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A Framework for Designing Learning Management Systems to Support Undergraduate Thesis Projects

With a Focus on Sri Lankan Universities

Colombage Ranil Peiris

Doctoral Thesis in Computer and Systems Sciences at Stockholm University, Sweden 2022

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Academic dissertation for the Degree of Doctor of Philosophy in Computer and Systems Sciences at Stockholm University to be publicly defended on Monday 21 November 2022 at 14.00 in Lilla hörsalen, NOD-huset, Borgarfjordsgatan 12.

Abstract

In Sri Lankan public universities about 41000 undergraduate projects are conducted every year, and on average, the total man-hours spent on the thesis projects is about 1.2 million. Although the universities widely use information technology to support teaching and learning, a specific system supporting undergraduate thesis projects is lacking and literature documents many problems related to these projects. Hence, the present research endeavour was commenced in a Sri Lankan university to develop a framework to guide the design process of a Learning Management System (LMS) that can be used to address those problems and support Undergraduate Thesis Projects (UTP). The following three research questions guided the study: 1) What are the problems of UTP? 2) Which learning theories and pedagogical concepts should be considered when designing an LMS to support the UTP? 3) What are the requirements and components of an LMS which would support the UTP? The Soft Design Science Research Methodology was applied to answer three research questions, and the main findings are as follows: 1) Six main problems areas were identified based on a specific case, 2) These problems were related to unsatisfied requirements of student student-supervisor interaction, scaffolding, and self-regulation processes 3) These requirements further analysed using related learning theories and specific problems were condensed into a general problem. The general problem is the lack of a learning environment that supports the theoretical foundation (pedagogical implications) and practical facilitation (Information and Communication Technology tools), which could support the student-supervisor interaction, scaffolding, and self-regulation processes, 4) The general problem was analysed, comparing the theoretical foundations and pedagogical implications and a framework was suggested as a general solution for designing an LMS with four basic modules. These modules include software subcomponents that can be used to enhance student-supervisor interaction, peer collaboration, students' self-regulation skills, and students' motivation, 5) The general solution was evaluated, and it was shown that supervisors accepted the proposed components as parts of an LMS that supports UTP. The findings show that this framework offers features and components that enhance the quality and importance of thesis projects.

Keywords: *Thesis projects, Self-regulation learning, Scaffolding, Zone of Proximal Development, Constructivist learning theories, Thesis project management systems.*

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Dedicated to:
my Parents,
my wife Vichithra,
my son Ravindu,
and all my Teachers

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Colombage Ranil Peiris

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List of Abbreviations

I	API	: Application Programming Interface
II	CMI	: Capability Maturity Index
III	DSR	: Design Science Research
IV	DSV	: Department of Computers and Systems Sciences
V	EBP	: Evidence-Based Practice
VI	EDT	: Explanatory Design Theory
VII	GDP	: Gross Domestic Production
VIII	HDI	: Human Development Index
IX	ICT	: Information and Communication Technology
X	IT	: Information Technology
XI	LMS	: Learning Management System
XII	LMSs	: Learning Management Systems
XIII	PBE	: Practice-Based Evidence
XIV	SDSRM	: Soft Design Science Research Methodology
XV	SRL	: Self-Regulated Learning
XVI	SSI	: Student-Supervisor Interaction
XVII	UGCSL	: University Grant Commission of Sri Lanka
XVIII	ZPD	: Zone of Proximal Development

Abstract

In Sri Lankan public universities about 41000 undergraduate projects are conducted every year, and on average, the total man-hours spent on the thesis projects is about 1.2 million. Although the universities widely use information technology to support teaching and learning, a specific system supporting undergraduate thesis projects is lacking and literature documents many problems related to these projects. Hence, the present research endeavour was commenced in a Sri Lankan university to develop a framework to guide the design process of a Learning Management System (LMS) that can be used to address those problems and support Undergraduate Thesis Projects (UTP). The following three research questions guided the study: 1) What are the problems of UTP? 2) Which learning theories and pedagogical concepts should be considered when designing an LMS to support the UTP? 3) What are the requirements and components of an LMS which would support the UTP? The Soft Design Science Research Methodology was applied to answer three research questions, and the main findings are as follows: 1) Six main problems areas were identified based on a specific case, 2) These problems were related to unsatisfied requirements of student student-supervisor interaction, scaffolding, and self-regulation processes 3) These requirements further analysed using related learning theories and specific problems were condensed into a general problem. The general problem is the lack of a learning environment that supports the theoretical foundation (pedagogical implications) and practical facilitation (Information and Communication Technology tools), which could support the student-supervisor interaction, scaffolding, and self-regulation processes, 4) The general problem was analysed, comparing the theoretical foundations and pedagogical implications and a framework was suggested as a general solution for designing an LMS with four basic modules. These modules include software subcomponents that can be used to enhance student-supervisor interaction, peer collaboration, students' self-regulation skills, and students' motivation, 5) The general solution was evaluated, and it was shown that supervisors accepted the proposed components as parts of an LMS that supports UTP. The findings show that this framework offers features and components that enhance the quality and importance of thesis projects.

Key words:
Thesis projects, Self-regulation learning, Scaffolding, Zone of Proximal Development, Constructivist learning theories, Thesis project management systems.

Sammanfattning (in Swedish)

Under de senaste åren har det blivit obligatoriskt med examensarbeten vid alla universitet i Sri Lanka. I Sri Lanka genomförs cirka 41 000 grundutbildningsprojekt varje år, och den totala tiden som spenderas på examensarbetet uppskattas till cirka 1,2 miljoner timmar. Även om universiteten i stor utsträckning använder informationsteknologi för att stödja undervisning och lärande, saknas ett specifikt system som stödjer arbetet med examensprojekten. I den internationella forskningslitteraturen har många problem relaterade till examensarbeten identifierats och dessa förekommer även i Sri Lanka. Denna studie har genomförts vid ett universitet i Sri Lanka med syftet att utveckla ett ramverk för att vägleda designprocessen för ett Learning Management System (LMS) specifikt för examensarbeten på grundnivå. Följande tre forskningsfrågor formulerades: 1) Vilka är problemen med examensarbeten? 2) Vilka inlärningsteorier och pedagogiska begrepp bör beaktas när man utformar ett LMS för att stödja examensarbetet? 3) Vilka är kraven och komponenterna i ett LMS som kan stödja arbetet med examensarbetet? De första fem stegen i Soft-design Science Research Methodology användes för att besvara forskningsfrågorna. De övergripande resultaten var följande: 1) Sex specifika problem relaterade till grundexamensprojekten identifierades, 2) Nyckelproblemen är relaterade till interaktion mellan student och handledare, struktur och självregleringsprocesser, 3) De specifika problemen omformulerades till ett generellt problem. Det generella problemet är avsaknaden av en lärmiljö som är teoretiskt förankrad (pedagogisk planering) och praktisk facilitering (IKT-systemet), som skulle kunna stödja interaktionen mellan student och handledare samt strukturera arbetet och främja självregleringsprocesser, 4) Det generella problemet analyserades. Lösningen presenteras som ett ramverk för informationssystem för att designa ett LMS med fyra grundläggande moduler: initiering, planering, implementering och slutförande för att förbättra interaktion mellan student och handledare, studentsamarbete, studenters självregleringsförmåga och studenters motivation, 5) Den generella lösningen utvärderades och den visade att handledare accepterar de föreslagna komponenterna som delar av ett LMS som stödjer examensarbeten. Enligt resultaten erbjuder detta ramverk funktioner och komponenter som förbättrar kvaliteten och effekten av examensarbeten.

Nyckelord:
Examensarbeten, Självreglerat lärande, Struktur, Zone of Proximal Development, Konstruktivistiska lärandeteorier, Examensprojektledningssystem.

A new idea or artifact (a design) may provide totally new opportunities to improve practice long before practitioners recognize any problem; it may also provide totally new opportunities

Juhani Iivari

List of Papers

This thesis is based on the following six published papers, the cover paper (or 'kappa') provides context and grounding and constructs an overarching thread for my work.

Peiris, C. R., Hewagamage, K., Hansson, H., & Wickramanayake, G. (2013). An Analysis of Existing Issues in Students' Research and Project Initiation Stage: Information and Communication Technology Perspective. *7th International Technology, Education and Development Conference -INTED2013*, 1760–1769.

Peiris, C. R.,Hansson, H., & Moberg, J., (2014). SciPro Matching: ICT Support to Start a Quality Thesis. *International Journal on Advances in ICT for Emerging Regions*, *7*(3), 75–84. http://journal.icter.org/index.php/ICTer/article/view/164

Peiris, C. R., & Hansson, H. (2017). ICT Support for The Thesis Process: A Case as a Literature Review. *Proceedings of the European Distance and E-Learning Network 2017 Annual Conference*, 113–122. https://doi.org/doi.org/10.38069/edenconf-2017-ac-0018

Peiris, C. R., Barbutiu, S. M., & Hansson, H. (2018). About the Challenges in Undergraduate Research Projects: An Explorative Case Study in a Sri Lankan National University. *International Journal of Learning, Teaching and Educational Research*, *17*(2), 25–44. https://doi.org/10.26803/ijlter.17.2.2

Peiris, C. R., Männikkö-Barbutiu, S., & Hansson, H. (2019). A Constructivist Perspective on the Thesis Supervision Process: A Case Study of Sri Lankan Undergraduate Thesis Projects. *Journal of Interactive Learning Research*, *30*(4). https://www.learntechlib.org/noaccess/184712/

Peiris, C. R., Männikkö-Barbutiu, S., & Hansson, H. (2022). A Framework for Designing Learning Management Systems for Thesis Projects. *The Journal of Research Innovation and Implications in Education*, *6*(3). https://jriiejournal.com/wp-content/uploads/2022/10/JRIIE-6-4-001.pdf

1 Introduction

1.1 Evolving systems for e-Learning

In Sri Lankan public universities, about 41,000 undergraduate research projects are conducted every year (University Grant Commission Sri Lanka, 2021), where a student spends approximately four to six months conducting a small research project under the supervision of a supervisor and the research project is documented in a report (thesis). However, most thesis reports are locked away in bookshelves after the grading stage. Is there a way to use these huge research efforts more effectively? What are the problems in undergraduate thesis projects? Can information and communication technology (ICT) help thesis projects to overcome these problems? If yes, why are we not utilising them? What should change? These questions motivated me to research and write this thesis.

With the extensive development of ICTs for teaching and learning, the educational sector has undergone major changes. E-learning refers to the use of ICT to support academic and administrative activities in education institutions (Drlik & Skalka, 2011; Sejzi et al., 2012). E-learning started with personal productivity software tools (Gros & García-Peñalvo, 2016), and today, it has evolved into complex information systems such as collaborative virtual learning environments that provide the appropriate learning elements for learners to meet and exchange their thoughts, ideas, and products, independent of any space and time constraints (Akar et al., 2004).

During the last two decades, higher education institutions have implemented ICT infrastructure to promote e-learning (Kwok & Yang, 2017). As a result, many universities have employed Learning Management Systems (LMS) to support academic and administrative processes. However, the lack of adequately developed information systems is a common issue in higher education institutions in developing countries. For example, the 'Capability Maturity Index' (CMI) can be used to measure the success of Information Technology (IT) governance, and it was recorded to be at level 1.0 (on a scale from 0 to 5) in Sri Lankan higher education institutions, while the value of universities on a global level is around 2.5 (University Grant Commission Sri Lanka, 2013, p. 39). Level one of CMI indicates no development process, no quality control, and unpredictability of the development costs and product quality. This situation limits the effective use of ICT infrastructure and the efficiency and effectiveness of academic and administrative processes. The Sri Lankan

government has started many projects to enhance the ICT infrastructure in public universities but still there is a lack of properly designed information systems. One of the most prominent examples is the lack of a potential use of ICT to support undergraduate thesis projects. From a design perspective, designing a specific software tool is straightforward, and thus, numerous tailor-made standalone solutions are available. However, designing an LMS is a highly challenging task since it affects the whole learning process. Therefore, extensive research is essential to develop such an information system.

1.2 Undergraduate thesis projects

Students' independent thesis work or learning through research could be understood as an application of inquiry-based pedagogy based on the constructivist learning theory of how learning takes place (Healey & Jenkins, 2009). Research-based and project-based thesis projects are two fundamental types of inquiry-based methods (Brew & Jewell, 2012). They are becoming popular in undergraduate degree programmes, and the entire undergraduate thesis project is arranged to provide students with experience of multiple aspects of inquiry (National Research Council, 1996, p. 2).

In general, the undergraduate thesis process can be described as follows: in research-based studies, students practice how to solve a problem when conducting research, and in project-based learning, students practice how to apply existing knowledge to solve a practical problem innovatively. Although the approaches are different, research-based and project-based independent studies follow a similar process. There is an assigned supervisor in both approaches to guide the process, but students conduct learning activities independently. In a thesis project, students follow a standard process that includes learning activities such as selecting a research problem, preparing a research plan, implementing the plan, and writing a report to share the process and findings.

A higher weight has been given to classroom-based course work in undergraduate curricula, where students follow a standard curriculum and meet lecturers and peers regularly. For instance, according to the Sri Lankan Qualifications Framework in undergraduate degree programmes, it is mandatory to offer a minimum of six credits (5% of total credits) as research work (thesis project), and most of the remaining 114 credits are offered as traditional face-to-face lecture-based course modules. This is a common practice in undergraduate degree programmes. According to the Swedish Higher Education Policy, arts, sciences, social sciences, and artistic bachelor programmes' mandatory weight is 8% of credits (15 credits out of 180).

The inquiry-based, independent work is only a small part of undergraduate studies but a growing body of evidence indicates that undergraduate research offers many benefits to students in the short and longer term (Laursen et al., 2012). Research experiences can powerfully shape the students' knowledge creation, and application skills are necessary to ensure readiness for careers and graduate education. According to the University Grant Commission statistics, about 41000 students should conduct thesis projects annually (University Grant Commission Sri Lanka, 2021). Even undergraduates, who are not experienced researchers, they conduct thesis projects with experienced supervisors. On average duration of a thesis project is about six months. Therefore, thesis projects offer 41000 mini-research projects for the country. Although many research works highlight the benefits of undergraduate research, there is a lack of studies about designing a learning environment that supports such undergraduate research projects.

1.3 Terms used in undergraduate thesis projects

Two main terms, "Thesis" or "Dissertation" are used for the process in which students practice how to conduct a research. But, in general, "dissertation" is the term used to denote PhD level research while "thesis" denotes undergraduate and master level projects. In general, the process to conduct undergraduate research or a project is called the "thesis process", and the written report is called a "thesis". The term "thesis project" denotes both the process and the product. Although the meanings of "Thesis", "Thesis process", and "Thesis projects" are different, in some contexts these terms are used interchangeably. Therefore, these terms are discussed here to avoid misunderstanding.

Thesis

In general terms, a thesis (dissertation) is a written document submitted in support of candidature (student) for an academic degree or professional qualification as proof of the research process and findings.

Thesis projects

A "Thesis" is the product of the "Thesis process". A thesis project will be created when a thesis process starts with resources (time, persons, materials). Therefore, a thesis project has a time frame (process with a specific duration), resources (such as student, supervisor, and learning materials), and an objective (producing a thesis). The term "Thesis project" has a wider scope when compared with the terms "Thesis" and "Thesis process", however, in practice, all these terms overlap. For instance, support to produce a quality thesis denotes activities intended to produce a quality thesis. However, the thesis process and resources should be considered to produce a quality thesis. Therefore, this study considers "supporting thesis", "supporting thesis process", and "supporting thesis projects" as synonymous.

1.4 Problems in thesis projects and the use of ICT

In general classroom-based courses, teachers provide a specific schedule with a common course content and all students follow a set of common learning activities. But in thesis projects students are more responsible for planning and conducting their learning activities when compared with classroom-based learning and teaching activities. Therefore, students face many challenges in thesis projects. Almost four decades ago, Neale (as cited in Armstrong & Shanker, 1983) compared the supervision of research projects with coursework teaching and described it as more difficult than conducting undergraduate coursework programmes. Even today, thesis supervision is identified as a more complex and problematic pedagogy than general classroom-based pedagogies (Jaldemark, 2012; Rowley & Slack, 2004).

Numerous studies have documented the challenges of undergraduate thesis projects. Burton and Steane (2004) argue that completing a thesis is a difficult and stressful activity, and most students find a range of problems arising during their studies. Hansson et al. (2009) have discussed these issues and reported that around 30% of master's students at a Swedish university failed to finish their thesis. McMichael (1993) identified thesis management, academic knowledge and skills, interpersonal relationships, and institutional support as common issues in undergraduate thesis projects. Hewagamage et al. (2012) has listed three issues in relation to thesis projects, namely: 1) many students did not register to follow the projects 2) they dropped out from the course before completion, 3) the majority of students who took the project examination failed to defend their project work and dissertation.

There are many studies on designing and using LMSs for general classroom teaching activities but only a few studies about the designing of LMSs to support undergraduate thesis project-related learning activities. The Department of Computer and Systems Sciences, Stockholm University, has developed a tailor-made system to support their undergraduates. The preliminary results reveal that using this web-based system, named 'SciPro', has helped to smoothen the thesis process and improve its outcome in producing a defendable thesis that satisfies the requirements set by the relevant authority (Aghaee, 2015; Bider & Jalali, 2016; Byungura et al., 2015; Karunaratne et al., 2017).

Källkvist et al. (2009) explored creating and using the personalised virtual learning space for supporting, guiding, and supervising undergraduate preservice teachers, in order to support undergraduates' thesis projects. Nozal et al. (2013) developed a prototype using Moodle to support undergraduate and master's theses. Few other studies using ICT to support undergraduate thesis projects are available, but there is a lack of knowledge on designing a learning management system to support thesis projects.

From a theoretical perspective, learning through a thesis project is a constructivist pedagogical approach, with the basic underlying principles of constructivism, particularly active, collaborative, and authentic learning (Karagiorgi & Symeou, 2005). Information and Communication Technology has been used to create learning environments to support constructivist learning activities (Chan & Yang, 2018; Paily, 2013; Rovai, 2004) and ICT has recognised to have the potential of addressing issues in thesis projects (Aghaee & Keller, 2016; Hansson & Hansen, 2017; Jaldemark & Lindberg, 2012; Kjellman & Peters, 2011). However, Sri Lankan universities have paid little attention to using the ICT potential to support undergraduate thesis projects. Although many Sri Lankan universities have implemented LMSs, these systems are basically used in some classroom teaching activities but have limited use for collaborative leaning activities (Hasmy, 2020). Kandambli conducted a study using a model introduced by Jannosy (2008) to measure the LMSs usage of Sri Lankan state universities and found that the average is level 1. In level 1, LMSs is used only for basic activities such as sharing content, which implies that they do not use LMSs for collaborative activities such as conducting undergraduate thesis projects. Almost all Sri Lankan public universities have been using MOODLE-based LMSs which is mainly suitable for course-centric learning activities (M Liyanage et al., 2014). The general MOODLE-based LMSs can be used to support most of the learning activities since many courses in Sri Lankan universities mostly focus on teacher-centred learning rather than student-centred learning (Senanayake et al., 2015). In thesis projects students are involved in constructivist learning but the learning environment in the Sri Lankan university sector has not been developed to support constructivist learning activities (Markar et al., 2006). Therefore, insufficiency of the engagement in interactivity in the use of e-Learning within Sri Lankan academic institutions was identified as a particular problem (Gamage & Fernando, 2012).

Authors of previous studies have discussed the success stories of individual cases and the potential use of ICT to support undergraduate thesis projects (Aghaee & Keller, 2016; Hansson & Hansen, 2017; Jaldemark & Lindberg, 2012; Kjellman & Peters, 2011); however, comprehensive studies on developing LMSs or highlighting the advantages of using ICT in thesis projects are lacking. Therefore, it is interesting and important to investigate why they are not using ICT even though the basic infrastructure is available and find a solution that can be used to increase the use of ICT to support undergraduate thesis projects.

1.5 Research problem

The background of the problem describes how universities have been expanding ICT infrastructure to support academic and administrative processes. Even though ICT infrastructure is available and previous studies suggest that ICT has the potential to address the problems in thesis projects, ICT is rarely used to support undergraduate thesis projects.

The available studies on using ICT to support the thesis projects do not address some of the essential aspects of the thesis projects. The use of general LMSs to support thesis projects (Nozal et al., 2013) has been limited since they are designed to support coursework learning activities. Personal Learning Environments (PLE) (Sharafuddin et al., 2018) can create a personalised learning environment for individual students, but there is a lack of reusable resources, and a PLE is highly unstructured and difficult to manage the thesis project learning activities using PLEs. In addition to general systems, there are a few tailor-made systems available (Hansson et al., 2010). These are specifically designed to meet a specific department's requirements and do not consider general requirements. Similarly, many empirical studies explore the usefulness of ICT tools (Jaldemark, 2012; Källkvist et al., 2009; Larsson & Hansson, 2011), however, they have not focused on the design perspective. There is a particular lack of knowledge on designing information systems based on pedagogical assumptions of the thesis projects. Hence, this study mainly addresses the prevailing issues of lack of knowledge on information systems design in supporting undergraduate thesis projects.

1.6 Aim and objectives

Previous studies show that ICT can help to create efficient and effective learning environments for constructivist learning and can support the students' self-regulation processes (Chan & Yang, 2018; Paily, 2013; Rovai, 2004). Learning through thesis is a type of constructivist learning activity and student need self-regulation learning skills. Nevertheless, universities rarely use ICT to support thesis projects (Pimmer et al., 2017). Also, the author searched and found that there is a lack of knowledge in the literature on designing LMSs for undergraduate thesis projects concerning the pedagogical practices. Therefore, this study aims to 1) understand the pedagogical practices of the learning through thesis projects and related problems, 2) identify the requirements to satisfy those pedagogical practices, and 3) develop an information system design framework to design LMSs to support the undergraduate thesis projects. Three research objectives were formulated based on these aims:

1) the study will identify problems and challenges associated with the undergraduate thesis projects and analyse the root causes of these problems.

2) the study will analyse the underpinning learning theories relevant to the undergraduate thesis projects and explore the requirements of underpinning learning theories that can be used develop an ICT solution to address challenges and problems associated with the undergraduate thesis projects.
3) the study will create an information system framework for designing an LMS that supports undergraduates' thesis projects.

1.7 Research questions

The research problem is linked with the lack of scientifically constructed knowledge of designing learning management systems to support the undergraduate thesis projects. Accordingly, the main research question is formulated as follows: 'How should an LMS be designed to support the undergraduate thesis projects?'

Design is a solution to a problem (Simon, 1996), and it is necessary to precisely understand the problem before starting to develop a solution (Alan Hevner & Chatterjee, 2010; Johannesson & Perjons, 2014). Some of the explicit problems may be symptoms of the problems, and solutions should be designed to identify and address the root causes of the problems (Johannesson & Perjons, 2014). Also, there may be hidden problems even without visible symptoms. Importantly, a design may improve practices long before practitioners recognise any problem; it may also provide totally new opportunities (Iivari, 2007).

As already discussed, thesis projects are based on a complex pedagogy but have the potential of bringing opportunities to students, supervisors, universities, and society from different perspectives (Hansson & Moberg, 2011). Therefore, understanding the thesis process is necessary before designing a LMS to support the undergraduate thesis projects and the first sub-questions were formulated as follows: **Sub-question 1:** What are the problems of undergraduate thesis projects?

As discussed in an earlier section, developing a new information system to support a learning process needs an in-depth analysis of the whole process of interest. Therefore, the analysis should concern the empirical findings and theoretical underpinnings of the learning process of thesis projects. Therefore, a research question (sub-question 2) was formulated as follows to understand the thesis process from related theoretical perspectives. **Sub-question 2:** Which learning theories and pedagogical concepts should be considered when designing an LMS to support the undergraduate thesis projects?

The objective of this study is to develop a framework for designing an LMS that can be used to support thesis projects. A framework is a real or conceptual structure intended to serve as a support or guide for the building of something that expands the structure into something useful (Idri et al., 2012, p. 1). Therefore, this study will focus on understanding a general structure that can be used

to design an LMS to support undergraduate thesis projects. According to Baskerville and Pries-Heje (Baskerville & Pries-Heje, 2010) the foundation of an information system structure is constituted of requirements and components. Therefore, the third research question is: **Sub-question 3:** What are the requirements and components of learning management systems which would support the undergraduate thesis projects?

1.8 An Overview of research papers

This thesis is based on a collection of six selected articles that stem from a research effort conducted following the design science research approach. A Sri Lankan public university was selected as a context to understand the research problem and develop the framework.

The first and second papers are empirical exploratory studies with the aim of understanding the specific problems and requirements of undergraduate thesis projects. The third study investigated the theoretical foundation and pedagogical concepts that are related to the thesis projects' learning activities. The fourth and fifth studies discussed an already developed solution at the Department of Computer Science, Stockholm University, as a model solution. In the sixth study, a framework for LMS to support thesis projects was developed following the Explanatory Design Theory model. Also, the sixth study was conducted to get the supervisors' hypothetical view of the features/components of the proposed framework. The following papers are included in this thesis.

1.8.1 Paper 1: An Analysis of Existing Issues in Students' Research and the Project Initiation Stage: Information and Communication Technology Perspective

Many students select research topics without a proper understanding of the topic. Students, supervisors, and industry representatives have research ideas important for each other, but a lack of communication between these parties prevents their initiation as valuable research projects. Hence, there is a lack of industry-related student projects in the Sri Lankan university system, although the industry is an important source of ideas. ICT enabled information systems are developed to support teaching, learning, and administrative activities. However, there is a shortage of research to study ICT uses for the thesis supervision process. The focus of this study identifies issues in the initial stage of the research supervision process to design an ICT-enabled framework for the thesis supervision process. This study utilises both quantitative and qualitative data analysis techniques and follows a mixed method. A survey was conducted to identify issues in the thesis initiation stage, and four types of

questionnaires were distributed to supervisors, students, administrators, and industry representatives. Coordinators were interviewed to clarify unclear problematic areas, and finally, issues were explained with a model that can act as a foundation for future studies.

Author's contribution: The author designed and implemented the research and was primarily involved in writing the report. A survey was conducted to collect data, which the author summarised and analysed. The author contributed approximately 70% of the study, and the other authors contributed the rest.

Peiris, C. R., Hewagamage, K., Hansson, H., & Wickramanayake, G. (2013). An Analysis of Existing Issues in Students' Research and Project Initiation Stage: Information and Communication Technology Perspective. *7th International Technology, Education and Development Conference -INTED2013*, 1760–1769.

1.8.2 Paper 2: About the Challenges in Undergraduate Thesis Projects: An Explorative Case Study in Sri Lanka

This study explored the specific challenges in undergraduate thesis projects in management degree programmes by conducting an explorative case study in a Sri Lankan national university. Data were primarily collected via interviews and focus group discussions in six degree programmes, with around 40 participants. The study focused on exploring problematic areas, creating a general picture of why students' thesis projects were not progressing favourably. The following six main challenges were identified: 1) lack of student motivation, 2) lack of student-supervisor interaction, 3) an unstructured research process, 4) lack of skills and knowledge, 5) students' high workload, and 6) resource sharing issues.

Author's contribution: The author was mainly responsible for designing, implementing, and writing of the study. As an approximate value, the author contributed about 70% of the study, and the other authors contributed with the rest. The author conducted the interviews, transcribed the recorded audio files, and analysed the results.

Peiris, C. R., Barbutiu, S. M., & Hansson, H. (2018). About the Challenges in Undergraduate Research Projects: An Explorative Case Study in a Sri Lankan National University. *International Journal of Learning, Teaching and Educational Research*, *17*(2), 25–44. https://doi.org/10.26803/ijlter.17.2.2

1.8.3 Paper 3: A Constructivist Perspective on the Thesis Supervision Process: A Case Study of Sri Lankan Undergraduate Thesis Projects

This study's aim was to understand the pedagogical assumptions based on theories related to the thesis supervision process. The socio-cultural learning theory and our empirical findings suggest that the undergraduate research supervision environment should focus on facilitating students' self-regulation learning processes, student-supervisor interactions, and peer interactions. In traditional classroom learning activities, students, teachers, and peers meet in a specific place (classroom) according to a schedule, and discuss a set of predefined topics. By contrast, in thesis projects, most learning activities are individual, students need to interact with a real phenomenon (outside the classroom context), and it is difficult to schedule learning activities in advance. Hence, research supervision should be designed in the form of personalised and contingent interactions with supervisors. It is difficult to implement a static schedule (project plan), but a basic schedule is required to guide the research process, and this should be subject to changes when needed. Although students are involved in different research projects, peer learning activities may enhance the students' learning and motivation. Thus, research project supervision should be framed by a personalised learning environment with a flexible structure supporting student-supervisor interaction and peer collaboration. Since the learning environment requires collaborations between multiple participants, face-to-face meetings as the primary interaction method (in many research projects, interactions were limited to face-to-face meetings) hinder knowledge construction.

Author's contribution: The author was mainly responsible for designing, implementing, and writing of the study. As an approximate value, the author contributed about 70% of the study, and the other authors contributed the rest.

Peiris, C. R., Männikkö-Barbutiu, S., & Hansson, H. (2019). A Constructivist Perspective on the Thesis Supervision Process: A Case Study of Sri Lankan Undergraduate Thesis Projects. *Journal of Interactive Learning Research*, *30*(4). https://www.learntechlib.org/noaccess/184712/

1.8.4 Paper 4: SciPro Matching: ICT Support to Start a Quality Thesis

A good start is vital to producing a good thesis. Student-idea-supervisor matching is the essence of starting a good thesis, and the administration of this process is highly complex. Although information technology is widely applied in higher education, there is a lack of IT support in thesis projects. The specially developed SciPro IT system was selected as a model for discussion, and future developers may enhance the features elaborated in this discussion. One

of the innovative components of SciPro is an Internet-based Idea bank as a repository for ideas and the Idea bank facilitate matchmaking between students and supervisors. The selection of an idea is an important initial phase in the process of creating quality theses. The idea bank can be linked with external sources to enhance the richness of ideas.

Author's contribution: The author was mainly responsible for designing, implementing, and writing of the study. As an approximate value, the author contributed about 60% of the study, and the other authors contributed the rest.

Peiris, C. R.,Hansson, H., & Moberg, J., (2014). SciPro Matching: ICT Support to Start a Quality Thesis. *International Journal on Advances in ICT for Emerging Regions*, *7*(3), 75–84. http://journal.icter.org/index.php/ICTer/article/view/164

1.8.5 Paper 5: ICT Support for the Thesis Process: A Case as a Literature Review

This study was conducted as a literature review and was limited to a particular project initiated by the Department of Computer and Systems Sciences (DSV). Research papers were selected only if the article concerned the SciPro system. Google Scholar and Stockholm University Library search tools were used for collecting published papers. We found 34 papers on the SciPro system between 2009 and 2017. The findings of this study contributed to understanding the requirements and components designed over the last few years in DSV. Despite the different contexts, as a case, this study provides a history of a system purposefully developed to address issues in the thesis supervision process. Therefore, the findings of this study helped to design an innovative and feasible solution.

Author's contribution: The author was mainly responsible for designing, implementing, and writing of the study. As an approximate value, the author contributed about 80% of the study, and the other co-authors contributed the rest.

Peiris, C. R., & Hansson, H. (2017). ICT Support for The Thesis Process: A Case as a Literature Review. *Proceedings of the European Distance and E-Learning Network 2017 Annual Conference*, 113–122. https://doi.org/doi.org/10.38069/edenconf-2017-ac-0018

1.8.6 Paper 6: A Framework for Designing an LMS to Support Thesis Projects

Learning through thesis projects is based on a constructivist pedagogical approach; it needs a personalised learning environment where students can interact with supervisors, peers, and the study context. Thesis supervision has been highlighted as one of the most complex pedagogies, and numerous studies have attempted to understand the complexity. Also, we found many studies

related to the application of e-learning systems and tools for thesis supervision, but there is a lack of studies on the design and development of a comprehensive LMS to support undergraduate thesis projects. Therefore, this study aims to develop an information systems design theory for designing LMSs to support undergraduate thesis projects.

Author's contribution: The author was mainly responsible for designing, implementing, and writing of the study. As an approximate value, the author contributed about 70% of the study, and the other co-authors contributed the rest.

Peiris, C. R., Männikkö-Barbutiu, S., & Hansson, H. (2022). A Framework for Designing Learning Management Systems for Thesis Projects. *The Journal of Research Innovation and Implications in Education*, *6*(3). https://jriiejournal.com/wp-content/uploads/2022/10/JRIIE-6-4-001.pdf

1.9 Chapter Summary

More than 41,000 undergraduate research/projects are conducted every year in public universities in Sri Lanka. Even though students are new to the field of research they conduct the research or project with an experienced supervisor. Therefore, these studies and projects can be considered as a collection of free research opportunities. However, there is no evidence of the effective use of these research works. Furthermore, working on thesis projects is reported to be a challenging task for both students and supervisors. Conducting a research project resulting in a thesis can be regarded as a constructivist learning activity. The constructivist learning environment can be empowered using ICT-enabled LMSs to address the above-stated issues. Although LMSs are used for general classroom teaching and learning, there is a lack of use of LMSs for thesis projects. One of the main reasons for the lack of use of LMSs for thesis projects is a lack of knowledge on designing and using LMSs for thesis projects. Therefore, the objective of this thesis is to develop a framework that can identify requirements and software components for LMSs to support thesis projects.

2 Extended background

2.1 Undergraduate thesis projects

A thesis project can be regarded as an inquiry-based constructivist pedagogical learning activity where the student is supposed to learn from an independent study (Healey & Jenkins, 2009). Research-based and project-based independent studies are two types of inquiry-based methods (Brew & Jewell, 2012 emphasis added) that are becoming popular in undergraduate programmes (Ministry of Higher Education Sri Lanka, 2012), and thesis projects are arranged to furnish experiences of students in terms of multiple aspects of inquiry (National Research Council, 1996, p. 2). In research-based studies, students practice how to solve a research problem, and in project-based studies, students practice how to apply existing knowledge in an innovative way to solve a practical problem. Although the approach is different, both research-based and project-based independent studies follow a similar process. In both approaches, an experienced adviser is assigned as a supervisor to guide the thesis project. Following the constructivist learning pedagogy, students are made responsible for constructing knowledge by actively engaging in authentic learning activities while interacting with the environment (Savery & Duffy, 1994). Even though students' projects are unique, they have to follow a general process that includes selecting a research problem, preparing a research plan, implementing the plan, and writing a report to share findings and the research process.

2.1.1 The undergraduate thesis processes

Undergraduate students learn mainly by following the structured learning activities commonly known as coursework. In addition to course work, there is a trend to include research work called a thesis project, where each student should follow a unique study plan, which mainly comprises field works. The supervisor supports the thesis project, but as the student and the supervisor do not meet regularly, the learning environment for thesis projects should provide essential functionalities such as facilitation of flexible and structured interpersonal communication, collaboration, and support. In course work, students regularly meet the teachers and peers in a classroom according to a prescheduled timetable. The curricula are fixed, and all students follow common learning activities. In contrast, in thesis projects, students select a problem to solve

based on their own interests and skills, and each student may have to engage in different learning activities. Furthermore, they have more autonomy when planning and conducting learning activities, and they need to develop self-regulation skills. Most thesis projects are individual, while some are undertaken as a group project, with a limited number of students (commonly two students).

Humanities and social science thesis projects are often related to real-world problems (Rowley & Slack, 2004), and such thesis project activities need more interaction with external entities and people than pure science and engineering thesis projects. For instance, a chemistry student's thesis activities may include a study of chemical reactions in a laboratory, while a management student needs to interview people. Therefore, the learning environments of humanities and social sciences thesis project activities are more dynamic and unpredictable. For example, students may plan to collect data from a survey, but the response rate may be insufficient.

Post-graduate curricula also include thesis projects as a module but comparing the undergraduate thesis projects with postgraduate thesis projects enables us to identify certain significant differences. First, undergraduate thesis project duration is shorter than the duration of postgraduate thesis projects. At the same time, postgraduate programmes offer thesis projects with more credits for the thesis components, including additional supervision hours. Similarly, a supervisor of undergraduate students often guides many students; their supervision hours are limited, and the student and supervisor relationship is weak in undergraduate level thesis projects. Compared to students conducting postgraduate thesis projects, undergraduate students are beginners in research work.

2.1.2 Importance of undergraduate thesis projects

The Council of Undergraduate Research (2005, p. 1) introduced undergraduate research as the pedagogy for the 21st century, and contemporary studies highlight undergraduates' thesis projects as representing an essential learning method (Bauer & Bennett, 2003; Craney et al., 2011; Gonzalez, 2001; Greenbank & Penketh, 2009; McInnes, 2018; Seymour et al., 2004; Taraban & Logue, 2012; Valentin & Alexandra, 2011). Hansson et al. (2010) discuss the benefits of thesis projects, referring to three levels named micro, meso and macro.

The first level, the micro level, is about the benefits of thesis projects for individuals such as students and supervisors. Thesis projects provide an opportunity for students to practice and apply theories in authentic environments (Birdsong & Schuster, 2006). Robert (cited in James, 1998) considers thesis projects to represent an approach that develops students' knowledge, competence, awareness, critical abilities, and intellectual maturity. In addition, thesis projects offer students a unique opportunity to demonstrate their independent

learning and knowledge acquisition (Rowley & Slack, 2004; Todd et al., 2006), and are valuable training for either further studies and/or employability (Harrison & Whalley, 2008; Morris & Labhard, 2005). Thesis projects are helpful, not only for students but also for supervisors, to expand their research activities. For example, supervisors can implement their research ideas through undergraduate research students.

The second level, the meso level, relates to the benefits for organisations, such as firms, government agencies, and community organisations. These organisations have problems that should be investigated, but they may lack funding for a research unit. From these organisations, especially, small and medium-scale organisations may have limited or no funding for research and development activities. Undergraduate students are novice researchers, but they conduct research with experienced supervisors. If supervisors closely monitor, even undergraduates can conduct quality research. Therefore, these organisations could have the opportunity to investigate their problems by connecting them with thesis projects.

The third level, the macro level is about the use of thesis projects for regional and national developments. Although a university's mission in society has traditionally been researching and teaching (Scott, 2006), when scientific knowledge is undeniably crucial for innovation and new business development, politicians and governments want universities to take a more direct role as leaders in regional and national development. From the university perspective, thesis projects can be used as a strategy to increase the research related to regional and national economic development. As a long-term benefit, students' thesis projects could contribute to increasing the research and development activities that are essential to creating an innovative nation. Imagine 41,000 undergraduate theses aligned with critical issues in the country being produced each year.

In contrast to studies highlighting the importance of thesis projects, some studies (Brew & Boud, 1995; Hattie & Marsh, 1996) criticise the effectiveness of undergraduate thesis projects. Despite this problem, many institutions have introduced thesis projects into the curriculum, and the higher education institutions have increased the priority for thesis projects at undergraduate level (Goodlad, 1998; Kinkead, 2003; Petrella & Jung, 2008; A. Wilson et al., 2012). For example, according to a policy decision (Ministry of Higher Education Sri Lanka, 2012, p. 27), all Sri Lankan undergraduate programmes should include a research project as a mandatory component. On average, the duration of a thesis project is about six months. Consequently, on average, about 41,000 undergraduate students' research projects should be conducted each year (University Grant Commission of Sri Lanka, 2021). In a country like Sri Lanka, with a population of almost 22 million, the number of potential students aiming for an undergraduate degree is much higher than the number that can be accommodated with the existing capacity of the universities. Therefore, increase the capacity-of conducting thesis projects are highly importance.

2.2 Issues in the undergraduate thesis projects

Although undergraduate thesis projects are considered an effective pedagogy, completing a thesis project is a stressful, complex, and problematic process, requiring more resources than traditional classroom teaching methods (Connell, 1985). Deborah (2010) argues that study skills taught to students during their schooling and at the extra classes (tuition) encourage teacher dependency and memorisation and adversely affect research activities. Due to its complexity and problematic nature, the thesis component has adversely affected the completion rate and duration of degree programmes (Acker et al., 1994; Hansson et al., 2009). Thesis project-related issues are mainly connected with students, supervisors, and student-supervisor interaction. Central student-related issues in undergraduate thesis projects are the lack of motivation, lack of self-regulation skills, lack of information, and lack of research experience (Afzal et al., 2010; Pintrich, 2003). Problems related to supervisors include the absence of a suitably prepared supervision plan, lack of suitable pedagogical approach or lack of understanding of the best practices; i.e. supervisors often start the supervision process with ad-hoc approaches (Calvert & Casey, 2004). A thesis project should encourage trial and error in some of the activities such as data collection, but trial and error in the whole project is not a good approach.

A high level of academic performance is needed to complete a thesis project. Analysis of the general literature about education shows that student motivation is one of the central issues in understanding their academic performances (Adedokun et al., 2010; Kember, 2016). There is a causal relationship between students' motivation and academic performance (Afzal et al., 2010; Ayub, 2010; Everaert et al., 2017). The literature on thesis projects identifies the lack of student's motivation as one of the main challenges (Afzal et al., 2010; Pintrich, 2003) in thesis projects.

Studies reveal that students have problems with time management, planning their studies, coping with their workload, and organising group work (Brew & Jewell, 2012; Harrison & Whalley, 2008; M. Todd et al., 2004; Wenderholm, 2004). All these factors affect student motivation (M. Todd et al., 2004). Moreover, previous studies have discussed how the design of the thesis course may prevent students from successfully completing the thesis projects (Wenderholm, 2004), which suggests that the thesis course design is crucial, as it may support students in the thesis process (Brown et al., 2016; M. Todd et al., 2004; Wenderholm, 2004), and a less-planned design may prevent students from successfully completing their thesis projects.

As highlighted in previous studies, another central issue is related to the student-supervisor interaction. Perera (2014) has highlighted the hierarchical relation and the lack of interaction between students and their teachers in higher education institutions. Furthermore, Christie and Jurado (2013) report a significant proportion of incidents involving power struggles and lack of

professional and emotional support, as well as poor communication during the thesis projects. For successful supervision, supervisors need to play multiple roles during the research project (Atkins & Brown, 1988; Cook, 1980).

In addition to academic advice, students require support and encouragement to gain the confidence needed to complete their thesis projects (M. J. Todd et al., 2006). Students come from diverse social, economic, and personal backgrounds (Morgan, 2013), and have different learning styles (Ramburuth & McCormick, 2001). Therefore, supervisors should be sensitive to these differences between students (Manathunga, 2007) to build a functional student-supervisor relationship.

Particularly in developing countries, a lack of resources, such as access to literature, computers, and the internet, affects thesis projects (Ngozi & Kayode, 2013; Zenzele, 2010). According to Barratt (2004), students' problems start with the topic selection. They find it challenging to obtain relevant information, filter the available information, and use the information. Investigations have proved that the study and research skills of the students play a central role in the success of thesis projects. It has also been observed that their subject knowledge is insufficient. Ling et al. (2008) also state that the thesis quality of undergraduates majoring in science and technology are low due to the lack of excellent instructor and teaching resources. Wenderholm (2004) discusses how the students' lack of knowledge prevents progress in research projects. Perera (2014) reports the lack of English language proficiency and difficulties in reading research papers as two crucial issues that prevent students achieving success in the Sri Lankan higher education context.

In undergraduate thesis projects, many challenges have been identified and they are linked to multiple sources. Of these challenges, the main ones are student motivation and the student-supervisor relationship, and the design of the thesis course directly affects both. Because the challenges are intertwined, further studies are required to comprehensively understand the dynamics of student-supervisor relationships related to student motivation and the design of the thesis course. In addition, these challenges need to be studied and understood in different contexts.

2.3 Context of the study – Sri Lankan country profile

The present research project is situated in Sri Lanka, a lower middle-income country with a GDP of USD 3,680 per capita and a total population of 21.4 million (The World Bank, 2020). Despite regional disparities, poverty in Sri Lanka continues to decline in line with strong economic growth (The World Bank, 2020). Although Sri Lanka is a lower middle-income country, according to United Nations development bank reports, Sri Lanka's Human Development Index (HDI) is 72, which is considered a higher rank than that of the other countries in the region. Between 1990 and 2019, Sri Lanka's HDI value

increased from 0.625 to 0.782; an increase of 25.1 per cent (UNDP, 2020). Figure 1 illustrates Sri Lanka's progress in each HDI indicator.

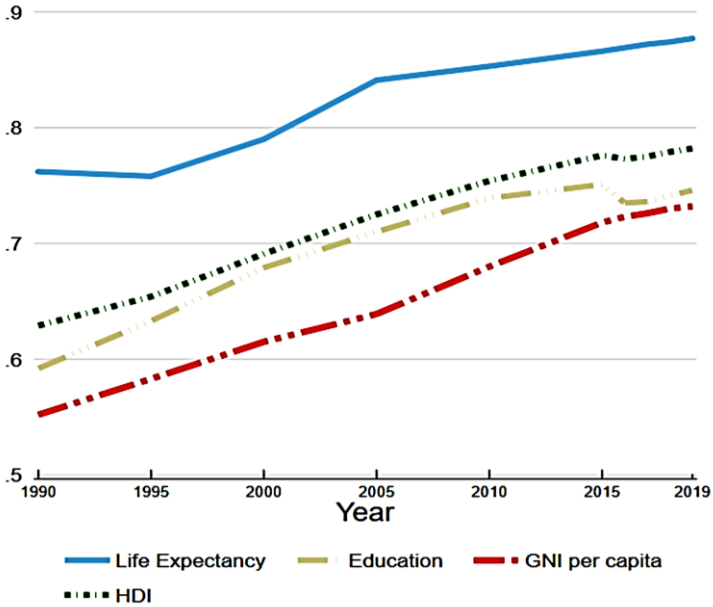

Figure 1. Trends in Sri Lanka's HDI component indices 1990-2019 (UNDP, 2020)

An average Sri Lankan's literacy rate is 93%, and the government provides free education up to the undergraduate level. In 2020, in 15 public universities, the full-time internal undergraduate and postgraduate student enrolment was 109,660 and 41,074, respectively (University Grant Commission of Sri Lanka, 2021). In 2020, about 301,171 students participated in the university entrance exam, and 65% of students qualified for higher education (Department of Census and Statistics of Sri Lanka, 2021). Due to limited opportunities, the university entrance exam is highly competitive; only about 20% have been selected for the university during the last few years. It is a trend that during the previous two decades, student enrolment increased, but the number of academic staff has not increased proportionately (see Figure 2).

Although the high-ranking students enter the university, undergraduate unemployment is a major issue in Sri Lanka (Singam, 2017). It is difficult to find the exact undergraduate unemployment rate since government institutions mix graduate unemployment data with advanced-level education and above. However, previous studies reveal that the unemployment rate of undergraduate is higher when it compares with lower education levels (Singam, 2017; World Bank, 2018).

The government has a policy to provide employment for undergraduates in public sector organisations; therefore, about 77% of graduates are employed by the public sector. A recently completed survey from 2017 finds that about

half a million vacancies exist in the private sector, suggesting a skills mismatch (World Bank, 2018). Concerning the unemployment issue, the University Grants Commission introduced several reforms and projects to improve the relevance and quality of undergraduate education (Dissanayake, 2011). The latest changes and suggestions were introduced in 2015, one of which is to include a research project for all undergraduate degree programmes. Similarly, with foreign funding agencies, the UGCSL has improved the ICT infrastructure in all Sri Lankan national universities. For example, UGCSL provides Lanka Education and Research Network funds to maintain a high-speed internet connection for all national universities. At present, most universities are connected via fibre optic cables, and the speed ranges from 700Mbps to 1Gbps with the Eduroam (education roaming) service (LEARN, 2022)

The author conducted a preliminary study and interviewed thesis course coordinators from six Sri Lankan universities and found out that the use of ICT-enabled systems to support the thesis projects is limited to activities such as posting common notices, collection of reports etc. This study was conducted at one of the management faculties of a Sri Lankan national university; while some physical ICT infrastructure is available, but the faculty still lacks the use of ICT to support the undergraduate thesis process. The term "faculty" will be used throughout the rest of this thesis to refer to the place where this study was conducted.

2.4 The importance of studying the issues in undergraduate thesis projects

The importance of undergraduate thesis projects and potential benefits has already been discussed in section 2.3. Several problems have also been discussed above, which hamper the realisation of benefits of thesis projects. In the Sri Lankan context, two main changes that increase the importance of the study of solving issues in undergraduate thesis projects have been identified. The first change is the increase in the volume of thesis projects. Although the number of undergraduate students is constantly increasing in Sri Lankan universities, the number of academic staff does not increase proportionately. To highlight this problem, the author compared the number of full-time undergraduate student intake and the number of academic staff members in all Sri Lankan universities. As Figure 2 (calculated based on University Grant Commission of Sri Lanka, 2021) highlights, the student-lecturer ratio has constantly increased from 1995 to this date. This is a trend and it creates problems related to all learning activities, but is especially problematic for thesis projects, since they require one-to-one interactions between supervisors and students. Most of the learning activities are designed for traditional classroom learning activities, where a lecturer conducts a common session for a large

number of students. For example, the selected faculty intake is about 1200 students, divided into classes where the average number of students is 100 to 150. Therefore, even if there are 100 to 150 additional students, either a new class can be formed, or the students can be distributed among other classes. However, when the number of students increases for thesis projects, a supervisor should be allocated for each thesis project, and the supervisor needs to prepare an individual project plan to match the student's potential capabilities, to guide and monitor, communicate and collaborate, maintaining a proper interpersonal relationship with each student. Therefore, the increasing number of students severely affects the supervisor's workload and may worsen the problems related to thesis projects. When the workload is high, there is a potential additional adverse effects such as supervisor burn-out and other stress-related illnesses, which could result in even fewer available supervisors in the long run. Therefore, finding a solution to address the increase in the number of students per supervisor is very important for Sri Lankan higher education institutions.

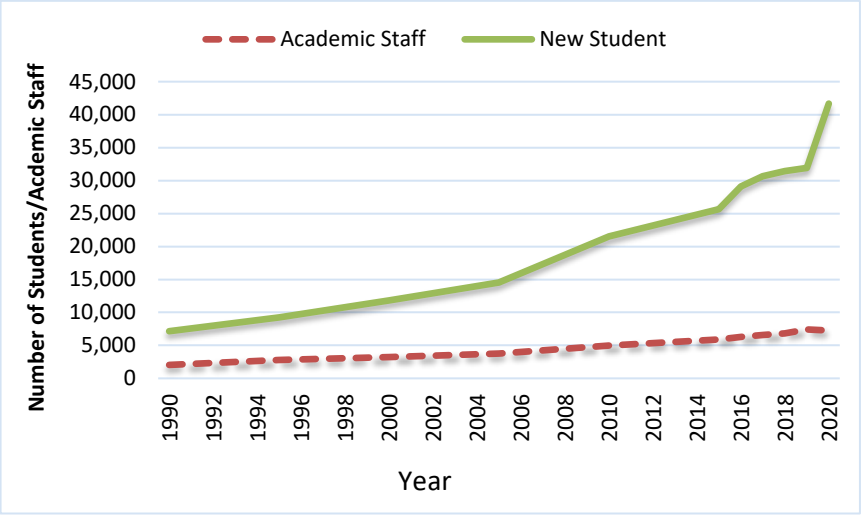

Figure 2. New Intakes for Sri Lankan National Universities for Internal Undergraduate Degree Programmes from 1995 to 2017, and the number of academic staff

The second change is related to the students' characteristics, such as self-efficacy, motivation, and self-regulation skills, which are necessary for them to be constructive students. Previous studies highlight the fact that these skills directly affect academic performance (Adedokun et al., 2010; Kember, 2016). The new policy will force students to conduct a thesis project even if they do not have these characteristics and experience. Students engage in thesis projects to fulfil a requirement of the degree programme, and thesis will be graded as other course modules. For example, in the selected faculty, students should follow about 40 course modules (to earn 120 credit points) to complete an

undergraduate degree programme. A thesis project is also considered a course; the allocated credit range is from 4 to 6, and the average weight for the thesis project is about 3% to 6% credits. Until 2015, universities had the authority to offer a thesis as a mandatory or optional component of a degree programme. Therefore, many degree programmes included a thesis project as an optional module, and students selected thesis projects only if they were interested. When considering all the programmes, out of 1200 students, about 34% students have selected research project courses (including programmes that offer thesis projects, both as mandatory and optional modules). However, only 4% (50 out of 868) of students have selected thesis projects when the thesis project is offered as an optional component. This result indicates that many students are either not ready to see thesis projects as an opportunity or they are afraid of selecting them when they are offered as an optional course module, either because they lack self-efficacy, motivation, or self-regulation skills, or perhaps because of the fear of receiving too little support from the university. However, in the future, students will not have an option and all students will have to conduct a thesis project even if they are not interested in doing so. This situation may increase the problems regarding thesis projects.

Therefore, it is crucial to study and find potential solutions to address the challenges associated with thesis projects. Despite the availability of numerous studies on postgraduate level thesis projects, studies on undergraduate level thesis projects are scarce. For example, the main concern of Rowley and Slack (2004) has been the lack of interest in thesis projects in higher education institutions, and they urge from higher education institutions to pay more attention to the thesis process to support students' learning and ensure the quality of the thesis.

2.5 Important theoretical aspects of the thesis process

The first step of the design science research approach is to understand the gap between a desirable state and the current state (Johannesson & Perjons, 2014). To understand the desirable state, it is necessary to understand the underpinning learning theories of the thesis projects. Learning theories describe how humans and animals learn and help us understand the complex learning process (Guney & Al, 2012). In education, constructivism is a widely accepted learning theory; as the name suggests, learning is viewed as a process of actively constructing knowledge by the individual rather than passively acquiring it. The theory considers the learners' social, cultural, and contextual conditions and emphasises experience as essential for knowledge construction (Guney & Al, 2012).

Oliver (as cited in Conole et al., 2004) claims that studies have described the instances of e-learning upon theoretical positions, such as constructivism,

without explaining how they embody the principles and values of that approach; this is also the case for studies related to ICT support for thesis projects. There are many studies of learning through thesis projects, but there is a lack of systematic studies about the relationships between learning theories and practices that can help us understand the problems and solutions in thesis projects. Conole et al. (2004) discuss this issue and conclude that e-learning designs more often reflect 'common-sense' rather than theoretically informed design. Therefore in this section, learning theories and theoretical concepts are discussed in thesis processes to understand the requirements of LMSs for supporting the undergraduate thesis process. Initially, the whole thesis process is discussed in relation to relevant learning theories. Thereafter, the applicable models and concepts of related learning theories are discussed.

Learning through a thesis project is a kind of Inquiry-Based Learning (IBL) activity that promotes students' learning through student-driven and instructor-guided investigations (Aditomo et al., 2011). As a kind of IBL, learning through thesis projects is a constructivist approach (Adedokun et al., 2010; Fair et al., 2003; Harland, 2003), where learners integrate and connect their existing knowledge with new information and create awareness through communication and practice (Jirasatjanukul & Jeerungsuwan, 2018). According to Bruning, "constructivism is a psychological and philosophical perspective contending that individuals form or construct much of what they learn and understand" (as cited in Schunk, 2012, p. 229). Constructivist epistemology is somewhat complex to define, as there are many interpretations (Murphy, 1978). Nonetheless, many studies, educators, and researchers have agreed that this constructivist epistemology should affect educational practice and learning (Murphy, 1978). This discussion will focus on constructivist epistemological concepts relevant to undergraduate thesis projects.

Within the constructivism paradigm, the most important original ideas are contributions from Jean Piaget and Lev Vygotsky to a large extent. Piaget focused on individual learning processes (Flavell, 1996). Central to Vygotsky´s theory is the cultural and historical context and social interaction with teachers and peers (Palincsar, 2005). He emphasised the importance of communication for learning; with teachers and more capable peers. The cognitive and sociocultural perspectives are complementary. The cognitive and social-cultural perspectives assume that students construct new knowledge (or reinforce it) based on previous knowledge, and that learning needs to be student-centred. These pedagogical principles are relevant for thesis projects. The thesis project is offered at the end of the degree programme so that students can use previous knowledge as a foundation. In general, there are no lectures or classroom activities when conducting a thesis project, and students learn actively by participating in thesis project activities; it is assumed that students construct knowledge themselves rather than receiving it from teachers. Learning through thesis projects also includes learning in social interactions, when stu-

dents attempt to solve a real problem with external actors, and when the supervisor assists students in enhancing their skills and when interacting with peers. The thesis project is a student-centred learning activity, and to be able to manage this aspect, they need self-regulation skills. Based on these theories, a learning environment for undergraduate thesis projects should be designed to support interactions and students' self-regulation processes.

Concerning interactions in thesis projects, Vygotsky's socio-cultural theory brings to light two main concepts: the zone of proximal development (ZPD), and scaffolding (Peer & McClendon, 2002). The concept 'ZPD' highlights the importance of designing the learning environment with student-supervisor interaction and peer interactions. The concept 'scaffolding' highlights the importance of designing the learning environment to support the students' learning process stepwise. Self-regulated learning is another important aspect that needs to be considered when designing a learning environment for thesis projects. These three concepts – zone of proximal development, scaffolding and self-regulated learning – should be considered when implementing ICT support systems for learning in higher education.

2.5.1 Zone of proximal development

In thesis projects, a supervisor guides the learning process. The importance of the supervisors' role can be described using the concept of the ZPD. The concept of the ZPD is defined as "the distance between the actual development level, determined by independent problem-solving, and the level of potential development, determined through problem-solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1980, p.86). The core idea of the ZDP is illustrated in Figure 3.

Applied in the context of thesis supervision, the ZPD could be considered the difference between a students' capability to construct knowledge alone on the one hand and their ability to build knowledge with a supervisor on the other. According to Vygotsky, although students have the same physical age, their actual developmental levels differ and change over time. Supervisors, therefore, need to recognise the potential capabilities of individual students at the initial stage of supervision and should be aware of the changes throughout the learning project.

Many studies have highlighted supervisors' mediation as a success factor in thesis projects (Harrison & Whalley, 2008; Hewagamage et al., 2012; Ismail & Hassan, 2011; Johnson et al., 2015). Similarly, students highly appreciated the encouragement and emotional support given by their supervisors, considering it as an influential factor for their success (Armstrong & Shanker, 1983). Many students readily acknowledge that the supervisor was a key person to turn to for advice, guidance, and resolution of problems (Harrison & Whalley, 2008). A supervisor is not limited to being an academic adviser and should play multiple roles to create a successful thesis project

(Cook, 1980; Hewagamage et al., 2012). According to Keogh (2006), the supervisor's role has been variously described as; "subject expert; gatekeeper of academic standards; resource person and adviser on the research literature, research methodologies; 'midwife' of the dissertation; director, project manager, shaper; scaffolder and supporter; editor; and promoter of student self-efficacy."

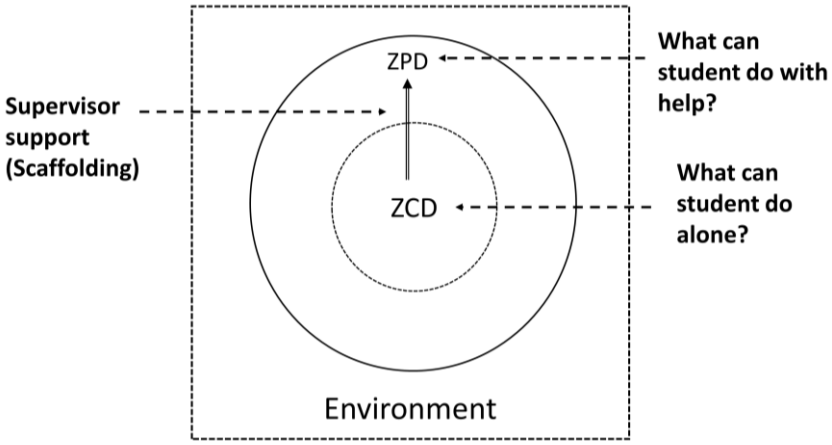

Figure 3. Zone of Proximal Development

Vygotsky died in 1934 and could not foresee the Internet; a student's zone of proximal development is greatly expanded with this resource. By using the Internet and asking the right questions via search engines, students' capacity to develop the skills required to complete an undergraduate thesis project may greatly enhanced.

2.5.2 Peer interactions

Peer interaction, peer review, peer assessments, and peer learning are similar concepts and refer to how students interact with other students to share knowledge and experiences. Peer interaction is not a single, undifferentiated educational strategy. Griffiths et al. (as cited by Boud et al., 2014) explains it as a broad range of activities, for example, researchers from the University of Ulster identified ten different peer learning models, and they are traditional proctor model, discussion seminars, private study groups, *parrainage* (a buddy system) or counselling, peer-assessment schemes, collaborative project or laboratory work, projects in different sized groups, workplace mentoring, and community activities.

We are familiar with and often make peer comments in our everyday lives. When we have questions or uncertainty, we informally contact friends, helping each other solve problems, which might happen between two persons or between groups of people intentionally or unintentionally. For instance, when students interact with each other (Rajamanthri & Bulumulle, 2006), one can help the other understand something, which could be explained as unintentional. In addition, there are intentionally arranged peer collaborations also exist. For example, informal group discussions of the subject matter called "Kuppi", a very popular learning method in Sri Lankan universities (Kommalage & Thabrew, 2011). Students interact informally at a place of convenience where they like to socialise and enjoy the learning process by freely sharing knowledge and experience. It is a kind of problem-solving to be able to understand and mainly discuss pass papers and the main focus is preparation for the examinations.

Some studies highlight the importance of proper integration of peer interaction (Aghaee & Hansson, 2013). If not correctly planned, a peer interaction will create an additional burden and degrade the quality of learning. David et al. (as cited by Boud et al., 1999, p. 413) discuss this issue, stating,

> *"however [that], many existing assessment practices act to undermine the goals of peer learning and lead students to reject learning cooperatively. If assessment gives students the message that only individual achievement is valued and that collaborative effort is akin to cheating, then the potential of peer learning will not be realised. Inappropriate assessment practices may also lead to unhelpful competition within and between groups that prevent groups from functioning effectively."*

Aghaee and Hansson (2013) analysed peer reviews in thesis writing and identified the possibility of using peer review in thesis projects, but different support mechanisms are required to improve the overall quality of peer review and make the interactions fair among students.

2.5.3 Scaffolding

The concept of scaffolding can help us understand the practical use of supervisor mediation in the learning process. If students are alone, they will face obstacles that delay or hinder the learning process. Figure 4 illustrates this concept. Students need supervisors' support to reach the outer areas of their ZPD. This idea suggests that students need support from teachers (or peers) to bridge the gap between their current abilities and the intended goal (Barak & Carla, 1992; K. Wilson & Devereux, 2014). According to Vygotsky's arguments, the mediation of experts or capable peers is essential for the constructivist learning environment. Scaffolding in higher education is a complex

topic, and various models and tools that can be used in the scaffolding process have been discussed in the literature (Coulson & Harvey, 2013; Stanier, 2015).

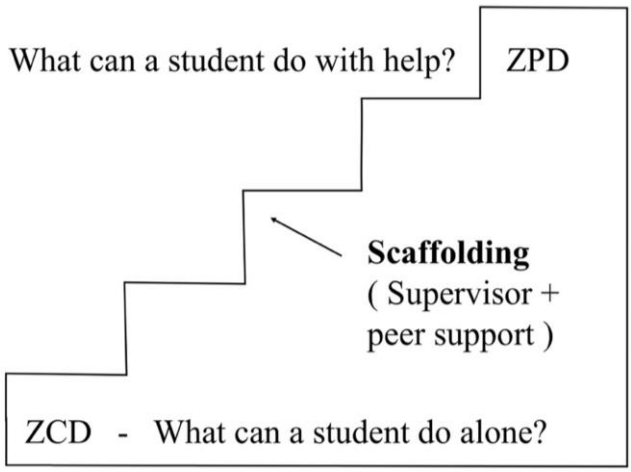

Figure 4. Scaffolding

One requirement in thesis projects is that the students must select a problem from the real world, which is a challenge to students, and the level of the difficulty varies based on the students' experience of constructivist learning activities. If the students have no experience of constructivist learning activities, the thesis project is a considerable challenge to them. Wilson and Devereux (2014) argue that scaffolding enhances students' engagement in highly challenging tasks and helps them reach far into their ZPD; without scaffolding, students will be frustrated or find shortcuts, such as plagiarism.

Referring to the Zone of proximal development concept Gibbons and Hammond (2005) suggest a scaffolding model that can be used in thesis project supervision. The model suggests two types of scaffolding called designed-in and contingent scaffolding. Furthermore, Saye and Brush (2002) highlighted another similar model, including two types of scaffolding, called hard and soft scaffolding, that are respectively matched with designed-in and contingent scaffolding. Both models can be used to understand how the scaffolding should be designed in the thesis supervision process. Designed-in scaffolding (hard) relates to learning goals and provides a framework to plan scaffolding in advance with a proper structure for the thesis project activities such as project planning, data collection, data analysis, and report writing.

Contingent scaffoldings (soft) are related to the ad-hoc support needed when students are engaged with thesis activities. Soft scaffolding is dynamic and situation-specific, and supervisors need to continuously diagnose learners' understandings and provide timely support based on student responses (Saye & Brush, 2002).

2.5.4 Students' self-regulation

The Zone of Proximal Development highlights the supervisors (or more capable peers) as vital for student learning. However, according to the constructivist learning theories, knowledge cannot be transferred from teachers to students (Olusegun, 2015), and students need to construct knowledge actively by engaging in learning activities. Constructivist learning includes student-centred forms of instruction, social learning, situated knowledge-creating, and inter-subjective pedagogies in contrast to instructivist learning's well-formulated, teacher-directed and didactic learning pedagogies (Porcaro, 2011). In thesis projects, students follow activities according to constructivist learning practices (Rowley & Slack, 2004) and need a higher degree of self-regulation capacity. Undoubtedly, all learners use self-regulatory processes to some degree (Zimmerman, 1990), but students learning through thesis projects require a higher level of self-regulation (Harrison & Whalley, 2008; Zenzele, 2010). Therefore, if students lack self-regulation, the thesis project will be a considerable challenge, and they will try to avoid learning through thesis projects if it is offers as an optional course (Rowley & Slack, 2004). However, thesis projects are becoming mandatory in an increasing number of undergraduate curricula (Peiris et al., 2018; Roberts & Seaman, 2018). Therefore, the number of students who conduct a thesis project without self-regulation skills will increase, and without self-regulation skills, students can become overwhelmed, resulting in delayed thesis completion or even dropping out (Ge, 2013). Previous studies suggest that technology-rich environments can be used to improve self-regulation skills and active knowledge construction (Ge, 2013).

Furthermore, it is important to note that literature identifies the lack of students' motivation as one of the main challenges in thesis projects (Afzal et al., 2010; Pintrich, 2003), which tends to prevent students' engagement in thesis project activities. Motivation and self-regulation are reciprocal and mutually reinforcing (Ning & Downing, 2010; Schunk & Zimmerman, 2012). Self-regulated learning refers to the processes whereby learners personally activate and sustain cognitions, affects, and behaviours that are systematically oriented towards attaining personal goals with or without seeking help from peers, coaches, and teachers (Schunk & Zimmerman, 2012). Several distinct models have been developed to explain the self-regulation process, but many of them have overlapping concepts (Carneiro et al., 2011, pp. 4–17). These models can be categorised into two major aspects, namely, "process" and "component" (Dettori & Persico, 2008). Zimmerman's social learning psychologist (2002, p. 67) model can be used to understand the process aspect. The process model views SRL as consisting of three phases that are cyclically repeated during learning activities of self-regulated learners and that influence each other. The three phases are: forethought, performance, and self-reflection. Figure 5 explains the structure of the self-regulatory processes by referring to three cyclical phases that can be applied to supervision of the thesis project.

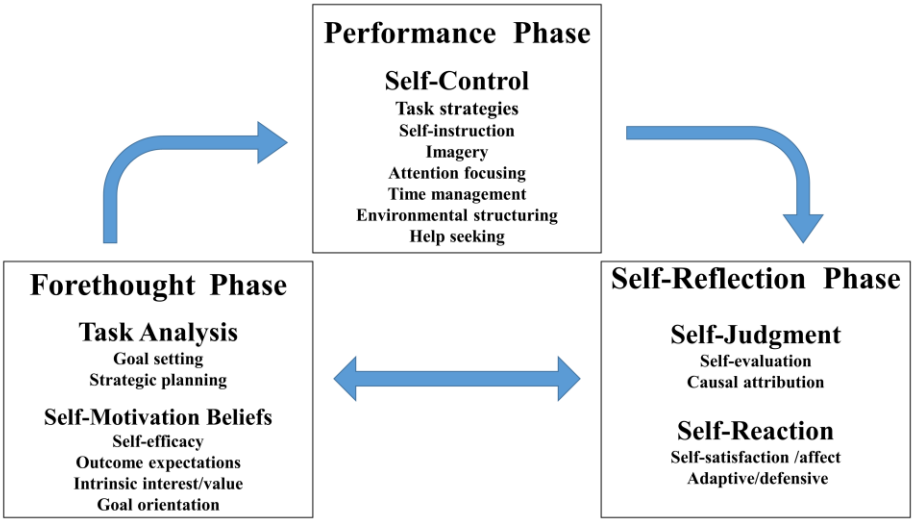

Figure 5. Phases and sub-processes of self-regulation

This model can be applied to the entire thesis process as well as to each sub-activity of the thesis process. The forethought phase refers to processes and beliefs that occur before the learning efforts; the performance phase refers to processes that occur during behavioural implementation, and self-reflection refers to processes that occur after each learning effort (Zimmerman, 2002). This model emphasises a learning environment that enhances and supports learners' abilities to plan, monitor, and evaluate their own learning process (Dettori & Persico, 2008).

Zimmerman's (1989) triadic model of self-regulation can be used to understand the component aspect of self-regulation. The triadic model has been developed based on Bandura's work (Figure 6), incorporating social learning constructs and assumptions. The essence of Bandura's triadic formulation (as cited in Zimmerman & Schunk, 1989, p. 11) is that the behaviour is a product of both self-generated and external sources of influence. In line with Bandura's social cognitive perspective, self-regulation learning can be mediated by external influences and Cassidy (2011, p. 991) defines SLR as a reciprocal process;

> *"self-regulated learning occurs is a result of reciprocal causation between three influence processes; personal processes such as perceptions of ability (e.g., academic self-efficacy) and self-motivation (e.g., goals); the learning environment, including task demands and encouragement from teachers; and individual behaviour, such as performance outcomes (e.g., previous marks/grades)."*

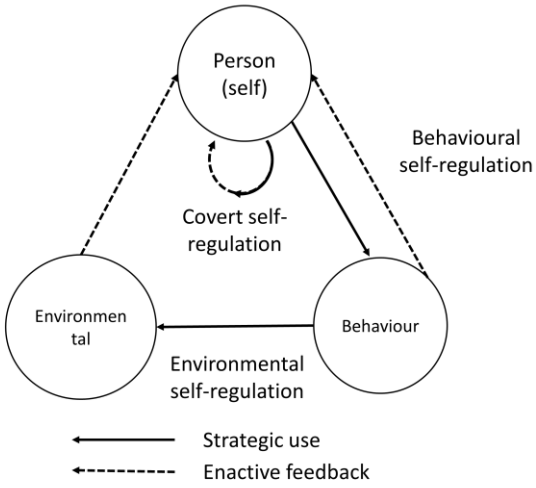

Figure 6.A triadic analysis of self-regulated functioning

According to this model, merely personal processes do not determine self-regulated learning; these processes are assumed to be influenced by environmental and behavioural events in a reciprocal fashion. This model emphasises the influence of student-supervisor interaction and peer interaction on self-regulated functioning. From a theoretical perspective this model suggests that LMSs for supporting thesis projects needs to consider including subcomponents that enhance the student-supervisor and peer interactions while conducting a thesis project. In addition, this model suggests that the learning environment should implements a mechanism to help students to manage their behaviour during the thesis projects.

2.6 ICT for thesis supervision

Although many research studies have been conducted on the use of ICT for thesis supervision, the majority of them focus on the postgraduate level, and less attention has been paid to the undergraduate level. Even out of these studies, many of the research studies share their experience on how they used ICT to support the thesis projects. Similarly, much research has focused on one specific aspect of thesis projects such as idea selection, allocation of supervisors for thesis projects, student-supervisor interaction and peer collaboration. This section first discusses a few studies that have been conducted in a few higher education institutions, and secondly, it summarises a specific project called SciPro. The SciPro project was initiated by the Department of Computer and Systems Sciences, Stockholm University, and its objective is to support the department's thesis projects.

At the initiation stage of a thesis project, students need information and support to search for ideas and supervisors. A few studies have focused on the initiation stage of the thesis process. Foster & Gibbons (2007) highlighted the importance of selecting a good title to increase the research interest. Furthermore, they mentioned that a poor choice of topic and problems concerning developing a topic are obstacles to a good research study. Lei (2009), argues that the selection of a thesis topic is a time-consuming and complex process, and highlights the lack of information sources for students as one of the main problems. Gutkowski et.al (2007), proposed a design to manage the topic selection of high school level projects; the students can post their ideas including files and comments, teachers can select ideas and the coordinator can create reports of ideas and selections by teachers. The system is limited to the topic selection and does not include details about the compatibility with other LMSs. Gao et al. (2015) developed a system called OfficeHours, a recommender system that assists students in finding potential supervisors for their dissertation projects. Additionally, the system allows students to search for information about all the current faculty members without browsing individual web pages.

Student-supervisor interaction is another main aspect of thesis projects. In general classroom-based courses, students and lecturers physically meet and interact frequently. Nevertheless, in thesis projects, students mainly conduct thesis project activities alone and meet supervisors infrequently, and usually students are involved in thesis project activities from a distance. MacKeogh (2008) conducted a study at Dublin City University, Ireland and identified the challenges in supervising research dissertations at a distance and showed that it is possible to use e-Learning methodologies to provide a supportive environment for students embarking on undergraduate research. MacKeogh used Moodle as the technical system and a module named 'Conference' to communicate between students and supervisors. The study outlines the approach to research supervision adopted in a distance education psychology module, which combines online supervision, face-to-face meetings, and peer supervision.

De Beer & Mason (2009) conducted a study of the development of Blended Learning (BL) in postgraduate supervision of full theses of master's and doctoral candidates at Durban University of Technology (DUT), South Africa and discussed a framework for research supervision. The main issues in the supervisory process are the heavy workload for supervisors and the high dropout rate. The research presents a case study based on a framework that was originally designed for blended learning activities. It is based on different types of interaction between postgraduate research students and their supervisors. The findings show that a blended approach to postgraduate supervision improves the supervision process, reduces the administrative workload of the supervisor, and creates a dynamic record of the supervision process. The results to

date imply that traditional supervision practice needs to be revisited and modified to include digital procedures. However, this research study mainly focused on using ICT for communication and record-keeping only.

Yan et al. (2012) studied the master's level degree programme and focused on the workflow of how the thesis is to be completed and monitored. The system developed includes three modules called research process, research group and knowledge-sharing. The research process module includes functions to plan the whole project. The research group module includes functions to work as a group. The knowledge-sharing module aim at sharing knowledge including instructions, references, and research data. As the authors explained, they combine problem-based learning, cognitive apprenticeship learning, and collaborative learning.

A few research studies were conducted about the use of ICT to provide learning resources for students. Ling et.al, (2008) argue that the lack of instructor support and teaching resources negatively impact of the quality of the thesis projects (majoring in science and technology). They proposed a new model to help to reduce the deficiency of excellent instructors and teaching resources by coaching as a team rather than individuals.

Hewagamage et al. (2012) implemented a Moodle-based Virtual Learning Environment (VLE) and measured the progress. They argued that although the online learning environment has a significant effect on other courses (subjects), it has not led to a significant change in the pass rate as they expected in the project course, and they suggested addressing key issues in the final year project course.

The Department of Computers and Systems Sciences, Stockholm university initiated a project to implement ICT support for the thesis supervision process in 2009 to address the issue of the quality of thesis projects. The project name is SciPro and has grown into a mature system. Thirty-four published research papers were studied and summarised in study five. A summary of the SciPro system is discussed here.

The concept of developing a thesis support system first appeared as a design concept and the title of the research was "Open and flexible ICT: support for student thesis production - a design concept for the future" (Hansson et al., 2009). This study discusses the importance of supervisor feedback and shows that a supervisor's time is a limited resource. Therefore, these authors suggested that information and communication technology could be used as a tool to enhance supervision, and proposed an innovative organisational model. The authors suggested the features of a new ICT-based model for the thesis process including supervision pathways, hyper-video, chatterbots, anti-plagiarism methods, and social learning. The design aimed to use ICT technology to facilitate higher quality face-to-face meetings with the supervisor and between peer students. The model included a concept called "supervision pathways" which involved six phases; a research plan, background and methods, a data

collection method, data collection, data summary and data analysis. They suggested enhancing the quality and efficiency of each of these phases, including both face-to-face meetings with peer students and supervisors, as well as online collaboration and social integration. A model called "Structured and flexible process" guides and helps students generate a personalised project plan using the ICT tools, which include hyper-video, content creation and web2 collaborative technologies, and they proposed a conceptual framework that can support the thesis supervision process. The overall aim is to propose a design concept for a flexible and semi self-adaptive ICT system for the mass-individualisation of supervision in the thesis process at various levels.

Bencherifa (2012) shows how ICT can be used in the project initiation stage and introduced the concept of Idea Bank, with more details on how to integrate the Idea Bank concept into the thesis supervision process. As a part of the SciPro project, a comprehensive study of the project initiation phase was conducted by Bencherifa (2013), and a framework for idea creation was proposed, displaying these ideas to related stakeholders and including external (industry partners) partners in the process.

In exploring the use of ICT in the thesis process, the student's perspective is crucial. The SciPro system provides a facility to share e-resources with students, and they find the e-resources provided by the ICT system to be useful in the thesis initiation and writing process (Aghaee et al., 2014). ICT can also be used as a tool in the thesis process for peer interaction and assessment (Aghaee, 2015; Aghaee & Hansson, 2013). The SciPro system can support a peer review scheme since students work on their theses individually. SciPro demonstrates how peer review can be implemented in a technical sense. The introduction of a peer review system reduces the supervisor’s workload, and peer reviews provide feedback to students. However, since not all the reviews are of good quality, Aghaee et al. (2016) highlighted strategic solutions for developing the pedagogical and technical aspects when developing a peer review system.

The SciPro system shows how to integrate text-matching systems with thesis supervision, to address the plagiarism issue (Larsson & Hansson, 2012). SciPro also makes the thesis process transparent. Larsson & Hansson (2012) argue that the transparency and fairness of the process enhance the supervisor–student relationship in a positive way in terms of prevention of plagiarism. Karunaratne et al. (2017) investigated the change in the quality and efficiency of thesis supervision after introducing the Scipro system within the DSV. The results show that thesis quality has progressively increased throughout this period. Similarly, they found that the number of low-quality theses has significantly decreased, and the completion rate of theses has progressively increased. From an efficiency perspective, the study shows that there has been a significant increase in supervisor productivity, and, on average, five more theses are completed per supervisor per year.

A study of the DSV thesis supervision management system shows that ICT can support both the thesis process and the product. The literature shows how ICT can be used to enhance the efficiency of the thesis process, its quality, and the effectiveness of the product, thereby benefiting industry and business. The SciPro mainly considered the requirements of the DSV, and these studies discuss how the DSV used ICT to support their thesis projects. A review of the above papers shows that the use of ICT in thesis supervision reduces the workload of supervisors and administrators and motivates students by supporting self-directed learning. From a process perspective, an ICT system can support the entire thesis process, including initiation, supervision, and assessment; from an interaction perspective, an ICT support system enhances student-supervisor, supervisor-supervisor, and student-student interactions. Regardless of many studies, there is a lack of studies that discuss the underpin pedagogical assumptions and design knowledge that can be used for developing a thesis support system for undergraduate thesis concerning general requirements.

2.7 Chapter summary

A thesis project is an inquiry-based constructivist pedagogical project where the student is supposed to learn from an independent study. Sri Lankan undergraduate programmes have had to include a research project as a mandatory component since 2015, and consequently, on average, about 41,000 undergraduate students' research projects should be conducted each year only in public-funded universities. Although undergraduate thesis projects are considered an effective pedagogy, completing a thesis project is a stressful, complex, and problematic process that requires more resources than traditional classroom teaching methods. From the theoretical perspective, ZPD, scaffolding, and self-regulation are identified as central components in the learning process. According to the concept of ZPD, students need systematic support to reach their potential skills. Scaffolding is a type of systematic support, and students need planned and ad-hoc forms of this. Self-regulated learning is considered as a process in which students direct their learning and attainments by setting goals for themselves and applying appropriate strategies to achieve their goals.

3 Methodology

3.1 Philosophical assumptions

Philosophical assumptions include beliefs about the nature of reality (Ontology), conditions of acquiring knowledge (Epistemology), how the inquirer can go about finding reality (Methodology) and what is of value (Axiology) (Vaishnavi & Kuechler, 2013). A paradigm or perspective represents a set of interrelated ontological, epistemological, and methodological beliefs that match each other. Vaishnavi and Kuechler (2013) discuss three paradigms, i.e. positivist, interpretive and design, see Table 1.

This thesis aims to design a framework for LMSs to support undergraduate thesis projects. To meet the objective, a series of research studies were conducted, which are listed in Chapter 1. Since this study focuses on supporting students' learning, it also includes research activities to extend the understanding of the thesis process and the application of relevant learning theories. Moreover, it is necessary to explore and interpret the stakeholders' (such as students, supervisor, and course coordinators) experiences and opinions and the researchers' insights about the thesis process and related learning theories. In relation to this study the author's philosophical assumptions mostly matches with the design paradigm. People interpret phenomena with multiple realities based on their understandings, and the context and situation may shape the interpretations. For example, people may interpret the same phenomenon differently and also the same person's view of the same phenomenon may change with time and context. Therefore, opinions are not consistent but dependent on situations (contextually situated alternative world-status). The participants' culture decides the thesis process, and the use of ICT and the selected technology should match with the social requirements (socio technologically enabled). This study intends to create a framework as an artefact to construct the knowledge (development) that can be used to design and develop LMSs to support thesis projects (knowing through making). Designing an information system framework for thesis projects is an attempt to construct knowledge placed within the context. The developed framework should be repeated with different settings to understand the effect of the artefact (iterative circumscription reveals meaning). The impact of the framework should be evaluated as a whole, including the thesis report, thesis process and impact on stakeholders (measures artificial impacts on the composite system). Similarly, this study looks at the related value systems, understanding, control and

value creation during and after the process. Therefore, the design perspective's philosophical assumptions are matched with the philosophical assumptions of this study.

Table 1. Comparison of research paradigms and philosophical assumptions

Basic beliefs	Positivist	Interpretive	Design
Ontology	A single reality, knowable, probabilistic.	Multiple realities, constructed.	Multiple, contextually situated alternative world-status, Socio technologically enabled.
Epistemology	Objective, dispassionate. Detached observer of truth.	Subjective, i.e. values and knowledge emerge from the researcher-participant interaction.	Knowing through making objectively constrained construction within a context. Iterative circumscription reveals meaning.
Methodology	Observation, quantitative, statistical.	Participation, qualitative, hermeneutical, dialectical.	Development, Measures artificial impacts on the composite system.
Axiology: what is of value	Truth: universal and beautiful; prediction.	Understanding: situated and description.	Control; creation; progress (i.e. improvement) and understanding.

Source: Vaishnavi and Kuechler (2013, p. 9)

3.2 Design science research in information systems

The main research question of this thesis is "How should an LMS be designed to support the undergraduate thesis process". To answer the research questions, the author intends to develop a framework for designing LMSs to support thesis projects as an artefact. Therefore, design science was used as an approach to design the research project. The natural sciences are concerned with how things are, while design science is concerned with how things ought to be, devising artefacts to attain goals (Simon, 1996). Hevner and Chaterjee (2010) define design science research as follows:

> *"Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artefacts, thereby contributing new knowledge to the body of scientific evidence. The designed-artefacts are both useful and fundamental in understanding that problem."*

And argue that the first principle is;

> *"The fundamental principle of design science research is that knowledge and understanding of a design problem and its solution are acquired in the building and application of an artefact."*

The five types of artefacts in design science are constructs, models, methods, instantiations, and better theories (Vaishnavi & Kuechler, 2013). This study aims to develop a theoretical framework for developing LMSs for supported thesis projects. Gregor (2006) identifies five types of theories: analysis, explanation, predicting, explaining and prediction, and design and action. Out of these five types of theories, this study aims to develop a design and action type of theory (The Design-Based Research Collective, 2003) that contains imperative and prescriptive statements. The scope of this study was limited to developing a proto-theory, which tends to emphasise an intermediate theoretical scope (Phillips et al., 2012) and provide a clear rationale for the suggestions and implications for practitioners to design learning environments (The Design-Based Research Collective, 2003). The target practitioners are designers who intend to use ICT for designing LMSs to support thesis projects.

3.3 Soft system design science research methodology

In the design science approach, the focus is on changing the world, to create something that was not there before in order to improve. We discover more about the world in the active making of new things. We live in a technology-driven society, and new technologies substantially change life conditions, often in unforeseen ways. In this thesis, the goal is to contribute knowledge that can also be applied to produce real change for the better quality of theses, better satisfaction for students and supervisors, higher relevance of theses, positive impact on the society and employability, and that can contribute to sustainability goals. In terms of connecting multiple stakeholders for collaboration, using ICT and facilitating the thesis process with a new innovative ICT approach could create great benefits for Sri Lanka.

Design science in information systems is a broad research discipline in literature, and design science research has been discussed as a framework (A. Hevner & Chatterjee, 2010) rather than a specific methodology. Although the literature on information systems design theory is broad and rich enough, complete agreement about the characteristics and components of design theories cannot be found (Baskerville et al., 2009). Baskerville et al. (2009) suggest a specific research methodology called Soft Design Science Research Methodology (SDSRM) with specific activities where a specific problem situation is identified and expressed as a set of specific requirements in real-world terms. Then, these requirements are systematically abstracted into a general problem

leading to a general design solution, expressed as general requirements in the Design thinking domain (Rohde et al., 2017). The study starts with a specific problem and the design of a general solution that addresses the problems in similar contexts. Similarly, SDSRM provides a flexible methodology to integrate different methods to develop a solution.

Baskerville & Pries-Heje (2010) suggest Soft System Design Science Research Methodology, and discuss adapting it into design science research. SDSRM emerged from the combination of action research and systems science, and it is more often used purely as a systems development methodology, making it effective for developing systems (including information systems) that succeed in complex social organisational settings (Baskerville et al., 2009). The SDSRM was selected since it provides a model that researchers can use to solve a specific problem developing a reusable solution (artefact) and the artefact can be used to solve similar problems. SDSRM suggests analysing the specific problem as a general problem and developing a general solution. The general solution should be developed concerning the related theories of the problem domain. In this study, the specific problem is how to solve the problems in the thesis projects in a selected faculty in a Sri Lankan public university. Therefore, thesis projects are analysed concerning the theories related to them. Thesis projects constitute a constructivist learning activity, and therefore constructivist learning theories are used to develop a general solution. The process will be discussed in detail in the findings section.

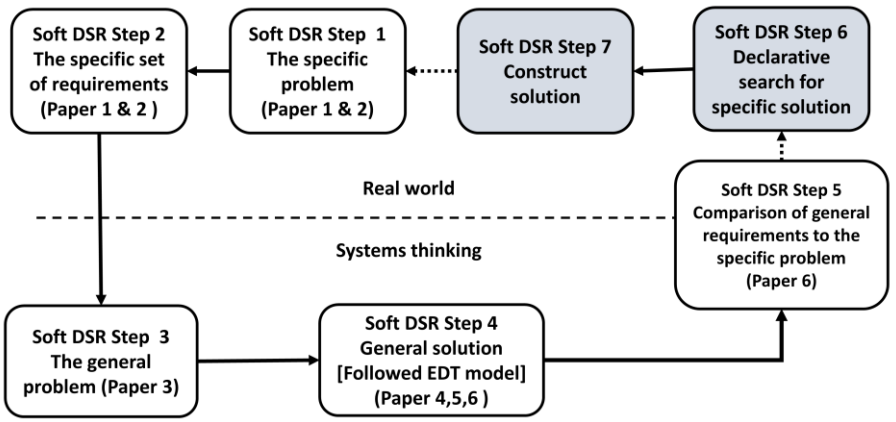

Figure 7.Soft Design Science Research Methodology (Baskerville et al., 2009).

Figure 7 illustrates the seven steps of the SDSRM. These seven steps have been described in section 2.4. Similarly, Figure 7 shows related research papers for these steps. For example, studies 1 and 2 are related to step 1 of the SDSRM. Even though there are seven steps in the SDSRM, this thesis only follows steps one to five. The sixth and seventh steps are beyond the scope of this thesis.

3.4 The Application of SDSRM

This thesis aims to develop a framework for designing learning management systems to support undergraduate thesis projects. As a model, the SDSRM (Baskerville et al., 2009) was followed to develop the framework (Table 2).

Table 2. The applications of the steps of SDSRM

SDSRM steps (Baskerville et al., 2009)	The application of SDSRM to this thesis
1. The specific problem. The SDSRM process starts from a specific problem. The aims of this step is to identify a specific problem/opportunity in a specific context.	Specific problems are identified in the undergraduate thesis projects conducting two case studies (Studies 1 and 2). A faculty of management in a Sri Lankan university was selected as a case.
2. The specific set of requirements The second step aims to understand the reasons for the problems in terms of missing requirements. This problem must be expressed as a specific set of requirements.	Study 2 deeply analysed the problems in thesis projects (in the selected context) and identified the requirements / sources of the problem.
3. The specific problems are systemically abstracted and translated into a general problem with both technical and social dimensions.	Study 3 analysed the specific problem as a general problem and tried to understand the root causes of the problems. The specific problem was formulated with the help of learning theories.
4. A general solution design (a class of solutions) for the general problem is derived through systems thinking and expressed in terms of general requirements.	Studies 4 and 5 are literature reviews of similar specific solution, and the findings of these two studies helped the author to identify a general solution. Study 6, a framework for designing LMS to support thesis projects, was developed as a general solution. The Explanatory Design Theory Method was followed for the framework development process.
5. The general design requirements are compared with the specific problem for fit.	Study 6 compared the proposed features of the framework with the selected faculty. A ex-ante evaluation was conducted to get supervisors' opinion of the system.
6. Declarative search for a specific solution A specific solution should be explored to match the requirements identified in the SDSR Step 2.	Step 6 is not covered in this thesis
7. Construct solution An instance of the proposed solution deployed in the social system.	Step 7 is not covered in this thesis

The SDSRM suggests seven steps, and the last two steps suggest how to construct a solution for a specific client. This thesis discusses designing a common solution. Therefore, steps five and six are not relevant to this study. Column 1 of Table 2 shows the first five steps of the SDSRM. Column 2 shows the application of these SDSRM steps and gives a summary of this thesis project.

3.5 Data collection

In Design Science research, data is collected from two main sources; the environment or the knowledge base (A. R. Hevner et al., 2004). Considering the environment, the DSR researcher can make use of observations, interviews, and questionnaires. In contrast, considering the knowledge base, data collection techniques include a selection of theories for a theoretical framework, and systematic literature reviews. See Table 3 for an overview of the data collection procedures. The main data collection methods were focus group discussions with supervisors, and interviews with supervisors and students. All the interviews and focus group discussions were conducted in Sinhalese since it was more convenient for the participants. More details about data collection have been discussed in research papers.

Table 3. Summary of data collection

Study	Data collection methods	Details
Study 1 An Analysis of Existing Issues in Students' Research and Project Initiation Stage: Information and Communication Technology Perspective.	Online Survey	35 Students, 9 Supervisors, 9 Industry representatives 4 Coordinators
	Interview	4 Coordinators
Study 2 About the Challenges in Undergraduate Research Projects: An Explorative Case Study in a Sri Lankan National University.	Interview	10 Supervisors and 9 Students
	Focus group discussion	Discussion 1 with 8 supervisors Discussion 2 with 8 supervisors Discussion 3 with 6 supervisors
Study 3 A Constructivist Perspective on the Thesis Supervision Process: A Case Study of Sri Lankan Undergraduate Thesis Projects	Interview	10 Supervisors 10 Students
	Literature review	Previous studies about learning theories and especially ZPD, Scaffolding and Self-regulation Learning
	Focus group discussion	Discussion 1 with 12 supervisors Discussion 2 with 7 supervisors Discussion 3 with 5 supervisors
Study 4 SciPro Matching: ICT Support to Start a Quality Thesis.	Log data, Literature review,	Log data from the SciPro system and Previous research about SciPro

Study 5 ICT Support for The Thesis Process: A Case as a Literature Review	Literature review	34 papers on the SciPro system from between 2009 and 2017
Study 6 A Framework for Designing Learning Management Systems for Thesis Projects	Survey	52 Supervisors
	Literature Review	Papers related to learning theories

3.6 Data analysis

The main research question is "How should an LMS be designed to support the undergraduate thesis projects". The selected methodology, SDSRM, suggested deriving a general solution (a class of solutions) to satisfy general requirements to solve the general problem through system thinking (Baskerville et al., 2009). The main research question was divided into three sub-questions. In Systems thinking, synergistic analytic skills are used to improve the capability to identify and understand systems, predict their behaviours, and devise modifications to produce the desired effects (Amissah et al., 2020). This thesis used different data analysis methods to answer the subordinate research questions following systems thinking.

The first sub-research question, 'What are the problems of undergraduate thesis projects?' was answered by analysing the data collected from studies 1 and 2. In study 1, data was collected using multiple choice questions (MCQs) and open-ended questions. The MCQs were analysed using descriptive statistics, and thematic analysis used to analyse open-ended responses. The purpose of Study 1 is to understand the problem; in design science, multiple data analysis methods can be used to explicate problems (Johannesson & Perjons, 2014). The application of different methods (method triangulation) increases the rigour of the research; for example, the trustworthiness of the findings will increase if the interviews confirmed the results collected from MCQs.

The objective of the second study is also to identify the problems that exist in thesis projects. Participants expressed problems in thesis projects in their terms, which should be developed as concepts. The grounded theory recommends developing concepts from textual data (Denscombe, 2010). In general, Grounded Theory is used to develop theories, but if necessary, it can be used to identify categories (Thomas, 2006) and skip the theory development part. Therefore, in the second study, data were analysed using Grounded Theory. MaxQDA, qualitative data analysis software, was used for organising, transcribing, and coding. Data was coded carefully reading and writing memos, and the coding mainly focused on issues and challenges highlighted by the participants. These codes were further analysed and grouped by merging similar codes. These groups represent issues and unfavourable situations in the

research projects. Then, these challenges were cross-checked with the data and memos.

The third study aims to answer the second sub-research question, i.e. to explore which learning theories and pedagogical concepts should be considered when designing an LMS to support the undergraduate thesis projects. Thematic Analysis is a flexible data analysis method guided by different theoretical frameworks. Thematic Analysis can address most types of research questions and analyse most types of qualitative data, everything from interviews, focus groups, qualitative surveys, diaries, story completion tasks, and secondary sources such as newspaper articles and official documents (J. A. Smith, 2015). In this study, interviews, focus groups and previous studies about learning theories were used as data collection methods. Therefore, thematic analysis was used as the data analysis method. Students' and supervisors' responses and literature were reviewed to understand the learning activities of thesis projects from a pedagogical point of view. The findings from these three types of data sources were compared and analysed following a cyclic process to identify the related learning theories and pedagogical concepts.

The findings of the fourth, fifth and sixth studies contributed to answering the third sub-research question, i.e. what are the requirements and components of LMSs that would support the undergraduate thesis projects? In the fourth study, data was collected from the SciPro thesis support system that was used in the Department of Computer and Systems Sciences, Stockholm University. These data were analysed using descriptive statistics. In addition, research papers related to Idea Bank were analysed to understand the design concepts. In the fifth study, 34 research papers published between 2009 and 2017 were selected and analysed to identify the most valuable features of LMSs to support thesis projects.

In the sixth study, the Explanatory Design Theory was used as a model to analyse the students' and supervisors' empirical data, comparing it with the pedagogical implications of the three main theoretical concepts related to thesis projects. Zone of Proximal Development, Scaffolding, and Self-regulation learning process were explored and analysed to identify the requirements and subcomponents of an LMS to support thesis projects. The identification of subcomponents followed abduction reasoning. Dorst (2011) argues that the heart of design thinking is fundamentally different from formal logic. The basic reasoning pattern in productive thinking is abduction, and explains the use of abduction in design thinking based on the following formula.

WHAT (thing) + HOW (working principles) Leads to VALUE (aspired)

Dorst (2011) discusses two forms of adductive reasoning. The first, Abduction-1, is often associated with conventional problem-solving, and designers know both the values the designer wishes to create and the 'how' ('working principle'), and the designer's task is create a 'thing' that will help achieve the

value we aim for. The other form, Abduction-2, is more complex because at the start of the problem-solving process, the designer knows only the end value; this form of reasoning is more closely associated with (conceptual) design. The identification of components can be explained using the formula. A testable hypothesis represents the desired outcome or value. As an example, enhancing the students' motivation in thesis projects is the expected value. The author's contribution is the finding of working principles (kernel theories), and design things (subcomponents) based on the kernel theories. The author used this formula as a mental model to hypothetically evaluate the subcomponents. The use of different methods enhances the rigour of the analysis (Guion et al., 2011). Therefore, the author conceptually analysed the identified components using the discussed formula as a triangulation method.

3.7 Ethical considerations

Research studies conducted in Sweden should be approved by an Ethics Review Board (ERB) if the study is related to a specific set of conditions (Bengt et al., 2011, p. 48); specifically when the research collects personal data involving a physical intervention by a researcher, or there is an obvious risk of affecting participants physically or mentally. This study neither physically nor mentally harmed the participants, nor did it collect personal data. Therefore, the conditions of the act (Bengt et al., 2011, p. 48) that relevant for the ethical review of research involving humans and the personal data were not relevant for this study and general research ethics were applied to the research project. However, as there are many ethical considerations, it is always better to consider potential ethical aspects. There is an emerging theme in the field of information systems, and it extends the researchers' obligations from participants and communities to the whole society and is commonly named as 'relevance' (Benbasat & Zmud, 1999; Stahl et al., 2014). Therefore, the ethical considerations are discussed under the key themes, relevance, research ethics and professional ethics (See Figure 8).

Figure 8. Three key themes for ethical considerations

All three key themes should be considered throughout the whole research process. However, I understand that relevance is more related to the design phase, research ethics are more related to the data collection phase, and pro-

fessional ethics are more related to the analysis and discussion phase. Therefore, ethical considerations will be discussed by referring to these three key phases.

3.7.1 Relevance of research

The author was awarded a scholarship from the Sri Lankan government for his PhD studies, and government funding comes with the condition that the study should be relevant to the Sri Lankan context. At the beginning of this study, the aim was to develop an ICT-enabled framework to enhance the University-Industry collaborations (UI) via undergraduate thesis projects in Sri Lankan universities. When designing the study, the author realised that students and supervisors should have an ICT-enabled learning environment to reach the initially decided aim. Although universities have ICT infrastructure, the usage of information systems in undergraduate thesis projects was minimal. Similarly, the author believes that using an ICT learning environment for thesis projects could solve most of the existing problems and bring new opportunities to Sri Lankan universities. Therefore, the objective of the study was subsequently changed to designing a framework for LMSs to support undergraduate thesis projects in Sri Lankan undergraduate degree programmes.

3.7.2 Ethics of data collection

Participants' rights were strictly considered and they were informed that they had the right to opt out at any stage even after they had expressed their consent. Similarly, the author informed them that the collected data would be used only for research purposes.

The author considered four concepts discussed by Bengt et al. (2011) about handling research materials; secrecy, professional secrecy, anonymity, and confidentiality. The raw data was not shared with any third party and was carefully used when paraphrasing. The anonymity of participants is manageable, but the anonymity of the institution and programmes is difficult to implement. Although institutional names are anonymous, the introduction section discusses the background of the faculty and programmes. If the reader is familiar with Sri Lankan management faculties within its university system, it is possible to guess the faculty and degree programmes. Reiss (as cited in Christians, 2000, p. 136) highlighted this issue emphasising, "the single most likely source of harm in social science inquiry -, i.e. the disclosure of private knowledge that is considered damaging by experimental subjects". As a higher education institution, reputation is an essential resource, and these disclosures may have an effect. Since it was difficult to anonymise the institution, the author informed the university and was given their consent to disclose the institutional details.

Reducing and avoiding harm for the participants is a common ethical consideration of all research. Although this study does not physically or psychologically harm participants, the author considered the potential indirect effects of being a participant. The author was aware of the precarious power relation between supervisors and students. In order to avoid situations where supervisors might recognise their own students, the author refrained from exposing some of the student criticism to the supervisors. Therefore, the author ignored some clarification questions if the author felt they would affect participants.

Since participants know the author as a lecturer, the author explained that he was acting as a researcher and tried to create a friendly environment before starting the data collection. During the data collection phase, the author contacted the thesis programme coordinator and collected a list of students and supervisors. Then, the author randomly contacted a few students and supervisors. Therefore, the author did not limit the sample to a particular group the author associated with. The snowball method was used to include more participants. Therefore, the author did not intentionally select participants. Instead, participants suggested who should be interviewed, which minimised the bias in the process of participant selection.

3.7.3 The dual role of the researcher

The author's background, being both an insider and an outsider, has also been beneficial. The author has been able to observe new practices due to his experience from the Swedish context and his PhD educational background. At the same time, the author has had unique access to supervisors and students in the Sri Lankan university setting. Knowing the culture and language of Sinhala is another aspect that has contributed to a profound understanding. However, as a lecturer, the author has two roles – as a practitioner and a researcher – and therefore faces the issue of balancing between the researcher's role and other professional obligations (Mauthner et al., 2002). Then, the author faced a dilemma about how he could ethically use the information collected as a researcher as well as an practitioner. To avoid this issue, all the conclusions were made based on the codes created as a result of data analysis. Personal experience was used to explain situations but was not considered a source of evidence. During the data analysis and conclusion, all interviews equally treated all data to avoid personal interest. In the conclusion phase, special attention was given to validating findings with coded data segments to avoid personal bias.

3.8 Chapter summary

The design of this study followed the SDSRM since it provides a logical model that can be used to solve a specific problem, creating a reusable solution

(artefact). For example, the specific problem faced by a faculty in their thesis projects can be used to develop a framework for LMSs to support thesis projects in similar contexts. SDRSM has seven steps but this thesis implemented only the first five steps. Step 1 identifies a specific problem/opportunity in a specific context. In this study, the selected problems of undergraduate thesis projects in a selected faculty of a Sri Lankan university are discussed. Step 2 identifies the specific set of requirements of the selected problem or opportunities. The second step aims to understand the reasons for the problems related to thesis projects in the selected faculty. Step 3 formulates the specific problem as a general problem and investigates its root causes. In step 4, the study searches for a general solution for the general problem. As a general solution, this study is focused on developing a framework for designing LMSs to support undergraduate thesis projects. Step 5 is the last step in this thesis, which compares the general requirements (solution) with the specific problem. In step 6, a specific solution is designed considering the context of the selected problem, and in step 7 the solution will be constructed.

4 Results

The objective of this thesis was to answer the main research question, 'How should an LMS be designed to support the undergraduate thesis projects?' The main research question was divided into the following three sub-questions:
1) What are the problems of undergraduate thesis projects?
2) Which learning theories and pedagogical concepts should be considered when designing a LMS to support the undergraduate thesis projects?
3) What are the requirements and components of LMSs which would support the undergraduate thesis projects?

To answer research question 1, two studies were conducted in a Sri Lankan public university, and the results have been published in papers 1 and 2. Figure 9, given in section 4.1.1 summarises the problems identified in thesis projects. Study 3 is related to research question 2 and studied the thesis projects from theoretical point of view and identified the seminal learning theories and pedagogical concepts to be considered when designing an LMS to support undergraduate thesis projects. Using the abduction reasoning method, the following three theoretical concepts were selected as the most suitable ones to be considered when designing an LMS to support thesis projects: 1) ZPD, 2) Scaffolding, and 3) Self-regulation in learning processes. As cited in Fischer & Gregor (2011), Martin argues that design thinking relies on abductive reasoning in which sense-making of observation occurs through drawing inferences to the best explanation. The author studied learning theories and found six common theories, namely behaviourism, cognitivism, constructivism, experiential, humanistic and social-situational. Then, the author compared the learning through the thesis process with these learning theories and found that constructivism was the best-matched learning theory for thesis projects. Later, it was identified that constructivism is a broad theory and ZPD, scaffolding and self-regulation are the most relevant concepts for designing an LMS to support thesis projects

In the fourth and fifth studies, a tailor-made LMS to support thesis projects in Stockholm University was utilised to understand how the LMSs can support the learning activities of thesis projects. Based on the knowledge constructed in study 4 and 5, the third research question was answered in study 6 and recommends a common set of requirements and software subcomponents as part of the framework for designing an LMS to support thesis projects. In addition, all findings are summarised in the study 6 as a framework which can be used

for designing an LMS to support undergraduate thesis projects. The framework is the answer to the main research question. The framework has four modules; initiation, planning, implementation, and completion, and each module suggests a list of software sub-components. More details will be discussed under the following subsections.

4.1 Problems in undergraduate thesis projects

The results will be presented following the SDSRM steps and standard key terms used in the SDSRM. The terms 'specific' and 'general' have a specific application in SDSRM. SDSRM starts with a real problem in a real context. The term "specific" always refers to that context. For example, this thesis starts with a real problem that exists in a faculty in a Sri Lankan university. Therefore, a specific problem refers to the problem existing in that context, and a specific solution means a solution for that specific problem in that context. The term "general" refers to a common or generalised situation. For instance, the general problem in thesis projects refers to general thesis projects without a specific place or context.

4.1.1 SDSRM Step 1: The specific problems

Two studies (Study 1 and Study 2) were conducted with the purpose of identifying the specific problems related to undergraduate thesis projects and are summarised in Figure 9.

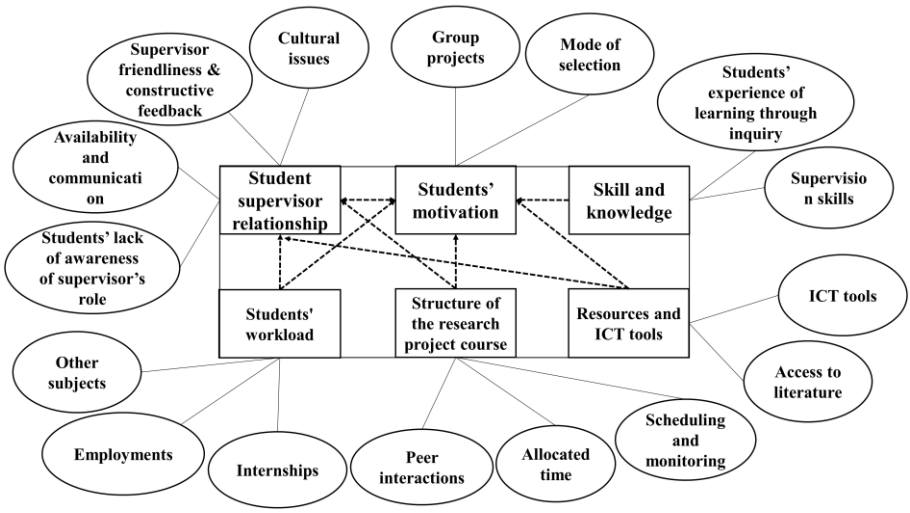

Figure 9. Problematic areas related to thesis projects in undergraduate management programmes

Study 1 demonstrates how the lack of proper channels for communication between students, supervisors and the study coordinators can cause problems in thesis projects. Study 2 identifies six specific problems 1) lack of student motivation, 2) lack of student-supervisor interaction, 3) an unstructured research process, 4) lack of skills and knowledge, 5) students' high workload, and 6) resource sharing issues. These problems are interrelated; their relationships are shown in dashed lines in Figure 9.

4.1.2 SDSRM Step 2: The specific set of requirements

The identified problems were analysed to identify the reasons behind them. In the SDSRM context, reasons (sources of the problems) and requirements are used interchangeably. According to the SDSRM, these problems exist due to unsatisfied requirements (see table 4).

Table 4. Identified problems and requirements of thesis projects

The problem description (from Step1)	The requirements
Lack of facilities for student-supervisor interaction The second study found that the lack of student-supervisor interaction had four main reasons:	Facilitate student-supervisor interaction The requirements abstracted from the identified problems. Thesis support systems should have subcomponents to facilitate student-supervisor interaction.
Reason 1 The lack of availability of a supervisor, and communication problems are crucial issues since face-to-face meetings are the only official channel for interactions between students and supervisors.	Requirement 1 This situation raises the requirement that the student-supervisor interaction should not be limited to face-to-face meetings, and that synchronous and/or asynchronous online communication methods are needed.
Reason 2 Students' lack of awareness of the role and the responsibility of their supervisor.	Requirement 2 The thesis support system includes features that both students and supervisors can see the role and responsibilities of the supervisors should include features that encourage supervisors to support students on time.
Reason 3 Cultural issues, for example students do not complain even if supervisors do not provide proper supervision.	Requirement 3 The thesis support system includes features that empower the students' rights and encourage supervisors to support students.
Reason 4 Lack of supervisor friendliness and constructive feedback are interdependent problems.	Requirement 4 There should be tools to help supervisors to give friendly and constructive feedback.

Lack of support for student's motivation and self-regulation skills The lack of students' motivation and managing self-regulation was one of the main problems. Students face more challenges in thesis projects than in course work since they are responsible for maintaining a higher level of motivation and managing the thesis project activities and extra-curricular activities themselves. Up to 2015, most degree programmes offered the thesis project as an optional course module, but from 2019 a thesis project was made a compulsory module. Only about 30% of students would have selected a research project if it had been offered as an optional course. (Peiris et al., 2018)	Support students' motivation and self-regulation skills According to the new policy framework, all students (about 1400 students) should conduct thesis projects from the academic year starting in 2019. As a result of this policy, there may be many students without intrinsic motivation and self-regulation skills but they have to conduct thesis projects to complete their degree programme. Therefore, it is essential to increase students' motivation, and support self-regulation learning.
The lack of planning support for thesis projects Study 2 shows that some thesis projects were not started with a proper plan. When there are many thesis projects, supervisors need to spend a significant amount of time preparing thesis project plans for individual students. Although students are also responsible for preparing a thesis project plans, many supervisors think they should prepare the structure of the thesis project.	Planning support for the thesis project There should be a procedure and supporting tools that encourage a proper preparation of thesis project plans. Furthermore, both supervisors and students need support to create or reuse thesis project plans to structure thesis projects.
Lack of skills and knowledge Students are not familiar with constructivist learning activities like thesis projects. Besides, supervisors need support to learn how to supervise according to constructivist pedagogy.	An environment to support constructivist and self-regulated learning Special attention should be paid to improving the students' experience of constructivist learning activities. Also, supervisors need extra training if they do not have research supervision experience or experience of constructivist learning activities.
Resource sharing issues Studies 1 and 2 reveal that students claim they do not have access to literature and ICT tools for thesis projects. However, the university library has subscribed to journals, and many open access journals are free to access. Also, there are plenty of ICT tools for research work, and students can use free or trial versions.	Provide valuable resources in one place Enhance the students' ability to find resources they need for thesis projects. Even though there are many resources, students do not know about them. It is a requirement to enhance the visibility/access to these resources.
Students' high workload Students' high workload depends on the number of other courses they study in parallel to the thesis projects.	This issue cannot be solved using ICT and is considered a matter beyond the scope of this study. It is a matter of improving the organisation of the education programme with students' needs at the centre. A thesis project should be either full-time with no other courses, or part-time with part-time courses in parallel to be feasible for a student to manage.

The identified problems (in step 1) exist since the faculty either has not fulfilled or lacked the requirements. The SDSRM step 2 suggests identifying the requirements and analysing the selected problem. Since the requirements are related to the problems, this section presents a more detailed account of the problems (identified in step 1) and the corresponding requirements (see table 4).

4.2 Pedagogical ideas to support thesis process

4.2.1 SDSRM Step 3: The general problem (Logical base)

The SDSRM step 1 identifies problems of a specific context. The specific context in this study is a faculty of a public university in Sri Lanka. In the SDSRM step 2, those problems were analysed according to the requirements of that specific context. In this step (SDSRM 3), the specific problems and requirements are systemically abstracted and translated into general problems. Based on the results, the general problems of thesis projects were identified as: the lack of a theoretical foundation (lack of pedagogical planning) and practical facilitation (no LMS/ICT system) to support the student-supervisor interaction, as well as lack of scaffolding (from supervisors and peers) and lack of support to enhance self-regulation processes.

A central finding is that constructivist learning activities need a proper supportive learning environment (Peiris et al., 2019). The specific problems were compared with the hypothetically suggested learning environment, and it was found that one of the primary sources of these specific problems is the lack of a proper learning environment to support thesis projects. Although students conduct the thesis project as an independent research study, constructivist learning theories highlight the importance of interactions. Drawing on Vygotsky's (1980) socio-cultural theory that serves as a foundation for the constructivist approach to learning (Kretchmar, 2013) in undergraduate research projects, students are expected to construct knowledge mainly through student-supervisor interactions, student-context interactions, and peer interactions. In study 3, Vygotsky's (1980) concept of ZPD is applied to identify the importance of student-supervisor interaction in undergraduate thesis projects (Peiris et al., 2018).

Similarly, study 3 highlights the importance of supervisors' mediation for the thesis projects concerning designed-in and contingency scaffolding models. The designed-in scaffolding model suggests that students must have predefined scaffolding for thesis project activities. The contingent scaffolding model highlights the importance of establishing ad-hoc support. The essence of the concept of ZPD and scaffolding models is that a learning environment

for undergraduate thesis projects should be designed with methods that facilitate efficient interaction between students and supervisors according to a plan and should supplement ad-hoc interactions. Furthermore, in thesis projects, students are mainly alone when engaging in learning activities in the research field, and supervisors are unaware of what students are doing and what kind of help they need, until the students interact with their supervisors. Therefore, the learning environment for thesis projects should be built based on the learning theories relevant to that particular learning process, and should support the pedagogical practice concerning contextual scenarios. Interactions between students and supervisors are essential in thesis projects, but the current learning environment for undergraduate thesis projects lacks features that facilitate student-supervisor interaction. For instance, many students were doing internships, but they were expected to come to university to meet their supervisors during regular working hours. However, in addition to face-to-face meetings, there was a lack of alternative interaction methods.

Another problem is that although the constructivist and self-regulation learning theories suggest that peer interactions represent an essential component in learning, in thesis projects students conduct the thesis work entirely on their own and, as a result, feel isolated. The current learning environment lacks support and an organisation for potentially important peer collaborations that could support students in their thesis projects.

In thesis projects, students should engage in constructivist learning activities and need to be self-regulated learners, and the students are responsible for being active, constructive, goal-directed, diagnostic, and reflective (Simons, 1993). However, according to the findings, students lack the self-regulation skills needed to be constructivist learners (Peiris et al., 2018). They need support to develop problem-solving skills, self-directed learning skills, teamwork skills and collaboration, and self-regulation skills in learning (Savery, 2006). According to previous studies, some students' performance will decrease when they are allowed to take responsibility for their learning (Simons, 1993). Many students involved in industry-related events have reported that they did not begin their thesis project until the very last moment. It appears that they spent their time on other courses and industry-related activities, and there was no proper monitoring system to issue a warning about this lack of engagement with thesis project activities. Students did not feel they were behind in this process until the deadlines approached. Some supervisors warned students when they felt they were not active, but most supervisors may busy and could not send reminders when they were supervising many thesis projects. Therefore, monitoring procedures for both supervisors and students and tools that enhance students' motivation and self-regulation should be included as components in the scaffolding plan when designing the thesis course structure.

4.3 Designing LMS for thesis support

This step suggests developing a general solution (a class of solutions) for the general problem that derives from systems thinking, and describes general requirements (Baskerville et al., 2009). Figure 10 shows an abstract view of the framework. According to the framework, a suggested system is divided into four modules following the thesis process: initiation, planning, implementation, and completion. The initiation module includes functions that support the thesis process from the very beginning to until a supervisor is formally assigned to a student by the department or thesis project coordinator. The planning module supports the activities that students and supervisor plan for the thesis process. The implementation module is the most critical and it supports the thesis project activities until the students complete the thesis according to the prepared project plan. The completion module covers the activities after submitting the thesis project as a final report. Each module has subcomponents to support the learning activities that are related to the phase. The design process utilised knowledge collected from these four main sources: 1) theoretical frameworks within pedagogy (related to thesis projects), 2) practical input from students' and supervisors' interviews, 3) observations of a specific thesis support systems including the system developed at Stockholm University, and 4) the author's experience as a supervisor and instructional designer. Based on these sources, the general problem is analysed, and a framework is developed to support thesis projects in undergraduate degree programmes. The framework is a general structure, and LMSs designers can use it as a guide to identify requirements and subcomponents. They can modify the general structure to suit the socio-technical requirements of their specific context.

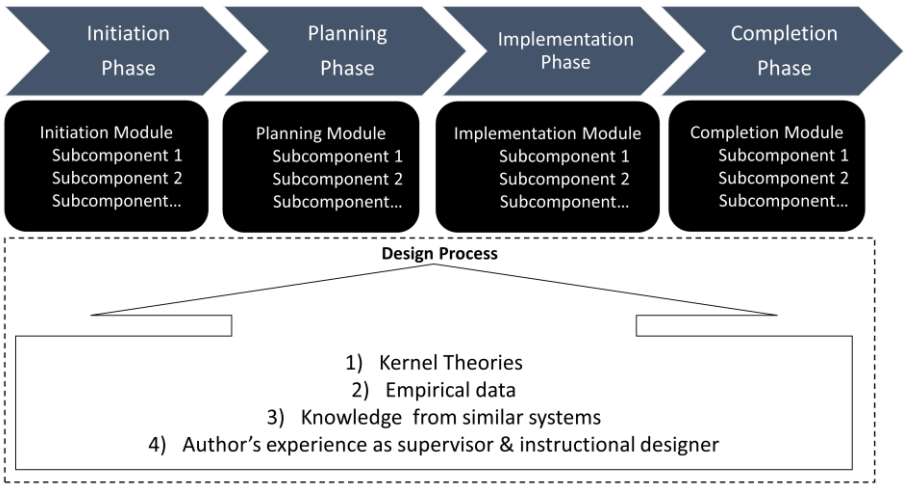

Figure 10. General view of the design process

4.3.1 SDSRM Step 4 - The general solution

The knowledge constructed during this thesis is organised as a framework. The proposed framework is the general solution for the general problem and can be classified as prescriptive knowledge. A framework is a real or conceptual structure intended to serve as a support or guide for the building of something that expands the structure into something useful (Idri et al., 2012, p. 1). This definition of framework matches with the artefact type of "requirements" introduced by Offermann et al. (2010) within the area of IT and information systems. Offermann et.al, (2010) describe the requirements as statements about the required behaviour and functions of a system. In the context of SDSRM, the term meta-requirements use to identify the general requirements of a class of solutions. The identified meta-requirements were analysed to construct an appropriate structure for the proposed framework. Figure 11 shows a framework which suggests a structure for a thesis support system with four modules. Each module includes subcomponents, and a subcomponent consists of a set of requirements. As Figure 11 illustrates, these requirements have been identified based on the kernel theories.

The framework design process was published in paper 6, and Figure 11 shows an overview of the framework with related theoretical concepts, requirements, and proposed solution components. The framework consists of three sections. The top section presents the related pedagogical concepts, which mainly derive from three main theoretical concepts: 1) ZPD, 2) Scaffolding and 3) Sub-processes of Self-regulation. The middle section illustrates four main modules of the proposed system based on the sequence of learning activities and the thesis process is divided into four phases: 1) initiation, 2) planning, 3) implementation, and 4) completion. The framework suggests developing the LMS, including one module for each phase. The bottom section shows meta-requirements and subcomponents of the modules based on related pedagogical concepts (Kernel theories - KT). Testable hypothesis did not included in Figure 11 due to the lack of space in Figure 11. Testable hypothesis have included in Figures that illustrate individual modules (Figure 12,13,14 and 15).

The initiation module suggests software subcomponents that can support students before formally starting a thesis project. The planning module includes subcomponents that support the thesis project planning related activities. These subcomponents have been identified based on the kernel theories related to the planning phase. The implementation module includes subcomponents that support learning activities such as selection of methodology, literature review, data collection, data analysis and report-writing etc. The completion module does not directly support students or supervisors. These subcomponents also have been identified based on the related kernel theories that enhance students' and supervisors' motivation. In the following sections, the

design process, where interrelated pedagogical theories, requirements, sub-components and testable hypotheses are involved, is further explained under the four modules.

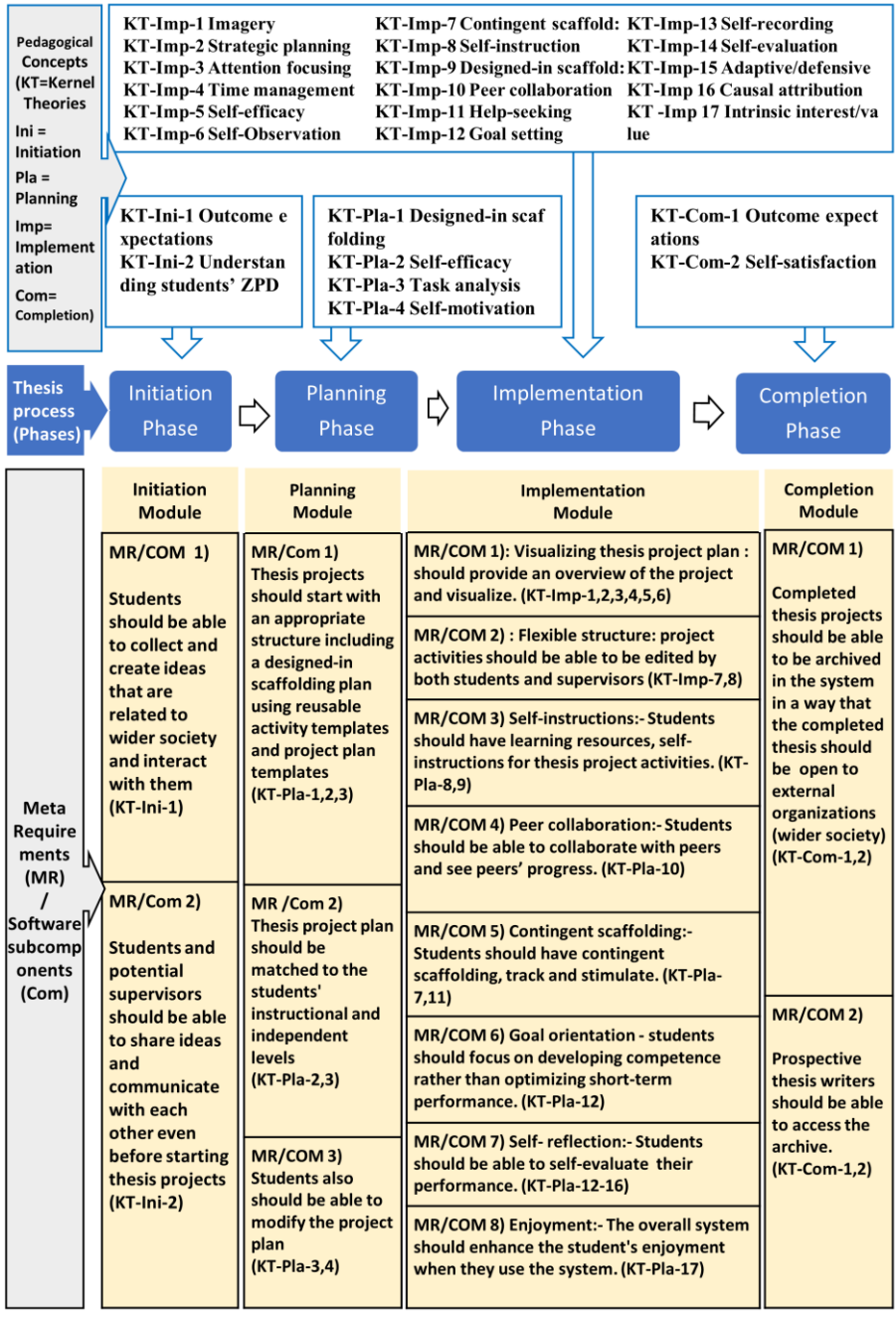

Figure 11. The framework for designing LMS to support thesis projects

4.3.1.1 The initiation module

Figure 12 summarises the findings related to the initiation phase and discusses related theories, meta-requirements, subcomponents of meta-design, and testable hypotheses. The notion of "meta-" to emphasise the abstract nature of (Baskerville et al., 2009) and the meta-requirements are potential common requirements and meta-design denotes a potential common solution. The framework suggests two subcomponents that enhance the students' motivation and student-supervisor interaction as parts of this module. Figure 12 shows that students' outcome expectations enhance the students' motivation for thesis projects. The framework suggests enhancing the students' outcome expectations by linking students' thesis projects with real-world problems (external organisations) or wider society. Additionally, the student-supervisor interaction during the initiation phase would improve the supervisors' understanding of the students' ZPD.

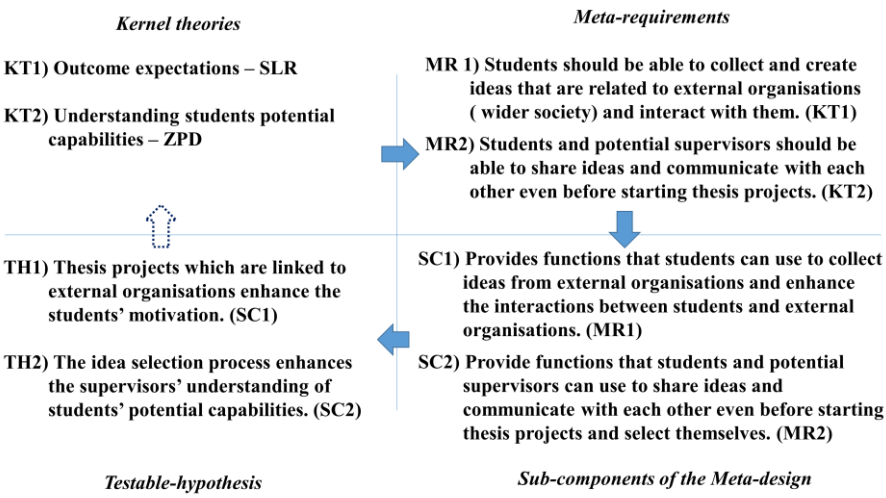

Figure 12. Initiation module

4.3.1.2 Planning module

Figure 13 summarises the findings of the planning phase and discusses related theories, meta-requirements, subcomponents of meta-design, and testable hypotheses. Figure 13 illustrates how the thesis project plan module implements the scaffolding, self-efficacy, and self-motivation concepts. The planning module provides an efficient and effective tool for implementing these concepts in thesis projects.

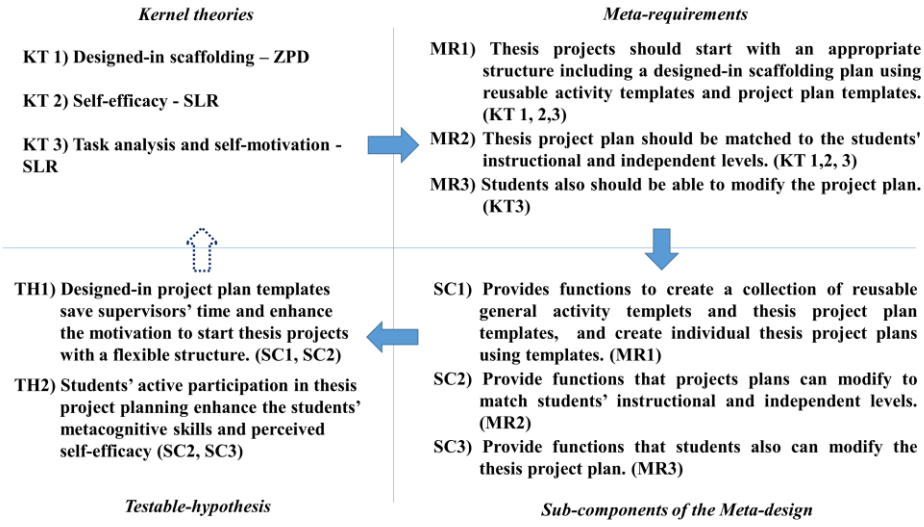

Figure 13. Planning module

4.3.1.3 Implementation module

Figure 14 summarises the findings of the implementation phase and discusses related theories, meta-requirements, subcomponents of meta-design, and testable hypotheses. Students use functions of this module while engaging in thesis project activities. The implementation module includes functions to enhance student-supervisor interaction, implement scaffolding, and support students' self-regulation processes. Students mainly interact with the research context during the implementation phase and implement the research plan. The implementation phase starts when the thesis project plan is prepared and ends with the thesis report. The average duration for an implementation phase varies between four to six months. Findings indicate that the ZPD, Scaffolding and Self-regulation learning processors should be considered when designing the implementation module. More details have been discussed in the sixth study.

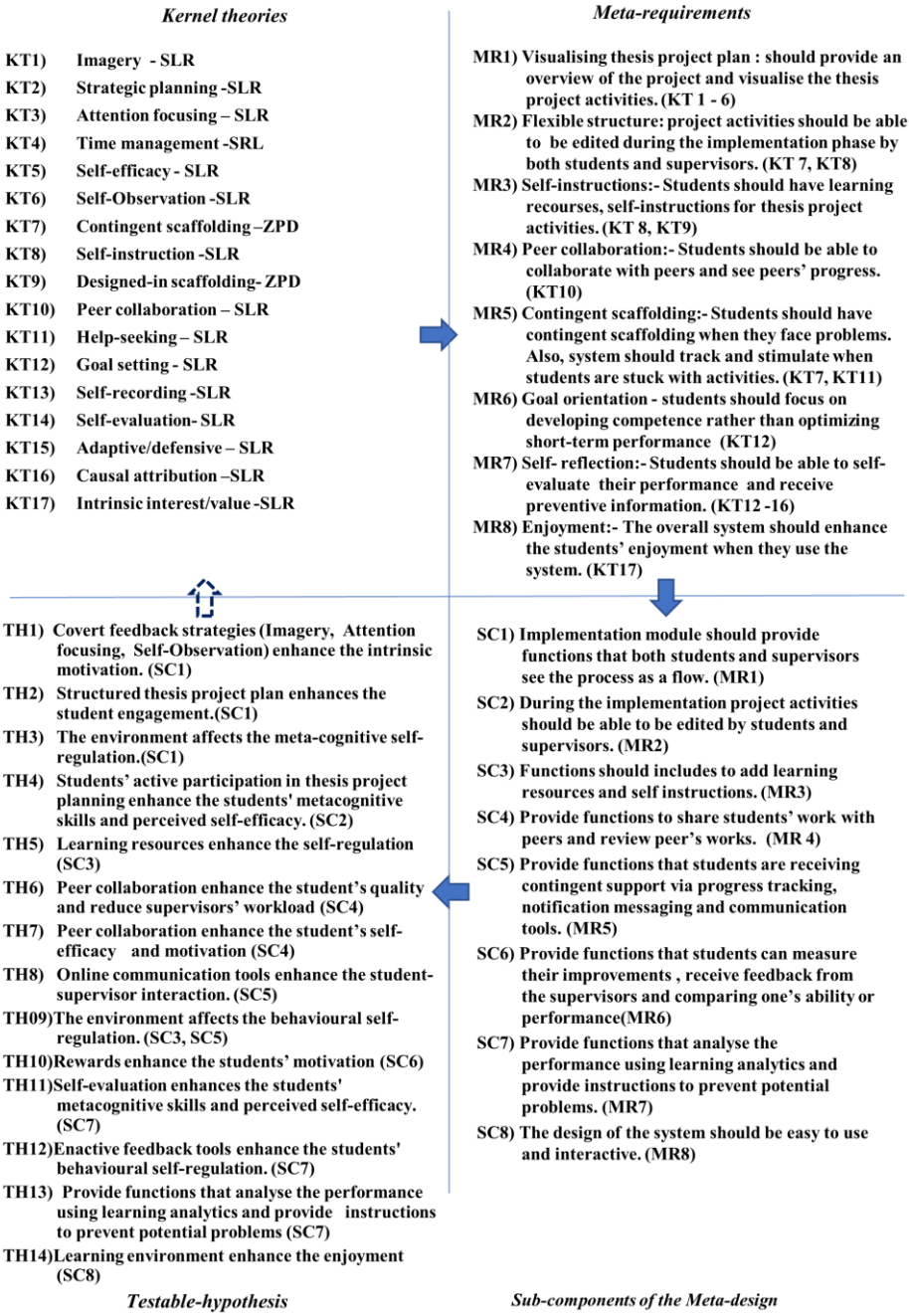

Figure 14. Implementation module

4.3.1.4 Completion module

Figure 15 summarises the findings of the completion phase, discussing the related theories, meta-requirements, subcomponents of meta-design and testable hypotheses. The completion module allows the thesis reports to be shared with external organisations using a portal, and it will lead to enhancement of the students' outcome expectations and self-satisfaction.

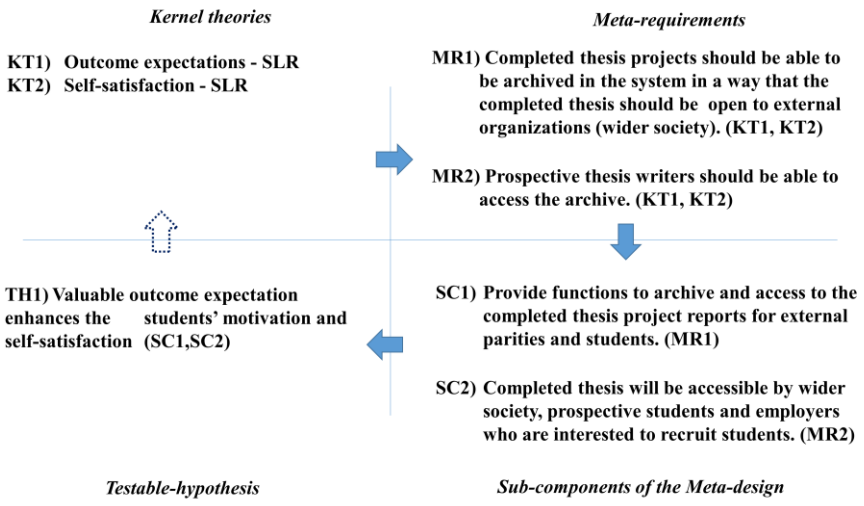

Figure 15. Completion module

4.3.2 SDSRM Step 5: Comparison of the general solution with the specific problem

Figure 11 illustrates the developed framework for designing LMSs to support thesis projects. It is considered the general solution, as it was developed mainly considering general requirements. According to the SDSRM, the next step is to compare the proposed general solution with the specific problem (as a solution for the selected case). The general solution of this thesis is a framework, and now, it should be compared as a solution for the specific problem (compared with the requirements of the selected faculty).

An evaluation strategy suggested by Pries-Heje et al. (2009) was applied to evaluate the developed framework. Following this strategy, the evaluation was conducted as an ex-ante and artificial evaluation. When regarded from the perspective of design research, ex-ante evaluation provides a model for theoretically evaluating a design without implementing the design (Pries-Heje et al., 2009). In other words, the artefact is evaluated based on its design specifications alone. The purpose of this thesis is to evaluate the suitability of the proposed subcomponents as a design. Therefore, the author decided to consider

the feedback from supervisors as a form of an ex-ante evaluation. The proposed framework was introduced by using a short video clip, and a set of questions about the potential importance of the proposed features on thesis projects were presented to 52 supervisors. More details can be found in study 6.

This survey type of evaluation can be regarded as artificial as there was no real system in a real setting involved (Pries-Heje et al., 2009; Venable et al., 2012). The drawback of an artificial evaluation is that participants respond with hypothetical opinions since a real system is not used. Therefore, the outcome may be different from the real-world outcome. But, at this stage, the purpose of the evaluation is formative; to identify weaknesses and areas of improvement for the framework. Therefore, even though the evaluation method is not naturalistic (not a real experiment) the result can be used to identify the suitability of the design for the purpose.

Supervisors mainly evaluate the framework based on their experience and concerning the details given in the questionnaire. More than 91% of the participants agreed that features of the framework create a positive or very positive impact as a general solution and as a specific solution for the faculty thesis projects. Similarly, both mean values are greater than 4, implying that the respondents considered features were important as a specific solution as well as a general solution. Study 6 provides more details about the result. According to the participants' opinion, the components/requirements of the general solution are equally important as a general solution and a specific solution.

The results of the questionnaire show a positive general attitude towards the suggested framework and its potentially favourable impact on thesis projects. In summary, the findings show that the identified meta-requirements and subcomponents can be used as a basic structure to design LMSs to support undergraduate thesis projects.

4.4 Chapter summary

The steps of the SDSRM are used as a structure to present the findings. The first step is understanding the specific problem. Six main problems were identified in the selected faculty, and in the second step, it was revealed that an ICT-based learning management system is one of the requirements for solving problems in the selected faculty. In the third step, the specific problem was analysed as a general problem, leading to the discovery that there is a lack of design knowledge to design LMSs to support undergraduate thesis projects. In step four, a framework for designing learning management systems for thesis projects was developed as a general solution for that general problem. The design mainly considered the implications of the related learning theories. The findings show that ZPD, Scaffolding and Self-regulation are the central concepts that are related with the projects when analyse the learning process from

constructivist and socio-cultural point of view. The framework suggests designing LMSs with four modules to support the undergraduate thesis process; initiation, planning, implementation, and completion. These modules should have subcomponents to create a learning environment where supervisors can interact with students to understand students' ZPD, provide systematic support (scaffold) to reach students' ZPD, and support in utilising self-regulation learning strategies.

5 Discussion and conclusions

A plethora of research, both theoretical and practical, argues that Learning Management Systems support learning and teaching in higher education institutions. However, the authors' 20 years' experience suggests that although LMSs supports classroom-based learning and teaching activities, LMSs lacks tools that can be used to support for thesis project-related activities. Similarly, the literature depicts thesis projects as more problematic and stressful than classroom learning. According to the author's experience as a supervisor, most of these problems are due to the lack of a proper learning environment. Nevertheless, there is a lack of understanding of thesis project-related learning activities that are based on theoretical foundations and pedagogical practices. This understanding is essential in designing an LMS to support thesis projects. Hence, this thesis proposes a framework that can be utilised for designing an LMS for undergraduate thesis projects, choosing the appropriate theoretical foundations and pedagogical practices to match the contextual requirements. In this chapter, the author discusses theoretical and practical contributions in relation to the three research questions. The discussion emphasises the important aspects of designing an LMS to support undergraduate thesis projects.

The main research question of this thesis is "How should an LMS be designed to support the undergraduate thesis projects", and it is answered by dividing the main research question into three sub-questions. The first sub-question is "What are the problems of undergraduate thesis projects?". Based on Study 1 (Peiris et al., 2013) and Study 2 (Peiris et al., 2018), six main problems are identified and they are 1) lack of student motivation, 2) lack of student-supervisor interaction, 3) an unstructured research process, 4) lack of skills and knowledge, 5) students' high workload, and 6) resource sharing issues.

The second sub-question, "Which learning theories and pedagogical concepts should be considered when designing a Learning Management System to support the undergraduate thesis projects?" is formulated to understand the thesis process from related theoretical perspectives. In study 3 Peiris et al (2019) discussed this question and Vygotsky's concept of ZPD, Scaffolding, and Self-regulated learning concepts were identified as the central theoretical perspectives needed when designing an LMS to support the undergraduate thesis projects. One of the important findings of this study is that if the learning environment has not been designed to support these theoretical perspectives, it may create the problems identified in the first sub-question.

The third sub-question is, “What are the requirements and components of learning management systems which would support the undergraduate thesis projects?”. Study 4 (Peiris et al., 2014), 5 (Peiris & Hansson, 2017) and 6 (Peiris et al., 2022) contributed to answering the third sub-question. Answering the third sub-question mainly concerned the theoretical perspectives (answers to the second sub-question) and problems identified in the first sub-question. As an answer to the third sub-question, a framework is suggested. The answer to the third sub-question has been discussed in detail in section 4.3.2. The framework mainly concerns the requirements of the pedagogical concepts, which mainly derive from three main theoretical concepts: 1) ZPD, 2) Scaffolding and 3) Sub-processes of Self-regulation. The framework suggests designing an LMS based on the sequence of learning activities and divided into four phases: 1) initiation, 2) planning, 3) implementation, and 4) completion. Section 5.1 discusses the proposed framework and how ICT can be used for designing an LMS to support undergraduate thesis projects.

5.1 Application of the framework for designing an LMS for thesis projects

This thesis recommends a framework that can be used for designing LMSs to support undergraduate thesis projects. In general, the duration of a thesis project is approximately four to six months, and the framework suggests dividing the whole process into four phases, with four modules developed for the phases, i.e. initiation, planning, implementation, and completion. The framework suggests the related theoretical concepts should be considered in each phase, out of which the LMSs designers must select the relevant theoretical concepts considering their context and problems. The importance of the suggested theoretical concepts may vary from one degree programme to another, making the selection of theoretical concepts optional. This division of the whole process into phases make easy to go for a profound analysis of the problems in each phase, considering the theoretical concepts, to identify the solutions for the problems and innovative features to support the learning activities of the phase. LMSs designers should lead the design process but supervisors and thesis project coordinators also should be the main persons involved in the analysis since they have knowledge and experiences of the real process.

The recommended framework provides a basic structure considering the general problems, which may, however, not be valid for some contexts, in which case the designers should analyse their context to identify the present or potential problems and develop features to avoid those problems. For example, the framework has identified the students’ lack of motivation as one of the main issues. The framework was developed considering management un-

dergraduates, and it was suggested to design a feature where students' interaction with the industry is promoted, enabling them to select a research problem from the industry. The framework assumes that the suggested student-industry interaction features will actively motivate students to write a higher quality thesis. The assumption is based on the concept of outcome expectation concept (self-regulation process). The students interacting with industry while creating employment opportunities will enable them to showcase their skills and knowledge through their thesis project activities, resulting in higher motivation during the thesis project. When designing a system for a specific context (University/Faculty/Department), there may be different requirements. For example, if there is a degree programme in which employability is less important (a degree programme with no employability problems), students may not be motivated by industry-related thesis projects. Then, the LMS should be able to configure the idea bank for that degree programme without industry partners.

There may be universities that may not have resources to develop or buy an LMS as suggested by the framework. Although it is not a perfect solution, there are general LMSs that can be used to implement some of the functions suggested by the framework. Moodle is an example, and it is a free and open source LMSs. The author has experience as a Moodle administrator for more than 20 years and found that there are many functions in Moodle that can be used to support thesis projects. Moodle is an acronym, and it means Modular Object-Oriented Dynamic Learning Environment. As the name implies, extra functionalities can be added as plugins (Modular) and these features can be configured to create a flexible learning environment (Dynamic).

A Moodle-based LMS has two main types of features: 1) Resource and 2) Activity. A resource can be considered as a one-way tool and teachers can share resources with students. For example, teachers can share a learning material such as a presentation, URL, journal paper etc. An activity type feature provides an interactive learning environment and students can also actively participate in the learning activity. For example, in discussion forums students can also ask questions and receive responses. There are many activity type plugins in Moodle. They have been developed by the Moodle core system developers and third-party volunteer developers. A university's Moodle administrators can select and install these plugins and add extra features. The philosophy of the Moodle LMS is constructivism, and the core has been developed to support constructivist pedagogical practices (MOODLE, n.d.). Although the primary objective of these plugins (activities) is to support large size classroom learning activities, some of the activities can be used to implement the suggested features of the framework. For example, the database activity is a core plugin in Moodle, and it can be used to implement the Idea Bank concept. Another solution is Brito et al. (2019) has developed a third-party plugin to indicate dropout risk in the Moodle virtual learning environment. Almost all Sri Lankan public universities use Moodle-based LMS and

they can use Moodle activities as a feasible start to implementing the framework.

5.1.1 ICT support at the initiation phase

Currently, when the thesis project is offered as a mandatory course, most supervisors are not satisfied with the students' active engagement. Bandura (1994) explains that the students are motivated to produce a higher outcome only if they see the value of that outcome. Therefore, one aspect of this framework is to enhance the outcome expectations of students by allowing them to select real-world (from external organisations/industry/society) problems for their theses. The fourth study suggests an innovative feature named "Idea Bank" — a Web-based repository — to manage ideas, and it facilitates matchmaking between students and supervisors. In this scenario, both students and supervisors publish their ideas in the web system. In addition, the Idea Bank can be opened up to industry and society to share real-world problems. If students choose a real-world problem, they will see the outcome as an opportunity to increase their employability. The supervisors will also benefit from the Idea Bank. They can publish their ideas, and if matched, they will have the opportunity to get free research assistants (students) to research their ideas. Furthermore, if they can supervise industry-related projects, they will have more updated knowledge and recognition. From industry's perspective, they will get free researchers for their research and development activities. At the same time, the university will gain more recognition with more industry-related research projects. Although it may seem easy to create a win-win situation on sharing ideas, there may be challenges beyond technical problems. For example, challenges about the ownership of ideas and rights on the research outcome are a few of many issues that may arise. Especially, as the industry is concerned about trade secrets, they will hesitate to share their ideas with students and supervisors if they are not satisfied with the environment and privacy of their ideas.

The selection of ideas and matching of students and supervisors is time-consuming and tedious. The course coordinator or department representative should spend considerable time manually matching students, supervisors, and ideas. As discussed in this thesis, if industry/society can submit ideas, it may enhance the students' motivation. However, it will create another task for coordinators from the administrative perspective. As discussed in this thesis, an ICT support tool like Idea Bank can be used for idea matching and project creation. In addition to matching ideas, the framework suggests providing students and supervisors with a feature where interaction is possible even before officially assigning supervisors and students. Frequent interactions between students and supervisors should start when the project officially starts. However, if there is a method to interact with a potential supervisor before the commencement of the project, even during the idea generation, it will help

supervisors understand the students' ZPD. Understanding the student's ZPD will help supervisors plan the project to match the student's knowledge and to the skills level.

5.1.2 ICT support at the planning phase

The support of the ICT for the planning phase is two-fold. From the supervisors' perspective, preparing a thesis project plan is a time-consuming activity, and novice supervisors may lack experience of preparing project plans. According to the ZPD concept, a personalised scaffolding plan is needed to help students reach far into their ZPD. In comparison to an undergraduate thesis, a supervisor may have more students in the supervision of postgraduate and PhD programmes. Therefore, supervisors need a support system to create and reuse project plans. The suggestion is to use modern web-based technologies that can be used to create a thesis project plan template and reuse when necessary. These templates could be easily changed to match with the students' level of understanding and the topic. As reported in previous studies, the absence of a properly prepared supervision plan, prepared with sound pedagogical principles in mind, is a common problem. In that case, supervisors start the supervision process with ad-hoc approaches (Calvert & Casey, 2004). Students are frustrated if the thesis project plan is not matched with their capacity. These reusable templates can be used to avoid the ad-hoc approaches. Also novice supervisors can use these project plan templates that have been developed by experienced supervisors.

In addition, ICT-enabled features can enhance the efficiency of the supervisors and course coordinators. For instance, supervisors need to do repetitive activities during thesis projects, such as preparing project plans. If all the supervisors create project plans manually, even if they use word processors it may take a few hours. If there is an LMS with templates, technically it may take only a few seconds to create a project plan. But the challenge is the creation of templates. A template may give a frame, but supervisors need to fill it with proper content. Computer-based information systems need more time and effort at the beginning (when launched). But once created the resources can be reused. Consider the following, although it may be an optimistic calculation: suppose there are 41,000 thesis projects per year; if a supervisor spends one hour to create a thesis project plan, it takes 41000 hours. However, if all the supervisors have LMS with project plan templates, they can save these 41,000 hours per year.

From the students' perspective, the project plan activities should be possible for students to implement and they also should be able to participate in the planning process. The concept of self-efficacy includes how people feel, think, motivate themselves, and behave (Bandura, 1994). Margolis and McCabe (2004) suggest an instructional principle to enhance students' self-efficacy, which should be considered during the planning phase. The principle is that

task difficulties should match the learners' instructional and independent levels. Therefore, the supervisor needs to assess the student's performance to match the tasks with the student's skill level. It is possible that the planning module can abstract students' performance in other courses and update the student's profile. Then, when it comes to the planning, supervisors have a good idea of the student's performance, and the project plan can be adjusted to fit the students' performance level. If students are too weak, supervisors can arrange extra support with the help of the others. For example, in the author's experience, supervisors arrange extra support for students with language issues by contacting the business communication department.

Another meta-requirement for the planning module is related to task analysis and self-motivation (Zimmerman, 2002). The task analysis sub-process is about the students' participation in learning activities, goal-setting and the planning process. As known from previous studies, the students' participation as a metacognitive self-regulation strategy positively influences academic performance (Delen & Liew, 2016, p. 27). This suggests a new function for the planning module, in which students can plan their own learning activities. This contrasts to the general LMSs for courses where teachers set the plan and students follow the plan without modifications. Students should be allowed – and be able – to add and modify the project plan. In order to partly keep supervisor control and empower students to a certain degree, an additional function could be added so that students cannot change the initial core plan, but they can add new, additional activities and modify them as they like.

5.1.3 ICT support at the implementation phase

In general, the duration of thesis project implementation is about four to six months, and students and supervisors should regularly interact during the thesis project implementation phase. Supervisors need to instruct students regularly, and most of the time, supervisors give the same set of instructions and guidelines. For example, most of the students conduct surveys, and supervisors need to give instructions on creating questionnaires. It may not suit everyone, but supervisors can use ICT tools such as sharing learning materials to conduct a survey, and supervisors can reduce the extent to which they repeat the same guidance for many students. Although online resources may not be equally appropriate for all activities, supervisors can still use ICT tools to enhance the efficiency of the supervision process.

According to the empirical study and literature results, many problems are encountered during the implementation phase. These problems are rooted in the lack of a proper learning environment to support students during the implementation phase but some of the issues are linked with the initiation and planning phases. For example, if students do not select an interesting idea or cannot see a higher outcome from thesis projects, it will reduce their motivation. Similarly, if students do not have a proper plan, they will not actively

engage in thesis project activities. Students need to actively engage in thesis projects to complete the project within the given timeframe (within a few months) successfully. Even though a supervisor is assigned to guide the thesis process, students should implement thesis project activities alone, since thesis project is designed as a constructivist learning activity. Therefore, the learning environment should have functions that support students' self-regulation processes. Student-supervisor interaction and peer collaborations are other critical success factors, and the proposed framework should have supporting features for these activities.

5.1.3.1 How could ICT be of support for self-regulation

Constructivist learning is self-regulated, and the learner is responsible for being active, constructive, goal-directed, diagnostic, and reflective (Simons, 1993). According to constructivist pedagogy, students are expected to be independent and to regulate learning activities themselves in thesis projects. However, according to the findings, students lack the self-regulation skills needed to be constructivist learners (Peiris et al., 2018). They need support to develop problem-solving skills, self-directed learning skills, teamwork skills and collaboration, and self-regulation skills in learning (Savery, 2006). According to previous studies, giving people more opportunity to regulate their activities and bear responsibility is often problematic in practice, and some people will perform (even) worse when left to themselves (Simons, 1993). Many students involved in industry-related events such as internship or employments reported that they did not begin their thesis project until the very last moment. It appears that they spent their time on other courses and industry-related activities, and there was no proper monitoring system to issue a warning about this lack of engagement with thesis project activities. Students did not feel they were lagging far behind in this process until the deadlines approached. Some supervisors warned students when they felt that students were not active, but most supervisors were busy and could not send reminders because they had so much other supervision work. Monitoring procedures for both supervisors and students and tools that enhance students' motivation and self-regulation should be included as components in the scaffolding plan when designing the thesis course structure. For example, an automatic activity report (progress report) can be created including students' progress and sent as a message to both the student and supervisor.

5.1.3.2 Student-supervisor interaction

From study 2, the lack of student-supervisor interaction was observed as one of the main problems, which was affirmed by the findings of many previous studies in relation to developing countries (Mapolisa & Mafa, 2012) as well as developed countries (Orsmond et al., 2004). Multiple factors affect the student-supervisor interaction, and the vital element is the communication chan-

nel. Study 2 revealed that face-to-face meetings are the only formally implemented communication channel (Peiris et al., 2018). Since both the students and supervisors are busy, the number of face-to-face meetings was limited and not conducted to build on appropriate student-supervisor interaction as suggested in related learning theories. For example, according to Vygotsky's Zone of Proximal Development, student and supervisor interactions are equally important from the beginning to end of the thesis writing process (Peiris et al., 2018).

One of the main findings of the studies is that the thesis project learning environment should ensure a convenient and effective communication channel for student-supervisor interactions. The empirical research revealed the potential to address the lack of student-supervisor interaction using ICT tools. Both students and supervisors are familiar with face-to-face meetings and often prefer them, but face-to-face meetings are not always efficient and effective. For example, the lack of a proper communication method makes students put their projects on hold until they meet their supervisors, even in the case of minor matters. Therefore, it is essential to introduce complementary communication methods so that face-to-face meetings are not always needed. Email is a possibility, but students rarely use it. There may be different reasons for the lack of email usage; students may be reluctant to use email due to unfamiliarity with it or the belief that it will disturb the supervisor. Similarly, both students and supervisors need to track previous discussions before interacting. Therefore, the framework recommends implementing a discussion forum as a part of the learning environment, where it is convenient to track previous discussions, and messages do not mix with other types of communication, as in e-mails.

It is important to note that even though students may need more supervision they refrain from questioning the situation, or complaining because it is not culturally accepted. Sri Lankan society is hierarchical (Riswan, 2014; *Sri Lanka - Geert Hofstede*, 2017), and this is reflected in the culture within Sri Lankan universities:

> *"This leads to an expectation of obedience by children, at least formally, and obedience which is supposed to last for life, even after the children have grown up. … Students are expected to show respect to teachers, and to treat them as sources of wisdom, never openly disputing their teachings. One-way, ex-cathedra teaching is customary in such a cultural setting* (Hofstede, 1984, p. 90)*."*

Supervisors are also busy with other activities and consciously or unconsciously may delay giving feedback or necessary guidance. Still, students might hesitate to contact them, leading to unnecessary delays. A discussion forum records how supervisors respond to students' requests, and therefore, computer-mediated communications would motivate supervisors to engage

with thesis projects, and students may get better and more frequent responses from supervisors.

5.1.3.3 Peer collaboration

Peer collaboration is considered an essential component of constructivist learning, and previous studies have documented peer collaboration activities as highly productive in research supervision (Bowman & McCormick, 2000). Peer interactions motivate students since they can see their progress when interacting with other students. However, peer learning activities should be appropriately planned and integrated into the supervision process. Arranging peer collaboration is a challenge since the student focus is minimal without specific assignments, instructions, and face-to-face meetings. Previous studies have reported the challenges of implementing peer collaboration through ICT support systems (Aghaee & Hansson, 2013; Kjellman & Peters, 2011). When the number of students is high, these support systems can help in managing peer collaborations and reduce the workload of supervisors. However, we found that peer collaboration has been neglected when designing the structure of thesis projects in Sri Lanka. Therefore, students feel isolated during the thesis projects. Baker (2014) argues that peer support also benefits students and enhances the efficiency of the faculty. For example, peer assessments can be used to implement formative assessments when there are many students.

There are two types of assessments, called formative and summative. Formative assessments give feedback during the learning process and require more time and effort. Therefore, sometimes formative assessment ignores since supervisors may not have time or motivation to conduct formative assessments, but such assessments are needed to maintain the quality of thesis projects. If there is no formative assessment, the thesis project report may not be assessed until it is presented at the final defence. An ICT-enabled LMS can use peer collaboration as an alternative formative assessment method, which saves supervisors' time and enables a few formative assessments during a thesis project.

5.1.4 ICT support at the completion phase

As discussed earlier, students consider the thesis project as another learning activity from which they can earn credits needed for the completion of their degree; Therefore, students will not be motivated to engage in thesis projects but will merely attempt to obtain a passing grade. However, there is an opportunity to share the constructed knowledge from students' thesis projects with external organisations. As Bandura (1994) suggests, students are motivated to produce a higher quality result if they see the value of such outcomes. Even though undergraduate students are novice researchers, they conduct research projects with academic staff who have research experience. According to one supervisor, three papers had been published in conferences out of four thesis

projects. While discussing his supervision experience, he was delighted with the students' motivation. However, practically, it is difficult to publish all project works in conferences or journals. Therefore, the framework suggests that the thesis project reports should be shared with interested parties, which would lead to enhancing students' outcome expectations. Sharing thesis project reports may be beneficial, but a few related challenges may affect the process. If the quality of the thesis is low, supervisors and students will resist sharing these reports. Low quality theses are not good for the institution's reputation and may adversely affect the students, supervisors, and administration. Similarly, some students can copy previous reports and submit them with minor modifications.

Final thesis report assessment is a time-consuming and it is a challenge to mark thesis reports since they have different structures and lengthy. Moreover, it is important for new supervisors to have a guide for grading thesis projects. ICT-enabled rubrics are popular tools for essay type activity marking. Predefined criteria can be used to assess thesis project reports. These rubrics save time and protect the fairness of the grading process. Also, it is common practice that, in general, as a summative assessment the final thesis report will represent only about 30% to 50% of the total course grade and the rest will be for the formative assessments (continuous assessment). The use of an LMS for a thesis project makes it easy for supervisors to grade the whole course since the LMS records all thesis project-related activities. Another advantage is, if the supervisor changes during a thesis, the new supervisor can easily understand the history of the thesis project and continue the supervision and grade accordingly.

5.2 Reflection on the framework

5.2.1 Theoretical contribution

The main theoretical contribution of this study is that it highlights the importance of developing LMSs to support undergraduate thesis projects based on theoretical foundations and pedagogical practices. The findings show that it is common among course designers, supervisors, and students to be ignorant of the importance of theoretical foundations and pedagogical practices. The theoretical contribution can be discussed under three main themes. First, the findings of this thesis recommend designing the learning environment for thesis projects so that it supports students' self-regulation. The thesis highlights the importance of students' self-regulation learning skills and suggests to design a learning environment that support these skills. Secondly, this thesis highlights the importance of understanding the students' ZPD and developing a learning environment where supervisors can identify it. If there is a lack of

understanding of students' ZPD, both supervisors and students will face difficulties during the thesis project. Thirdly, this thesis contributes by emphasising the importance of scaffolding and discusses the types of scaffolding that should be considered when designing an LMS to support thesis projects. In addition to supervisor's support, this thesis highlights the importance of peer collaboration and designing LMSs to implement peer interactions. Although there are studies of using ICT to support thesis projects they have not specifically discussed the relationship between thesis project activities and related learning theories with applicable pedagogical concepts. Therefore, theoretically this study provides a framework to conduct further studies and update the design knowledge of LMSs to support undergraduate thesis projects.

5.2.2 Practical contribution

One of the central issues identified in this study is the lack of knowledge of designing LMSs to support undergraduate thesis projects concerning the implications of related pedagogical theories. The practical contribution of this study is that LMSs designers can use the proposed framework to identify the requirements and software components of LMSs to support undergraduate thesis projects. There are many studies about standalone tools, but only a few about complete LMSs solutions to support thesis projects. Studies of LMSs also discuss the already developed systems as examples. However, the lack of knowledge in design guides for developing LMSs to support thesis projects concerning pedagogical theories remains the same. Therefore, this study aims to fill that gap by developing knowledge and presenting a framework that can be used as a basic structure for designing LMSs to support undergraduate thesis projects. As a result of a series of studies, a framework was developed and explained in chapter four.

Following SDSRM, the identification of the problem was initiated in the selected faculty (SDSRM steps 1 and 2), but the specific problem was analysed as a general set of problems and requirements, and the framework was designed as a common solution (SDSRM steps 3 and 4). Therefore, the framework can be used as a basic model for other contexts too. According to the contextual requirements, these basic features may be ignored, or new features can be brought in. For example, in the Sri Lankan context, still, medical science students do not have employability issues, and they would not be interested in selecting ideas from the industry. Therefore, the integration of external idea sources would not be essential for a LMS for medical science undergraduate programmes.

According to the author's knowledge, no such framework has been discussed in previous studies concerning the requirements of Sri Lankan higher education institutions. Even other countries also lack comprehensive studies of designing LMSs to support undergraduate thesis projects concerning the implications of related pedagogical theories. Therefore, this study practically

contributes field of information systems by adding design knowledge of LMSs to support undergraduate thesis projects.

5.2.3 Methodological considerations – Limitations

The aim of this thesis was to develop a framework for designing LMSs to support undergraduate thesis projects in Sri Lanka. Therefore, the whole study was designed to cover practical problems in the undergraduate thesis projects, potential opportunities of thesis projects, learning theories relevant for the thesis process, blended learning environments, design theories related to information systems, and implementation issues. Consequently, this study lacks an in-depth analysis of certain areas. Soft design science research methodology is a seven-step design science research approach used as the methodology for this thesis. The reason for selecting SDSRM is that it provides a model to address both research rigour and relevance.

One of the main limitations applied to the empirical work is the author interviewing students after the thesis project was graded. This was because, since students would no longer be afraid of effects on their grades, they would feel free to explain their opinions about the process and their lecturers. The limitation was that they may have forgotten their experiences. It would have been better if data had been collected during the thesis process. The author used probes during the interview process to remind interviewees of their experience during the thesis process and also to ask questions concerning the key events of the thesis process. In parallel, the author asked the supervisors questions following the same procedure. The requirements identification process is also divided into four phases to simplify it. During the interviews, the author conducted brief demonstrations using DSV thesis support systems and Moodle tools as a way of evaluating the requirement identification. That was in addition to the survey conducted in Study 6. One of the limitations of the evaluation process was participants' lack of experience of using personalised LMSs. However, all participants expressed a positive attitude towards designing a system to support undergraduate thesis projects using the proposed framework.

Good design science research depends on the synergy between relevance and rigour (A. R. Hevner, 2007). Relevance is the view that academic research addresses ‘street level’ problems (Kuechler & Vaishnavi, 2011), and rigour refers to the application of scientific theories and engineering methods to the design process (A. R. Hevner, 2007). The SDSRM methodology provides a guide to satisfy both relevance and rigour. When determining what works in education, researchers tend to emphasise evidence-based practices (EBPs) supported by research that is rigorous and internally valid, whereas practitioners tend to value practice-based evidence (PBE) that is relevant and externally valid (G. J. Smith et al., 2013). The SDSRM step four suggests designing a general solution (class of solution) concerning theoretical foundations of the

problem domain (EBP). Also, the general solution should be used to solve similar practical problems (PBE); therefore, the usefulness (relevance) of the research conducted using the SDSRM is also high.

Stokes (1997) introduced a slightly similar model that can be used to categorise research into four types. Hevner & Chatterjee (2010, p. 3) used that model with a modification. According to Stokes' modified matrix, research can be divided into two types concerning whether the research creates fundamental knowledge or not. Also, research can be categorised as having either a high or low level of usefulness. Hevner & Chatterjee (2010) recommend that design science research should focus on the right top corner of the Stokes matrix, maintaining high usefulness with fundamental knowledge (Figure 15).

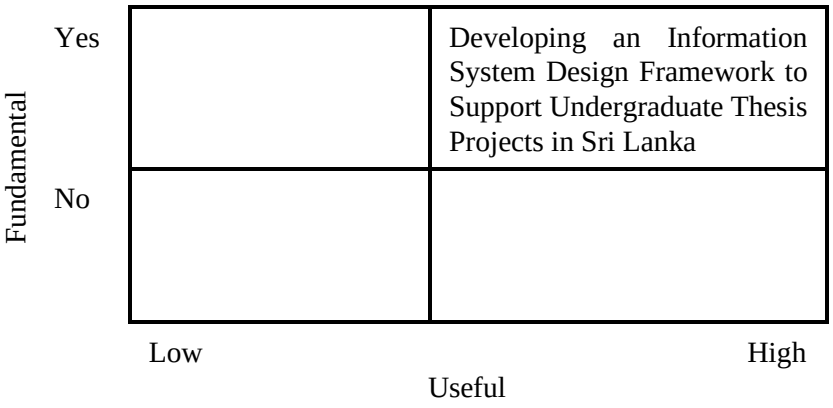

Figure 16. Positioning the thesis in the Stokes matrix quadrants

The SDSRM was selected since it guides to conduct a research study maintaining high usefulness with fundamental knowledge (reach of the right top corner of the Stokes' matrix). Steps 1,2,5,6, and 7 are related to relevance and steps 3 and 4 are relevant to rigour. Answers of the sub-research questions mapped to the Stokes' matrix analysing the type of knowledge created by the studies. As a value addition, answers to the first sub-question, the identification of problems in thesis projects in a specific institution is fundamentally low and the usefulness is low. Answers to the second sub-question, the new knowledge of related learning theories that should be considered when designing LMSs can be considered as fundamentally high, but this study usefulness also is low. The answers to the third sub-question, the knowledge of how LMSs should be designed presented as a general framework is fundamental and highly useful for LMSs designers. Therefore, the outcome of this thesis adds a fundamental to the knowledge base, and the usefulness also is high. The SDSRM steps are simple and clearly guides even novice researchers to conduct research to construct fundamental knowledge and with a higher level of usefulness. Therefore, the author recommends SDSRM as a strategy to conduct research with a higher level of rigor and relevance.

The SDSR methodology is a fairly new approach, and it was a challenge to apply Baskerville's (2009) model since there are unclear technical terms and also since there is a lack of previous studies that have applied the SDSRM. The most challenging task was the use of the term "requirement" in different stages. For example, step 3 suggests abstracting the requirements for the specific problem and translating them into a general problem. Step 4 suggests designing a general solution (a class of solutions) for the general problem through design thinking and expressing the solution in terms of general requirements. The term 'requirements' confused the author and also may confuse readers too; therefore, the author referred to a few related studies to clarify the use of terms in these two steps. Previous researchers (Mshangi et al., 2016; Razali et al., 2010) have used the term 'requirements' when referring to the identification of general requirements (in step 3). In step 3, the researcher should analyse identified problems as symptoms and this analysis should be deep in order to identify root causes with reference to theories related to the problem domain. In step 4, the researcher should design a general solution (class of solution) that addresses the root causes. Therefore, the author suggests using 'Identification of the general problem' as the title of the third step and 'Designing a general solution' as the title of the fourth step to avoid misunderstandings.

This thesis completes only the first five steps out of the seven steps. A general framework — which can be used to design an LMS to support a thesis project — is identified at the end of step 4. The framework is the intended outcome of this thesis and construction of a real system is suggested as future work concerning the limitations of the time and resources. The SDSRM suggests a cyclic process, and if the general problem is not solved, the process should continue until it finds a feasible solution and modifies the solution. Steps 6 and 7 suggest constructing a real system. The author suggests future interested researchers should construct LMSs based on the framework and evaluate the impact using the testable hypothesis and update the knowledge base.

5.3 Future work

As discussed in the limitations of this study, the present investigation recommends a set of testable hypotheses, which are not evaluated. These hypothesis formulations should be based on the related kernel theories, and a series of studies to assess these hypotheses need to be conducted. For instance, this study suggests that ICT can be used to create a helpful learning environment that supports scaffolding, students' self-regulation, motivation, peer collaboration and student-supervisor interactions. Therefore, future research can explore the validity of these assumptions. Another crucial area is how ICT can be used to assist thesis project administrators. An administrator has to manage

many thesis projects in an undergraduate degree programme, and some academic programmes have 150 students. If the administration can be made more efficient and higher in quality, it would save time and money while increasing the satisfaction of the administrators, students and supervisors.

The study revealed that some of the supervisors were not familiar with learning practices based on constructivism and were hesitant to give autonomy to students. Similarly, some students did not understand the supervisor's role as a person who helps them construct knowledge. Some students try to depend entirely on supervisors, while some completely ignore the concept of scaffolding. Therefore, this research suggests more research is required on students' and supervisors' understanding of constructivist learning processes in undergraduate thesis projects.

As an ICT-based learning environment is borderless, future development may investigate the potential for collaboration between international students and supervisors, multidisciplinary team supervision and large scale collaboration, including with industry partners and public organisations. If 41000 undergraduate students in Sri Lanka could be aligned to one or several of the 17 UN sustainability goals yearly, it would increase meaning of the thesis projects and thereby student motivation, solve the problem of student loneliness, create engaging networks for career development and recruitment, and contribute to the whole society. It is possible that some studies could provide a foundation for innovative start-ups.

5.4 Chapter Summary

Undergraduate thesis projects are more problematic and stressful than classroom learning activities. In the author's experience as a supervisor, most of these problems are due to the lack of a proper learning environment. The main theoretical contribution of this thesis is that it highlights the importance of developing LMSs based on theoretical foundations and pedagogical practices to support undergraduate thesis projects. A practical contribution is that the thesis recommends a framework that can be used by LMSs designers to identify the requirements and software components of an LMS to support thesis projects. SDSRM was selected as the research methodology since it provides a structure that enhances the rigour and relevance of this study. SDSRM is not a mature methodology, and the author faced some challenges due to lack of examples of how to apply the methodology.

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