25

	☐ 26 - 30 ☐ > 30
Q18) What is the subject area of your study?	☐ Electronics and Computer Science ☐ Health Science and Medical Education ☐ Financial and Accounting Management ☐ Other. Please specify......................... ....

Thank you very much for taking part in this study.