REQUIREMENTS ENGINEERING ASPECTS FOR SUSTAINABLE ELEARNING SYSTEMS

A thesis submitted in fulfilment of the requirements for
the degree of Doctor of Philosophy

Ahmed Dakhilallah Alharthi
BCompSc, Taif University
MSoftEng, Macquarie University

Supervisors:
Dr Maria Spichkova
Assoc. Prof. Margaret Hamilton

School of Science (Computer Science and IT)
College of Science, Engineering, and Health
RMIT University
Melbourne, Victoria, Australia

December, 2018
Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

Ahmed Dakhilallah Alharthi

School of Science (Computer Science and IT)
College of Science, Engineering, and Health
RMIT University
Melbourne, Victoria, Australia

13/12/2018
In the name of Allah, the most beneficent, the most merciful

I dedicate this thesis:

To the memory of my beloved mother, Noura (1951 - 2016), I miss her everyday; she always was supportive in each aspect of my life. You are gone in the middle of my PhD journey but your belief in me has made this journey to be completed. May Allah have mercy on you O mother,

To my beloved father: Dakhilallah for dealing with me being world away and for his prayers all the time,

To my beloved wife: Mary Jane for her devotion, patience, and encouragement,

To my beloved children: Ramy and Noura for their patience and excitement to see me home,

To my sisters, brothers, family members, friends and all colleagues who supported and encouraged me throughout.

Thank you Allah (Alhamdulillah) for everything.
Acknowledgements

All praises to Allah, my god, for the strengths and his blessing in completing this thesis.

Firstly, I would like to express my sincere gratitude to my academic supervisors Dr Maria Spichkova and Assoc. Prof. Margaret Hamilton for the continuous support of my Ph.D study and related research, for their patience, motivation, and immense knowledge. Their guidance helped me during the last three and a half years. Without their support, this work would not be accomplished. Both funded a part of my travel to present and attend conferences. I appreciate their enthusiasm for my research and their assistance in writing this thesis. In particular, I would like to thank Maria for being incredibly patient while teaching me valuable research techniques. She pushed me beyond my comfort zone and, for the first time, I learnt the power of resilience, passion and perseverance.

I take this opportunity to express my appreciation to the higher degree research and services teams in the School of Science at RMIT University, specifically Dr Lisa Dias, Emma Stockham, Dora Poulakis, and Tania Piraino.

I would also like to show my gratitude to my sponsoring institution, Umm Al-Qura University for granting me this extraordinary opportunity to continue my studies at RMIT University. Also, I extend my appreciation to RMIT University for rewarding me travel grants to cover partly my travel for local and international research activities.

On another note, I am deeply grateful to the special people who provided me with suggestions, assistance and comments during my PhD journey. Those people start with Ahmad Falatah, a brother who spent time supporting one another, pushing our limits and becoming better researchers. I had a great enjoyable time with Eidah Alzahrani, Tawfeeq Alsanoosy, Dr Yoosef Abushark, Dr Ayad Turky, Hui Song and Xi Chen.

I thank Islamic community at RMIT University, Saudi community in Melbourne, the Islamic Council of Victoria and Melbourne Madinah Masjid community. You were my family to me while I was far from home. I celebrated Eids and attended Islamic activities with you. I thank all friends, colleagues and every one draw a smile on my face during my PhD journey. I spent time laughing out loud.
Most importantly of all, there were great women supporting me for not giving up in my life, particularly PhD. Among them my mother who unfortunately did not see me continuing this journal, my beloved wife, Mary Jane, who did not let me fall and were there to get me back on my feet, and my [PhD] supervisors for advice and ultimate support are on the top of list.

Last but not least, I would like to thank my family: my parents, brothers, sisters, aunts, uncles and cousins for your concern about my PhD journey.

To the joy of my heart and apple of my eyes, Ramy and Noura, you are the gifts Allah gave me. You cheer me up every day I go home. I do not want you to grow up, so I can carry both of you at the same time and then run around home as well as take you down to the beach and playground.

I also would like to acknowledge Elite Editing for proofreading my thesis. The editorial intervention was restricted to Standards D and E of the Australian Standards for Editing Practice.

Thanks to you all!
Statistical Summary

• Total number of pages: 203 pages
• Total number of word count: 69,584 words
• Total number of figures: 42 figures
• Total number of tables: 33 tables
• Total number of references: 267 scientific publication
Credits

Portions of the material in this thesis have already appeared in the following publications published in:

Book chapter:

   This book chapter is presented in *Chapter 4*.

Peer-reviewed journal:

   Q2 journal according to 2017 SCImago journal rankings¹ and this work is presented in *Chapter 3*.

Conferences:

   According to CORE 2018 conference rankings², ISD is an A-ranked conference. This survey is presented in *Chapter 4*.

4. **Ahmed D. Alharthi**, Maria Spichkova, and Margaret Hamilton. Susoftpro: Sustainability profiling for software. In *Proceedings of the 26th IEEE International Requirements Engi-

---

¹https://www.scimagojr.com
²http://www.core.edu.au/
According to CORE 2018 conference rankings\(^3\), RE is an **A-ranked** conference and this work is presented in **Chapter 5**.


This paper is presented in **Chapter 3**.


This paper presents in **Chapter 3**.


According to CORE 2018 conference rankings\(^3\), ASWEC is ranked as **Australasian** conference this paper is presented in **Chapter 1**.

**Workshops:**


This paper presents in **Chapter 6**. Workshop at a CORE 2018 **A-ranked** conference.


According to CORE 2018 conference rankings\(^3\), ECSA is an **A-ranked** conference. This paper presents in **Chapter 7**.


This work is discussed in **Chapter 5**.

\(^3\)http://www.core.edu.au/
The thesis was written in the TeXstudio editor on Windows 7, and typeset using the \LaTeX{} document preparation system.
All trademarks are the property of their respective owners.
## Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>xii</td>
<td>Contents</td>
<td></td>
</tr>
<tr>
<td>xv</td>
<td>List of Figures</td>
<td></td>
</tr>
<tr>
<td>xvii</td>
<td>List of Tables</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>1.1</td>
<td>Motivation</td>
<td>5</td>
</tr>
<tr>
<td>1.2</td>
<td>Research questions</td>
<td>6</td>
</tr>
<tr>
<td>1.3</td>
<td>Overview of research methodology</td>
<td>7</td>
</tr>
<tr>
<td>1.4</td>
<td>Thesis outline</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Background</td>
<td>11</td>
</tr>
<tr>
<td>2.1</td>
<td>Sustainability in software engineering</td>
<td>12</td>
</tr>
<tr>
<td>2.1.1</td>
<td>Requirements engineering for sustainable systems</td>
<td>12</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Sociocultural aspects of sustainability</td>
<td>13</td>
</tr>
<tr>
<td>2.1.3</td>
<td>Sustainability profiling</td>
<td>14</td>
</tr>
<tr>
<td>2.2</td>
<td>eLearning</td>
<td>14</td>
</tr>
<tr>
<td>2.2.1</td>
<td>eLearning systems</td>
<td>15</td>
</tr>
<tr>
<td>2.2.2</td>
<td>Sustainable eLearning</td>
<td>16</td>
</tr>
<tr>
<td>2.2.3</td>
<td>Sustainable eLearning systems</td>
<td>16</td>
</tr>
<tr>
<td>2.3</td>
<td>Cultural dimensions theory</td>
<td>18</td>
</tr>
<tr>
<td>2.4</td>
<td>Quantitative approaches for software sustainability profiling data analysis</td>
<td>20</td>
</tr>
<tr>
<td>2.4.1</td>
<td>Data collection</td>
<td>20</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Data analysis</td>
<td>22</td>
</tr>
<tr>
<td>2.5</td>
<td>Summary</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>Systematic Literature Review on Sustainability Requirements for eLearning Systems</td>
<td>29</td>
</tr>
<tr>
<td>3.1</td>
<td>Review methodology</td>
<td>30</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Review questions</td>
<td>30</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Systematic literature review</td>
<td>31</td>
</tr>
</tbody>
</table>
6 Evaluation of SuSoftPro Framework

6.1 Comparison with other frameworks
   6.1.1 Procedure
   6.1.2 Analysis
   6.1.3 Results

6.2 Case studies
   6.2.1 eLearning systems
   6.2.2 Skin cancer information system

6.3 Evaluation Questionnaire
   6.3.1 Procedure
   6.3.2 Results

6.4 Discussion

6.5 Summary

7 Conclusions

Bibliography

A List of Studies for Systematic Literature Review

B Ethics approval and survey documents

C Sustainable Software Profile for Case Studies
   C.1 Canvas sustainability profile
   C.2 Desire2Learn sustainability profile
   C.3 SCIS sustainability profile
   C.4 Screen shot of SuSoftPro tool-support
List of Figures

1.1 Research methodology overview .................................................. 7
2.1 Research field ................................................................................. 17
2.2 An extract of a specification of non-functional requirements on eLearning systems ............................................................... 18
2.3 Comparison of Australia and Saudi Arabia using Hofstede’s cultural dimensions ................................................................. 19
2.4 Fuzzy rating scale for sustainability profiling .................................. 23
3.1 Review process and outcomes ........................................................... 32
3.2 Distribution of the number of studies over the years (2005–2017) ................................................................. 34
3.3 The classifications of studies in percentage ...................................... 36
3.4 Dimensions of sustainable eLearning systems (2005–2017) ............. 37
4.1 Design for data collection and analysis .......................................... 50
4.2 Coding process for extracting values from responses ......................... 53
4.3 Overall participant demographics .................................................... 55
4.4 Used functionalities: learners’ and instructors’ responses .................. 56
4.5 Requested functionalities: learners’ and instructors’ responses ............ 57
4.6 Deficient functionalities: learners’ and instructors’ responses ............. 57
4.7 Required data retention time from learners’ and instructors’ perspectives ................................................................. 60
4.8 Gender percentage of participants from Australia and Saudi Arabia .... 65
4.9 Functionality usage: comparison by gender and country ..................... 67
4.10 Functionalities requested: comparison by gender and country .......... 68
4.11 Comparison of deficient functionalities between female and male responses ................................................................. 68
5.1 SuSoftPro: process model ................................................................. 72
5.2 The developed fuzzy rating scale in SuSoftPro .................................. 76
5.3 Sustainability profile of a software system using the default colour schema ................................................................. 77
5.4 Simulation of different colour deficiencies ....................................... 78
5.5 Sustainability profiling as a part of Requirements Engineering (RE) activities ................................................................. 81
6.1 Overview of evaluation approaches ................................................. 86
6.2 SuSoftPro: rating of one Canvas requirement’s effect on social sustainability ................................................................. 92
6.3 Generated result for Canvas sustainability profile .............................. 93
6.4 The result of sustainability for each requirement in Canvas systems .... 94
6.6 Generated result for D2L sustainability profile .................................. 95
6.5 The result of sustainability for each requirement in D2L systems ......... 95
# List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Comparison of rating scale classifications</td>
<td>21</td>
</tr>
<tr>
<td>3.1</td>
<td>Primary sources</td>
<td>31</td>
</tr>
<tr>
<td>3.2</td>
<td>Primary sources and number of papers</td>
<td>32</td>
</tr>
<tr>
<td>3.3</td>
<td>Sustainability meta-requirements for eLearning systems</td>
<td>35</td>
</tr>
<tr>
<td>3.4</td>
<td>Sustainability meta-requirements with software product quality identified</td>
<td>44</td>
</tr>
<tr>
<td>3.5</td>
<td>Journal rank used in the systematic literature review</td>
<td>47</td>
</tr>
<tr>
<td>4.1</td>
<td>Example of coding phases showing annotation against responses</td>
<td>54</td>
</tr>
<tr>
<td>4.2</td>
<td>Number of participants for each role in each eLearning system</td>
<td>54</td>
</tr>
<tr>
<td>4.3</td>
<td>Functionality categories</td>
<td>55</td>
</tr>
<tr>
<td>4.4</td>
<td>Descriptive statistics: learners’ and instructors’ responses</td>
<td>59</td>
</tr>
<tr>
<td>4.5</td>
<td>ANOVA testing result</td>
<td>59</td>
</tr>
<tr>
<td>4.6</td>
<td>IT support personnel and administrators’ responses</td>
<td>60</td>
</tr>
<tr>
<td>4.7</td>
<td>Participants: statistics by gender and country</td>
<td>65</td>
</tr>
<tr>
<td>4.8</td>
<td>Descriptive statistics: gender and country</td>
<td>66</td>
</tr>
<tr>
<td>4.9</td>
<td>ANOVA testing result</td>
<td>66</td>
</tr>
<tr>
<td>5.1</td>
<td>Key chart in software sustainability profiling</td>
<td>77</td>
</tr>
<tr>
<td>5.2</td>
<td>Comparing initial proposed colour scheme with three types of colour vision deficiencies</td>
<td>78</td>
</tr>
<tr>
<td>5.3</td>
<td>Comparing alternative colour scheme with three types of colour vision deficiencies</td>
<td>78</td>
</tr>
<tr>
<td>6.1</td>
<td>Comparisons of employing multi-criteria decision analysis in requirements engineering</td>
<td>88</td>
</tr>
<tr>
<td>6.2</td>
<td>Assigned sustainability dimensions to stakeholder groups</td>
<td>90</td>
</tr>
<tr>
<td>6.3</td>
<td>Generated questions (instructions) to rate requirements in the case studies</td>
<td>91</td>
</tr>
<tr>
<td>6.4</td>
<td>Number of stakeholders for each role in each eLearning system</td>
<td>91</td>
</tr>
<tr>
<td>6.5</td>
<td>Number of questions for each role in the questionnaire</td>
<td>92</td>
</tr>
<tr>
<td>6.6</td>
<td>The results of Canvas requirements</td>
<td>93</td>
</tr>
<tr>
<td>6.7</td>
<td>The results of D2L requirements</td>
<td>94</td>
</tr>
<tr>
<td>6.8</td>
<td>Assigned sustainability dimensions to stakeholder groups</td>
<td>96</td>
</tr>
<tr>
<td>6.9</td>
<td>The results of SCIS requirements</td>
<td>99</td>
</tr>
<tr>
<td>6.10</td>
<td>Descriptive statistics results of the six statements</td>
<td>101</td>
</tr>
<tr>
<td>6.11</td>
<td>ANOVA testing result of the six statements</td>
<td>101</td>
</tr>
<tr>
<td>A.1</td>
<td>List of studies for sustainable eLearning systems</td>
<td>131</td>
</tr>
<tr>
<td>C.1</td>
<td>The results of Canvas requirements</td>
<td>171</td>
</tr>
</tbody>
</table>
C.2 The results of D2L requirements . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 181
C.3 The results of SCIS requirements . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 190
Abstract

Sustainability in software engineering is about (1) continued functionality and maintainability in changing circumstances, and (2) functionality’s effect on the surrounded environment, economic and people. Frequent changes of software requirements negatively affect sustainability of software systems. To reduce the number of requirements’ changes and improve sustainability, sustainability requirements have to be considered from the beginning of the requirements engineering stage of software development. Sustainability in requirements engineering has five dimensions including individual, social, technical, economic and environmental dimensions. Most of the existing work analysed only one or two dimensions and ignore the interrelated effects among other dimensions. To address this issue, we selected eLearning systems because they provide comprehensive example to study. This thesis focuses on analysing sustainability requirements of eLearning systems with regard to the five sustainability dimensions. The following studies were performed: (1) identifying theoretically the sustainability requirements of eLearning systems, (2) investigating empirically the sustainability of eLearning systems, (3) constructing a methodology for the analysis and evaluation of sustainability requirements on eLearning systems, and (4) evaluating the constructed methodology.

To the best of our knowledge, this is the first research conducted to investigate sustainability requirements of eLearning systems covering the five sustainability dimensions. Our findings highlighted that (1) technical, economic and environmental sustainability requirements are similar to other software domains, where individual and social sustainability requirements are specific for the domain of eLearning systems, (2) individual and social sustainability requirements need to be carefully considered and analysed together because of the strong correlation, and (3) culture and gender diversity play an important role for sustainability requirements. On this basis, we developed a framework for analysing sustainability requirements of software systems as well as a web-based tool SuSoftPro (the name stands from Software Sustainability Profiling) that allows requirements engineers to: investigate sustainability of software systems based on the systems’ requirements, analyse the sustainability dimensions of software systems, measure the sustainability of each individual requirement, visualise analysis results to support decision making towards high-quality software, involve stakeholders to rate their requirements for one or more of the five sustainability dimensions, and
manage requirement and stakeholder details easily. We evaluated the SuSoftPro framework through case studies, comparative evaluation and a quantitative questionnaire. Our framework successfully provides a comprehensive view of analysing sustainability requirements to improve the attention to sustainability and allow practitioners to develop sustainable software.
Chapter 1

Introduction

“Since most corporate competitors have the same problems with sustainability and social reputation, it’s worth trying to solve them together.”

– Simon Mainwaring, 2011

Sustainability is the capacity to endure (Becker et al. 2016). Addressing the sustainability of software systems is one of the important quality concern in addition to concern regarding usability, safety and security, as per (Penzenstadler et al. 2014b). Numerous studies have demonstrated that if a software system is developed without taking sustainability requirements into account, the system could have negative effects on individual, social, technology, economic and environmental sustainability, cf. (Berkhout and Hertin 2001, Lago and Jansen 2011, Naumann et al. 2011, Penzenstadler and Femmer 2013).

A system is sustainable when it will continue fully to exist and function, even as circumstances change (Becker et al. 2016). Hence, the sustainable systems must satisfy the sustainability requirements that cover the related sustainability dimensions identified in (Becker et al. 2016, Goodland 2002, Penzenstadler and Femmer 2013, Razavian et al. 2014):

- **Individual sustainability**: Individual needs should be protected and supported with dignity and in a way that developments should improve the quality of human life and not threaten human beings;

Copyright/credit/reuse notice:

This chapter content is based on materials that have been previously published as:

• **Social sustainability**: Relationships of people within society should be equitable, diverse, connected and democratic;

• **Technical sustainability**: Technology must cope with changes and evolution in a fair manner, respecting natural resources;

• **Environmental sustainability**: Natural resources have to be protected from human needs and wastes; and

• **Economic sustainability**: A positive economic value and capital should be ensured and preserved.

The sustainability comprehensively explained by Calero and Piattini (2017), Lago et al. (2015), Penzenstadler (2014) as two concepts:

1. The concept of ‘green in’ software systems, which means reducing energy and resources consumption and wastage in processes, and

2. The context of ‘green by’ software systems, which improve human and economic sustainability.

One aspect of sustainability cannot be reinforced without considering others.

The analysis of system sustainability has to be initiated at the Requirements Engineering (RE) phase, that is, requirements elicitation, evaluation, specification, and design producing the functional requirements and Non-Functional Requirements (NFRs) because it will significantly affect how to develop software systems and how to perform RE (Koçak et al. 2013, Penzenstadler 2014). Following this idea, Becker et al. (2016) emphasised that the importance of identifying stakeholders whose external and responsible for sustainability are affected and the use of long-life scenario techniques during requirements elicitation could forecast potential effects. Duffy (2014) highlighted that sustainability could be achieved especially in the social dimension through ensuring usability, which is a NFR, and its traditional methodologies. This question is especially important for long-living systems, where the stakeholders’ requirements and preferences might change over the time the system is in use. For example, a system considered sustainable currently might be rated environmentally unsustainable in a few years, when new techniques to increase environmental sustainability are developed.

We define sustainability requirements of software systems through this thesis as ‘requirements being quantified their impact and capacity to endure in the five dimensions of sustainability through the lifecycle of software’. For example, the impact and capacity of a certain software requirement are measured and specified in the individual, social, technical, economic and environmental sustainability dimensions to sustain the software.

Sustainability requirements are crucial for eLearning systems, since these deal not only with a large amount of teaching data, but also with a large number of users. eLearning systems are a special type of software system, developed to provide a platform for accessible teaching and learning, including online access to learning materials and online support for learning and teaching.
eLearning systems are commonly composed of modules containing video conferences, discussion boards, assignments and assessment management, grade books and weekly content units, or views different organisational structures. These systems have become a very important part of the learning and teaching process, owing to their flexibility and accessibility for instructors and learners: The eLearning system may assist in delivering knowledge and information any time and everywhere to anyone (Casquero et al. 2010). When developing an eLearning system, a large number of requirements need to be collected from, and negotiated with, various stakeholders, as well as a large number of diverse technical, cultural and/or legal requirements.

Our research focuses on RE aspects for sustainable eLearning systems. To address the limitations of existing research on sustainable eLearning systems, this research aims to develop a methodology for the analysis and evaluation of sustainable eLearning requirements. To fulfil these aims, a Systematic Literature Review (SLR) is conducted to identify open problems and to present the state of the art. In addition, a mixed-method strategy is applied to explore and determine sustainability requirements. Three cases studies, that is, on two eLearning systems and one eHealth system are conducted to evaluate and generalise our methodology and the corresponding tool-support. Further, an online questionnaire and a comparison evaluations are conducted to examine the usefulness and capabilities of our framework. The following sections discuss the research motivation, research questions, methodology, and thesis outline.

1.1 Motivation

eLearning systems have become an essential part of teaching, both as web-based systems for on-line education and as auxiliary tools for face-to-face study, providing additional learning support for on-campus learners. eLearning is also a domain where the social transformation potential of software could be productive because of the relationship between instructor and learner as well as the cooperation between learners. eLearning not only provides learning materials, but also contributes to social communication aspects (Mocigemba 2006). To ensure the sustainability of eLearning systems on individual as well as social levels, we address many dimensions of sustainability requirements: individual, social, technical, economic, and environmental.

An eLearning system should satisfy the needs of the key stakeholders, such as administrators, learners and instructors (Borchers 2003), and also address the following issues:

- Large number of requirements that need to be gathered and negotiated by various stakeholders; and
- Stakeholders’ diverse backgrounds, which could affect their particular requirements.

Quality requirements, such as sustainability, availability, performance, portability, reliability, safety and security, can also depend on the background-related requirements.

The aims of our research are to:
CHAPTER 1: INTRODUCTION

• Identify the sustainability requirements for eLearning systems,
• Develop a methodology for the analysis and evaluation of sustainability requirements for not only sustainable eLearning systems but also long-living software systems, and
• Develop and evaluate a tool-support for the produced methodology.

1.2 Research questions

To address the limitations of existing research, we propose a methodology to address the five dimensions of sustainability (individual, social, technology, economic and environmental dimension), and to take into account diversity aspects through involving stakeholders to analyse and evaluate sustainable eLearning requirements. Our overall research objective is to investigate the RE process for sustainable eLearning systems. This work aims to answer the following research questions:

RQ1 What are the sustainability aspects of an eLearning System?

Sustainability requirements differ from one domain to another, particularly human (individual and social) sustainability requirements. For instance, requirement of individual sustainability regarding the reuse of the learning content resources is a specific requirement in the educational software domain (Ossiannilsson and Landgren 2012) while controlling energy consumption is an environmental requirement in eLearning and other domains, such as the health domain. If the sustainability requirements of eLearning systems are not taken into account, it will adversely affect on individuals and the environment.

RQ2 How can we systematically address and model the sustainability dimensions as well as sustainability requirements as part of a requirements engineering process while developing or extending an eLearning system?

Owing to the complexity of the vast number of sustainability requirements that have to be determined, developed and evaluated, various aspects need to be addressed and included. As a consequence, without a methodology for modelling sustainability as a part of the RE process, complexity could increase during the development or extension of an eLearning system.

Security, performance, and sustainability as NFRs need to be evaluated to ensure the sustainability of eLearning systems and to meet present and future stakeholder needs. Sustainability requirements with the corresponding sustainability assessment (e.g., criteria-based assessment), indicators and metrics could be evaluated and measured.

With the growth of borderless higher education, that is, universities between nations, geopolitics and business requirements affect the development of eLearning systems. Privacy and cultural are cases in point. As the number of national, regional and international universities grows, domain requirements might be similar but not identical. Therefore, the challenge is to address diversity to ensure the sustainable development of eLearning systems.

(October 31, 2019)
SECTION 1.3: OVERVIEW OF RESEARCH METHODOLOGY

RQ3 Which features of sustainable requirements engineering do we need to embed into the framework to improve the requirements engineering process for an eLearning system?

A significant number of tools are used to facilitate consistency and efficiency of eliciting, analysing and managing requirements. With regard to tool capabilities, they need to be reviewed and improved to deal with sustainability requirements.

1.3 Overview of research methodology

To answer the proposed research questions, we structure our work in the following phases, as shown in Figure 1.1:

- **Phase 0: Feasibility Study**
  - **Outcome:** Research Proposal
  - **Chapter:** 1 & 2

- **Phase 1: Theoretical Study**
  - **Outcome:** Systematic Literature Reviews
  - **Chapter:** 3

- **Phase 2: Empirical Study**
  - **Outcome:** Sustainability of eLearning Systems
  - **Chapter:** 4

- **Phase 3: Framework Construction and Application**
  - **Outcome:** Framework and tool for Software Sustainability Profiling (SuSoftPro)
  - **Chapter:** 5

- **Phase 4: Evaluation**
  - **Outcome:** Evaluation of SuSoftPro
  - **Chapter:** 6

Figure 1.1: Research methodology overview

**Literature reviews** We performed this phase to acquire knowledge about the topic during this research. Narratives or traditional literature reviews during this research project were conducted to understand the state-of-art and to analyse the existing practical and theoretical approaches on RE, especially focusing on sustainability dimensions and on sustainable eLearning systems. For example, we conducted a literature review to understand the best practice of performing the SLR. The SLR is a type of method to identify, analyse and interpret all available evidence related to our topic. Further, we complemented the SLR methodology with snowballing to overcome the disadvantages of the SLR as suggested in the literature. Another example, we examined Multi-Criteria Decision Analysis (MCDA) approaches to select the appropriate one and then employe it in our framework.

**Phase 0:** A feasibility study was conducted in an earlier stage to design and confirm our research. The feasibility study was based on the initial literature reviews to determine the viability of our research. **Outcome:** We provided a research proposal to help us in defining the research problem and its significance as well as in highlighting its novelty. Then, we
formulated research questions and designed our methodology to answer the questions, see Chapters 1 and 2.

Phase 1: We conducted a theoretical study to provide comprehensive understanding using systematic literature review for identifying, selecting, and critically appraising of relevant research. We applied an approach recommended in evidence-based Software Engineering (SE), see (Kitchenham et al. 2004) and (Keele 2007). **Outcome**: We provided systematic literature review on sustainability requirements and sustainable architecture for eLearning system, see Chapter 3.

Phase 2: An empirical study was conducted to explore the quality in use, user needs and deficient functionalities of eLearning systems. **Outcome**: We developed a questionnaire on eLearning requirements (focusing on sustainability and diversity aspects) to obtain feedback from learners, instructors, administrators and IT support personnel. Thus, a sequential exploratory strategy, which is a mixed-method qualitative and quantitative approach, was considered suitable for meeting the objectives of our research. In the strategy, the data collection instrument was an open-ended, multiple choice questions. Then, the results were analysed in two phases, with the qualitative method (using coding method) followed by the quantitative method (using statistical analysis) to assist the interpretation of the qualitative findings, see Chapter 4.

Phase 3: The outcome of the two previous phases (the literature review and the questionnaire) assisted us in developing a framework and tool-support. The developed framework is for the analysis and evaluation of sustainability requirements in eLearning systems and other long-living software systems, which covers sustainability dimensions. **Outcome**: We developed a framework and tool-support to analyse sustainability requirements of software systems, see Chapter 5. The constructed framework is based on a questionnaire for collecting data, MCDA for data analysis, and profiling for reporting sustainability.

Phase 4: In the final phase, we aimed to explore and apply the produced framework based on the acquired knowledge during this research. Thus, we evaluated and improved the developed framework. **Outcome**: The evaluation was on the basis of the produced framework and its evaluation of the existing eLearning systems, that is, Canvas and Desire2Learn (D2L) as well as an eHealth system, to justify the use of framework in another domain, see Section 6.2. Significantly, we planned to analyse Blackboard (Bb) in RMIT University and D2L in Umm Al-Qura University (UQU) during the evaluation phase. However, in mid-2017, RMIT University commenced replacement of its eLearning system, Bb, which is a proprietary system, with a new system, Canvas, which is an open-source system, in a parallel approach of running both systems to minimise the risks associated with replacement. Thus, we conducted a study about Bb and D2L during phase 2, but in this phase (Phase 4) we used Canvas and D2L because of the university system replacement. Further, we compared
our framework with two frameworks in RE to understand the capability and usefulness of
the produced framework. Another evaluation approach was designed to capture the views
of academics and professional practice experts in sustainability requirements was through
our quantitative questionnaire. The data was collected via an online questionnaire. Then,
the questionnaire was statistically analysed, providing information such as the usefulness
and capability of the framework and tool-support, and the potential of adapting these, see
Chapter 6.

Ethics Application

This research is approved and classified as negligible or low risk by the Science Engineering
and Health College Human Ethics Advisory Network (CHEAN) under ethics approval number
ASEHAPP 72-15 which is valid from 30 March 2016 to 30 March 2019 (see Appendix B). Based on
the rules set down by CHEAN, all data should be stored on the RMIT University network system.
The information technology department in RMIT University have located a secure data storage
facility in the system for this research.

1.4 Thesis outline

The following chapters of the thesis are organised as follows. Chapter 2 introduces the background
of sustainability in SE, eLearning, and quantitative approaches. In Chapter 3, an SLR and analysis
on sustainability requirements for eLearning systems is demonstrated with its methodology, analysis,
results and discussions. User’s perspective of eLearning systems is explored in Chapter 4. Chapter 5
presents our framework for software sustainability profiling (SuSoftPro) to analyse sustainability
requirements. Evaluation of the SuSoftPro framework is carried out in Chapter 6, which present
comparison evaluations and the quantitative questionnaire. Finally, Chapter 7 summarises this
thesis, and its main contributions.
“Sustainable development is the pathway to the future we want for all. It offers a framework to generate economic growth, achieve social justice, exercise environmental stewardship and strengthen governance.”

–Ban Ki-moon, 2013

The context of this research is Requirements Engineering (RE) aspects for sustainable eLearning systems. This chapter introduces an overview of topics that provide the background for this thesis by examining the definitions of sustainability in Software Engineering (SE), and in RE in particular, and in sustainable eLearning systems. These topics provide a standpoint as a core concept of our work that covers the three overlapping pillars of education, software engineering and sustainability. Recognising the three pillars assists in comprehending the analysis on sustainability requirements of eLearning system. In addition, we explain a quantitative approach for analysing sustainability requirements using rating scales for data collection and Multi-Criteria Decision Analysis (MCDA) as an analysis method. These quantitative approaches are adopted for developing our framework that will be discussed later in Chapter 5. We also discuss the theory of cultural
dimensions to understand the social influences towards sustainability, because it can be seen as a social activity.

2.1 Sustainability in software engineering

Sustainable software was defined by Naumann et al. (2011) as ‘software, whose direct and indirect negative impacts on economy, society, human beings, and environment that result from development, deployment, and usage of the software are minimal and/or which has a positive effect on sustainable development’. Following this definition, Naumann et al. characterised sustainable SE for developing sustainable software as ‘the art of developing green and sustainable software with a green and sustainable software engineering process’.

To fulfil the defined sustainable SE process, Lami et al. (2012) defined a sustainable software process as one that ‘meets its (realistic) sustainability objectives, expressed in terms of direct and indirect impacts on economy, society, human beings, and environment that result from its definition and deployment’. For identifying these outlooks, Penzenstadler et al. (2012) presented a Systematic Literature Review (SLR) on sustainability in SE, with the aim of providing an overview of different aspects of sustainability in SE-related research with regard to aspects such as topics investigated, limitations identified, methods used and available studies. Berkhout and Hertin (2001) proposed to distinguish between three orders of the effects of information and communication technologies on environmental sustainability:

- first-order effects, producing direct environmental effects,
- second-order effects, producing indirect environmental effects, and
- third-order effects, producing rebound effects.

Hilty et al. (2006) conducted the corresponding simulation study and demonstrated a model to assess the three potential positive or negative effects of information and communication technologies on environmental sustainability.

2.1.1 Requirements engineering for sustainable systems

RE, which is one of the key disciplines in SE, was defined as ‘the subset of systems engineering concerned with discovering, developing, tracing, analysing, qualifying, communicating and managing requirements that define the system at successive levels of abstraction’ (Hull et al. 2010).

RE activities comprise elicitation, analysis, specification, validation, and management. Nuseibeh and Easterbrook (2000), Sawyer et al. (1997), Sommerville (2010), Thayer and Dorfman (2000) defined these activities as the flows:

- Requirements elicitation is the practice of understanding and determining stakeholders’ needs and constraints.
- Requirements analysis is the practice of refining stakeholders’ needs and constraints by defining the process, data and object of the required system.
• **Requirements specification** is the practice of writing down stakeholders’ needs and constraints, and this documentation should be unambiguous, complete, correct, understandable, consistent, concise, and feasible.

• **Requirements validation** is the practice of checking that the specification captures users’ needs and constraints.

• **Requirements management** is the practice of scheduling, controlling changes and tracking requirements over time.

The effect of software systems on social and economic activities is increasing each year, which makes the analysis of sustainability requirements of these software systems more and more important. Becker et al. (2016) highlighted that software systems are a major driver of social and economic activity, which demands a paradigm shift in the SE mindset to consider sustainability. The key point for this is in RE activities, which should consider sustainability design principles.

Penzenstadler (2015) defined RE for sustainability as follows: ‘It denotes the concept of using requirements engineering and sustainable development techniques to improve the environmental, social and economic sustainability of software systems and their direct and indirect effects on the surrounding business and operational context.’ We defined sustainable system in Chapter 1 as a system satisfying the sustainability requirements that cover individual, social, technical, economic and environmental sustainability dimensions.

Several RE tools with general or specific features are used for eliciting, analysing, modelling, tracing, documenting, managing, verifying and validating requirements (De Gea et al. 2012). Some of these tools, such as Cradle and Rational DOORS, are being used to facilitate web-based solutions to allow collaborative access to resources, while others, particularly the widely used tools are becoming more complex and difficult to use (Yos and Chua 2018). However, none of these has the ability to analyse sustainability requirements by involving stakeholders with regard to the sustainability dimensions.

### 2.1.2 Sociocultural aspects of sustainability

In this section, we discuss the related work on sociocultural aspects of sustainability in SE as well as on cultural aspects within RE. Willis et al. (2009) analysed how education systems can help create social sustainability. The authors defined social sustainability as ‘a positive and long-term condition within communities and a process within communities that can achieve and maintain that condition,’ highlighting that this concept focuses attention on the mid-to-long-term future. Al Hinai and Chitchyan (2014) conducted a systematic literature review on social sustainability, and identified over 600 indicators of social sustainability, which they aggregated into 12 groups: employment, health, education, security, services and facilities, equality, human rights, social networks, social acceptance, resilience, cultural and political. Al Hinai (2014) also introduced a number of metrics and an accompanying method for analysing social sustainability requirements of software systems. The method is not systematic and it is not easy to elicit the values because of
the varieties for translating value, and the potential of conflicting value types. From this scenario emerges the need for a framework to analyse systematically the social sustainability requirements, which we will discuss in Chapter 5.

Gibson et al. (2017) analysed the perception of sustainable SE among UK students enrolled in computing degree programs and among junior software developers in industry. The authors conducted an interview study with respect to sustainability, sustainability requirements, and the relationship of these concepts to SE principles and practices. Their study found that while the study participants do not consider sustainability a primary focus, they highly valued the concept of sustainability. Thus, we recruited in our research not only students but also academics and practitioners to provide their perceptions on sustainable software. We will address this matter in Chapters 4 and 5.

2.1.3 Sustainability profiling

Sustainability profiling has been used mostly for software energy and data centre consumption, as well as in cities and urban settlements. James (2014) highlighted that a holistic and integrated understanding of urban life is essential. He presented an urban profile framework for sustainability of cities including four main domains, ecology, economics, politics and culture as well as, seven sub-domains for each main domain. Stewart and Khare (2015) also applied the framework to the sustainability of eLearning. This framework involves providing rating on a nine-point scale that is imprecise, and it has to be extended to fit the software development process and to cover the corresponding sustainability dimensions. The framework inspired us to develop a systematic framework for analysing sustainability requirements for software systems, and for providing software sustainability profiling.

Gmach et al. (2010) proposed a profiling approach for ensuring the sustainability of data centres by quantifying energy use during their design and operation. Similarly, Jagroep et al. (2016) demonstrated a software energy profiling method to analyse software changes in energy consumption between releases of a software product. Although both studies focused on energy consumption that could affect environmental and economic dimensions of sustainability, they ignored individual and social dimensions in the measurement. Our approach covers the five dimensions of sustainability to quantify the sustainability of any software system, starting from the requirements phase and continuing over the phase of maintenance.

2.2 eLearning

Researchers have defined eLearning as a means of providing and delivering education. One recent definition of eLearning is ‘an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication and interaction and that facilitates the adoption of new ways of understanding and developing learning’ (Sangrà et al. 2012).
Many researchers have proposed critical success factors for eLearning and all agree that the three main dimensions of eLearning and distance education are the following:

- Learners,
- Instructors, and
- eLearning technologies.

For example, Selim (2007) investigated these three main dimensions along with university support. He proposed 13 factors in eLearning technology that are related to the quality of the eLearning systems. Menchaca and Bekele (2008) introduced a conceptual framework with five dimensions of success factors including eLearning technology dimension. In the eLearning technology dimension they identified asynchronous and synchronous features as well as availability and usability of the eLearning system. Alhabeeb et al. (2017) explored learner characteristics, instructor characteristics, support, instructional design and learning systems that influence the implementation and acceptance of eLearning systems in Saudi Arabia. Thus, although most researchers have addressed critical success factors of eLearning systems, their findings differ with respect to the quality of eLearning systems. For instance, reliability and usability were identified by Selim (2007) while Alhabeeb et al. (2017) investigated the acceptability of eLearning systems. Thus, all of the qualities of eLearning systems are yet to be covered and measured within the eLearning system dimension. The following subsections discuss eLearning systems, sustainable eLearning, and sustainable eLearning systems, that are the main focus of this research.

### 2.2.1 eLearning systems

An eLearning system can be defined as an educational solution to deliver knowledge, facilitate learning and improve performance by creating, using and managing appropriate technological processes and resources, cf. (Ghirardini 2011, Richey 2008). eLearning systems, such as Blackboard (Bb) and Canvas, provide innovative services for learners, instructors, and institutions in the learning process. Instructors can create modules to organise course content by weeks or units. A course’s content can have discussions, assignments, quizzes and learning materials, so that learners will engage in the learning process either on campus or off it.

Mridha et al. (2013) stated that in developing countries such as Bangladesh, particularly in rural areas, eLearning systems allow educational equity for people who cannot afford to pay for private tutors. Likewise, Stepanyan et al. (2013) provided examples of how technological affordances might assist with new approaches for learners to learn. One popular example of an eLearning system is a Learning Management System (LMS) that includes a discussion board, virtual classroom, collaboration features and instructor- and learner-led courses. As per Dagger et al. (2007), there are two LMS types from the development perspective:

- Proprietary commercial LMS, e.g., Bb and Desire2Learn (D2L); and
- Open-source LMS, e.g., Moodle and Canvas.
2.2.2 Sustainable eLearning

Several researchers have discussed sustainability success factors for eLearning as a new quality domain. Sridharan et al. (2010) examined three main dimensions of critical factors: pedagogical strategies, supporting technologies and management technologies. The longevity of eLearning systems and the protection of natural resources were not included. Also, Gunn (2010) analysed multiple issues that are faced with respect to 65 sustaining eLearning initiatives. Thus, critical success in sustaining eLearning involves different stakeholder perspectives; a major problem in many cases is that nobody is considered to be responsible for sustaining eLearning. Thus, if there is an initiative to have sustainable eLearning, its success will depend on one or a few individuals who might be powerful leaders to introduce strategic initiatives. This factor was recognised by Mahaux (2013), who argued that participation could support sustainability in software development; thus, the more that participants engage, the more sustainable are eLearning systems.

Robertson (2008) defined sustainable eLearning as ‘eLearning that has become normative in meeting the needs of the present and future’, and discussed a notion activity theory that has organisational, technical and pedagogical features of eLearning to achieve sustainability. However, the environmental sustainability dimension, such as energy consumption and its emission, was not included or explored. Littlejohn and Shum (2003) suggested that the reuse of course materials and the support of importing and exporting learning resources may sustain eLearning systems. In addition, Kanwar et al. (2010) considered that national governments and educational institutions in developed countries should support open education programmes in developing countries by sharing knowledge, proposing a transnational qualification, building capacity and developing a relevant policy on copyright. Although open education and reuse of resources could sustain educational resources, Kanwar et al. did not consider how to sustain eLearning systems from the technical and environmental sustainability perspectives.

2.2.3 Sustainable eLearning systems

To define a sustainable eLearning system, we have to specify and analyse the corresponding sustainability requirements. Many studies focus on the sustainability of eLearning systems, but they usually cover only a single aspect of sustainability. For example, many researchers have studied individual dimensions (Kanwar et al. 2010, Kruchten 2015), while other scientists have discussed the economic dimension (Downes 2007, Koohang and Harman 2007), and the social dimension (Littlejohn and Shum 2003). The environmental dimension of eLearning system sustainability was analysed by Dong et al. (2009) and Roy et al. (2008).

To provide a sustainability profile for an eLearning system, Stewart and Khare (2015) employed the Sustainability Circle Framework, developed by the Global Compact Cities Programme for the urban sustainability profile of a particular city or region (James 2014). This framework has four domains including, ecology, economy, culture and politics. Each domain has seven sub-domains to assist in assessment through the completion of a survey having seven questions for
The assessment is conducted on a nine-point scale that ranges from 1 being critical to 9 labelled vibrant. The framework is based on the colours of traffic-lights with critical marked red and vibrant marked green (James 2014). The authors proposed this method to generate a clear graphical representation of the sustainability profile for eLearning systems (Stewart and Khare 2015). Even though this adoption framework could rank the specific nuances in the economic dimension, it needs to be reformulated to fit eLearning development. For example, collaboration, which is part of the individual dimension, is not included. Moreover, the sustainability requirements may identify and follow sustainable SE to cover all the five dimensions and to be standardised with other software domains.

Sustainability is a very complex research area, and although there may be five aspects identified, they overlap and interact. Ideally, they should not be separated and have to be tackled together under one umbrella because of the overlapping aspects as well as to provide a ‘big picture’. For example, providing eLearning systems with sustainable eLearning processes and without reducing energy consumption could lead to increase in the electricity costs. This could encourage educational institutions to increase tuition fees for covering costs. Learners might be affected and the high cost will cause them to drop courses when they cannot afford. For these reasons, we cover all aspects of sustainability in eLearning, systems as illustrated in Figure 2.1, to include high-level sustainability requirements. To provide an example, Figure 2.2 presents a short extract of a specification of non-functional requirements on eLearning systems. This demonstrates the variety of the possible requirements and the corresponding dimensions. As illustrated, SUS-1 is related to environmental sustainability; SUS-2 belongs to technical sustainability dimension; SUS-3 is a human sustainability; SUS-4 is considered as social sustainability; and SUS-5 must be an economic sustainability where a user can calculate the costs of running and developing courses and their profits.
Each aspect of sustainability affects others and many studies tackle either one or two aspects of sustainability. The impact of eLearning systems on sustainability can be identified and recognised during RE activities (elicitation, analysis, specification and validation) where there is a commitment to treat sustainability as a first-class concern (Becker et al. 2016). For instance, during requirements elicitation, stakeholders could be involved in defining the long-term scenarios to predict the potential effects of sustainable eLearning systems.

<table>
<thead>
<tr>
<th>4. Nonfunctional Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3 Quality requirements specification</td>
</tr>
<tr>
<td>4.3.1 Sustainability</td>
</tr>
<tr>
<td>SUS-1  eLearning systems shall run on green data centre,</td>
</tr>
<tr>
<td>SUS-2  eLearning systems shall share learning content with other eLearning systems and social networks,</td>
</tr>
<tr>
<td>SUS-3  eLearning systems shall provide extension for Massive Open Online Courses (MOOCs) for anyone to enrol,</td>
</tr>
<tr>
<td>SUS-4  eLearning systems shall allow collaboration on a document to use real-time co-authoring, and</td>
</tr>
<tr>
<td>SUS-5  eLearning systems shall calculate the return on investment formula for curriculum development and implementation, and power consumption per business transaction.</td>
</tr>
</tbody>
</table>

Figure 2.2: An extract of a specification of non-functional requirements on eLearning systems

### 2.3 Cultural dimensions theory

Stakeholders usually have different cultural backgrounds that could affect sustainability negatively during the requirements process. They could have a concern about the sustainability of software but may not take part in raising this issue because of the power distribution in their culture. Hofstede et al. (2010) introduced the cultural dimensions theory based on a survey conducted on IBM employees in more than 70 countries. Based on this survey, he introduced the first four listed below; the other two were added years later following extensive additional research:

- **Power distance index**: concerns about inequalities of the distribution of power among society members;
- **Individualism versus collectivism**: the extent to which people are attached to the community, society, or family;
- **Masculinity versus femininity**: the extent to which the social gender roles are distinct (i.e., in a masculine society the gender roles are distinct, in contrast to a feminine society in which social gender roles overlap);
- **Uncertainty avoidance index**: the extent to which people feel tolerant or intolerant in unstructured situations and an unknown future;
- **Long-term versus short-term orientation**: the extent to which the society maintains and links the challenges of the present and the future with its own past; and
SECTION 2.3: CULTURAL DIMENSIONS THEORY

- **Indulgence versus restraint**: the extent to which society opts for gratification ranging from enjoyment to restriction.

Understanding the culture of various stakeholders could assist in understanding their needs and preferences, that is, to elicit the correct requirements. For instance, in countries such as Saudi Arabia, female opinions and needs might be ignored during requirements’ elicitation. To resolve this issue, engineers would need to determine which differences in software system requirements that are because of gender to fill the gap and to consider prosperity when including special functions or providing intensive resources and information. Thus, engineers should be educated about gender and cultural background of stakeholders as well as understanding software domains. We adopted Hofstede’s cultural theory when analysing participants’ responses to understand gender-based differences and cultural background.

Figure 2.3 presents the differences between Australia and Saudi Arabia as regards the six cultural dimensions according to (Hofstede et al. 2010). The power distance of Australia was lower than that of Saudi Arabia. This indicator in the educational context means that Australian instructors expect learners to take the initiative in the class, whereas in Saudi Arabia, instructors take the initiative. Australia had a higher individualism percentage than Saudi Arabia, which indicates that the latter was higher in collectivism than the former. This finding demonstrates that the goal of the Australian education process is to encourage learners to discover their own abilities. In contrast, Saudi education is more about passive learning where learners depend on the instructor. Saudi Arabia, with a score of 80, is a high uncertainty avoidance culture where instructors are supposed to have all the answers. In contrast, Australia instructors, in a low uncertainty avoidance culture may say ‘I do not know’.

Both Australia and Saudi Arabia had a 60% masculinity index value which determines they both had low femininity value. In education, this indicator means that men and women study

Figure 2.3: Comparison of Australia and Saudi Arabia using Hofstede’s cultural dimensions: Power Distance Index (PDI), Individualism versus collectivism (IDV), Masculinity versus femininity (MAS), Uncertainty Avoidance Index (UAI), Long-Term versus short-term Orientation (LTO), and Indulgence Versus Restraint (IVR)
different subjects. The societies in both Australia and Saudi Arabia had a long-term orientation. Although in education, learners associate their academic success with effort and work hard, the Australian culture was more indulgent while Saudi Arabia ranked midway between enjoyment and restriction. The education systems of these two countries are extremely different. In Australia, as in Europe and the United States, women and men attend the same campuses and classes, that is, women are not excluded from any learning activities and have access to exactly the same tutorials, labs presentations and resources. In contrast, Saudi Arabia has single-gender education, which means that women and men attend different campuses that are physically disconnected. All classes and learning activities (including eLearning) are separated, which implies the need to duplicate them.

2.4 Quantitative approaches for software sustainability profiling data analysis

In this section, we discuss quantitative approaches that will be employed in our framework in Chapter 5. Quantitative approaches are used to analyse data and to measure qualities in SE, such as goal-oriented requirements and user experience (Horkoff and Yu, 2011, Tullis and Albert, 2013). Creswell (2009) reported that the data collection in quantitative approaches measures attitudes and the main strategies of are:

- Surveys including closed-ended questionnaires and structured interviews, and
- Experiments having numerical data of observation and measurement.

Quantitative approaches can be applied to several types of data that can be analysed through statistical methods, and hence, the type of data might influence the choice of the approach. Tullis and Albert (2013) suggested distinguishing the following four types of data:

- **Nominal data** are categorised or classification data that are not in any particular order, such as gender or hair colour;
- **Ordinal data** are ordered classified data, but the differences between them are not meaningful, such as product and movie ratings;
- **Interval data** are classified data where the difference between two data items is meaningful, but without natural zero points, such as temperature units;
- **Ratio data** are interval data with absolute zero, such as weight and height.

The following sections present the quantitative data collection and analysis used in the present study.

2.4.1 Data collection

Scale-based questionnaires are used in SE to collect data for analysis and measurement purposes. For instance, goal-oriented requirements and user experience are analysed and measured via
quantitative approaches having a rating scale of probability between satisfaction and denial of satisfaction. The questionnaires, particularly online questionnaires, have potential advantages such as that these are accessible and save time and money (Wright 2005). Thus, the questionnaires are easy to distribute to a large number of stakeholders in software projects, assist in providing truthful responses when stakeholders’ responses are anonymous, and allow stakeholders to respond at their own pace.

The rating scale techniques for data collection vary from one quantitative approach to another. Some approaches use a five-level Likert scale while others employ a nine-point scale to present peoples’ attitudes by ranking their responses on a scale. Hjermstad et al. (2011), Lubiano et al. (2016) classified rating scales as:

- Linguistic (descriptive),
- Likert (numerical or point), and
- Fuzzy Rating Scale (FRS) (continuous rating scales).

Table 2.1 presents equivalent rates for each scale class, and the following sections provide an explain.

**Likert rating scale**

Likert (5-point) rating scales and the nine scales that give a several options are closed format and placed between two extreme poles. For example, if a questionnaire has a closed five-point Likert scale with two extreme poles as extremely satisfactory and extremely unsatisfactory, participants can only express their opinion through one of the five choices. These closed format options are imprecise, difficult to choose between and limited. A solution to overcome drawbacks of closed formatted scales is the FRS (de Sáa et al. 2015).

**Linguistic rating scale**

In a linguistic (descriptive) rating scale, each rating level has to be labelled in descriptive words. Then, each label is assigned numerical values; thus in general, it is similar to the Likert rating scale having closed format options; see Table 2.1.

<table>
<thead>
<tr>
<th>Likert</th>
<th>Linguistic</th>
<th>Fuzzy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Triangular</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>1</td>
<td>Critical (0,0,1)</td>
<td>(0,0,1,1.5)</td>
</tr>
<tr>
<td>2</td>
<td>Unsatisfactory</td>
<td>(1,2,3)</td>
</tr>
<tr>
<td>3</td>
<td>Basic (2,3,4)</td>
<td>(2,2.5,3,5,4)</td>
</tr>
<tr>
<td>4</td>
<td>Satisfactory</td>
<td>(3,4,5)</td>
</tr>
<tr>
<td>5</td>
<td>Green (Vibrant)</td>
<td>(4,5,5)</td>
</tr>
</tbody>
</table>

Table 2.1: Comparison of rating scale classifications
The fuzzy rating scale

The FRS, also called visual analogue or continuous rating scale, allows capturing the diversity and unambiguosness of individual responses in questionnaires, also avoiding imprecision while rating a questionnaire (de Sáa et al. 2015). The FRS provides a continuous rating scale with two extreme poles to a set number of values. There are two types of FRS, the triangular and trapezoidal scales. The triangular scale usually is encoded and balanced similar to the Likert or linguistic scales having semantic representations (Abbasbandy and Hajjari 2009, Lubiano et al. 2017). Although the triangular scale is a choice to overcome closed formatted scales, non-intuitive results of diversity and subjectivity are lost to some extent and this may reflect the imprecision in the standpoint of participants.

However, trapezoidal rating scales have more precision and freedom to capture variability, adjustment, diversity and subjectivity in the standpoint of participants (Lubiano et al. 2017). Table 2.1 presents comparison of these rating scales. To implement the FRS, we adopt the fuzzy trapezoidal rating scale method proposed by Lubiano et al. (2016):

**Step 1:** Considering a representative rating on the bounded interval;

**Step 2:** Determining a core response to be considered *fully compatible*;

**Step 3:** Determining a support response to be considered *compatible to some extent*; and

**Step 4:** Creating a trapezoidal fuzzy number from the two intervals, which are *linearly interpolated*, as \( \text{Tra}(a, b, c, d) \), where \( 0 \leq a \leq b \leq c \leq d \leq 1 \). Where \( b \) and \( c \) are the range of core responses, \( a \) and \( d \) are the extent to support responses.

For our sustainability profiling in Chapter 5, stakeholders are required to rate the corresponding sustainability dimensions. For example, as an alternative of stakeholders’ choice from a five-point classified rating scale, they can select their range and extend it between a range of two extreme poles. Thus, we can capture individual differences, variability, adjustment, diversity and subjectivity of stakeholder’s perspective.

Figure 2.4 presents an example on application of the above method within our framework (see, Chapter 5): The scale is from 0 to 100%, where 0 corresponds to the worst case (critical value), and 100 corresponds to the best case (green value). For simplicity, it is also possible to use a scale from 0 to 1, where 1 corresponds to 100%.

### 2.4.2 Data analysis

We employed MCDA to analyse qualitative data of the FRS because the sustainability complexity and human needs are multi-dimensional concepts. MCDA is an approach to evaluate multiple conflicting criteria in decision making for future directions, and it has been used for sustainability in different disciplines (Munda 2016). Velasquez and Hester (2013) conducted a literature review and
Figure 2.4: Fuzzy rating scale for sustainability profiling

analysis of common MCDA, and Antunes and Henriques (2016) discussed the most popular MCDA used in the energy sector. Both studies identified the following methods as the most common:

- Multi-Attribute Utility Theory (MAUT),
- Analytic Hierarchy Process (AHP),
- Case-Based Reasoning (CBR),
- Data Envelopment Analysis (DEA),
- Goal Programming (GP),
- Simple Multi-Attribute Rating Technique (SMART),
- ELimination Et Choix Traduisant la REalité (Elimination and Choice Expressing Reality; ELECTRE),
- Preference Ranking Organisation METHod for Enrichment Evaluation (PROMETHEE),
- Simple Additive Weighting (SAW), and
- Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).
Multi-attribute utility theory

MAUT is based on the attributes (criteria) of alternatives, and it is an ordinal additive value function (Dyer 2016). The alternatives can incorporate performance and present them in the context of certainty. The main problems with MAUT are that alternatives need stronger assumptions and substantial input to make precise alternatives as well as to allow MAUT to derive ordinal judgement (Dyer 2016, Velasquez and Hester 2013).

Analytic hierarchy process

AHP, including its more generalisation extension analytic network process, is a pair-wise comparison method and it is similar to MAUT. However, AHP has the characteristic of dependence assumptions and derives ratio judgement (Saaty 2016). Although the AHP is a structured dependence method and does not need intensive input, inconsistency in inherent assumptions is its main limitation (Saaty 2016, Velasquez and Hester 2013).

Case-based reasoning

The CBR approach provides a conclusion of decisions based on previous and most similar cases (Richter and Weber 2013). The CBR can be improved over time by adding more cases but if these cases are invalid, the results may be invalid because of uncertain and inconsistent data in the cases (Chen et al. 2008, Velasquez and Hester 2013).

Data envelopment analysis

DEA is a linear programming method to measure the efficiency of decision making alternatives. It requires a mix of MCDA to rate alternatives and then evaluates the efficiencies by comparing them (Cooper et al. 2004). In addition, DEA assists in uncovering relationships that remain hidden on using other methods but all input output data need to be precisely known (Velasquez and Hester 2013).

Goal programming

Similarly, GP requires a combination of MCDA to measure the weighted sums of deviations among alternatives against each other (Jones and Tamiz 2016). Although GP needs other MCDA to weight coefficients, it has the ability of producing infinite alternatives compared with other MCDA methods (Jones and Tamiz 2016).

Simple multi-attribute rating technique

SMART is the simplest form of MAUT. Rating alternatives against criteria in SMART or other weight assignment techniques produces the algebraic mean that becomes its ranking value (Velasquez and Hester 2013). SMART is simple and requires less effort compared with other MCDA.
However, the use of weight coefficients in this method is not convenient, and hence, SMART has to be combined with another MCDA to determine its coefficients (Konidari and Mavrakis 2007).

Elimination et choix traduisant la réalité (elimination and choice expressing reality)

ELECTRE family consists of methods using pair-wise comparisons to rank and sort alternatives under each criterion, based on a concordance index and non-discordance analysis (Figueira et al. 2016). ELECTRE having several improved methods, such as ELECTRE I, II, III, IV and TRI, is convenient only with a large number of alternatives and a few criteria (Velasquez and Hester 2013). In addition, ELECTRE methods ignore the difference level between alternatives (Wang et al. 2009).

Preference ranking organisation method for enrichment evaluation

The PROMETHEE family is similar to ELECTRE but the former does not ignore the difference level between alternatives (Velasquez and Hester 2013). PROMETHEE consists of information between the criteria as well as within each criterion (Brans and De Smet 2016). However, rank reversal may occur under some conditions (Brans and De Smet 2016, Verly and De Smet 2013).

Simple additive weighting

SAW is a method in which each alternative value is equal to additive weighting of the criterion weight and attribute data (Antunes and Henriques 2016). SAW is simple but its result might not be logical because one criterion value largely differs from that of other criteria (Verly and De Smet 2013).

Technique for order of preference by similarity to ideal solution

TOPSIS identifies the best alternative that is nearest to an ideal solution and farthest from a negative ideal solution (Mairiza et al. 2014). The principles of TOPSIS are simple and positive ideal solutions and negative ideal solutions are formed (Mateo 2012). The benefit criteria in the positive ideal solution are maximised and the cost criteria are minimised, while the cost criteria in the negative ideal solution are maximised and the benefit criteria are minimised (Behzadian et al. 2012). Although TOPSIS is based on the preference ratio, the uncertainty assumption and vagueness of human feelings affect solutions (Wang et al. 2009).

Considering the simplicity and flexibility of use as well as the fact that it identifies both the shortest distance from the positive ideal and farthest distance from negative ideal solution, TOPSIS should be considered an important solution to analyse the positive and negative impact of sustainability. Further, to overcome imprecision or the vagueness of human feeling, TOPSIS has to be combined with FRS (see, Section 2.4.1). To analyse sustainability requirements, we utilise the FRS to collect stakeholders ranking and then analyse them through TOPSIS; see Chapter 5. For these reasons, we provide here a more detailed description of this method.
TOPSIS procedure

The following is the stepwise procedure of TOPSIS according to Behzadian et al. (2012):

Step 1: Construct a normalised decision matrix $r_{ij}$

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad \text{for } i = 1, \ldots, m, \quad j = 1, \ldots, n$$ (2.1)

if $x_{ij}$ is an element of original decision matrix, $x$ is the value in the $i$-th row and $j$-th column, while $m$ and $n$ are the number of alternatives and criteria, respectively.

where $r_{ij}$ is a normalised value of $x_{ij}$ in the decision matrix

Step 2: Construct the weighted normalised decision matrix $v_{ij}$

$$v_{ij} = w_i r_{ij}$$ (2.2)

where $w_j$ is the weight for $j$ criterion.

Step 3: Determine the positive ideal ($A^*$) and the negative ideal solutions ($A'$):

Positive ideal solutions

$$A^* = \{ (\max(v_{ij} \mid i = 1, 2, \ldots, m) \mid j \in J_-), (\min(v_{ij} \mid i = 1, 2, \ldots, m) \mid j \in J_+) \} \equiv \{ v_{ij}^* \mid j = 1, 2, \ldots, n \},$$ (2.3)

Negative ideal solutions

$$A' = \{ (\min(v_{ij} \mid i = 1, 2, \ldots, m) \mid j \in J_-), (\max(v_{ij} \mid i = 1, 2, \ldots, m) \mid j \in J_+) \} \equiv \{ v_{ij}' \mid j = 1, 2, \ldots, n \},$$ (2.4)

where,

$J_+ = \{ j = 1, 2, \ldots, n \mid j \}$ $J_+ = \{ j = 1, 2, \ldots, n \mid j \}$ associated with the positive criteria, and

$J_- = \{ j = 1, 2, \ldots, n \mid j \}$ $J_- = \{ j = 1, 2, \ldots, n \mid j \}$ associated with the negative criteria.

Step 4: Calculate the separation measures:

The separation from positive ideal is

$$S^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}^*)^2}, \quad i = \{ 1, \ldots, m \}$$ (2.5)

Similarly, the separation from negative ideal is

$$S' = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{ij}')^2}, \quad i = \{ 1, \ldots, m \}$$ (2.6)
**Step 5:** Calculate the relative closeness to the ideal solution $C^*_i$

$$C^*_i = \frac{S'}{S^* + S'}, \quad 0 < C^*_i < 1, \quad i = \{1, \cdot \cdot \cdot, m\} \quad (2.7)$$

$C^*_i = 1$ if $A_i$ solution has the best condition,

$C^*_i = 0$ if $A_i$ solution has the worst condition.

### 2.5 Summary

In this chapter, we provided background information for our research. The research is focused on the context of sustainability in SE and RE in the domain of sustainable eLearning systems. We also introduced cultural dimensions theory since this means recognising the whole of stakeholders culture of those involved in analysing sustainability requirements. We provided a cultural overview of Saudi Arabia and Australia where we conducted our investigations in this research. Finally, we explained quantitative approaches within the three types of rating scales and the eleven most common approaches of MCDA and presented the reasons that we used them for our developed methodology that will be discuses later in Chapter 5.
Chapter 3

Systematic Literature Review on Sustainability Requirements for eLearning Systems

“We already have many of the technologies and tools that we need to build a sustainable future. What we don’t have is a new way of thinking, and that’s really the hardest part.”
—Alex Steffen, 2007

This chapter provides a Systematic Literature Review (SLR) on the research conducted on sustainability for eLearning systems to analyse the state of the art of this research area and to enable us to recognise open problems. We identified and categorised Sustainability Meta-Requirements (SMRs) which are high-level requirements, that is, a generalised class of goals. The SMRs need to be refined to produce functional requirements and Non-Functional Requirements (NFRs) for sustainable eLearning systems. These were mapped to a software quality model, which included

Copyright/credit/reuse notice:

This chapter content is based on materials that have been previously published as:


the greenability characteristic explained in Section 3.4. In addition, we analysed the reviewed papers by the type of study investigating the sustainability requirements for eLearning systems, and classified them into three types: empirical, theoretical and hybrid studies.

The rest of this chapter is organised as follows. Section 3.1 presents the methodology of the conducted SLR, and Sections 3.2 and 3.3 present the core findings. In Section 3.4, we discuss further suggestions on SMRs that were not covered in the literature, and propose a mapping from the identified SMRs to the Software Product Quality Model (ISO/IEC 25010). Finally, Section 3.5 discusses threats to the validity of the SLR, and Section 3.6 summarises the chapter.

3.1 Review methodology

In this section, we discuss the research questions and SLR methodology complemented by snowballing and Non-Systematic Review (NSR) for additional papers.

3.1.1 Review questions

The main aim of this work is to answer the following three sub-questions of the research question RQ1 in Chapter 1:

RQ1.1 What are the requirements for eLearning systems that cover sustainability aspects?

To answer this question, sustainability requirements are identified by forming a search string to include the following criteria:

- **sustainability**: including the three forms as sustainability, sustainable and sustain;
- **eLearning**: considering learning, e-learning, eLearning, electronic learning and distance education terms;
- **requirements engineering**: within singular or plural keywords of requirement; and
- **system identification**: the system may be an environmental system or ecosystem, or it may be Learning Management System (LMS).

RQ1.2 How can we classify sustainability requirements for eLearning systems from the software engineering perspective?

We analyse the sustainability requirements from a Software Engineering (SE) perspective. To answer RQ1.2, we need to consider the eLearning system as software and apply the same sustainability requirements to it.

RQ1.3 Which sustainability requirements are specific to eLearning systems?

Sustainability requirements differ from one domain to another, particularly human (individual and social) sustainability requirements. For instance, the lifelong learning requirement of individual sustainability is a specific requirement in the educational software domain (Ossiannilsson and Landgren 2012) while controlling energy consumption is an environmental requirement in eLearning and other domains, such as the health domain.
In the SLR, we included studies that were not considered previously and analysed the SMRs of eLearning systems. We believe that performing the SLR covering the five overlapping sustainability aspects with requirements of eLearning systems is important investigating previous results together under one umbrella. The impossibility of reducing all dimensions to a single dimension or tackling a single dimension without consideration of other dimensions is a critical issue in satisfying the goal of sustainability.

### 3.1.2 Systematic literature review

We followed the SLR methodology in (Kitchenham et al. 2004) and (Keele 2007). This approach consists of the following steps:

- **Planning the review**
  - Identification of the need for a review,
  - Development of a review protocol;

- **Conducting the review**
  - Identification of research,
  - Selection of primary studies,
  - Study quality assessment,
  - Data extraction,
  - Data synthesis;

- **Reporting the review.**

Figure 3.1 presents a visualisation of our methodology, including the review process and outcomes. In the first step, we selected the primary sources in Table 3.1 suggested by Brereton et al. (2007) to perform automated and manual searches.

<table>
<thead>
<tr>
<th>Automated search</th>
<th>Manual searches</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEEExplore Digital Library(^1)</td>
<td>Springer Link(^2)</td>
</tr>
<tr>
<td>ACM Digital Library(^3)</td>
<td>Wiley(^4)</td>
</tr>
<tr>
<td>Scopus(^5)</td>
<td>—</td>
</tr>
</tbody>
</table>

---

\(^1\) [http://ieeexplore.ieee.org](http://ieeexplore.ieee.org)
\(^2\) [http://springerlink.com](http://springerlink.com)
\(^3\) [http://dl.acm.org](http://dl.acm.org)
\(^4\) [http://onlinelibrary.wiley.com](http://onlinelibrary.wiley.com)
\(^5\) [http://scopus.com](http://scopus.com)
CHAPTER 3: SYSTEMATIC LITERATURE REVIEW

For the automated search, the following search string was used over the title, abstract and keywords fields of the papers in the digital libraries:

\[(\text{sustainability OR sustainable OR sustain}) \text{ AND (requirement OR requirements OR requirements engineering}) \text{ AND (learning OR e-learning OR eLearning OR (distance AND education) OR (electronic AND Learning))}) \text{ AND (system OR systems OR environment OR ecosystem)}\]

![Review process and outcomes figure]

Figure 3.1: Review process and outcomes

Table 3.2: Primary sources and number of papers

<table>
<thead>
<tr>
<th>Primary Sources</th>
<th>Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEEExplore</td>
<td>87</td>
</tr>
<tr>
<td>ACM</td>
<td>113</td>
</tr>
<tr>
<td>Scopus</td>
<td>459</td>
</tr>
<tr>
<td>Springer: Requirements Engineering Journal</td>
<td>26</td>
</tr>
<tr>
<td>Springer: Empirical Software Engineering</td>
<td>39</td>
</tr>
<tr>
<td>Springer: Education and Information Technologies</td>
<td>77</td>
</tr>
<tr>
<td>Wiley: Software Practice and Experience</td>
<td>29</td>
</tr>
<tr>
<td>Wiley: Journal of Software: Evolution and Process</td>
<td>71</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>901</strong></td>
</tr>
</tbody>
</table>
The result after Step 1 was a total of 901 studies; see Table 3.2. In Step 2, as part of the refinement shown in Figure 3.1, the results were refined by removing any papers that did not meet the following criteria:

- Journals, grey literature (i.e., technical reports) and conference proceedings;
- Publication data between January 2005 and June 2017;
- Papers related to three main topics (sustainability, education and RE); and
- Papers written in English.

Moreover, many papers were excluded if they were pedagogical strategies, extended abstracts, editorials and workshops or tutorials, or duplicated studies (where the same study was presented in several publications). The total result after Step 2 was 473 studies on sustainability, education and/or SE including Requirements Engineering (RE).

In Step 3, we refined the results to remove papers that did not focus on:

- RE phase of software development, or
- The analysis of sustainability in eLearning or distance education systems or ecosystems or educational software.

We excluded studies on environmental curriculum and pedagogy, as well as on sustainability in education as curriculum and pedagogy, which left 63 papers on the four topics:

- Sustainability,
- Education,
- RE, and
- eLearning systems.

### 3.1.3 Additional non-systematic review

We also added results of the NSR that we conducted in an earlier stage of our research to identify state of the art mainly focusing on learning and teaching system perspectives. Thus, from the NSR, we included the following:

- Three papers (Littlejohn 2003, Littlejohn and Shum 2003, Schoenwald 2003) were published in 2003, which was out of the selected SLR search range, but they provide an important background for the research on sustainability requirements for eLearning Systems.
• Four papers (Attwell 2007, Downes 2007, Koohang and Harman 2007, Stewart and Khare 2015) were not published in the selected sources. However, these papers (Attwell 2007, Downes 2007, Koohang and Harman 2007) are highly cited having 764, 589, 63 citations respectively. One paper (Stewart and Khare 2015) was published in a new series. ‘World Sustainability’, started in 2015 by Springer.

• Six further papers covered sustainability aspects within RE and eLearning, but their title, abstract and keywords did not contain the words of our selected search string, such as ‘requirement’, and ‘sustainability’. Three papers (Dong et al. 2009, Kruchten 2015, Tuparov et al. 2014) were published at the IEEE; the three other papers (Ossiannilsson and Landgren 2012, Sridharan et al. 2010, Stepanyan et al. 2013) are counted by Scopus.

As a result of the NSR, 13 further papers were added to the pool of studies for analysis. In Step 5, we merged the studies from the systematic and non-systematic parts of the review.

3.1.4 Snowballing procedure

Then, we complemented the SLR in Step 6 with the snowballing technique using the reference list of a paper to identified additional papers. We followed a backward iteration of the snowballing procedure as in (Wohlin 2014) and refined it based on Step 2 and Step 3 criteria. In the first iteration, we examined papers in the reference list of the 76 studies, and identified 31 referred papers. Then, we accomplished a second iteration which resulted in 14 papers. The 14 papers led to 2 papers that also referred to another paper in a fourth iteration. Thus, 48 studies were identified during the snowballing procedure and added to the merged list. The merged list of 124 studies was analysed in Step 7 to extract the sustainability requirements and the results are discussed in Section 3.3.

3.2 Results of SLR

We identified the requirements listed in column 2 of Table 3.3 by examining the 124 papers, and evaluated them by inspection.

Figure 3.2: Distribution of the number of studies over the years (2005–2017)
Table 3.3: Sustainability meta-requirements for eLearning systems

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Sustainability meta-requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual and Social</td>
<td>R1.1 Personalisation</td>
</tr>
<tr>
<td></td>
<td>R1.2 Learner-centred features</td>
</tr>
<tr>
<td></td>
<td>R1.3 Collaboration</td>
</tr>
<tr>
<td></td>
<td>R1.4 Leadership development</td>
</tr>
<tr>
<td></td>
<td>R1.5 Privacy and security</td>
</tr>
<tr>
<td></td>
<td>R1.6 Analysis of learning progress</td>
</tr>
<tr>
<td></td>
<td>R1.7 Reuse of learning materials</td>
</tr>
<tr>
<td></td>
<td>R1.8 Integration with social networks</td>
</tr>
<tr>
<td></td>
<td>R1.9 Standardisation of the LORs</td>
</tr>
<tr>
<td>Technical</td>
<td>R2.1 Support of LORs</td>
</tr>
<tr>
<td></td>
<td>R2.2 Support of shared services</td>
</tr>
<tr>
<td></td>
<td>R2.3 Software quality requirements</td>
</tr>
<tr>
<td></td>
<td>R2.4 Portability</td>
</tr>
<tr>
<td></td>
<td>R2.5 Modularity</td>
</tr>
<tr>
<td>Environmental</td>
<td>R3.1 Cloud computing</td>
</tr>
<tr>
<td>Economic</td>
<td>R4.1 Reducing the cost</td>
</tr>
<tr>
<td></td>
<td>R4.2 Ensuring the growth</td>
</tr>
</tbody>
</table>

The three pillars of sustainability requirements for eLearning systems are sustainability, education and software and requirement engineering, which are represented in Figure 2.1. The overlaps across these three pillars provide us with four combination aspects:

1. Sustainability in education,
2. Sustainable SE (with the focus on RE phase of SE),
3. Educational software, and
4. Sustainability requirements for eLearning systems which is the main scope of our research and has 124 studies.

Figure 3.2 presents the distribution of 531 publications between 2005 and 2017. The number of studies on sustainability (including sustainability of education RE/SE) increased by two and a half times over the 2005 to 2017 period: from 14 studies in 2005 to 30 studies in 2017. There was constant interest in research on sustainable eLearning systems, ranging from 7 papers in 2005, peaking at 17 in 2007 and finishing at 4 in July 2017.

Further, we classified these 124 studies into three types:

- **Empirical studies**: Knowledge is gained by observations or experience methods. Perry et al. (2000) stated that an empirical study is a test comparing what we believe to what we observe to help us understand how and what things work;

- **Theoretical or conceptual studies**: These use methods consisting of concepts with definition of knowledge being considered to describing a phenomenon of interest; and

- **Hybrid studies**: These are combinations of empirical and theoretical studies or other studies such as systematic reviews.
CHAPTER 3: SYSTEMATIC LITERATURE REVIEW

Figure 3.3: The classifications of studies in percentage

Figure 3.3 shows the classification result for the 124 studies. Of the studies, 40% were classified as empirical studies, while 56% of the studies are theoretical and 4% have a hybrid nature.

A few studies from the empirical category have well-structured and well-presented statistical data. For example, Randelin et al. (2013) pointed out the background of participants, such as their academic level, gender and age in their study describing the characteristics of learning programs to promote sustainable well-being at work. Conversely, some studies lack evidence, which reduces the truthfulness of their claims. For instance, Mridha et al. (2013) claimed that eLearning increases educational equity and improved English language proficiency, but they did not show the extent of the increase and improvement.

3.3 Analysis of sustainability meta-requirements for eLearning systems

To analyse the SMRs, these being a generalised class needed to be combined with further information to provide actual requirements for eLearning systems and to answer (RQ1.1) and (RQ1.2). Hence, the meta-requirements identified within the review process were distributed among related sustainability requirement dimensions as per (Penzenstadler 2014), that is, among the individual, social, technical, environmental and economic sustainability dimensions.

To illustrate these dimensions and the corresponding studies, Figure 3.4 provides a chart with the five dimensions and percentages of 124 related papers. As shown in the chart, individual SMRs comprised 32% of the requirements that were the most significant part of the research contributions over the 2005 to 2017 period, while the social and technical dimensions have 29% and 24% respectively. The economic and environmental dimensions were covered only in 11% and 4% of the studies, respectively. A reason that the individual dimension has the highest percentage while the environmental dimension has the lowest percentage of studies is the nature of eLearning systems: These systems have a very strong impact on the human dimension of sustainability, whereas their impact on the environmental dimension is perceived as rather small. Nevertheless, the environmental dimension plays an important role in the development of eLearning systems. For example, a specific requirement in the educational software domain is the reuse of learning content resources for individual sustainability requirement (Ossiannilsson and Landgren 2012)
while controlling energy consumption that is an environmental requirement is needed in eLearning and other domains, such as the health domain. It can be argued that each aspect is affected by energy consumption, not only the environmental aspect. Individuals consume power to access and learn from the system. The social aspect consumes power when discussion boards are accessed and lectures are uploaded.

![Figure 3.4: Dimensions of sustainable eLearning systems (2005–2017)](image)

### 3.3.1 Individual and social sustainability requirements

Individual sustainability focuses on individual needs and rights of users of the system, and in the case of eLearning systems, these are instructors, learners and administrators. We identified six core individual sustainability requirements (R1.1-6) within the reviewed studies.

Social sustainability comprises community, institutional and individual dimensions. It covers societal wellbeing as well as availability, and equality of education (Assembly 2015). The social sustainability dimension of eLearning systems is currently not well covered in the existing approaches. In the reviewed papers, we identified only three social SMRs related to learning materials and objects (see, R1.7-9 below). While analysing the individual and social SMRs for eLearning systems, we identified that most of these requirements are heavily correlated to individual as well as social dimensions, if we take into account not only the first-order but also second-order effects, as per Berkhout and Hertin (2001) who proposed to distinguish between three orders of the effects, see Section 2.1. For this reason, we prefer to analyse both dimensions jointly. Theoretically, the following four options are possible:

- **Individual SMR**: the requirements having first-order effect within the individual dimension, but having no impact within the social dimension;
- **Social SMR**: the requirements having first-order effect within the social dimension, but having no impact within the individual dimension;
- **Individual-social SMR**: the requirements having first-order effect within the individual dimension, as well as second-order effect within the social dimension;
• *Social-individual SMR*: the requirements having first-order effect within the social dimension, as well as second-order effect within the individual dimension.

However, in the case of eLearning systems, the first two options are irrelevant, and in all cases we have to consider either individual-social or social-individual SMRs.

**R1.1: Personalisation:** eLearning systems should support personalisation features.

As an example of personalisation, apart from customisation of contents and layout, eLearning systems shall allow learners and instructors to integrate their private cloud storage, hosting websites and web services with their account as well as to synchronise their data securely with other eLearning systems and academic systems. Ossiannilsson and Landgren (2012) believed that personalisation features, which reflect learners’ personal demands and preferences, should be crucial for eLearning systems. An important aspect of the features might be connecting the eLearning system with their academic and personal networks. Attwell (2007) stated that personalisation features could create a personalised learning path according to individual data. For instance, an eLearning system could provide suggestions on the learning paths, based on the analysis of the learner’s progress or demonstrated learning ability, as well as provide a certain content or activity based on the knowledge, skills and objectives demonstrated in the corresponding online quizzes. Thus, having a personalisation feature may help learners increase the efficiency of the training.

R1.1 is an individual-social SMR:

- Individual dimension: first-order effect.
- Social dimension: second-order effect (via networking, efficiency of training, etc.).

**R1.2: Learner-centred features:** An eLearning system should be aligned to the learner-centred approach.

For instance, eLearning systems shall provide a self-assessment rubric. The learner-centred approach puts education responsibility and independence in the learner’s hand, which also provides a basis for lifelong learning. According to Attwell (2007), learners need to improve their occupational knowledge and skills by continuing to learn during their work life. Kendall (2005), Kruchten (2015) presented the importance of lifelong learning, such as facilitating retention of the learner’s employability and development of critical thinking.

This requirement could also be addressed by providing open education (Friesen 2009, Hylén 2006, Pellias 2016) as well as through the government’s and society’s support (Rahanu et al. 2015, Secundo et al. 2013) in formal and informal learning methods (Kendall 2005). Thus, as Ossiannilsson and Landgren (2012) highlighted, the support of lifelong learning would become crucial for sustainable eLearning systems.

R1.2 is an individual-social SMR:

- Individual dimension: first-order effect.
- Social dimension: second-order effect (via lifelong learning, employability, etc.).
R1.3: Collaboration: An eLearning system should support collaboration features. For example, eLearning systems shall provide discussion boards that allow users to participate in a conversation with an entire class or group. Using the discussion board or tools for instant feedback between learners and instructors could improve the learning curve (Ellis 2016, Pellas 2016). In the same way, Pellas (2016) highlighted that providing real-time feedback could affect learners as regards their failure or success as well as enhance practice-based tasks. Ossiannilsson and Landgren (2012) stated that collaboration is a key element of success in eLearning systems.

The collaboration feature may increase the success rate of the learning process as well as have a social-transforming potential. Mocigemba (2006) stated that it is perceived as fast, direct and less bureaucratic. However, from our point of view the mentioned perception points are controversial. R1.3 is an individual-social SMR:

- Individual dimension: first-order effect.
- Social dimension: second-order effect (via the social-transforming potential).

R1.4: Leadership development: An eLearning systems, for instance, shall provide leadership development through raising awareness of sustainability information and supported availability. To make an eLearning system sustainable, people awareness (Lago and Jansen 2011), academic leadership and institutional transformation (Stepanyan et al. 2013) have to be incorporated within the strategies. R1.4 is an individual-social SMR:

- Individual dimension: first-order effect.
- Social dimension: second-order effect (via institutional transformation).

R1.5: Privacy and security: Learners and the instructor in eLearning systems shall not be placed in breach of the certain National Privacy Act. Stewart and Khare (2015) as well as Roy (2012) pointed out privacy and security as the political dimension that should be included in eLearning systems to protect the individual rights. These quality requirements should be implemented to protect users’ data and profiles as well as authors’ rights (Neila and Rabai 2014, Pardo et al. 2012, Sridharan et al. 2010, Törngren et al. 2015).

R1.5 is an individual-social SMR.

R1.6: Analysis of learning progress: eLearning systems shall produce the evaluation of individual components, a course and learner performance. Analysing the usage of users’ behaviour is describing a real individual behaviour without any influence by person factor for data collection and statistics (Cápay et al. 2011). To analyse the usage, there are different layers for log file analysis in infrastructure, contents, tools, and terminal layers (Zheng et al. 2014). System load, network traffic, learning behaviours, accessed learning resource and learner assessment could be caught automatically and visualised. Therefore, when the progress of learning is monitored, measured and analysed by the eLearning system, it could assist learners and instructors to improve their productivity. R1.6 is an individual-social SMR.
CHAPTER 3: SYSTEMATIC LITERATURE REVIEW

R1.7: **Reuse of learning materials**: An obvious example is that eLearning systems shall allow instructors to extract course content, assignments and quizzes from previous terms and import them into current courses. A crucial success factor for eLearning ecosystems is the reuse of learning materials (Sridharan et al. 2010). As explained by Stepanyan et al. (2013), reusable learning materials may not only reduce the instructors’ workload but also offer additional potential for cost-effectiveness. For instance, if one instructor with a greater technical ability to design course materials than other instructors shares his work with them, it will lead to time and cost savings (Scoppio and Luyt 2017, Sowe et al. 2013). This requirement is specific to eLearning systems, and could be facilitated by a Learning Object Repository (LOR).

R1.7 is a social-individual SMR.

R1.8: **Integration with social networks**: eLearning systems shall provide to the learner and instructor roles optional integration with social networks and a variety of third-party providers. The importance of integrating social networks with academic activities is explored. Manca and Ranieri (2017) discussed the challenges of incorporating social networks into teaching and learning, such as policy, and cultural and social factors. Wang et al. (2014) introduced guidelines to maximise the educational potential of social networks in higher education, and thus, integrating features of social networks could help personalisation and collaboration. However, maintaining privacy and security during integration would be crucial.

R1.8 is a social-individual SMR.

R1.9: **Standardisation of the learning object repositories**: eLearning systems shall support a variety of standards of learning object repositories. Standardisations, particularly the open standards of LORs, have high potential to be interoperable with other eLearning systems and adopted by open-source and proprietary eLearning systems (Dinevski 2008). The standards could asset reuse of learning objects for the long-term goal of educational culture change and for benefiting instructors to develop and support their own courses (Gunn et al. 2005). However, challenges related to content and sharing learning objects remain, such as copyright, quality control, and cultural assimilation that should be addressed (Friesen 2009, Gunn et al. 2005, Rovai and Downey 2010). Thus, LORs should be standardised with regard to ownership, multilingualism and learning styles.

R1.9 is a social-individual SMR.

3.3.2 Technical sustainability requirements

Technical sustainability includes reducing negative effects of technology, such as consumption and pollution.

R2.1: **Support of learning object repositories**: eLearning systems shall support LOR, which is a specific requirement. To facilitate the reusable learning material requirement, eLearning systems should support LORs having learning elements, attributes and content. However, there are some
challenges for LORs, such as LMS support, ownership, copyright and validation of resources as discussed by Sridharan et al. (2010). Another essential point is learning object meta-data that help users to store, search, reuse learning objects quickly and effectively particularly if there are too much meta-data and content to search (Yigit et al. 2014). Thus, sustainable eLearning systems should support different standards for LORs to be used by different institutions worldwide.

**R2.2: Support of shared services**: eLearning system shall support a variety of third-party providers, such as Adobe Connect and Google Calendar. To enable eLearning sustainability, the corresponding IT services might be shared among universities and campuses. This may reduce cost and improve services (Stewart and Khare 2015). For instance, the Ethiopian government implemented an eLearning system in medical schools across the MEPI-Ethiopia consortium including the Addis Ababa, Hawassa and Haramaya Universities, and the Defense College of Health in order to enhance the quality and efficiency of medical education (Vvides et al. 2014). As another example, British Columbia in Canada shares IT infrastructure and application services with province’s Post-Secondary sector. Therefore, this requirement might standardise services to facilitate integration as well as reduce eLearning costs and energy consumption (Stepanyan et al. 2013, Stewart and Khare 2015).

**R2.3: Software quality requirements**: For example, eLearning systems shall sustain quizzes with not less than five minutes in the absence of network. Many reviewers asserted that while availability and equality of education should be taken into account, the software should meet quality requirements, such as performance, security, usability and longevity (Assembly 2015, Mahmood and Hafeez 2013, Nwokediuko 2012, Stepanyan et al. 2013). These qualities that belong to NFR should be satisfied (Calero et al. 2013, Mahmood and Hafeez 2013). Further, the quality requirements contribute to sustainability of software. For example, if an eLearning system has a high quality of performance, security and longevity, it might not be replaced. These requirements lead to the reduction of energy consumption during new software development, and the protection of peoples’ information and rights.

**R2.4: Portability**: eLearning systems shall run on various devices with a large, medium or small screen. Portability and optimising graphical design as technical sustainability may assist people to use eLearning systems everywhere and with any device (Garg and Varma 2015). For instance, rural areas in developing countries that have low-bandwidth network could benefit from access to an eLearning system to obtain high-quality education from developed countries. To illustrate, the University of Nsukka in Nigeria has started to use mobile devices to receive lectures (Ghirardini 2011). Despite the potential of mobility, optimisation and downsizing of websites need to be improved to assist in accessing knowledge, reminders, and reviews through assorted mobile devices (Garg and Varma 2015).
Although there is rapid technological change, eLearning systems are not yet fully supported. These systems have the potential to shape learning processes, and they need to streamline tools to be portable with various devices such as mobiles, tablets and laptop and desktop computers (Attwell 2007, Scoppio and Luyt 2017).

R2.5: Modularity: eLearning systems shall allow instructors to create, modify and delete modules for organising course content by week or units. Modularisation in eLearning systems is of two kinds: modular architectural design and modular learning design. The first, the modular architectural design, is a concept of designing the system to support interoperability. Therefore, the sustainable eLearning systems functionality should be divided into modules to alleviate the integration in a flexible manner (Dagger et al. 2007, Mahmood and Hafeez 2013).

The modular architecture may reduce the cost of eLearning systems and enable interoperability. The second, modular learning design, is an approach to present course materials in a logical, sequential fashion to guide learners (Tomkinson and Hutt 2012). This approach could assist learners to complete the part of the course that is relevant to their needs instead of having to complete the entire course.

3.3.3 Environmental sustainability requirements

Environmental sustainability contains resource consumption and waste. Therefore, resource use should be reduced during eLearning system operation to decrease energy and pollution. Many scientists showed that better design of the system (Berkhout and Hertin 2001), tracking resource use (Roher and Richardson 2013), monitoring physical waste and energy bills (Penzenstadler and Femmer 2013) could decrease energy consumption and pollution, which leads to protecting natural resources.

R3.1: Cloud computing: eLearning systems shall deliver on-demand computing resources over the internet. Cloud computing enables sharing resources and infrastructures that not only results in energy efficiency but also in cost efficiency (Lago and Jansen 2011, Mahmoud and Ahmad 2013). For example, eLearning systems could be run through a virtual machine that offers large energy savings (Dong et al. 2009, Kumar and Buyya 2012). Hence, eLearning systems can leverage cloud computing to share sources, reduce cost and energy, and monitor usage (Demski 2012, Kumar and Buyya 2012, Sowe et al. 2013).

3.3.4 Economic sustainability requirements

The reduction of operating cost and the insurance of economic growth should be considered (Lago et al. 2015), in addition to software efficiency.
R4.1: Reducing the cost: For instance, eLearning systems shall support reusable learning object. Several scientists proposed a virtual and remote laboratory framework that shows major economic advantages (Castro-Schez et al. 2012, Gustavsson et al. 2009, Meneses 2011, Sowe et al. 2013, Stefanovic 2013). For example, electronic engineering learners who use a virtual lab could overcome classroom and laboratory limitations in term of equipment as well as space. This approach leads to reducing the cost of new equipment and maintenance (Meneses 2011). Virtual and remote laboratories in eLearning systems not only affect in the economic dimension but also the individual dimension (Stefanovic 2013), since they influence factors, such as creativity, teamwork and learning from failures.

R4.2: Ensuring growth: eLearning systems, for example, shall provide secure remote-access to the data laboratory and off-campus library. This economic sustainability requirement might ensure the growth of the economy. An example being claimed by Alrashidi (2013) as the economic benefit of using eLearning systems is that these systems could assist people in Saudi Arabia to stop migrating from rural areas to cities. This advantage may lead to developing and growing the economy in the learners’ area and to preventing population increase and pollution in cities.

3.4 Discussion

Based on our analysis of the reviewed studies in sustainability requirements, we observed that although numerous studies provide various solutions for sustainable eLearning systems, some issues remain to be addressed. We propose to include the following meta-requirement, which has not been covered by the identified 124 studies; based on several reviews about green and sustainable software engineering evidence (Berntsen et al. 2016, García-Mireles et al. 2018, Mourão et al. 2018, Penzenstadler et al. 2014a), we believe that it is required for developing a sustainable eLearning system, since it is fundamental for all systems and is also important for eLearning systems, cf. also (Calero and Piattini 2015). We label it Proposed Requirement (PR3.2), which belongs to the environmental sustainability dimension.

PR3.2: Green and sustainable software engineering [environmental SMR]: eLearning systems shall run on a green data centre. Green SE could enable developers to design better methods, metrics and tools to encourage green behaviour (Calero and Piattini 2015). eLearning systems should be based on green and sustainable software development processes, such as the GREENSOFT model (Naumann et al. 2011), sustainable business process management (Betz and Caporale 2014) and/or green and sustainable software models (Mahmoud and Ahmad 2013). These models that cover all aspects of green and sustainable SE might apply to sustain the eLearning systems from cradle-to-grave.
### CHAPTER 3: SYSTEMATIC LITERATURE REVIEW

Table 3.4: Sustainability meta-requirements for eLearning systems, within software product quality, that were identified in our systematic literature review, classification G for general domain and S for eLearning systems specific domain

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Sustainability meta-requirements</th>
<th>G/S</th>
<th>Software quality</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R1.6 Analysis of learning progress</td>
<td>S</td>
<td>Functional suitability, maintainability</td>
<td>Attwell et al. (2017), Ossian Milsson and Landgren (2012), Petterson and Mahdi (2009), Zheng et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>R1.7 Reuse of learning materials</td>
<td>S</td>
<td>Maintainability</td>
<td>Chua et al. (2006), Farooq et al. (2007), Friesen (2009), Gau (2010), Koo and Maha (2011), Sridharan et al. (2010), Sridharan et al. (2013), Stepanyan et al. (2013), Voids et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>R1.9 Standardisation of the LORs</td>
<td>S</td>
<td>Compatibility, maintainability</td>
<td>Dinescu (2006), Friesen (2009), Hylén (2006), Littlejohn (2010), Scoppio and Luyt (2017), Sridharan et al. (2009), Stepanyan et al. (2013), Voids et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>R2.2 Support of shared services</td>
<td>G</td>
<td>Compatibility</td>
<td>Dunnell (2011), Mohan et al. (2017), Stepanyan et al. (2013), Stewart and Khare (2015), Voids et al. (2014)</td>
</tr>
</tbody>
</table>

* This requirement does not emerge from the SLR but we proposed this sustainability requirement.
In Table 3.4, we illustrate our findings regarding the research questions. It summarises the meta-requirements identified within the SLR studies as well as the additionally proposed meta-requirement (marked by *). The meta-requirements marked by S are specific to the domain of eLearning systems, whereas the meta-requirements marked by G are general, that is, applicable to other domains. For example, in eHealth services, personalisation features are essential and assist to improve these services Hine et al. (2008). Conversely, learner-centred features, the reuse of learning materials and LORs belong to the education domain only, and should be seen as specific requirements (features) of eLearning systems. Our study has shown that requirements of technical, environmental and economic dimensions are general sustainability requirements, since these could be identified and analysed for any type of software. The questions

\textit{RQ1.1: What are the requirements for eLearning systems that cover the sustainability aspects?} and

\textit{RQ1.2: How can we classify sustainability requirements for eLearning systems from the software engineering perspective?}

are answered by the first two columns in Table 3.4. The column G/S is used to highlight the answer to the question

\textit{RQ1.3: Which sustainability requirements are specific to eLearning systems?}

Considering the main result, the identified SMRs could sustain eLearning systems if they cover all SMRs, particularly the human dimension, because the majority of SMRs in the individual and social dimensions have 41% and 27%, respectively. Nevertheless, those SMRs still have some issues in relation to providing sustainable eLearning systems. The influence of one SMR in the individual dimension on another SMR in the social dimension could reduce sustainability. For example, if an eLearning system has a personalisation features but does not support the standardisation of LORs, a learner who has set accessibility preferences in the system might not be able to access learning materials or perform assignments that do not support visual, auditory and mobility impairments.

As the next step of SMR analysis, we mapped the identified SMRs of eLearning systems to the elements of the Software Product Quality Model (ISO/IEC 25010) to ease the accomplishment of software quality. ISO/IEC 25010 (2011) is a division of an International Standard for System and Software Product Quality Requirements and Evaluation (SQuaRE). The ISO/IEC 25010 includes three quality models: \textit{Product Quality}, \textit{Data Quality} and \textit{Quality in Use}. The product quality model has eight main characteristics:

- **Functional suitability**: includes functional completeness, correctness, and appropriateness attributes;
- **Performance efficiency**: considers time behaviour, resource utilisation, and capacity;
- **Compatibility**: has interoperability, and co-existence as sub-characteristics;
- **Usability**: includes appropriateness recognisability, learnability, operability, user error protection, user interface aesthetics and accessibility attributes;
CHAPTER 3: SYSTEMATIC LITERATURE REVIEW

- **Reliability**: comprises maturity, availability, fault tolerance and recoverability sub-characteristics;

- **Security**: contains confidentiality, integrity, non-repudiation, accountability and authenticity;

- **Maintainability**: incorporates modularity, reusability, analysability, modifiability and testability; and

- **Portability**: covers adaptability, installability and replaceability sub-characteristics.

Calero and Piattini (2015), Calero et al. (2013) introduced a new sustainability-related characteristic for a quality model based on ISO/25010:

- **Greenability**: the degree to which a product’s energy and resources are optimised so that the product can be used over a long period. This main characteristic includes energy efficiency, resource optimisation, capacity optimisation, and perdurability sub-characteristics.

Similarly, the relationships between software quality and environmental sustainability criteria were analysed by Koçak et al. (2015). In our research, we follow the software product quality model introduced by Calero and Piattini (2015), which results in relationships between software quality and SMRs for eLearning systems presented in Table 3.4. Thus, the SMRs that are specific for eLearning systems mostly focus on qualities such as usability, greenability, maintainability, compatibility and functional suitability.

3.5 Threats to validity

Certain threats need to be taken into account as well. In this section, we follow the classification for the threats to validity by Wohlin et al. (2012), which includes construct, internal, external and conclusion validities.

**Construct validity**: The search string is the main threat in constructing this study. The concept of eLearning has been used differently in many studies. To ensure that we cover all these studies, we considered ‘learning’, ‘e-learning’, ‘eLearning’, ‘electronic learning’ and ‘distance education’ terms. In addition, we used system, environment, and ecosystem terms to ensure all the selected studies are related to the SMRs of eLearning systems. We performed the manual search on three Springer and two Wiley journals to ensure high coverage of potentially relevant studies. These five journals have a high ranking, according to SCImago Journal Rank (SJR) indicator; see Table 3.5. In addition, we complemented our search using the snowballing procedure in case our search string might not be sufficient.

**Internal validity**: We collaboratively reviewed, discussed and resolved any conflict during the inclusion and exclusion steps to reduced personal bias on as regards understanding the study. We have explained our study categories, and others may categorise them differently.

---

6http://www.scimagojr.com/
3.6 Summary

In this chapter, we provided SLR and analysis of SMRs for eLearning systems. We conducted manual as well as automated searches over the IEEE Xplore Digital Library, the ACM Digital Library, Scopus and a number of relevant Springer and Wiley journals, for the publication years between January 2005 and June 2017. As a result, 124 studies were analysed and investigated to achieve our main objective of identifying sustainability requirements of eLearning systems.

We extracted 17 high-level sustainability requirements (meta-requirements). We defined a new requirement of environmental dimension as a green and sustainability SE meta-requirement. In addition, we classified these meta-requirements according to the five dimensions of sustainability: individual, social, technical, environmental, and economic. Our analysis demonstrated that the individual dimension plays the most significant role for eLearning systems, since education (in on-line as well as traditional face-to-face versions) is part of the human dimension, while the role of the environmental dimension is similar to its role in other software domains. Many high-level requirements (especially within the environmental, economic, and technical dimensions) are not eLearning systems specific requirements. This allowed us to identify what aspects could be inherited from the other domains and what aspects are domain-specific for eLearning systems.

The elaboration of high-level sustainability requirements aimed to support the SE practitioners in developing long-living eLearning systems. For example, while implementing a discussion board for an eLearning system, the developers have to take into account not only modularity and portability features but also provide the support of existing and future learning objects.

External validity: We executed the search several times, to confirm that the exact string could be performed using different search engines. For example, we used the three forms of sustain within all the search strings instead of sustain* that cannot be used in the ACM search engine. In addition, we cannot guarantee the exact number of studies if some publishers add papers because of a merger or revisions.

Conclusion validity: There is no any threat for any future replicated study when researchers follow our method and categories.

Table 3.5: Journal rank used in the systematic literature review as SCImago Journal Rank (SJR) indicator in 2016, where Q1 is the highest and Q4 the lowest values

<table>
<thead>
<tr>
<th>Journal</th>
<th>SJR Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Springer: Requirements Engineering</td>
<td>Q2</td>
</tr>
<tr>
<td>Springer: Empirical Software Engineering</td>
<td>Q1</td>
</tr>
<tr>
<td>Springer: Education and Information Technologies</td>
<td>Q2</td>
</tr>
<tr>
<td>Wiley: Software Practice and Experience</td>
<td>Q2</td>
</tr>
<tr>
<td>Wiley: Journal of Software: Evolution and Process</td>
<td>Q3</td>
</tr>
</tbody>
</table>
Chapter 4

Sustainability of eLearning Systems from the User’s Perspective

“The basic DNA of good learning experiences is trying to do something and getting feedback.”

–Julie Dirksen, 2016

In this chapter, we examine which eLearning systems functionalities are the most used, requested and deficient from learners’ and instructors’ perspectives. We designed a survey and distributed it to students and academic staff in the computer science department at RMIT University, Australia, all departments in Umm Al-Qura University (UQU), Saudi Arabia, as well as administration and IT support in both universities. We analysed the results from two perspectives:

1. Participants’ role, and
2. Gender and cultural diversity aspects.

On both cases we applied mixed-methods design that includes qualitative and quantitative methods.

Copyright/credit/reuse notice:

This chapter content is based on materials that have been previously published as:

4.1 Survey scheme

Qualitative and quantitative methods were combined to address our research problem and to analyse quantitative variables extracted from qualitative data. The mixed-methods methodology employed qualitative and quantitative methods in a sequential exploratory approach adopted from (Creswell 2009). Figure 4.1 presents the data collection and analysis methods. Data collection was conducted via a survey using an open-ended questions. There were 179 participants. Statistical analysis was performed on the quantitative data constructed from the qualitative responses. This process is called coding and is an empirical Software Engineering (SE) approach to transforming qualitative data into quantitative data to understand and classify information (Runeson and Höst 2009, Seaman 1999). We explored the collected data from role preservative, cultural diversity and gender equality.

4.2 Data collection

We designed a questionnaire with open-ended questions, and sent it to three groups of stakeholders:

1. learners,
2. instructors, and
3. IT support personnel and administrators
at RMIT University in Australia between April and June 2016 and UQU in Saudi Arabia between September and October 2016. The goal was to explore and reconcile the various perspectives of stakeholders who use different systems.

The questionnaire included demographic questions: country, age, university, role and eLearning systems (see survey questions, participant information and recruitment advertisements in Appendix B). The following questions were asked of learners and instructors:

Q1: What kind of functionality are you using, such as chat, discussion board, etc.?
Q2: Which functionality do you request which is not provided (by now) in your system?
Q3: How long should the eLearning system keep your materials and data, from your point of view?
Q4: What would you change or improve features in the current system and how important?
Q5: Do you have anything to add?

Thus, the responses of learners and instructors were in the form of short answers regarding user functionalities, required functionalities, requested improvements to certain features of whole systems, and the period for storing learning materials and data. For instance, one instructor answered the question ‘Which functionality do you request, which is not provided (by now) in your system?’ with the statement ‘Communicate with students through notifications in the mobile application’.

IT support personnel and administrators were asked a different set of questions, about technical aspects and the policy of data storage:

Q1: Where and how do you store data (physically)?
Q2: How long do you keep old data?
Q3: How easy to add new functionality or remove a function such as discussion boards or virtual class? What process do you need?
Q4: What problems need to be solved in the current system?
Q5: How much power consumed by your eLearning system?
Q6: What would you change or improve features in the current system and how important?
Q7: Do you have anything to add?

IT support personnel and administrators, who were few in number, provided similar answers about a particular system and reported on physical data storage and data retention policies.
4.3 Learner and instructor perspectives

The literature reflects increased interest in determining the critical success factors of eLearning systems dimensions, especially for sustainable eLearning. However, this issue requires further investigation covering the requirements and the quality of eLearning systems. To ensure critical success and sustainability of eLearning systems, we must ensure that:

1. all features provided by the eLearning system are truly required,
2. all functionalities required by users (learners and instructors) are provided and do not have defects, and
3. learning materials and data are stored for sufficient time to minimise the negative effects and maximise the positive effects from a sustainability quality perspective.

These points lead to four sub-questions of research question RQ1 in Chapter 1 earlier on Page 6 that will assist us in addressing the problem, R1.1-R1.3 were addressed in Section 3.1.1:

RQ1.4: What types of functionalities of eLearning systems do learners and instructors use?

RQ1.5: What types of functionalities of eLearning systems are in demand if they are not provided—and what should be improved if they are provided—from the perspective of learners and instructors?

RQ1.6: How long should learning materials and data be stored on eLearning system?

RQ1.7: Where and how does the university store data (physically) and how much power does their eLearning system consume?

We will cover these question in Section 4.3.3.

4.3.1 Analysis

To categorise open-ended responses, we employed a coding process to extract a free description of short answers from learners and instructors, as illustrated in Figure 4.2. First, the answers on eLearning systems and roles from participants were treated as independent variables and were used to manipulate responses regarding types of eLearning systems and participants’ roles. Two eLearning systems, Blackboard (Bb) and Desire2Learn (D2L), were considered. In addition, learners and instructors were the main participants presenting their individual point of view.

Second, we assigned code keys to the text to extract values according to their variables. For example, one of the learners responded to ‘What kind of functionality are you using?’ with ‘Discussion board, downloading assignments, lecture slides and exercise sheets, looking at learning schedule, and checking grades’. Thus, the code key for this statement was the functionality known in the education domains. Each functionality was annotated as a value of 1 against discussion.
board, assignment submission system, course contents, schedule and calendar and grade book categories. These categories were either determined earlier from other responses or had to be initialised as new categories and annotated (see a snapshot example of annotation in Table 4.1). After interpreting responses and categorising them, similar categories were merged to reduce duplication. For instance, the Facebook and Twitter categories were combined into a single social media category. Also, the categories of functionality were performed for both systems and all three questions. We then performed a statistical analysis to examine data and to identify meaningful relationships (Creswell 2009).

4.3.2 Results

The questionnaire was sent via email to two universities in two countries. The Computer Science and Information Technology discipline at RMIT University in Australia utilises the Bb system (ver. 9.1), and UQU in Saudi Arabia uses the D2L system (ver. 10.5). Ethics approval was obtained to conduct this research and to send the questionnaire via email to learners, including undergraduate, postgraduate and higher-degree research students, academic staff and IT support personnel and administrators at RMIT University. In addition, learners, academic staff and IT support personnel and administrators were recruited at UQU.

We received 179 responses as shown in Table 4.2. Participants’ answers to demographic questions are presented in Figure 4.3; among the participants who completed and submitted responses to the questionnaire, 71% were learners, 26% were instructors and ∼3% IT support personnel and administrators. To address the research questions, we analysed three aspects of the
CHAPTER 4: SUSTAINABILITY OF ELEARNING SYSTEMS FROM THE USER’S PERSPECTIVE

Table 4.1: Example of coding phases showing annotation against responses within the role and the used system

<table>
<thead>
<tr>
<th>Role</th>
<th>eLearning systems</th>
<th>Responses of “What kind of functionality are you using?”</th>
<th>Category</th>
<th>Annotation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Course Contents</td>
<td>Discussion board</td>
</tr>
<tr>
<td>Instructor</td>
<td>Bb</td>
<td>‘Email, discussion board, quizzes’</td>
<td>1- Discussion board</td>
<td>2- Email</td>
</tr>
<tr>
<td>Instructor</td>
<td>D2L</td>
<td>‘Quizzes / content / discussions / grade book / delivery folder’</td>
<td>1- Course Contents</td>
<td>2- Discussion board</td>
</tr>
<tr>
<td>Learner</td>
<td>Bb</td>
<td>‘Discussion boards, looking up learning content’</td>
<td>1- Course Contents</td>
<td>2- Discussion board</td>
</tr>
<tr>
<td>Learner</td>
<td>D2L</td>
<td>‘Submitting assignments, downloading slides’</td>
<td>1- Course Contents</td>
<td>2- Assignment management</td>
</tr>
</tbody>
</table>

We placed functionalities into 28 categories (see Table 4.3) including:

- Learner and instructor stakeholder perspective,
- Perceptions of systems including Bb and D2L,
- IT support personnel and administrators’ procedures for data retention.

We placed functionalities into 28 categories (see Table 4.3) including:

- 17 functionalities (F1–F17) used by participants,
- 26 functionalities (F1–F15 and F18–F28) that either have a defect or have been requested to be added to the systems.

Table 4.2: Number of participants for each role in each eLearning system

<table>
<thead>
<tr>
<th>Role</th>
<th>System</th>
<th>Blackboard</th>
<th>Desire2Learn</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner</td>
<td>Blackboard</td>
<td>69</td>
<td>58</td>
<td>127</td>
</tr>
<tr>
<td>Instructo</td>
<td>Desire2Learn</td>
<td>20</td>
<td>27</td>
<td>47</td>
</tr>
<tr>
<td>IT support personnel and admin</td>
<td>Total</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>91</td>
<td>88</td>
<td>179</td>
</tr>
</tbody>
</table>

(October 31, 2019)
Stakeholder perspectives

Two groups of stakeholders—learners and instructors—used some functionalities of eLearning systems and needed others to be available or improved. The most used feature in eLearning systems was the Discussion board, followed by Text and video chat and Course content. However, the least used features were Remote service and Mind mapping. The most requested functionalities were Collaboration tools, Grade book, and Lecture recordings, while the least requested were Mind mapping and Progress analysis. The most needed improvements were the availability of functionality and its integration with the university community and resources.
systems from the learners’ and instructors’ perspectives was the discussion board (F1), as shown in Figure 4.4. There were 55% (of 69) and 60% (of 20) of learners and instructors, respectively, who used the discussion board in Bb; almost 45% of 27 instructors used the discussion board (F1) in D2L. Of the 58 learners who utilised D2L, more than 30% used the text and video chat features (F2). A similar proportion of the 174 participants used the course content function (F3) in both systems: 10%–20%.

Around 22% (of 27) instructors in D2L used text and quizzes (F4) while less than 8% of other participants did. Neither participants in D2L nor instructors in Bb used lecture recordings (F10), but 10% (of 69) learners in Bb used the feature (see, F10 in Figure 4.4). Learners in Bb reported that they used more features than did learners in D2L, while a higher percentage of instructors in D2L than in Bb used the provided functions other than the discussion board (F1); however, instructors in Bb utilised this function more. Collaborative tools (F8), lecture recordings (F10), calendars and schedules (F13) and remote services (F16) were not available in D2L for either learners or instructors. Overall, communication functionalities such as discussion board (F1), text and video chat (F2) and email (F5) were the most used by learners and instructors in both systems. Learners requested more functionalities than did instructors. These required functionalities in each system were considered less from the learners’ point of view in comparison with that of instructors, as illustrated in Figure 4.5. For example, the most requested function (12% of learners in the D2L) was the mobile version (F18); whereas ∼7% of instructors in D2L required better text and video chat functionality (F2) and improvements in usability (F21). Around 14% of instructors using Bb requested the availability (F20) of course materials from previous semesters and other features of the Bb system. Among learners in the Bb system, 10% requested better text and video chat functionality (F2) and availability of a mobile version (F18), similar to learners and instructors in the D2L.

Figure 4.6 shows the percentages of provided functionalities in the Bb and D2L systems that had defects and needed to be improved, according to learners and instructors. Improvement in usability (F21) was the most demanded, by 29% of instructors and 12% of learners in the D2L, and 24% of learners and 10% of instructors in Bb. In addition, 15% of instructors in the Bb system requested better text and video chat functions (F2), and ∼18% of instructors in the D2L...
required an improvement in test and quiz features (F4). Better performance (F19) was needed by almost 9% of learners in the D2L, while 13% of learners in Bb demanded standardisation of learning delivery (F27). Overall, learners and instructors in both systems requested improvements in almost all of the non-functionalities including usability, integrability, performance and portability in the form of a mobile version.

Figure 4.6: Deficient functionalities: learners’ and instructors’ responses on the Bb and D2L systems

System perceptions

Learners and instructors in both Bb and D2L were more familiar with the discussion board, text and video chat and course content features (see, F1, F2 and F3 in Figure 4.4). However, availability of a mobile version and improved text and video chat were required by learners and instructors who used Bb (see, F18 and F2 in Figure 4.5). In D2L, learners and instructors both needed a mobile version (F18), improved performance (F19) and virtual classrooms (F12) as presented in Figure 4.5. Overall, both systems provided synchronous functions, such as text and video chat and virtual classrooms, and asynchronous features, such as discussion boards and email functionalities.

Table 4.4 shows a statistical summary of the three questions that were asked of learners and instructors (see Section 4.2). Each question has the total of functionality categories, the sum, mean
and variance of functionalities for Bb and D2L systems. In Table 4.4, the count row gives the number of categorised functionalities. The sum is the total of all reported functionality among users, where many users reported more than one functionality for the three aspects. The mean (average) is the sum value divided by the count. Variance is the average of the squared differences between each functionality and means. The standard deviation is calculated from the square root of variance while the standard error is determined as the standard deviation divided by the square root of count. We used the standard error to calculate unequal variance $t$-test which tests how significant the differences between groups having different variances. The absolute $t$-value should be $\geq 1.96$ to consider the result significant at 5% significance level, as the standard normal density function $z$ returns 1.96 for the value of $\alpha \text{2}$, where $\alpha$ is 0.05, see Rice (2006). Two-tailed $p$-value is a statistic method which tests the relationship of means in the two sides of the normal distribution curve using a significance level of 0.05 (95%), which means: if $p$-value $\leq 0.05$, there is strong evidence of 95% probability of the impact on both examined groups.

We calculated $t$-test values using two-sample assuming unequal variances analysis. As result of the two-tailed $t$-test, the only statistically significant difference is between learners and instructors who used Bb at .05 level of significance ($df = 23, t = 2.221, p = 0.037$). This result shows that more than 95% of both groups have the same impact.

To determine the statistical significance between the four groups of users and systems for the three questions (aspects), we used the one-way analysis of variance (ANOVA) presented in Table 4.5. In the table, $SS$ is the sum of square between groups and within groups. $df$ is the degrees of freedom: $df_1$ between groups is equal to $n - 1$, where $n$ is the number of groups in conjunction with aspects, systems and roles (in our case, $n=12$); $df_2$ within group is to $k - n$, where $k$ is the number of groups in conjunction with functionalities, systems and role (in our case, $k=123$). $MS$ is the mean square which is $SS$ divided by $df$. $F$ column gives a ratio of two variances as a statistical test of $F(df_1, df_2)$, i.e., in our case $F(11, 111)$ as $df_1 = 12 - 1$ and $df_1 = 123 - 12$. This test examines if the differences between the means of two groups is jointly significant (checking if the two variances are equal or not). While $p$-value is calculated using $F$ and it is a probability distribution for the occurrence of different possible outcomes and its number is between 0 and 1. The smallest number of the $p$-value ($p$-value $\leq 0.05$) is strong evidence against the null hypothesis (no relationship among groups), see Rice (2006).

The one-way ANOVA test results ($F(11, 111) = 1.629, p = 0.05$). Therefore, there is no statistically significant difference between group means. This means that 95% (0.05) of functionality impact towards both studied groups are not the same.

**IT support personnel and administrator practices**

Table 4.6 presents questions regarding Bb and D2L presented to IT support personnel and administrators and their responses. Only five participants completed and returned questionnaires. The questionnaire responses for each system were similar. The reason for the low number of participants was that they answered the questionnaires as a group, as they acknowledged by email.
Table 4.4: Descriptive statistics: learners’ and instructors’ responses on the Bb and D2L systems

<table>
<thead>
<tr>
<th>Aspect</th>
<th>System</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groups</td>
<td>Blackboard</td>
<td></td>
<td>Desire2Learn</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Learner</td>
<td>Instructor</td>
<td>Learner</td>
<td>Instructor</td>
<td>Learner</td>
<td>Instructor</td>
</tr>
<tr>
<td><strong>Count</strong></td>
<td>16</td>
<td>8</td>
<td>10</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>110</td>
<td>24</td>
<td>57</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>6.88</td>
<td>3</td>
<td>5.7</td>
<td>3.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>9.36</td>
<td>3.70</td>
<td>6.07</td>
<td>3.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Standard Error</strong></td>
<td>2.34</td>
<td>1.31</td>
<td>1.92</td>
<td>1.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Variance</strong></td>
<td>87.58</td>
<td>13.71</td>
<td>36.9</td>
<td>11.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t-value</strong></td>
<td>1.445</td>
<td>0.992</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Two-tail p-value</strong></td>
<td>0.163</td>
<td>0.338</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 4.5: ANOVA testing result**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>374.2487483</td>
<td>11</td>
<td>34.02261</td>
<td>1.62937</td>
<td>0.10003</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2317.767512</td>
<td>111</td>
<td>20.88079</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2692.01626</td>
<td>122</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In addition, this could be the reason that researchers in the previously studied literature focused on the three main dimensions of eLearning (see, Section 2.2) and ignored IT support personnel and administrators. They might not spare sufficient attention to participate, or they could be fewer in number compared with the number of learners and instructors.

IT support personnel and administrators at RMIT stored data on Amazon cloud and reported that their current systems had problems with availability, reliability, integrability and usability. They had commenced replacing Bb by Canvas, which is an open-source system. In contrast to RMIT, UQU stored their D2L and its data on local servers and experienced no issues regarding adding a new functionality or removing an old one.

**Data retention**

Learners’ and instructors’ responses with respect to retention of learning materials and data are presented in Figure 4.7. Between 40% and 50% of learners in both systems preferred to keep their course materials and data only for a short time, during their study or less than one year after they...
CHAPTER 4: SUSTAINABILITY OF ELEARNING SYSTEMS FROM THE USER’S PERSPECTIVE

Table 4.6: IT support personnel and administrators’ responses for the Bb and D2L systems

<table>
<thead>
<tr>
<th>Questions</th>
<th>Blackboard</th>
<th>Desire2Learn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where and how do you store data (physically)?</td>
<td>‘Amazon’</td>
<td>‘On local servers’</td>
</tr>
<tr>
<td>How long do you keep old data?</td>
<td>N/A</td>
<td>‘We don’t delete them’</td>
</tr>
<tr>
<td>How easy to add new functionality or remove a function such as discussion boards or virtual class? What process do you need?</td>
<td>Students can initiate collaboration such as starting a discussion board. RMIT uses a third party product Blackboard Collaborate for virtual classrooms’</td>
<td>‘It is easy through admin account’</td>
</tr>
<tr>
<td>What problems need to be solved in the current system?</td>
<td>‘Availability, reliability, integration, and innovation’</td>
<td>‘No problem till now’</td>
</tr>
<tr>
<td>How much power consumed by your eLearning system?</td>
<td>‘Don’t know’</td>
<td>‘Enough energy for 24 servers’</td>
</tr>
<tr>
<td>What would you change or improve features in the current system and how important?</td>
<td>Ease of use integrating third party tools. Usability / ease of use. RMIT reliant on vendor updates for product innovation’</td>
<td>Increase free reporting system</td>
</tr>
<tr>
<td>Do you have anything to add?</td>
<td>‘A current review of the eLearning system is underway’</td>
<td>‘No thanks’</td>
</tr>
</tbody>
</table>

Figure 4.7: Required data retention time from learners’ and instructors’ perspectives on the Bb and D2L systems

graduate. Instructors using Bb were divided roughly equally among three categories of response with respect to an appropriate data retention period (<1; 1–5; >6 years). The same was true for instructors in the D2L. Thus, learners were in favour of short-term storage whereas most instructors preferred to keep materials for a period longer than a year. IT support personnel and administrators stated that data in the D2L system were stored physically on local servers whereas the data in the Bb system were stored in the cloud.

4.3.3 Discussion

This study explored the perspective of learners and instructors as well as the practice of IT support personnel and administrators using either Bb at RMIT University or D2L at UQU to analyse the used, requested and deficient functionalities of eLearning systems and to investigate data retention duration and policy. Learners and instructors were asked about the functionalities that were provided and that they used, requested or that needed to be improved; and the data retention period. IT support personnel and administrators answered questions regarding data retention policy and the energy consumption of their systems. Responses were collected and analysed using qualitative and quantitative methods. We now discuss the major findings with regard to the research questions.
RQ1.4: What type of functionalities of eLearning systems do learners and instructors use?

Various communication functions, such as discussion boards and text and video chat, were the most popular functionalities in the Bb and D2L systems used by both learners and instructors. This finding indicates that there is online communication via synchronous and asynchronous features between learners and instructors as well as among learners. This result agrees with those reported by Menchaca and Bekele (2008) and Sridharan et al. (2010).

The finding that course content function had the same range between 10% and 20% in Bb and D2L indicates that learners and instructors interact equally with the systems. Instructors are able to upload course materials such as slides and exercise sheets, so that learners can download these materials inside and/or outside classrooms. The course content and communication functions provide learners the ability to be engaged in the learning activities. This approach is called learner-centred instruction in that learners and instructors share the focus instead of instructors dominating learning activities; learners become receivers without any encouragement or collaboration (Mtika and Gates 2010).

However, although only 10% of instructors and ~20% of learners in the Bb reported that they used course content function, all instructors in RMIT are obligated to upload course materials via course content functions for all enrolled learners. Thus, they might have assumed that they needed to mention only functionalities that they are not obligated to use. We suggest that researchers use the functionality category that we found in our study in a list in any future quantitative research. Then, participants will be able to select functionalities that they used instead of typing script and reporting a few functionalities.

In addition, around 10 of 17 functionalities were either ignored or not used by learners and instructors. Similarly, they required functionalities are available in their system. However, these functionalities might be disabled by either system administrators or instructors. This suggests that awareness and training are required. Universities that implement virtual classrooms, spend money, time and energy. Thus, as only a few people are using these virtual classrooms, universities should encourage instructors and learners to utilise implemented functions of eLearning systems to increase the potential advantages of sustainable eLearning and sustainability development.

RQ1.5: What types of functionalities of eLearning systems are in demand if they are not provided—and what should be improved if they are provided—from learners’ and instructors’ perspective?

The results shown in Figures 4.5 and 4.6, suggest that improvements in eLearning system quality were requested and required. In the Bb and D2L systems, usability was the most requested functionality by learners and instructors. This quality functionality is an important factor in sustaining eLearning. According to Harrati et al. (2016), better usability and a positive experience of eLearning systems play a significant role in the acceptance, satisfaction and efficiency of educational institutions. Because of low usability quality of eLearning systems, learners and
instructors may have a negative user experience, which will affect the success of sustainable eLearning. The importance of usability of eLearning systems and courseware and their effects on learners and instructors has been discussed in many studies, e.g., (Koohang and Paliszkiewicz 2016, Orfanou et al. 2015).

In addition to usability as a vital part of quality functionalities in eLearning systems, learners and instructors considered integrability and portability important. For example, learners demanded that all features should be provided for mobile use and requested the ability to download materials over a wireless network to avoid excessive use of their cellular data by streaming on the way home from university on public transport. Instructors requested better integration between eLearning systems and admission systems to synchronise learner data and exam result records. Portability and integrability functionalities could lessen energy consumption and cost of using the systems and increase opportunities for ubiquitous learning advantages. For example, learners could download lecture recordings once and play them multiple times offline instead of streaming recordings, and could use eLearning systems with either advanced or low-cost devices. Bogdanović et al. (2014), Chen and Huang (2010) and Chen (2010) all mentioned that portability and integrability features of eLearning systems have positive effects on learning processes and learners’ performance, knowledge and interest.

Performance and availability, which are quality functionalities, were highly requested in both systems. Learners, for instance, needed better time responses for both eLearning systems and instructors replying to their questions. Instructors also demanded the availability of functionalities that had been deactivated, and of previous course materials, including assignments and assessments, so they could reuse them as an alternative to developing courses from scratch. Performance and availability are both critical factors, and learners and instructors may refuse to use eLearning systems because of low-quality functionalities.

Providing appropriate and high-quality functionalities will lead to acceptance, efficiency, satisfaction and increase in learners’ performance; thus, learners and instructors will tend not only to use eLearning systems but also to practice continuing professional education. Numerous studies have indicated a strong relationship between quality functionalities and learners’ performance. Learners will become more confident, satisfied and capable of eLearning, and can enhance their performance and productive capacity when they have appropriate and high-quality functionalities in their eLearning systems (Chiu et al. 2005, Pituch and Lee 2006, Wu et al. 2010).

**RQ1.6: How long should learning materials and data be stored on eLearning system?**

The results indicated different perspectives on how long learning materials and data should be stored. The main goal of learners may be to receive a qualification; they may not use learning materials after graduation and thus prefer a short period of data storage. They might not have an awareness of the importance of lifelong learning and/or universities may not permit them access to their systems after graduation. Conversely, instructors had different views on the appropriate term of data retention. Instructors who preferred a short period may be concerned about privacy
and maintenance costs. Those in favour of a long period may appreciate the importance of reusing course materials to develop a new course, to increase quality and save time and money. The literature review revealed no differences between learners and instructors with respect to the retention of learning materials and data, with the exception of Freitas et al. (2015), who reviewed the issue particularly in relation to open study courses. We believe there is a need for empirical investigation to determine the effects of the retention of materials and data on learners and instructors.

RQ1.7: Where and how does the university store data (physically) and how much power does their eLearning system consume?

Retention procedures and policies were not mentioned in the results from the IT support personnel and administrator questionnaires. However, Bb used Amazon cloud to store data physically, whereas D2L utilised local servers. IT support personnel and administrators at RMIT agreed with learners and instructors regarding the low quality of Bb, such as its integrability, availability and usability. In D2L, IT support personnel and administrators requested an improvement in the reporting system. Hence, the results showed that IT support personnel and administrators were not aware of the energy usage of eLearning systems. The lack of knowledge regarding energy consumption is a critical issue with respect to monitoring and controlling the effects of eLearning systems from the perspective of environmentally sustainable development. There is a direct correlation between the data centre and power consumption. Thus, if the data centre grows, the consumption of energy increases. Many studies (Bartalos et al. 2011, Jagroep et al. 2017, Lago and Jansen 2010, Roy et al. 2008) have proposed ways of practising environmental awareness as well as green strategies. Thus, universities should provide support and strategies to regulate energy consumption for IT through green metrics and energy profiling of eLearning systems.

4.4 Cultural diversity and gender equality

The literature reflects increased interest in determining the social sustainability of software systems, especially for cultural diversity and gender equality. Both culture and gender are an enabler and a driver of the five sustainability dimensions. Thus, we need to recognise them and not marginalised them. Nevertheless, this issue requires further investigation from psychological experts and software engineers on the cutting edge of social sustainability for the longevity of software systems. The broad research problem that guided this study was ‘How can we address cultural diversity and gender equality in sustainability requirements of eLearning systems?’ To ensure the social sustainability of software, we have to ensure that:

- There are equal opportunities and access to functionalities provided with high-quality across all cultures and genders;
- All functionalities and information that are tailored to meet the needs and interests are identified and provided; and
• A range of functionalities for systematic risk assessment and monitoring processes are implemented and specified for gender-based and sociocultural changes over time.

These points lead to the following sub-questions of the research question RQ1 in Chapter 1, R1.1-R1.3 were presented in Section 3.1.1, and R1.4-R1.7 in Section 4.3:

RQ1.8 What are the gender and cultural differences in the use of the features provided by the system?

RQ1.9 What are the gender and cultural differences in the needs of the system features?

We address both questions in the context of eLearning systems, which is closely related to social activities and has easier access to study; see Section 4.4.3. The study is performed in Australia and Saudi Arabia, that have different cultural profiles according to the theory of culture by Hofstede et al. (2010), see Section 2.3.

4.4.1 Analysis

We performed coding themes to extract the free description of short answers based on gender from those in learner and instructor roles. The themes included five characteristic categories of eLearning systems. Four characteristics content, communication, assessment and explicit learner support were identified by Goldsworthy and Rankine (2009). We added a new category, quality functionality, to cover functional as well as non-functional characteristics of eLearning systems during the analysis. We also believe the quality functionality is a crucial characteristic, and hence define the five categories as follows:

• **Content functionality:** including course content resources such as lecture notes, slides, and media recording, reading materials, and interactive resources;

• **Communication functionality:** having email, discussion board, social media, announcements, text and video chats;

• **Assessment functionality:** consisting of tests and quizzes, assignment management, grade books, practice activities, past exams, feedback and surveys;

• **Explicit learner support functionality:** involving calendar and schedule, Turnitin for plagiarism reporting, check-list for task and external supported software; and

• **Quality functionality:** involving all software quality such as availability, performance, integrability, usability and portability.

Each answer to the three open-ended questions was transformed from variables to values against the five categories. For example, one participant responded to ‘What kind of functionality are you using?’
with the statement ‘Discussion board and assignments page, as well as coursework page (lectures and tutorials/labs)’, so we annotated 1 against content functionality, communication functionality, and assessment functionality. Notably, we annotated 1 if a participant’s answer included more than one functionality of each category. For instance, if participant responded with ‘Discussion board, email and text chat’, we assigned 1 in front of communication functionality. This transforming in coding themes is to value what functionality is used, not how many times they have been used. Thus, the frequency of used functionality was ignored. After interpreting the responses, we performed a statistical analysis to examine the data, determine meaningful relationships and to visualise the representation of results.

### 4.4.2 Results

The questionnaire was sent via email to two different universities in Australia and Saudi Arabia. A total of 174 male and female participants, who used eLearning systems either as learners or as instructors, completed and returned their responses. There were 11% female and 40% male participants from Australia. In Saudi Arabia, there were 6% female and 43% male participants (see, Figure 4.8 and Table 4.7).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Country</th>
<th>Australia</th>
<th>Saudi Arabia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Australia</td>
<td>69</td>
<td>75</td>
<td>144</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>20</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>89</td>
<td>85</td>
<td>174</td>
</tr>
</tbody>
</table>

Figure 4.8: Gender percentage of participants from Australia and Saudi Arabia

A descriptive statistics of the used, requested and deficient functionalities presented in Tables 4.8 and 4.9, see statistics symbols and description on Page 58. The data is grouped by gender and country to determine the statistical significance between them using the one-way (ANOVA) and two-sample t-test. As result, there is a significant difference between the gender in the requested functionalities at 95% confidence interval ($p \leq 0.05$) for Australia ($p < 0.036$) and Saudi Arabia ($p < 0.020$), see Table 4.8. However, the differences between group means are not
statistically significant that determine by the one-way ANOVA \( F(11, 35) = 1.608, p = 0.139 \), cf. Table 4.9.

### Table 4.8: Descriptive statistics: gender and country

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Country Groups</th>
<th>Australia</th>
<th>Saudi Arabia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>Count</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td>80</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>20</td>
<td>8.33</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>23.19</td>
<td>6.66</td>
</tr>
<tr>
<td></td>
<td>Standard Error</td>
<td>11.60</td>
<td>3.84</td>
</tr>
<tr>
<td></td>
<td>Variance</td>
<td>53.8</td>
<td>44.33</td>
</tr>
<tr>
<td></td>
<td>t-value</td>
<td>0.955</td>
<td>1.550</td>
</tr>
<tr>
<td></td>
<td>Two-tail p-value</td>
<td>0.394</td>
<td>0.261</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requested functionalities</th>
<th>Count</th>
<th>5</th>
<th>5</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum</td>
<td>42</td>
<td>14</td>
<td>37</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td>8.4</td>
<td>2.8</td>
<td>7.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>4.22</td>
<td>1.30</td>
<td>3.78</td>
<td>0.71</td>
</tr>
<tr>
<td>Standard Error</td>
<td>1.89</td>
<td>0.58</td>
<td>1.69</td>
<td>0.50</td>
</tr>
<tr>
<td>Variance</td>
<td>17.8</td>
<td>1.7</td>
<td>14.3</td>
<td>0.5</td>
</tr>
<tr>
<td>t-value</td>
<td>2.836</td>
<td>3.346</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-tail p-value</td>
<td>0.036</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deficient functionalities</th>
<th>Count</th>
<th>5</th>
<th>4</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum</td>
<td>38</td>
<td>19</td>
<td>28</td>
<td>6</td>
</tr>
<tr>
<td>Mean</td>
<td>7.6</td>
<td>4.75</td>
<td>7</td>
<td>1.5</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>11.59</td>
<td>5.19</td>
<td>7.57</td>
<td>0.58</td>
</tr>
<tr>
<td>Standard Error</td>
<td>5.18</td>
<td>2.59</td>
<td>3.79</td>
<td>0.29</td>
</tr>
<tr>
<td>Variance</td>
<td>134.3</td>
<td>26.92</td>
<td>57.33</td>
<td>0.33</td>
</tr>
<tr>
<td>t-value</td>
<td>0.492</td>
<td>1.449</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-tail p-value</td>
<td>0.640</td>
<td>0.243</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4.9: ANOVA testing result

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>( F )</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1784.328723</td>
<td>11</td>
<td>162.2117021</td>
<td>1.608035227</td>
<td>0.1395026</td>
</tr>
<tr>
<td>Within Groups</td>
<td>3530.65</td>
<td>35</td>
<td>100.8757143</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5314.978723</td>
<td>46</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4.4.3 Discussion

In what follows, we discuss the major findings of the study, in connection with the research questions.

**RQ1.8: What are the gender and cultural differences in the use of the features provided by the system?**

Saudi Arabian females, as shown in Figure 4.9, provided the highest number of all participants who use the content and assessment functionalities of eLearning systems, at 30% and 40%, respectively. In Australia, more female participants than male participants used the content, communication and explicit learning support features. Males in Saudi Arabia had the lowest...
percentages for content and communication functionalities of eLearning systems, but they used the assessment feature more than Australian males.

The results presented in Figure 4.9 indicate that females’ and males’ preferences for usage of eLearning system features are different in Saudi Arabia, whereas in Australia both genders had no significant differences in the functionalities they used, cf. Table 4.9. This finding correlates with results of Pan and Jordan-Marsh (2010) as well as of Jones et al. (2009), who analysed gender and cultural differences in internet use. Similarly, Rovai (2007) reported culture and gender influence on communication and understanding during online discussions in eLearning systems. The reason that female learners in Saudi Arabia access and use eLearning systems more than male learners might be the single-gender education system: Female learners communicate with male instructors online, as they might not be allowed face-to-face in the classrooms. In contrast, in Australia learners of both genders can meet their instructors face-to-face interactions in classrooms.

**RQ1.9: What are the gender and cultural differences in the needs of the system features?** Thus, what type of functionalities of eLearning systems are in demand? What functionalities are not provided and what need to be improved from gender-based perspectives in Australia and Saudi Arabia?

Figure 4.10 illustrates the differences in requested functionalities of eLearning systems between Australia and Saudi Arabia for both genders. The quality and assessment functionalities were the most demanded by females in Australia and Saudi Arabia. Australian males requested more functionalities than did Saudi Arabian males. Further, the communication functionality in Australian systems was requested mostly by females. However, the results in Figures 4.10 and 4.11 show that there are differences across-culture in the requested functionalities as well as improvements required of features in eLearning systems. These findings agree with those Tuunanen and Kuo (2015) on the point that culture affects user needs.

More than 40% of females and males in Australia requested quality improvements for eLearning systems, which was the highest (see, Figure 4.11). Almost 25% of female participants in
Australia requested that the communication functionality of eLearning systems be improved while 20% of female participants in Saudi Arabia requested the improvement of the assessment feature. The content functionality of eLearning systems was requested to be improved by only by ~5% of Australian male participants.

![Figure 4.10: Functionalities requested: comparison by gender and country](image)

Figure 4.11: Comparison of deficient functionalities between female and male responses in Australia and Saudi Arabia

### 4.5 Validity and reliability

To ensure the validity and reliability of this research, we addressed and mitigated potential threats. Creswell (2002), Easterbrook et al. (2008) suggested four criteria for validity (construct, internal, external, and reliability) to provide an inference and valid study.

- **Construct validity:** Although the questionnaire was reviewed and the participant information having question and project details was provided, the questions might be misunderstood. This issue could affect the result. Some functionalities were requested, but they were available in their systems. Further, the questionnaire was translated into the Arabic language, and
hence, the received responses, which are in Arabic, were translated into English before extracting the description. The threat of extracting different responses in the languages was addressed through involving two external translators. Another threat in the coding process might be transferring functionalities with projective contents, and hence, the functionalities were identified as functionality units of both Bb and D2L through the developer website and guidelines as well as literature reviews. In addition, only two universities were selected because of time and cost limitation to present the two cultures of Saudi Arabia and Australia. The education systems of these two countries are incredibly different. This threat resulted in exploring only two eLearning systems, Bb and D2L.

- **Internal validity:** To ensure validity of developing knowledge about eLearning systems in different geographical areas, questionnaires were distributed to targeted participants at the end of the semester. In addition, we sent the questionnaire to two universities in two different countries because of the difficulty in requesting consent and ethical approval from others. This threat results in the analysis of only two systems used by those two universities, Bb and D2L.

- **External validity:** The questionnaire was voluntary, and selection of participants was not controlled. This threat led to have a small size of participants compared to the population of UQU and RMIT universities. We expected 300 participants would answer the survey, but we received 179 responses, so the completion rates is 59.66%. Another threat that might affect the results was the small number of females. We received around 17% responses from females. To mitigate the small number of participants and female threats, we sent the recruitment email two times.

- **Reliability:** To validate the transformation, apart from setting the coding strands of functionality units, we analysed the responses and inspected responses within assigned codes and categories. We randomly chose participants and checked their replies to ensure that values were assigned to appropriate categories. Further, the grouping of categories was checked to ensure that merged categories had similar characters.

### 4.6 Summary

In this chapter we discussed an empirical investigation of functionalities, retention procedures and policies and energy consumption of eLearning systems. Questionnaires were distributed to three stakeholder groups (learners; instructors; and IT support personnel and administrators) in eLearning systems at RMIT University and UQU. The completed and returned responses were analysed via mixed-method qualitative and quantitative approaches.

The findings of this survey are an important step in recognising the functionalities of eLearning systems that are provided and used; provided and need to be improved; and not provided and needed, for learners and instructors. These users demand appropriate and high-quality features
of eLearning systems. Improvement in the quality of eLearning systems will help to increase the acceptance, efficiency and satisfaction of learners and instructors. The period of retention of course material and data, as well as energy usage, was analysed and explored; universities should address the lack of knowledge about retention procedures and policies towards practising environmental awareness and employing green strategies.

This conclusion highlights the fact that gender and cultural background could be taken into account during Requirements Engineering (RE) activities and for eLearning software system operation to ensure social sustainability. Developing tailored and distinct needs analyses of stakeholders; providing resources and training; and reporting gender-disaggregated data and gender-sensitive indicators are core social sustainability requirements for the longevity of software systems. Hence, sustainable eLearning needs not only sustainable business models, pedagogical strategies and university support but also sustainable eLearning systems that will provide high-quality functionalities, meet stakeholder needs, ensure reduction in cost and respect natural resources.
Chapter 5

Framework for Software Sustainability Profiling (SuSoftPro)

“Serendipity. Look for something, find something else, and realize that what you’ve found is more suited to your needs than what you thought you were looking for.”

–Lawrence Block, 2008

This chapter introduces a framework for SuSoftPro (the name stands from Software Sustainability Profiling). The goal of the framework is to analyse sustainability requirements for long-living software systems including eLearning systems. To achieve this goal, we apply a quantitative approach that includes a Fuzzy Rating Scale (FRS)-based questionnaire to rank the sustainability requirements, and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to provide a basis for software sustainability profiling. The core profiling elements in our framework are:

Copyright/credit/reuse notice:

This chapter content is based on materials that have been previously published as:

1. Sustainability five-star rating,
2. Visualisation of the five sustainability dimensions, user can select between two views as a polar area chart or bar chart detailing combinations for individual, social, technical, economic and environmental dimensions, and
3. Bar graph of the sustainability level for each requirement.

The elaborated profiling framework covers the five dimensions of sustainability to quantify the first-order of sustainability requirements for any software system not only during the requirement gathering phase but also during the maintenance phase of the software system life-cycle.

The rest of the chapter is organised as follows. Section 5.1 introduces the framework. The tool-support for software sustainability profiling is presented in Section 5.2. Section 5.3 discusses the tool support for Requirements Engineering (RE) activities. Section 5.5 summarises the core contributions of our work.

5.1 Framework for sustainability profiling

The general idea of the framework workflow is presented in Figure 5.1. To measure the sustainability aspects of the requirements, we adopted the FRS approach (see Section 2.4.1). Requirements are rated against sustainability dimensions, which yields the input for the TOPSIS procedure (see Section 2.4.2). We selected TOPSIS for our sustainability profiling framework, since this technique has been successfully used for prioritising requirements and solving conflicts between Non-Functional Requirement (NFR), cf. (Achimugu et al. 2014, Behzadian et al. 2012, Mairiza et al. 2014). Previously, TOPSIS was used without taking into account sustainability aspects, but an extension to evaluate sustainability requirements is possible and easy to implement. In the sustainability dimensions, we have the same type of relationships among requirements:

1. Each requirement has effects on other requirements, and
2. Each requirement has positive or negative effects on sustainability dimensions that could be maximised or minimised during the TOPSIS procedure.

Figure 5.1: SuSoftPro: process model
The results provided by TOPSIS will create a basis for sustainability profiling. Using these results, our framework determines the sustainability of:

1. Each software requirement,
2. Software system as whole.

This is presented in a five-star rating within each level of sustainability dimension and the overall sustainability of each requirement. The analytical approach (see, Figure 5.1) consists of the following seven core steps that allow requirements engineers to:

1. Define stakeholder groups: through creating groups based on stakeholders’ role or expertise, and then assign this group to one or more of the five sustainability dimensions.
2. Define questions: generated automatically as five instructions with regard to a sustainability dimension for the FRS questionnaire;
3. Define requirements: via the specifications of the high-level requirements and allot them to related groups affecting stakeholders and requirement ownership;
4. Assign stakeholders: to related groups based on stakeholders’ role in the system and their areas of expertise after defining them;
5. Rate requirements: by enabling stakeholders to use the ratio quantity approach as FRS responses;
6. Analyse sustainability: with Multi-Criteria Decision Analysis (MCDA) using the TOPSIS approach to determine the level of sustainability dimensions and sustainability requirements measurements; and
7. Generate software sustainability profiling: including a five-star sustainability rating label, visualisation of sustainability dimension levels, and bar-chart graph for each sustainability requirements level.

Our approach to sustainability profiling provides insight solutions and predicts the outcome value before developing software systems for requirements engineers and stakeholders to:

- Identify the predictability of sustainability in software systems,
- Analyse requirement’s sustainability and dependencies, and
- Distinguish the sustainability dimensions that interact and overlap.

In the following sections, we discuss the core steps of the SuSoftPro methodology and tool-support.
5.1.1 Defining groups

A group has to be created and allotted to one or more of the five sustainability dimensions. Thus, the group assists requirement engineers in building the questionnaire and managing the requirements and stakeholders. For instance, if a group is allocated to the individual, social and economic sustainability dimensions, any stakeholder in this group will only answer relevant questions from the individual, social and economic sustainability aspects for each requirement assigned to this group. Assigning stakeholders and requirements to groups will reduce the number of questions. For instance, if there are 80 requirements and there is no group, a stakeholder has to answer 400 questions to rate all requirements (80 requirements × 5 sustainability dimensions). However, if a stakeholder is assigned to a group having 10 related requirements and 2 related sustainability dimensions, they would need to answer only 20 questions. Requirement engineers should group stakeholders based on their role in the system and their areas of expertise.

In addition, they have to allocate requirements to related groups with regard to affected stakeholders and requirement ownership. For example, administrators and managers could be grouped and assigned to social and economic sustainability aspects while environmental experts can be grouped and allocated to the individual, social and environmental sustainability aspects. In the same way, administrative requirements can be assigned to administrators, managers and environmental experts groups.

5.1.2 Defining questions

To build a new questionnaire, five questions (instructions to rate a requirement with regard to a sustainability dimension) are generated automatically. Thus, for each requirement, \( k \) questions will be created, where \( 1 \leq k \leq 5 \). Each question should present a single sustainability dimension perspective, which is covered by the requirement. The generated instructions can be revised and refined by requirements engineers as well as sustainability experts. However, all the amendments must be completed before at least one stakeholder starts answering the questionnaire: if even one stakeholder begins responding to the questionnaire, the corresponding instructions for updating requests are immediately locked. All instructions have the following format:

\[
\text{'Rate the influence of the requirement on the X sustainability'},
\]

where \( X \) is replaced in a concrete case by the corresponding sustainability dimension: \textit{individual}, \textit{social}, \textit{technical}, \textit{economic} and \textit{environmental}.

5.1.3 Defining requirements

Requirements engineers can create, export and/or import Comma Separated Values (CSV) files with the specifications of the high-level requirements, to assign them to created groups and to display them within a created questionnaire. The export and import feature allows the exchange of requirement specifications with other tools such as ReqMan and Rational DOORS. These tools
are using the standard format of CSV file. The CSV file should follow the Rational DOORS (Jazz-Platform 2017) prerequisite rules.

The first header row should contain \textit{artifact type, primary text, name, description} and \textit{owner}, where \textit{name} is a requirement name, and \textit{primary text} as the description of the requirement. An example of exported CSV file is:

\begin{verbatim}
ArtifactType, PrimaryText, Name, Description, Owner
\end{verbatim}

### 5.1.4 Assigning stakeholders

After creating and assigning a group to one or more of the sustainability dimensions and requirements, stakeholders can be allocated to the group. This allocation allows questions to be displayed and answered with regard to requirements of the selected sustainability dimensions.

SuSoftPro enables requirements engineers to create, export, and/or import stakeholder details. The details include a stakeholder’s name, email, and an allocated group that is assigned to one or more of the five sustainability dimensions. SuSoftPro generates an auto-sign-in and unique hyper-link for each of the stakeholder, permitting them to access and answer the questionnaire, which is customised for the corresponding group. The requirements engineers have the ability to update stakeholders’ details or delete them. The stakeholder list has a column to indicate the status of stakeholders, that is, \textit{waiting}, \textit{in progress} or \textit{submitted}. If a stakeholder is allocated to a group to rate requirements, their status in the project will become \textit{waiting} until they start answering the questionnaire. As soon as they start responding, their status will be updated to \textit{in progress} until they finish and submit their questionnaire; then the status will be changed to \textit{submitted}.

### 5.1.5 Rating requirements

Stakeholders can respond to a questionnaire when they receive an email with the corresponding access link. For each high-level requirement to be rated, the stakeholder can rate its influence on the sustainability dimensions using the interface presented on Figure 5.2, which shows how the FRS has been implemented. Each question includes

- Description of the requirement,
- Instruction to rate the requirement within the corresponding sustainability dimension,
- FRS to provide the rating.

The FRS is a form of trapezoidal fuzzy number from the two intervals as \( Tra(a, b, c, d) \), where \( 0 \leq a \leq b \leq c \leq d \leq 1 \) (see, Section 2.4.1). The stakeholders have the ability to ignore any question that they cannot, or do not want to, answer if they are not familiar with the requirements or these are not related to them. The ignored question will not be included while generating the sustainability profile.
The questionnaire displays the number of answered and ignored questions (i.e., the question that the stakeholder does not want to answer), as well as buttons to save the questionnaire for continuing at another time, for ignoring the question, and for moving between questions. Thus, each stakeholder answers allotted questions from varying views of certain sustainability dimensions by

1. Scaling a core response to be considered as *fully compatible*, and
2. Determining a support response to be considered as *compatible to what extent*.

The scale goes is 0 (critical value of sustainability) to 100% (green value). The two-level scales will prevent imprecision and error-proneness as per Lubiano et al. (2016). Finally, the stakeholder has to submit the questionnaire for analysis.

### 5.1.6 Analysing sustainability

The results of the rated requirements become inputs for the TOPSIS method (see, Section 2.4.2), which is applied twice as follows:

- **First round**: Apply sustainability dimensions as criteria to analyse each dimension within all requirements and overall sustainability rating for the software; and

- **Second round**: Apply requirements as criteria to determine overall sustainability within the statistical separation measures of requirements’ effect for each requirement.

The TOPSIS-based analysis is implemented as a dynamic feature: The calculations are (re)started as soon as any stakeholder submits the responses (and the status is labelled as *submitted*). The ignored questions within the response as well as any response currently having status *waiting or in progress* are not taken into account for the analysis.

### 5.1.7 Generating software sustainability profiling

The results of the TOPSIS analysis allows the generation of sustainability profiling which is visualised representing the result. Responses of the questionnaire are analysed and then presented on the dashboard and in a generated report. As presented in Figure 5.3, the profiling includes:
• **Sustainability five-star rating** to present the average values for sustainability dimensions and requirements (taking into account both TOPSIS rounds);

• **Five sustainability dimensions** to illustrate each sustainability level for each dimension, presented either as a polar-area diagram or as a bar graph, which allows the user to estimate how sustainable the system might be with respect to the five sustainability dimensions, and what parts might require improvements; and

• **Bar graph** to show the overall sustainability effect of each requirement and to identify easily the requirements that have a high positive or negative effect on the system sustainability.

A blueprint of a sustainability profile (sustainability rating label) for a software system is presented in Figure 5.3. Considering different information in the profiling, we simplify and visualise the

![Sustainability Profile Diagram](image)

Figure 5.3: Sustainability profile of a software system using the default colour schema.

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Colour Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-100</td>
<td>Dark green</td>
<td>Green (Vibrant)</td>
</tr>
<tr>
<td>60-79</td>
<td>Light green</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>40-59</td>
<td>Yellow</td>
<td>Basic</td>
</tr>
<tr>
<td>20-39</td>
<td>Orange</td>
<td>Unsatisfactory</td>
</tr>
<tr>
<td>0-19</td>
<td>Red</td>
<td>Critical</td>
</tr>
</tbody>
</table>

Table 5.1: Key chart in software sustainability profiling

result by creating a key chart with five categories as shown in Table 5.1. This key chart includes numeric variables in percentages, colour codes for visualisation, and linguistic variables as a description. We follow the colouring schema of traffic lights, where critical values are marked red and green (vibrant) are marked green to increase readability and graphic visualisation. These colours and their descriptions have been used in *Green IT* and *Sustainability Developments*.

### Accessibility

To increase accessibility of our framework, we provide another colouring option to present the visualisation of sustainability profiling for colour-challenged people with colour-deficient vision.
Table 5.2: Comparing initial proposed colour scheme with three types of colour vision deficiencies

<table>
<thead>
<tr>
<th>True colour</th>
<th>Protanopia</th>
<th>Deuteranopia</th>
<th>Tritanopia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Yellow</td>
<td>Green</td>
<td>Blue</td>
</tr>
<tr>
<td>Green</td>
<td>Red</td>
<td>Blue</td>
<td>Yellow</td>
</tr>
<tr>
<td>Blue</td>
<td>Green</td>
<td>Red</td>
<td>Yellow</td>
</tr>
</tbody>
</table>

Table 5.3: Comparing alternative colour scheme with three types of colour vision deficiencies

<table>
<thead>
<tr>
<th>True colour</th>
<th>Protanopia</th>
<th>Deuteranopia</th>
<th>Tritanopia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Brown</td>
<td>Blue</td>
<td>Yellow</td>
</tr>
<tr>
<td>Blue</td>
<td>Brown</td>
<td>Red</td>
<td>Yellow</td>
</tr>
<tr>
<td>Yellow</td>
<td>Brown</td>
<td>Blue</td>
<td>Red</td>
</tr>
</tbody>
</table>

Figure 5.4: Simulation of different colour deficiencies. By Johannes Ahlmann (2011), via Flickr/Wikimedia Commons. Used under Creative Commons Attribution 2.0 Generic License.

According to Chaparro and Chaparro (2017), one in every 12 people has a colour vision deficiency, and there are three different colour vision deficiencies, see Figure 5.4:

- **Protanopia (red-blindness)**: reduced or missing sensitivity to light/red colour,
- **Deuteranopia (green-blindness)**: reduced or missing sensitivity to green light/colour, and
- **Tritanopia (blue-blindness)**: reduced or missing sensitivity to blue light/colour.

Table 5.2 presents the initial propose colour scheme for colour vision (true colour) as well as the three types of colour vision deficiencies. Since protanopia and deuteranopia can confuse red and green colours in the initial proposed colour scheme, see the similarity of red and green in protanopia and deuteranopia columns in Table 5.2. Hence, the red colour in the proposed colour scheme is replaced with blue and the green with brown when the option to colour-deficient vision...
is selected. The reason of replacing red with blue, and green with brown is because both colours are dominated among the three types. This option ensures better accessibility and an equally user friendly experience to read sustainability profile. Therefore, Table 5.3 illustrate the alternative colour scheme with three types of colour vision deficiencies that adopted from (Wong 2011). The reason of replacing red with blue, and green with brown is because both colours are dominated among the three types.

There are also two options to present the five sustainability dimensions as a polar area chart or bar chart because it might be argued that the polar area chart could be harder to read and needs more effort to analyse represented data than the bar graph. Hence, we provided the bar graph option for representing the five sustainability dimensions.

5.2 SuSoftPro: Software Sustainability Profiling tool

We implemented the methodology as a web-based tool-support, *SuSoftPro*, for all requirement engineers to use, and this tool enables them to:

1. Investigate sustainability of software systems based on the systems’ requirements,
2. Analyse the five sustainability dimensions of software systems,
3. Measure the sustainability of each individual requirement,
4. Visualise analysis results to support decision making towards high-quality software,
5. Involve stakeholders to rate their requirements for one or more of the five sustainability dimensions, and
6. Manage requirement and stakeholder details easily.

In addition, it allows stakeholders to provide their standpoint of sustainability against requirements via rating scale-based questionnaires. To allow requirement engineers and stakeholders to access the SuSoftPro tool from any device having a browser and internet connection, we developed SuSoftPro\(^1\) as a web-based tool. The SuSoftPro was implemented using PHP, MySQL, JavaScript, CSS and HTML5. The current version of the tool provides the following functionality:

- Building a questionnaire with questions on sustainability dimensions,
- Creating and assigning a group for one or more sustainability dimensions,
- Establishing or importing requirement lists,
- Managing stakeholders,
- Rating requirements via FRS with regard to sustainability questions,
- Analysing responses using TOPSIS, and
- Generating software sustainability profiling.

An easy-to-use interface of SuSoftPro allows stakeholders to provide their input by rating high-level requirements from various sustainability perspectives, see Section 6.3. Two different colours are

\(^1\)https://susoftpro.ahmedalharthi.net

(October 31, 2019)
also provided in the tool for practitioners with colour-deficient vision. The SuSoftPro dashboard has the ability to swap colours from red to blue and vice versa for colour-deficient vision to increase the accessibility. The dashboard of the SuSoftPro contains:

- Statistical summary panels of stakeholders, requirements, and the stakeholders’ responses;
- Sustainability profile, including:
  - Overall sustainability five-star rating,
  - Visualisation sustainability dimensions, and
  - Sustainability impact of each requirement;
- Main menu, on the top, including functionality for
  - Creating new profile for certain software or project,
  - Listing all profiles that have been created for current or previous software or projects,
  - Checking and updating the user profiles, and
  - Getting help on how to use the SuSoftPro tool;
- Sidebar menu having the navigation of core features.

The SuSoftPro process is presented in Figure 5.1, and discussed in the previous Section 5.1. SuSoftPro tool-support provides the following features:

- Import/export functionality to exchange the requirements specifications in CSV format, following the Rational DOORS prerequisite rules;
- Functionality to manage the stakeholders and invite them to rate the requirements;
- Automated sustainability analysis using the TOPSIS technique;
- *Sustainability five-star rating* to present the overall rating of sustainability dimensions and requirements;
- *Visualisation of the five sustainability dimensions* to illustrate each dimension level combined in polar-area diagram or bar graph for the software having all rated requirements; and
- *Bar graph* to show an overall sustainability of each requirement.

Thus, requirements engineers (as well as business analysts) could analyse sustainability of systems by including SuSoftPro in their toolkit and involving stakeholders to present their perspective of requirements within sustainability dimensions.
5.3 RE activities support

Figure 5.5 demonstrates how the produced framework can be used during the RE activities. The white rectangles present our framework steps that are performed during RE activities (illustrated in the green chevron shape). We follow the definition of RE activities introduced by Nuseibeh and Easterbrook (2000), Sawyer et al. (1997), Sommerville (2010), Thayer and Dorfman (2000):

- **Requirements elicitation** is the practice of understanding and determining stakeholders’ needs and constraints. To rate the sustainability requirements using the produced framework, at this phase two actions are necessary:
  - \( (A) \) the stakeholders have to be assigned, and
  - \( (B) \) the questionnaires have to be generated.

However, taking into account the long-living nature of the system, reiteration of these steps might be necessary on the management phase, to ensure the sustainability over the software system life-cycle, and hence:

- \( (A') \) new stakeholders can be assigned and
- \( (B') \) the questionnaires can be updated.

- **Requirements analysis** is the practice of refining stakeholders’ needs and constraints by defining the process, data and object of the required system. In this phase, we conduct the following steps of our framework:
  - \( (C) \) the stakeholders rate the requirements,
  - \( (D) \) the sustainability of the system is analysed using TOPSIS,
  - \( (E) \) the sustainability profile is generated.

To ensure longevity of the system, these steps also can be repeated during the management phase.

- **Requirements specification** is the practice of writing down stakeholders’ needs and constraints, and this documentation should be unambiguous, complete, correct, understandable,
consistent, concise and feasible.
The sustainability profile could be seen as one of the inputs in the specification phase.

- **Requirements validation** is the practice of checking that the specification captures users’ needs and constraints. The produced framework does not cover the validation activities, which might be one of the future work directions.

- **Requirements management** is the practice of scheduling and controlling changes and tracking requirements over time. In the case of long-living systems, the management activities are crucial to keep the software system sustainable. Steps $(A) - (E)$ have to be repeated to provide an up-to-date sustainability profile of the system.

5.4 Discussion

Some works on embedding sustainability in the software development process, e.g. (Bovea and Pérez-Belis 2012), are focusing on environmental aspects. In SuSoftPro, contrary to them, we cover individual, social, economic, technical and environmental dimensions. Porras et al. (2017) proposed a manually model-based analysis to evaluate the ICT projects with regard to sustainability effect. Although the model covers sustainability dimension and impacts, the model is not simple and systematic approach to measure sustainability during software developments and usages. There is limited of stakeholders involving to provide sustainability perceptions, so this limitation will lead to a lack of sustainability perceptions.

Mahaux (2013) suggested that additional analysis activities need to have support from participants who are involved as stakeholders in the process of software developments. Hence, involving supported participants will ensure sustainable software. This argument emerges the need of a tool involving supported participants easily, and the SuSoftPro is developed to involve supported participants vis providing their perspective as support. Al Hinai (2014) introduced a number of metrics and an accompanying method for analysing social sustainability requirements of software systems. The method is not systematic and easy to elicit the values because of the variety of translating value, and the potential of conflicting value types.

Chitchyan et al. (2016) presented the results of a qualitative study, which goal was to explore perceptions and attitudes towards sustainability, of requirements engineering practitioners. The lack of methodological support was one of the identified barriers to the engagement with sustainability design in RE practice. The SuSoftPro is a solution to overcome this barrier through engaging practitioners and stakeholders to analyse sustainability.

Becker et al. (2016) compared two projects to illustrate the software development within and without sustainability design, so they stated that requirements engineering is the key to sustainability through following interdisciplinary, stakeholder-focused approach, and systems-oriented as well as supporting by higher management and executives. Their analysis approach is to visualise the systems’ potential impacts as immediate, enabling, and structural impacts within the five
sustainability dimensions. While SuSoftPro visualises the sustainability level of software and requirements within the five sustainability dimensions. Both practices could assist to understand the sustainability of software systems and their impact on sustainability aspects.

A number of requirements engineering tools with general or specific features for eliciting, analysing, modelling, tracing, documenting, managing, and verifying and validating requirements (De Gea et al. 2012). Some of these tools are begin to facilitate web-based solution in order to allow collaborative access to resources, while others particularly dominated tools are becoming more complex and difficult to use. However, none of them has the ability to analyse sustainability requirements by involving stakeholders with regard to the sustainability dimensions. Hence SuSoftPro was developed to enable the analysis of sustainability through extensive questionnaires on requirements which cover the sustainability context of the software and can include a wide range of stakeholders.

5.5 Summary

This chapter presented the SuSoftPro framework and the corresponding web-based tool to analyse sustainability requirements for long-living software systems. This methodology provides a software sustainability profiling that involves the FRS and uses the TOPSIS. Our developed tool-support presents sustainability as a five-star rating label, a visualisation for the degree of the five sustainability dimensions, and a bar graph that illustrates the overall sustainability level for each requirement. The methodology with tool-support enables requirements engineers to define stakeholder groups to be allotted to one or more of the five sustainability dimensions, build a FRS-based questionnaire with regard to a sustainability dimension, specify the high-level requirements and assign them to created groups, assign stakeholders and allow them to rate requirements, analyse sustainability, and generate software sustainability profiling.
Chapter 6

Evaluation of SuSoftPro Framework

“Validity, reliability, comparability, and fairness are not just measurement issues, but social values that have meaning and force outside of measurement wherever evaluative judgements and decisions are made”

–Samuel Messick, 1994

In this chapter, we evaluated the SuSoftPro framework and the corresponding tool-support of analysing sustainability requirements for software systems to gain deeper insight into the framework capability. Figure 6.1 presents a general structure for our evaluation approaches that we will discuss. We analyse the core features of SuSoftPro in comparison with two approaches that employ Multi-Criteria Decision Analysis (MCDA) in Requirements Engineering (RE). We conducted three case studies:

• Two case studies on the Canvas and Desire2Learn (D2L) eLearning systems. The goal was to confirm that the framework fits the purpose as well as to analyse the usability of the framework and to optimise it if necessary, and

• A case study on an eHealth system. The eHealth system case was performed because, after completing the first two case studies, we proposed a hypothesis that the developed framework might be applied to other software domains. Thus, the goal of this case study was to confirm that our framework is a generic method applicable to any domain.

Copyright/credit/reuse notice:

This chapter content is based on materials that have been previously published as:

In addition, we conduct an evaluation questionnaire about our framework with tool-support. The chapter is organised as follows. Section 6.1 discusses a comparison of SuSoftPro with other frameworks. Section 6.2 presents three case studies. The evaluation questionnaire is provided in Section 6.3.

6.1 Comparison with other frameworks

To analyse and evaluate our SuSoftPro framework, we compared the SuSoftPro framework against two approaches that developed a framework using MCDA and were used for RE domain. This comparative evaluation aims to check the capability and the flow within RE domain as a justification of the developed framework. In the next sections, we address the procedure, analysis and result of the comparative evaluation.

6.1.1 Procedure

To perform comparative evaluation against SuSoftPro, we defined three criteria for selecting frameworks from literature studies as follows:

- **Scope**: Developed for RE context,
- **Process**: Involved MCDA and stakeholders, and
- **Objective**: Analysed sustainability.

Because no study met the three criteria, we removed the objective criterion (analysed sustainability) because no MCDA technique has been used to analyse sustainability within RE as well as sustainability is a new growing topic in RE. Thus, only two frameworks were found: ReproTizer
and sureCM. Then, we specified nine sub-criteria to analyse the three frameworks (SuSoftPro, ReproTizer and sureCM) including the purpose of the methodology in requirement analysis, collection method, weight scale and analysis method that is one type of the MCDA, participant, rank updates such that the methodology can instantly re-compute results, having tool-support, computational complexity and number of criteria, see ‘examines criteria’ in Table 6.1.

6.1.2 Analysis

We analysed SuSoftPro’s core process and features discussed in Chapter 5 with regard to two other frameworks for requirement analysis: ReproTizer and sureCM.

ReproTizer: was elaborated by Achimugu et al. (2016). It allows requirements prioritisation via capturing stakeholders’ requirement ranks through numeric weight scales that are valued between 1 and 5; the prioritised requirements are then analysed using a Weighted Average Decision Matrix (WADM). ReproTizer framework has five steps as follows:

- Define requirements: Requirements engineers specify a requirements list;
- Add stakeholder: Requirements engineers add stakeholders and assign them to requirements;
- Score requirements: Stakeholders score each requirement using a Likert scale from 1 to 5;
- Compute requirements prioritisation: Requirements prioritisation is automatically determined using WADM, after scoring requirements by stakeholders; and
- Generate requirements prioritisation list: The weight of each requirement prioritisation is presented in an ordered list.

sureCM: was introduced by Mairiza et al. (2014), focusing on resolving Non-Functional Requirements (NFRs) such as security-usability conflicts. Similar to SuSoftPro, it also applies the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method to analyse the collected data, but unlike SuSoftPro the sureCM framework does not have any tool support. The sureCM framework has four steps:

- Identify NFRs conflict: via conflict relationship diagram, requirements engineers need to identify whether NFRs conflict;
- Rank characterize conflict: through recognising parameters of alternative functionality, metrics, or measures;
- Analysing solution: via TOPSIS the best alternative solution and the worst solution are calculated; and
- Present selected solution: An alternative solutions list is presented from the highest to the lowest rank.
Table 6.1: Comparisons of employing multi-criteria decision analysis in requirements engineering domain

<table>
<thead>
<tr>
<th></th>
<th>Examines criteria</th>
<th>SuSoftPro (Mairiza et al. 2014)</th>
<th>sureCM</th>
<th>ReproTizer (Achimugu et al. 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framework focus</td>
<td>Sustainability</td>
<td>Resolve conflict</td>
<td>Prioritisation</td>
<td></td>
</tr>
<tr>
<td>Collection method</td>
<td>Online questionnaire</td>
<td>Various methods</td>
<td>Online questionnaire</td>
<td></td>
</tr>
<tr>
<td>Weight scale</td>
<td>'rational numbers' (fuzzy rating scale)</td>
<td>'natural numbers' (several scales are used)</td>
<td>'natural numbers' (scale from 1 to 5)</td>
<td></td>
</tr>
<tr>
<td>Analysis method</td>
<td>TOPSIS</td>
<td>TOPSIS</td>
<td>WADM</td>
<td></td>
</tr>
<tr>
<td>Participants</td>
<td>All stakeholders</td>
<td>Some stakeholders</td>
<td>All stakeholders</td>
<td></td>
</tr>
<tr>
<td>Rank update</td>
<td>Yes</td>
<td>Not defined</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Tool support</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Manual computations</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Number of criteria</td>
<td>1st round: Five criteria, and 2nd round: Multi-criteria</td>
<td>Two criteria</td>
<td>Multi-criteria</td>
<td></td>
</tr>
<tr>
<td>for analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.1.3 Results

As shown in Table 6.1, both SuSoftPro and ReproTizer work with more than two criteria for analysis, and are supported by a tool, providing a fully systematic computation to prevent errors. The sureCM framework is based on a semi-automatic computation and data collection (requirements rating), which are more error-prone than a fully automated solution. Another advantage of SuSoftPro is utilising the Fuzzy Rating Scale (FRS), which allows higher precision of requirements’ rating. Although the FRS application provides a more accurate scale than the Likert scale to capture real-valued responses, the FRS is not a fully user-friendly scale (de Sáa et al. 2015). With minor orientation and guidance, it will be sufficient to use the FRS for responding. Neither ReproTizer nor sureCM support the sustainability context, whereas SuSoftPro supports and utilises a fully systematic and comprehensive discovery methodology to analyse sustainability requirements. The core results of the comparison are summarised in Table 6.1.

6.2 Case studies

We present two case studies from the domain of eLearning systems (i.e., learning management systems), where longevity plays an important role to enable a holistic review and to understand the capability of the SuSoftPro framework. In Chapter 3, we analysed the sustainability requirements of eLearning systems, which provides a basis for these case studies. Moreover, when we were presenting our vision of the SuSoftPro framework at the 23rd Asia-Pacific Software Engineering Conference, one of the questions that we received was whether our framework can be applied to other domains or is it specific to education domain. This conversation as well as the result of the first two case studies led to two sub-questions of research question RQ2 (Chapter 1) that will assist us in examining the generalised application of the SuSoftPro framework and tool:
RQ2.1: Does the proposed framework fit the purpose of sustainability analysis?

RQ2.2: Can we generalise the finding to cover sustainability dimensions in other domains such as eHealth systems?

Therefore, we conducted a case study from the eHealth domain to illustrate how SuSoftPro can be applied not only in the education domain but also in any software domain. The eHealth case is based on a real-life project, a Skin Cancer Information System (SCIS), cf. (Alharthi et al. 2013). In an overview of this section, we apply the seven core steps of the SuSoftPro framework for the three case studies, two on eLearning systems and one on an eHealth system.

### 6.2.1 eLearning systems

We selected two eLearning systems, which are used in two different universities of countries that have different cultural profiles according to the Hofstede’s cultural theory:

- Blackboard (Bb) in the RMIT University in Australia, and
- D2L in Umm Al-Qura University (UQU) in Saudi Arabia.

This allowed us to differentiate the social sustainability aspect of the two countries. We explored and analysed the sustainability of Bb and D2L, see Chapter 4 for more details. After we conducted this empirical study, RMIT University switched from Bb to another eLearning system, Canvas. Hence, to keep the same social environment, we conducted the further case studies on Canvas and D2L.

Canvas\(^1\) is a cloud-based Learning Management System (LMS) being developed as an open-source system by Instructure, Inc. We identified 38 high-level requirements of Canvas for higher education edition from Canvas documentation\(^2\). Further, D2L\(^3\) is a cloud-based system developed by Desire2Learn Corporation. In the D2L documentation, 36 high-level requirements of D2L for higher education are described\(^4\).

**Procedure**

For conducting the case studies, we identify the high-level software requirements of Canvas and D2L from the available documentation of these systems on developer websites. Both systems have the following four key stakeholders:

1. Learners,
2. Instructors,
3. Administrators and related staff, and
4. IT support personnel and developers.

\(^1\)https://www.canvaslms.com
\(^2\)https://community.canvaslms.com/docs/DOC-10745-canvas-basics-table-of-contents
\(^3\)https://www.d2l.com
\(^4\)https://www.d2l.com/en-apac/resources/
On obtaining ethical approval from RMIT University and UQU to recruit stakeholders, two separately sustainable software profiles in the SuSoftPro tool, the Canvas profile and D2L profile, are initiated (see survey questions, participant information and recruitment advertisements in Appendix B). In both profiles, we employ the SuSoftPro tool to implement the seven core steps that are discussed in Section 5.1. Thus, we:

1. Define four stakeholder groups and assign them to sustainability aspects as presented in Table 6.2. The assignment of sustainability dimensions approach, which was introduced by Penzenstadler et al. (2013), is based on stakeholders’ area of expertise and what the system might affect them on related sustainability dimensions (called the bottom-up approach). Firstly, we identified the role list of stakeholder and then matched them to the five sustainability dimensions on the basis of direct or indirect connection to stakeholders.

Table 6.2: Assigned sustainability dimensions to stakeholder groups of Canvas and D2L systems

<table>
<thead>
<tr>
<th>Group</th>
<th>Sustainability dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Individual</td>
</tr>
<tr>
<td>Learner</td>
<td>✓</td>
</tr>
<tr>
<td>Instructor</td>
<td>✓</td>
</tr>
<tr>
<td>Admin</td>
<td>✓</td>
</tr>
<tr>
<td>IT support/ developer</td>
<td>✓</td>
</tr>
</tbody>
</table>

Therefore, we assigned learner and instructor groups to the individual dimension. Stakeholders in both groups may utilise the eLearning systems to engage with learning in a more convenient way and time. This engagement could lead to enabling individuals to thrive, as the systems were developed to support their learning process. In addition, instructor and admin groups were allocated to the social dimension because they are decision-makers at the educational institution to codify learning process and administration process. Their responsibility and expertise may affect the surrounded and connected society to their institution. IT support and developers were assigned to the technical and environmental sustainability dimensions, as they are the experts of technology and related services, which might affect the systems and environment. Also, the admin group was assigned to economic dimension because they are responsible for investments, procurement and good governance in drafting the improvement of the educational institution. Their knowledge and awareness could lead to sustaining the economic aspect of the educational institution and its software systems.

The assignment of stakeholders’ groups to the sustainability aspects is an important step. However, its success also depends on the actions that are typically performed at the very beginning of the project: identification of the stakeholders’ groups and selection of individual stakeholders to gather the requirements. In the case they lack expertise in the corresponding field, the gathered requirements might lead to measuring of the perceived sustainability, instead of the actual sustainability. For example, it might be argued that learners are not yet experts on a related aspect of individual sustainability. If this is the case, the gathered data will lead to the measurement of the perceived sustainability instead of the real one, for the
corresponding dimension. However, as the students are typically aware of their learning patterns and most of their learning needs and expectations, we consider this case as unlikely for our case study. Overall, stakeholders were selected on the basis of their primary role involving and expertise and mapped to affect directly or indirectly sustainability dimensions to measure the actual sustainability.

2. Verify the five questions generated for rating requirements in the generated questionnaire; see Table 6.3.

Table 6.3: Generated questions (instructions) to rate requirements in the case studies

<table>
<thead>
<tr>
<th>Sustainability aspects</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>Rate the influence of the requirement on the individual sustainability</td>
</tr>
<tr>
<td>Social</td>
<td>Rate the influence of the requirement on the social sustainability</td>
</tr>
<tr>
<td>Technical</td>
<td>Rate the influence of the requirement on the technical sustainability</td>
</tr>
<tr>
<td>Economic</td>
<td>Rate the influence of the requirement on the economic sustainability</td>
</tr>
<tr>
<td>Environmental</td>
<td>Rate the influence of the requirement on the environmental sustainability</td>
</tr>
</tbody>
</table>

3. Import the identified requirements for both systems as in Tables 6.6 and 6.7, and assign them to relevant groups (see, complete requirements description and assignments in Appendix C),

4. Assign the defined four key stakeholders to related groups,

5. Distributing a public link for Canvas stakeholders in RMIT University, and another link for D2L stakeholders in UQU to access the questionnaire (see the interfaces of rating requirement in Figure 6.2),

6. Monitor the systematic analysis of sustainability requirements, and

7. Generate sustainable software profiles for Canvas and D2L systems.

**Results**

We distributed emails with an access link of the SuSoftPro tool to the four type of key stakeholders of Canvas and D2L. Subsequently, 125 participants voluntarily agreed to rate requirements with respect to their role and system; see Table 6.4. In addition, Table 6.5 presents the number of questions in the questionnaire for each role.

Table 6.4: Number of stakeholders for each role in each eLearning system

<table>
<thead>
<tr>
<th>Role</th>
<th>System</th>
<th>Canvas</th>
<th>Desire2Learn</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner</td>
<td>32</td>
<td>56</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>Instructor</td>
<td>7</td>
<td>14</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Administrator and related</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>IT support and developer</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>79</td>
<td>125</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 6: EVALUATION OF SUSOFTPRO FRAMEWORK

Questionnaire

Questionnaire for Canvas - RMIT profile.

Requirements: Arc

Requirements description: Canvas shall provide Arc to be a video learning platform that shall turn content into conversation, connection, and collaboration. Arc’s interface shall let students and instructors engage with media content by commenting directly on the media timeline.

Question 68

Rate the influence of the requirement on the social sustainability

Answer:

![Rating Scale]

Figure 6.2: SuSoftPro: rating of one Canvas requirement’s effect on social sustainability

Table 6.5: Number of questions for each role in the questionnaire

<table>
<thead>
<tr>
<th>Role</th>
<th>System</th>
<th>Canvas</th>
<th>Desire2Learn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner</td>
<td>Canvas</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>Instructor</td>
<td></td>
<td>68</td>
<td>66</td>
</tr>
<tr>
<td>Administrator and related</td>
<td></td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>IT support and developer</td>
<td></td>
<td>76</td>
<td>72</td>
</tr>
</tbody>
</table>

The generated Canvas profile is shown in Figures 6.3 and 6.4 as well as Table 6.6. Relying on responses from 46 participants, who submitted their standpoint on certain sustainability dimensions with regard to Canvas requirements, the overall sustainability of the Canvas at RMIT University has ★★★ three-star rating (3 out of 5). The indication for the five sustainability dimensions is as follows:

- Only the individual dimension is in a satisfactory range that is above 0.60 (the corresponding bar in the chart is light brown for colour-deficiency scheme).
- The technical, social and technical dimensions are between ~0.45 and 0.50 (the corresponding bars in the chart are yellow).
- The economic and environmental dimensions are in the unsatisfactory range, which is around 0.33 (the corresponding bars in the chart are orange).
SECTION 6.2: CASE STUDIES

Figure 6.3: Generated result for Canvas sustainability profile

Table 6.6: The results of Canvas requirements. The sustainability rate is the result given by 46 stakeholders who rated between 0 and 1 where 0 the worst and 1 is the best.

<table>
<thead>
<tr>
<th>Requirement name</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Announcements</td>
<td>0.653561</td>
</tr>
<tr>
<td>Assignments</td>
<td>0.610519</td>
</tr>
<tr>
<td>Calendar</td>
<td>0.594229</td>
</tr>
<tr>
<td>Chat</td>
<td>0.557077</td>
</tr>
<tr>
<td>Collaborations</td>
<td>0.527577</td>
</tr>
<tr>
<td>Conferences</td>
<td>0.581955</td>
</tr>
<tr>
<td>Groups</td>
<td>0.636811</td>
</tr>
<tr>
<td>Discussions</td>
<td>0.539979</td>
</tr>
<tr>
<td>Pages</td>
<td>0.489472</td>
</tr>
<tr>
<td>Outcomes</td>
<td>0.486183</td>
</tr>
<tr>
<td>Roll Call Attendance Tool</td>
<td>0.453021</td>
</tr>
<tr>
<td>Navigation</td>
<td>0.528323</td>
</tr>
<tr>
<td>Quizzes</td>
<td>0.489581</td>
</tr>
<tr>
<td>Question banks</td>
<td>0.440808</td>
</tr>
<tr>
<td>Grades and the Gradebook</td>
<td>0.488973</td>
</tr>
<tr>
<td>Grading schemes</td>
<td>0.43454</td>
</tr>
<tr>
<td>What-If Grades</td>
<td>0.482085</td>
</tr>
<tr>
<td>Rubrics</td>
<td>0.472837</td>
</tr>
</tbody>
</table>

The value in the result is between 0-1 where in the TOPSIS method, 0 represents the worst ideal solution and 1 is the best ideal solution (Behzadian et al. 2012). Further, in the Canvas profiling, four requirements of Canvas (Req. 1, 8, 2 and 30) are at the satisfactory level, whereas mobile features and course setting (Req. 31 and 21) requirements are at the unsatisfactory level at around 0.38 and 0.36, respectively. The rest of requirements of Canvas are at the basic level and are between 0.41 and 0.59. Figures 6.6 and 6.5, and Table 6.7 present the produced profile for D2L. In all, 79 participants responded and provided their perspective on requirements in D2L for allotting sustainability dimension, which is three-star rating (3 out of 5) ★★★ is the overall sustainability of the D2L at UQU.
The presentation of the five sustainability dimensions is as follows:

- Only the individual dimension is in the **satisfactory range**, which is more than 0.63 (the corresponding bar in the chart is **light green**).
- The social and technical dimensions are between 0.48 and 0.54 (the corresponding bars in the chart are **yellow**).
- The economic and environmental dimensions are in the **unsatisfactory range** being ∼0.36 and 31, respectively (the corresponding bars in the chart are **orange**).

As for the sustainability requirements levels of D2L, all requirements are in the basic range between 0.41 and 0.59, except the self-registration requirement (Req. 27) that is in a satisfactory range.

Table 6.7: The results of D2L requirements. The sustainability rate is the result given by 79 stakeholders who rated between 0 and 1 where 0 the worst and 1 is the best.

<table>
<thead>
<tr>
<th>Req.</th>
<th>Requirement name</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>News</td>
<td>0.520927</td>
</tr>
<tr>
<td>2</td>
<td>Calendar</td>
<td>0.50317</td>
</tr>
<tr>
<td>3</td>
<td>Chat</td>
<td>0.490526</td>
</tr>
<tr>
<td>4</td>
<td>Dropbox</td>
<td>0.537709</td>
</tr>
<tr>
<td>5</td>
<td>Virtual Classrooms</td>
<td>0.486143</td>
</tr>
<tr>
<td>6</td>
<td>Email</td>
<td>0.51225</td>
</tr>
<tr>
<td>7</td>
<td>Groups</td>
<td>0.481093</td>
</tr>
<tr>
<td>8</td>
<td>Discussions</td>
<td>0.538938</td>
</tr>
<tr>
<td>9</td>
<td>Course Layout</td>
<td>0.508773</td>
</tr>
<tr>
<td>10</td>
<td>Class Progress</td>
<td>0.519936</td>
</tr>
<tr>
<td>11</td>
<td>Attendance</td>
<td>0.57533</td>
</tr>
<tr>
<td>12</td>
<td>Navigation</td>
<td>0.502819</td>
</tr>
<tr>
<td>13</td>
<td>Quizzes</td>
<td>0.506062</td>
</tr>
<tr>
<td>14</td>
<td>Question Library</td>
<td>0.583901</td>
</tr>
<tr>
<td>15</td>
<td>Grade book</td>
<td>0.554914</td>
</tr>
<tr>
<td>16</td>
<td>Grading system</td>
<td>0.495104</td>
</tr>
<tr>
<td>17</td>
<td>Grading Schemes</td>
<td>0.567044</td>
</tr>
<tr>
<td>18</td>
<td>Surveys</td>
<td>0.532029</td>
</tr>
</tbody>
</table>

Figure 6.4: The result of sustainability for each requirement in Canvas systems, requirements defined in Table 6.6
6.2.2 Skin cancer information system

SCIS is a web-based software system to register the diagnoses of skin cancer along with the treatment. SCIS has five stakeholder roles:

1. Physicians,
2. Nurses,
3. Receptionists,
4. Administrators and managers, and
5. IT support personnel and developers.

Requirements engineers have selected 14 stakeholders (two physicians, two nurses, four receptionists, three administrators and managers, and three developers and IT support personnel). Five groups (corresponding to the stakeholder roles) are created and assigned to sustainability
dimensions; see Table 6.8. The assignment of sustainability dimensions, which was introduced by Penzenstadler et al. (2013), is based on stakeholders' area of expertise and what the system might affect them on related sustainability dimensions. For example, stakeholders in the developer and IT support group are experts on IT and what IT might affect. Groups are used not only to group stakeholders with related sustainability dimensions but also to associate requirements with related stakeholder groups. For instance, the nurse group is assigned to individual and social sustainability dimensions; further, each requirement affecting or related to nurses is assigned to this group. SuSoftPro generates questions/instructions according to the following format in Section 5.1.2. There is an option to adjust each question, but we decided to continue with the generated questions for our case study.

Further, 23 high-level requirements specification of the system in (Alharthi et al. 2013) are imported from a Comma Separated Values (CSV) file and assigned to related groups; see Table 6.9 and Appendix C.3. Each requirement is assigned to one or more groups only when the requirement will affect or belong to the associated stakeholders in the group. For example, Req. 2 ‘Create a new record’ is allocated to the physician, nurse, and developer and IT support personnel groups because they will utilise this requirement and it may affect them.

The user profiles for the stakeholders are created and then assigned to the groups; see Appendix C.3. Therefore, each group is assigned to related sustainability dimensions, requirements and stakeholders. In other word, stakeholders are grouped and designated to related sustainability dimensions and requirements. Adjustment of stakeholder details is automatically prevented when stakeholders start responding to the questionnaire. For example, when a nurse begins answering the questionnaire, the change of the group and other related details are frozen.

After building the questionnaire, and generating and sending the auto-sign-in link to the stakeholders to access the questionnaire, the status of all the stakeholders in the project becomes waiting, until they begin to respond to the questionnaire. For each high-level requirement to be rated, the stakeholder can rate its influence on the sustainability dimensions using the interface presented in Figure 6.7. In the SCIS case, to illustrate the flexibility of the tool, nurses have 30 questions to answer, where

- 15 questions are on the individual sustainability perspective for the 15 allotted requirements to physician and nurse group in the SCIS, and
- 15 questions are for the social perspective of the same requirements.

Table 6.8: Assigned sustainability dimensions to stakeholder groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Individual</th>
<th>Social</th>
<th>Technical</th>
<th>Economic</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physician</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Nurse</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receptionist</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administrator and manager</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Developer and IT support</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
Physicians have 45 questions:

- 30 questions are the same as for the nurse group,
- an additional 10 questions on the economic perspective of the same requirements.

There are 24 questions covering the individual, social, and economic perspectives for requirements related to receptionists. Administrators and managers are assigned 52 questions to answer for administration and management requirements covering the following perspectives (13 questions each): economic, technical, social and environmental perspectives. Developers and IT personnel have 92 questions for all the requirements covering 23 questions on each individual, technical, economic and environmental sustainability perspective; see Table 6.9 and Appendix C.3.

Guidance on how to use the FRS is provided for stakeholders, so that stakeholders such as nurses or physicians, who have not seen or used the FRS before, will find it easy to complete the questionnaire. They also had the ability to save their responses and return to continue. An option for skipping any question for certain requirements within a particular sustainability dimension is implemented. For example, a physician was asked to rate the influence of Req. 6 ‘Insert procedure’ on economic sustainability; the physician was able to skip this question. However, the question has a probability to be answered by other stakeholders, such as other physicians and developers who are assigned to rate Req. 6, for the economic dimension.

![Questionnaire](image_url)

**Questionnaire**

*Questionnaire for SCIS - Skin Cancer Information System profile.*

**Requirements:** Insert procedure

*Requirements description:* The SCIS shall enable physicians and nurses to select appropriate procedures for one problem or more than one.

**Question 21**

Rate the influence of the requirement on the individual sustainability 🎈

**Answer:** 🎈

Answered: 69, Not answered: 7, Ignored: 5

![Core response](image_url)

**Figure 6.7: SuSoftPro: rating of one requirement’s effect on individual sustainability**
As the next step, SuSoftPro applies the TOPSIS method and creates the sustainability profiling of the system. A systematic computation of TOPSIS is performed and recalculated when each stakeholder submits the response. In addition, rated requirements with their questions are automatically locked when any stakeholder begins to rate it, so that engineers cannot amend them.

The created profiling is presented in the dashboard in Figure 6.8. Based on the simulated responses we used to illustrate the example (where only 13 out of 14 stakeholders submitted their...
Figure 6.9: The result of sustainability for each requirement in SCIS systems

responses), the overall sustainability of the SCIS has ★★★ three-star rating (3 out of 5). The five sustainability dimensions are presented in a bar chart:

- The individual and social dimensions are in the satisfactory range, which are more than 0.61 (the corresponding bar in the chart is light green).
- The technical and economic dimensions are between 0.51 and 0.54 (the corresponding bars in the chart are yellow).
- The environmental dimension is in the unsatisfactory range, which is ~0.33 (the corresponding bars in the chart are orange).

The overall impact on sustainability of each requirement is indicated in Table 6.9 and Figure 6.9.

### 6.3 Evaluation Questionnaire

A web-based questionnaire is designed as a quantitative questionnaire to evaluate our framework and tool-support and to gain feedback from academics and practitioners who are specialists in

Table 6.9: The results of SCIS requirements. The sustainability rate is the result giving by 13 stakeholders who rated between 0 and 1 where 0 the worst and 1 is the best

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement name</th>
<th>Sustainability</th>
<th>#</th>
<th>Requirement name</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Login system</td>
<td>0.558696</td>
<td>13</td>
<td>Hold or un-hold bill</td>
<td>0.609793</td>
</tr>
<tr>
<td>2</td>
<td>Create new record</td>
<td>0.604063</td>
<td>14</td>
<td>Print bill</td>
<td>0.338953</td>
</tr>
<tr>
<td>3</td>
<td>Create new problems</td>
<td>0.599514</td>
<td>15</td>
<td>Create patients' information</td>
<td>0.510435</td>
</tr>
<tr>
<td>4</td>
<td>Create visit</td>
<td>0.624814</td>
<td>16</td>
<td>Edit patients' details</td>
<td>0.553727</td>
</tr>
<tr>
<td>5</td>
<td>Edit record</td>
<td>0.583649</td>
<td>17</td>
<td>Create waiting list</td>
<td>0.561173</td>
</tr>
<tr>
<td>6</td>
<td>Insert procedure</td>
<td>0.476776</td>
<td>18</td>
<td>Search feature</td>
<td>0.533224</td>
</tr>
<tr>
<td>7</td>
<td>Finalise procedure</td>
<td>0.636561</td>
<td>19</td>
<td>Generate and print Financial and business reports</td>
<td>0.470714</td>
</tr>
<tr>
<td>8</td>
<td>Access patients’ record</td>
<td>0.602394</td>
<td>20</td>
<td>Create new staff account</td>
<td>0.587723</td>
</tr>
<tr>
<td>9</td>
<td>Allocate pathology report to procedure</td>
<td>0.345824</td>
<td>21</td>
<td>Edit staff’s details</td>
<td>0.350823</td>
</tr>
<tr>
<td>10</td>
<td>Upload documents and image</td>
<td>0.383387</td>
<td>22</td>
<td>Administrator Manage role</td>
<td>0.350712</td>
</tr>
<tr>
<td>11</td>
<td>Generate and print form</td>
<td>0.34242</td>
<td>23</td>
<td>Create centre’s information</td>
<td>0.602745</td>
</tr>
<tr>
<td>12</td>
<td>Generate bill</td>
<td>0.343278</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
sustainable software development, Software Engineering (SE), and/or RE. We recruited academics and practitioners via social networks as well as asking those attended of the 26th IEEE International Requirements Engineering Conference RE’18 held in Banff, Canada during our demonstration of the tool.

6.3.1 Procedure

In the online questionnaire, we provided a short-clip describing the SuSoftPro framework and the tool-support with the ability to access the tool. Then, we required participants to place a slider point/mark on a line running from one extreme of the strongly agree criterion to the other extreme of strongly disagree criterion for the following six statements with an instruction, *To what extent do you agree with the following statements:*

1. The tool has a logical flow from the start to the end for analysing the sustainability requirements and sustainability aspects of software systems.

2. The tool has a systematic procedure to generate sustainability software profiling and star rating. It also analyses the sustainability requirements and sustainability aspects of software systems.

3. The tool is easy to use for analysing the sustainability requirements and sustainability aspects of software systems.

4. The tool provides for the assignment of stakeholders to a group and this group is later allocated to one or more of the sustainability aspects.

5. The tool contributes to analysing sustainability requirements for software systems.

6. I am likely to use the tool to measure sustainability aspects and sustainability requirements of software systems in future.

When the rate scale of the sixth statement was below 50, the following extra questions were displayed; otherwise they were not displayed.

(a) How do you measure and analyse sustainability requirements and sustainability aspects of software systems?

(b) Do you use any tool to analyse the sustainability aspects and sustainability requirements of software systems?

6.3.2 Results

In all, 19 participants responded to the six statements. Tables 6.10 and 6.11 presents the descriptive statistics and ANOVA results of the six statements, see statistics symbols and description on Page 58. The difference between the population means is considered statistically significant by
one sample t-test at .05 level of significance ($H_0: \mu=65, p \leq 0.05$), see Table 6.10. Further, we performed one-way ANOVA test, so the differences between statement means are not statistically significant that determine ($F(5, 108) = 0.6038, p = 0.6971$), see Table 6.11. This result by the one-way ANOVA was expected because there is no relationship between measured statements.

Table 6.10: Descriptive statistics results and one sample t-test of the six statements in the evaluation questionnaire

<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>79.68</td>
<td>80.00</td>
<td>76.95</td>
<td>80.21</td>
<td>83.79</td>
<td>75.68</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>11.38</td>
<td>15.81</td>
<td>22.11</td>
<td>10.32</td>
<td>12.04</td>
<td>19.43</td>
</tr>
<tr>
<td>Standard Error</td>
<td>2.61</td>
<td>3.63</td>
<td>5.07</td>
<td>2.37</td>
<td>2.76</td>
<td>4.58</td>
</tr>
<tr>
<td>Variance</td>
<td>122.64</td>
<td>236.74</td>
<td>463.31</td>
<td>100.90</td>
<td>137.32</td>
<td>377.37</td>
</tr>
<tr>
<td>Count</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>t-value</td>
<td>5.6229</td>
<td>4.1356</td>
<td>2.3559</td>
<td>6.4243</td>
<td>6.8026</td>
<td>2.3959</td>
</tr>
<tr>
<td>Two-tail p-value</td>
<td>0.0001</td>
<td>0.0006</td>
<td>0.03</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0277</td>
</tr>
</tbody>
</table>

Table 6.11: ANOVA testing result of the six statements

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>763.9169</td>
<td>5</td>
<td>152.7834</td>
<td>0.6038</td>
<td>0.6971</td>
</tr>
<tr>
<td>Within Groups</td>
<td>27327.4416</td>
<td>108</td>
<td>253.0319</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>28091.3585</td>
<td>113</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 6.10 shows participants responses for each statement, while Figure 6.11 presents the average rate of each statement. Overall, above 80% of the participants rated the six statements with ‘agreed’. For the first statement about the logical flow of the SuSoftPro framework, the average responses of participants were 79.68% and ‘almost agree’ responses were above 60% except for that of participant (P18) who partially disagreed, which was 43%. Similarly, there was a high agreement with the systematic procedure to generate sustainability profiling for software, with the average at 80% and individual responses at ~75%.

Only two participants (P8 and P18) assigned a rating for statement 2 of 30% and 53%, respectively. The average rate of statements about how easy to use the tool is (statement 3) and how likely the participant was to use the tool (statement 6) were ~77% and ~76%, respectively. Moreover, both statements (3 and 6) had a similar rating among individuals, and 16 participants rated these above 70% and 3 participants rated these below 58%. Statements 4 and 6 (about assigning stakeholders to sustainability aspects using the tool and the contribution of the tool) had the highest agreement with average 80% for the assignment and 83.79% for the contribution. Individual ratings for statement 4 and 6 were 17 participants these between ~70% and 100%, whereas two participants, particularly P18, rated these between 54% and 67%.

### 6.4 Discussion

SuSoftPro is an automated solution in the sustainability context to analyse sustainability requirements based on a questionnaire, in which quantity data were gathered via FRS questionnaire.
and analysed using TOPSIS. The result presented a sustainability profiling for software having a five-star rating label, visualisation of the degree of sustainability dimensions and a bar graph of overall sustainability level for each requirement.

In the case of long-living systems, it is crucial to keep the software system sustainable over the whole life-cycle of the system. Stakeholders, requirements and preferences might change over the period that the system is in use. The SuSoftPro framework allows analysing up-to-date system sustainability profiles, based on system characteristics and up-to-date ratings (questions) of the corresponding requirements.

From the comparative evaluation result, both SuSoftPro and ReproTizer approaches are based on individuals perspective. The perspective is important to change the sustainability of software when users’ opinions are addressed and taken into account. Scholars of social practice theory believe that practices and perspectives of individuals in the performance of daily tasks stimulate social, economic and environmental changes (Boyer et al. 2016). The SuSoftPro tool aggregated all stakeholders’ requirements. This enables the recognition of diverse visions and voices in decisions

Figure 6.10: Comparing 19 participants (P) responses with regard to the six evaluation statements
that are needed to develop sustainable software. Thus, the point of sustainability perspective while analysing requirements could be the main force in providing sustainable software in the early stages. Moreover, providing the FRS in SuSoftPro to capture individuals views was necessary to prevent imprecision. However, it is necessary to reconcile plurality through supporting stakeholders with the diversity of viewpoints that ensure sustainability (Mahaux 2013).

As the case studies demonstrated, practitioners were supplied with information related to sustainability aspects. The sustainability profiling presented sustainability scores for each requirement and sustainability dimension. These scores will improve the attention to sustainability and allow practitioners to provide sustainable software. For example, the lowest sustainability score in SCIS was for Req. 9 ‘Allocate pathology report to procedure’, and hence, practitioners could give more attention to improve this requirement and its acceptance as well as increase users’ satisfaction, which lead to sustainability (Al Hinai and Chitchyan 2016).

Additionally, the tool allows requirements engineers to create groups with regard to stakeholders’ diversity or role. For example, groups in Canvas and D2L profiling were divided by user
role. Grouping stakeholders and requirements is not only to reduce the number of questions that stakeholders answer but also to allow them to express their opinion about matters related to them. In addition, there are two ways to invite stakeholders: either with a public link to accommodate more stakeholders through self-registration or being registered by the engineers.

We employed the questionnaire technique, which is one of the RE technique, to analyse sustainability requirements based on the perception of stakeholders. We analyse sustainability in the same way of other software quality such as reliability, efficiency and usability. ISO/IEC 25010 (2011) defines External quality as the extent to which a product satisfies stated and implied needs when used under specified conditions. The focus of quality is moved from the product in isolation to the satisfaction of the requirements for particular users in particular situations (Bevan and Azuma 1997). For instance, different groups of stakeholders have different needs. They could demand different characteristics for a software product to have quality for their purposes. Thus, assessment of quality becomes dependent on the perception of the stakeholders (Febrero et al. 2017). Products can only have quality in connection with their intended purpose. This reason is a more fundamental reason for being concerned with stakeholder perceived quality (Kitchenham and Pfleeger 1996). For example, word processor software, the functionality, usability and efficiency attributes required by a trained user may be very different from those required by an occasional user. Another example is that programmers use text editors for producing code while secretaries use it for producing a letter. Therefore, stakeholders’ perceptions of quality drive satisfaction, preferences and consequently sustainability.

Intuitive design is taken into account when designing the tool. For practitioners, the tool is divided into logic sections, including a dashboard, questionnaire, requirements, stakeholders and profiling. A systematic computation of stakeholders’ responses after submitting is implemented to prevent error. Icons and colours also are provided for effortless understanding of the tool. However, we received a few comments from stakeholders in case studies regarding FRS. They reported that the rating method was difficult to understand because it is new to them and they are used to Likert rating scales. They also claimed that after answering many questions, they started to become used to it. This issue was expected because as de Sáa et al. (2015) stated, participants may face difficulty understanding the FRS when they start to respond. Thus, this unsettled issue needs more investigation between the information quality (accuracy) and data collection design (usability). To mitigate the problem, guidance with an example is developed to accomplish a higher rating quality and increase the usability and user experience.

The tool also allows integration with commonly used requirements engineering tools such as ReqMan and Rational DOORS: Its export and import features allow the exchange of requirement specifications using the CSV format.

SuSoftPro has emerged to:

- Capture more individuals’ perspective with diversity and provide accurate impression,
- Analyse software requirements in the sustainability context, and
- Present the result as sustainability profiling.
However, a few limitations need to be taken into account. There is a need to provide standards for the sustainability five-star rating label to specify the minimum level of sustainability performance that software should meet before it can be developed. In addition, when the number of requirements is increased and a group is assigned to more than two sustainability dimensions, the number of questions will be large; with either double or treble requirements. This large number could lead to a considerable increase in the time require for responding to a questionnaire, and hence, stakeholders might find it annoying. As an initial optimised solution, requirements engineers can divide a group that is allotted to more than two sustainability dimensions into two groups and then assign them to one or two different sustainability dimensions. Another solution is to leverage machine learning to assign stakeholders and divide questions between individuals in one group. We optimised the number of questions in the tool through establishing a group and assigned stakeholders and requirements to it. This solution assists in reducing the number of questions by about 20-50% in some cases.

### 6.5 Summary

The SuSoftPro framework and tool-support were evaluated by comparing against two approaches that developed a methodology using MCDA and were used in the RE domain to check the framework capability. The evaluation demonstrated a number of advantages of SuSoftPro for the sustainability analysis: such as tool support, FRS to allow better precision of requirements’ rating, and a systematic framework to analyse sustainability of the system in the earlier stages of software development. In addition, We demonstrated the utility as well as evaluated the usability and feasibility of the SuSoftPro framework and tool-support by conducting three case studies from the eLearning (Canvas, D2L) and eHealth domains (SCIS) to gain deeper insight on the developed framework. Further, we conducted an online questionnaire to evaluate whether the SuSoftPro framework is not only capable of analysing sustainability requirements of software systems but is also acceptable to academics and practitioners.
Conclusions

“We know very little, and yet it is astonishing that we know so much, and still more astonishing that so little knowledge can give us so much power.”

–Bertrand Russell, 1925

This chapter provides a summary of the research work presented in this thesis on requirements engineering aspect for sustainable eLearning systems and highlights the key contributions. It also presents the limitations of the study and the open research issues.

Summary

This thesis presents a novel approach to analyse sustainability requirements of software systems, in particular eLearning systems. In contrast to the traditional analysis, where either one or two dimensions of sustainability are analysed separately, we constructed a SuSoftPro framework to solve the issues that ignore the overlap of sustainability and requirement dependencies during software requirements engineering process. The contributions corresponding to sustainability requirements of software systems, particularly eLearning systems, issues that were tackled and elucidated in this thesis can be summarised as follows:

1. We identified 17 high-level sustainability requirements of eLearning systems through a systematic literature review as well as we proposed a new sustainability requirement which is green and sustainability software engineering.

2. We identified the most of sustainability requirements of eLearning systems that are heavily correlated to individual and social dimensions.

3. The identified sustainability requirements were mapped to sustainability dimensions and the elements of the software product quality model. Also, we classified the identified requirements to what aspect are domain-specific for eLearning systems, and general that are inherited from other domain.
4. We identified the differences from role and gender perspectives for functionalities of eLearning systems that are provided and used; provided and need to be improved; and not provided and needed.

5. We developed the SuSoftPro framework and corresponding tool-support. We employed Fuzzy Rating Scale (FRS)-based questionnaire and TOPSIS approach (technique for order of preference by similarity to ideal solution) to generate a software sustainability profile.

6. The developed framework is not limited to eLearning systems. It generalised to other software domains.

The main contributions of our research have answered the three research questions formulated in Section 1.2, and can be summarised as follows:

**RQ1 What are the sustainability aspects of an eLearning System?**

Chapters 3 and 4 addressed RQ1. In Chapter 3, we performed a Systematic Literature Review (SLR) on research conducted on sustainability requirements for eLearning systems to analyse the state of the art of this research area, and to recognise open problems. We identified, analysed and categorised sustainability requirements of eLearning systems. The identified sustainability requirements were mapped to a software quality model. Further, we analysed 124 studies in depth by focusing on sustainability requirements being investigated and classified them into three types: empirical, theoretical and hybrid studies. The key findings of the SLR were that individual and social should be analysed together because of their heavy correlation. In addition, the technical, economic and environmental sustainability requirements of eLearning systems are essentially identical to other software systems. Significantly, some sustainability requirements still have some issues that need to be solved to sustain eLearning systems.

We examined the most used, requested and deficient functionalities of eLearning systems from learners’ and instructors’ perspectives as well as the gender and cultural diversity aspects in Chapter 4. We established a survey and distributed it to students and academic staff in the computer science department in RMIT University, Australia and all departments in Umm Al-Qura University, Saudi Arabia, as well as administration and IT support personnel in both universities. The collected data were analysed considering participants’ role, and cultural and gender aspects. The result highlighted that the user awareness, non-functional requirement, culture as well as gender diversity plays an important role for sustainability requirements of eLearning systems.

**RQ2 How can we systematically address and model the sustainability dimensions as well as sustainability requirements as part of a requirements engineering process while developing or extending an eLearning system?**

**RQ3 Which features of sustainable requirements engineering do we need to embed into the framework to improve the requirements engineering process for an eLearning system?**
Chapters 5 and 6 mainly focused on solving RQ2 and RQ3. We developed the SuSoftPro framework for the analysis of sustainability requirements, and we implemented a web-based tool-support for the SuSoftPro framework in Chapter 5. The SuSoftPro framework allows engineers to analyse sustainability requirements for long-living software systems via providing sustainability profiling. The framework utilises a FRS-based questionnaires and TOPSIS approach (technique for order of preference by similarity to ideal solution) for generating a software sustainability profiling. The profiling includes an overall picture of how sustainable a software system really is. The profile is presented as three core elements: (1) a five-star rating, (2) five dimensions of sustainability in a polar area chart, and (3) an overall measure of sustainability for each requirement in a bar graph. SuSoftPro framework and tool-support allows requirements engineers to: investigate overall sustainability of software systems, analyse the five sustainability dimensions of software, discover the overall sustainability for each individual requirement, and involve stakeholders to rate their requirements from one or more of the five sustainability dimensions.

In Chapter 6, we conducted evaluation studies including: (1) comparative evaluation for determining and investigating the usefulness and feasibility of the developed framework and tool-support, (2) case studies for evaluating and generalising our methodology and the corresponding tool-support, and (3) survey to gain feedback from academics and practitioners about the capability and usefulness of the SuSoftPro. The results of the comparison evaluation reveal that the SuSoftPro is an automated solution in the sustainability context to analyse sustainability requirements based on questionnaires. Together these results as well as the results of the survey provide important insights into the SuSoftPro framework and the tool-support. An important insight for practitioners is that the SuSoftPro framework supports the development of sustainable software systems considering the individual, social, technical, economic and environmental sustainability dimension. Also, the framework provides an early warning alert to improve sustainability requirements as they developed. For example, practitioners can determine the level of sustainability from the sustainability profile (as seen in Figure 6.8). Thus, if the sustainability level of a requirement is low, they could improve the quality of the requirement or monitor it. For researchers, the SuSoftPro framework enriches the development of knowledge about sustainability in software engineering. For example, the SuSoftPro framework can be a means to determine related issues in the sustainability of software engineering. They could compare the sustainability of different software and investigate the surrounding environment.

Limitations of the study

Previously in Sections 3.5, 4.5 and 6.4, we discussed threats to validity, reliability and limitations in more detailed explanation for a specific part of this study. Further, the study has four main limitations including a time and place limitation, restriction of the scope, providing extra details in the developed SuSoftPro tool, as well as possible misunderstanding of actual sustainability.

Time and place tied up this study; we were not able to conduct further investigation. For example, we thought of performing further interviews with internal and external stakeholders of
the systems such as developers, administrators, decision-makers, and sustainability experts. This investigation needs more resource beyond what specified for our PhD project. In addition, we focused on eLearning systems from a sustainable software engineering perspective. Thus, it is beyond the scope of this study to examine eLearning as a teaching technique. For example, we did not focus on a particular software for teaching models such as a massive open online course or blended learning.

A limitation of the developed tool-support is that the SuSoftPro tool does not present the result for the individual requirement with the five levels of sustainability dimensions. However, the number of graphs is large, and it might negatively affect the usability of the tools. For example, the D2L system has 32 requirements in the case study. There will be 32 graphs to present individual ratings of the five sustainability dimensions for each requirement.

Also, one of the potential limitations of the research is that, in the case the stakeholders are not selected carefully based on their fields of expertise, the resulting sustainability profile might be measuring perceived sustainability of software systems, instead of the actual sustainability. This issue is out of the scope of our research, and respectively, out of scope of the proposed and developed framework. Nevertheless, we would like to highlight this point to re-iterate identification of the stakeholders’ groups and selection of individual stakeholders to gather the requirements, as this preliminary work creates the basis for requirements gathering. If the stakeholders, who involve in the rating of system’s sustainability, lack some corresponding knowledge, they will provide only their perceptions of the corresponding aspects (that might differ from the actual aspects dramatically), and as result, only the perceived sustainability will be measured. This issue is not any specific to sustainability, it is general for all kind of non-functional and functional requirements. Thus, the stakeholders are the key to elicit the correct requirements, including the sustainability aspects. Requirements engineers, before employing the developed framework, must follow one of the four approaches to identify stakeholders for sustainability that were proposed by Penzenstadler et al. (2013). We demonstrated this mitigation plan in Section 6.2.1, where we discussed the case studies.

**Future research directions**

While developing sustainable eLearning systems and analysing sustainability requirements of software systems have received considerable attention, there are many opportunities for further research. Below, we point some of the promising directions.

**Human sustainability in requirements engineering**

The study indicates that the individual and social sustainability requirements need to be carefully considered and analysed together because of the strong correlation. Most researchers have ignored the effect of individual aspect in requirements engineering. However, a few researchers have attempted to analyse human action and interaction, e.g., (Friedman et al. 2008) and (Thew and Sutcliffe 2018). Thew and Sutcliffe (2018) provided a taxonomy and guidance for eliciting and
analysing stakeholders’ values, motivations and emotions. Therefore, incorporating their taxonomy and guidance into our developed framework can lead to more realistic and useful decisions to group stakeholders.

**Sustainability metrics integration**

Since our developed framework provides sustainability profiling containing quantified data. The potential future direction is to integrate the data with metrics focusing explicitly on sustainability in the operational phase of software systems. This will allow monitoring requirements stability and behavioural-related that could affect the surrounded environment, economic and human dimensions. Monitoring sustainability of requirements will provide an early warning alert when sustainability requirements start to be decay.

**Green architecture for sustainable eLearning systems**

We identified sustainability requirements for eLearning systems as well as introduced the SuSoftPro framework to analyse sustainability requirements. We would like to explore how the above ideas can be applied on the next development step while elaborating a system architecture. A start in this direction has been made by conducting a SLR about the green architecture of sustainable eLearning systems. Then, we brought the sustainability requirements, which introduced in Chapter 3, to the architectural level. We proposed a general green cloud-based architecture for eLearning systems that aligns the sustainability requirements (Ahmed D. Alhaththi and Maria Spichkova 2017).

**Retention of materials and data**

The study also shows that there is abundant room for further progress in determining the effects of retention of materials and data on learners and instructors. Retaining materials longer than necessary demands additional data storage space, costs and energy consumption more than needed, which are crucial for sustainability. This unnecessary demand could affect negatively on the learners and instructors right and increase the over consumption of natural resources.

**Sustainable software certification**

The literature lacks metrics focused explicitly on sustainability to assess the sustainability of software systems. Multidisciplinary academics are essential (1) to developing a robust generic framework and (2) to provide sustainability certification that can leverage sustainability practices in the industry. Certifications will provide immediate recognition for sustainability with a clear differentiation between software. Albert Sustainable Production Certification and Sustainable Tourism Certification (Scarlat and Dallemand 2011) are examples of such certification.

---

1http://wearealbert.org/certification
Bibliography


ISSN 0164-1212.


116


R. A. Ellis. Students’ approaches to groupwork in a blended course, associations with perceptions of the online environment and academic achievement—when is learning engaged? Education and Information Technologies, 21(5), 2016.


ISO/IEC 25010. Systems and software engineering - software product quality requirements and evaluation (square) - software product quality and system quality in use models, 2011.


S. Manca and M. Ranieri. Implications of social network sites for teaching and learning. where we are and where we want to go. *Education and Information Technologies*, 22(2), 2017.


## Appendix A

### List of Studies for Systematic Literature Review

**Studies for systematic literature review of sustainability requirements in eLearning systems**

Table A.1: List of studies for sustainable eLearning systems

<table>
<thead>
<tr>
<th>No</th>
<th>Paper</th>
<th>Year</th>
<th>Step</th>
<th>Characteristics of paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>(Manca and Ranieri 2017) : Implications of social network sites for teaching and learning. Where we are and where we want to go</td>
<td>2017</td>
<td>SLR</td>
<td>Literature review</td>
</tr>
<tr>
<td>4</td>
<td>(Scoppio and Luyt 2017) : Mind the gap: Enabling online faculty and instructional designers in mapping new models for quality online courses</td>
<td>2017</td>
<td>SLR</td>
<td>Comparative</td>
</tr>
<tr>
<td>5</td>
<td>(Nunes et al. 2016) : Mobile serious game proposal for environmental awareness of children</td>
<td>2016</td>
<td>SLR</td>
<td>Experimental</td>
</tr>
<tr>
<td>6</td>
<td>(Toppin and Toppin 2016) : Virtual schools: The changing landscape of K-12 education in the US</td>
<td>2016</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>7</td>
<td>(Ellis 2016) : Students’ approaches to groupwork in a blended course, associations with perceptions of the online environment and academic achievement—when is learning engaged?</td>
<td>2016</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>No</th>
<th>Paper</th>
<th>Year</th>
<th>Step</th>
<th>Characteristics of paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>(Koshkin et al. 2016) : Monitoring social media: Students satisfaction with university administration activities</td>
<td>2016</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>9</td>
<td>(Pellas 2016) : Bolstering the quality and integrity of online collaborative university-level courses via an open Sim standalone server in conjunction with soodle</td>
<td>2016</td>
<td>SLR</td>
<td>Survey</td>
</tr>
<tr>
<td>10</td>
<td>(Garg and Varma 2015) : Systemic Requirements of a Software Engineering Learning Environment</td>
<td>2015</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>11</td>
<td>(Törngren et al. 2015) : Education and training challenges in the era of Cyber-Physical Systems: beyond traditional engineering</td>
<td>2015</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>12</td>
<td>(Kruchten 2015) : Lifelong Learning for Lifelong Employment</td>
<td>2015</td>
<td>NSR</td>
<td>Commentary</td>
</tr>
<tr>
<td>13</td>
<td>(Rahanu et al. 2015) : Towards relating delivery methods and examination success: lessons learned from the VALO LLP project case study</td>
<td>2015</td>
<td>SLR</td>
<td>Observational</td>
</tr>
<tr>
<td>14</td>
<td>(Stewart and Khare 2015) : eLearning and the Sustainable Campus</td>
<td>2015</td>
<td>NSR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>15</td>
<td>(Weichhart 2015) : Supporting the evolution and interoperability of organisational models with e-learning technologies</td>
<td>2015</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>17</td>
<td>(Suhonen and Sutinen 2014) : The four pillar model-Analysing the sustainability of online doctoral programmes</td>
<td>2014</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>18</td>
<td>(Colomo-Palacios et al. 2014) : Using social media as a tool for business improvement and certification of knowledge workers</td>
<td>2014</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>19</td>
<td>(Tuparov et al. 2014) : Approaches for competencies assessment in open source e-learning environments</td>
<td>2014</td>
<td>NSR</td>
<td>Comparative</td>
</tr>
<tr>
<td>21</td>
<td>(Neila and Rabai 2014) : Deploying suitable countermeasures to solve the security problems within an e-learning environment</td>
<td>2014</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>22</td>
<td>(Burton et al. 2014) : Educational edifices need a mobile strategy to fully engage in learning activities</td>
<td>2014</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>23</td>
<td>(Wang et al. 2014) : Tapping the educational potential of Facebook: Guidelines for use in higher education</td>
<td>2014</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>24</td>
<td>(Keengwe and Malapile 2014) : Factors influencing technology planning in developing countries: A literature review</td>
<td>2014</td>
<td>SLR</td>
<td>Literature review</td>
</tr>
<tr>
<td>25</td>
<td>(Vogel et al. 2014) : Mobile inquiry learning in Sweden: Development insights on interoperability, extensibility and sustainability of the LETS GO software system</td>
<td>2014</td>
<td>SLR</td>
<td>Case study</td>
</tr>
<tr>
<td>26</td>
<td>(Yigit et al. 2014) : Web-based learning object selection software using analytical hierarchy process</td>
<td>2014</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>27</td>
<td>(Breslow et al. 2013) : Studying learning in the worldwide classroom: Research into edX's first MOOC</td>
<td>2013</td>
<td>SP</td>
<td>Empirical</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>No</th>
<th>Paper</th>
<th>Year</th>
<th>Step</th>
<th>Characteristics of paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>(Randelin et al. 2013) : Towards sustainable well-being in SMEs through the web-based learning program of ergonomics</td>
<td>2013</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>29</td>
<td>(Mridha et al. 2013) : E-learning for empowering the rural people in Bangladesh opportunities and challenges</td>
<td>2013</td>
<td>SLR</td>
<td>Experimental</td>
</tr>
<tr>
<td>30</td>
<td>(Secundo et al. 2013) : Developing the next generation of engineers for intelligent and sustainable manufacturing: A case study</td>
<td>2013</td>
<td>SLR</td>
<td>Case study</td>
</tr>
<tr>
<td>31</td>
<td>(Shen and LeClair 2013) : Use of sustainable and systematic plan to assess student learning outcomes for non-traditional IT students</td>
<td>2013</td>
<td>SLR</td>
<td>Survey</td>
</tr>
<tr>
<td>32</td>
<td>(Sowe et al. 2013) : A model for creating and sustaining information services platform communities: Lessons learnt from open source software</td>
<td>2013</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>33</td>
<td>(Stepanyan et al. 2013) : Sustainable e-learning: toward a coherent body of knowledge</td>
<td>2013</td>
<td>NSR</td>
<td>Scoping review</td>
</tr>
<tr>
<td>34</td>
<td>(Mahmood and Hafeez 2013) : Performance assessment of an e-learning software system for sustainability</td>
<td>2013</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>35</td>
<td>(Amador and Oliveira 2013) : Integrating Sustainability into the University: Past, Present, and Future</td>
<td>2013</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>36</td>
<td>(Stewart and Khare 2012) : Athabasca University Reduces ICT Carbon Footprint</td>
<td>2012</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>37</td>
<td>(Secundo et al. 2012) : Industry-University Learning Network to create competences for intelligent and sustainable manufacturing: A case study</td>
<td>2012</td>
<td>SLR</td>
<td>Case study</td>
</tr>
<tr>
<td>38</td>
<td>(Pettersson and Vogel 2012) : Reusability and interoperability in mobile learning: A study of current practices</td>
<td>2012</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>40</td>
<td>(Tikhomirova et al. 2012) : Knowledge management in the smart university</td>
<td>2012</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>41</td>
<td>(Iatagan 2012) : Strategies for ongoing professional training of human resources in a globalized economy</td>
<td>2012</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>42</td>
<td>(Zon et al. 2012) : A learning, training &amp; mentoring framework (LTM) &amp; the role of serious games to facilitate sustainable change in the aviation industry</td>
<td>2012</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>43</td>
<td>(Pardo et al. 2012) : A distributed collaborative system for flexible learning content production and management</td>
<td>2012</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>44</td>
<td>(Ruyters et al. 2012) : Sustainability of a university designed and developed media annotation tool to prepare learners with skills needed for future employment</td>
<td>2012</td>
<td>SLR</td>
<td>Case study</td>
</tr>
<tr>
<td>45</td>
<td>(Bensch and Rager 2012) : Cloud-based online learning platforms</td>
<td>2012</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>46</td>
<td>(Ossiannilsson and Landgren 2012) : Quality in e-learning - a conceptual framework based on experiences from three international benchmarking projects</td>
<td>2012</td>
<td>NSR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>47</td>
<td>(Tomkinson and Hutt 2012) : Online PBL: A route to sustainability education?</td>
<td>2012</td>
<td>SLR</td>
<td>Survey</td>
</tr>
<tr>
<td>48</td>
<td>(Manuja et al. 2011) : Industry academia collaboration model: The design challenges</td>
<td>2011</td>
<td>SP</td>
<td>Conceptual</td>
</tr>
<tr>
<td>49</td>
<td>(Cápy et al. 2011) : Analysis of students' behaviour in e-Learning system</td>
<td>2011</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>50</td>
<td>(Rajasingham 2011) : Will mobile learning bring a paradigm shift in higher education?</td>
<td>2011</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
</tbody>
</table>

(Continued)
Continuation of Table A.1

<table>
<thead>
<tr>
<th>No</th>
<th>Paper</th>
<th>Year</th>
<th>Step</th>
<th>Characteristics of paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>(Gunn 2011) : Sustaining e-learning innovations</td>
<td>2011</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>52</td>
<td>(Sousa 2011) : Information systems architecture modeling based on loosely coupled structures: An e-learning use case</td>
<td>2011</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>53</td>
<td>(Kazancoglu and Aksoy 2011) : A fuzzy logic-based QFD to identify key factors of e-learning design</td>
<td>2011</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>54</td>
<td>(Miliszewska and Sztendur 2011) : Critical success attributes of transnational IT education programmes: The client perspective</td>
<td>2011</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>55</td>
<td>(Lizhong et al. 2011) : The Function of the University Libraries in Constructing Lifelong Education System</td>
<td>2011</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>56</td>
<td>(Bhat 2011) : Technological ambidexterity in the management of national infrastructure programmes</td>
<td>2011</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>57</td>
<td>(Memmel 2011) : Interoperability Requirements for a Sustainable Component to Support Management and Sharing of Digital Resources</td>
<td>2011</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>58</td>
<td>(Meneses 2011) : Design of an electronic instrumentation virtual laboratory based on free-open resources</td>
<td>2011</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>59</td>
<td>(Gunn 2010) : Sustainability factors for e-learning initiatives</td>
<td>2010</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>60</td>
<td>(Colasante 2010) : Future-focused learning via online anchored discussion, connecting learners with digital artefacts, other learners, and teachers</td>
<td>2010</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>61</td>
<td>(Rovai and Downey 2010) : Why some distance education programs fail while others succeed in a global environment</td>
<td>2010</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>62</td>
<td>(Buchan 2010) : Putting ourselves in the big picture: A sustainable approach to project management for e-learning</td>
<td>2010</td>
<td>SP</td>
<td>Case study</td>
</tr>
<tr>
<td>63</td>
<td>(Demirkan et al. 2010) : A Reference Model for Sustainable E-Learning Service Systems: Experiences with the Joint University/Teradata Consortium</td>
<td>2010</td>
<td>SP</td>
<td>Case study</td>
</tr>
<tr>
<td>64</td>
<td>(Allen et al. 2010) : K-State's Distributed Learning Commons: Achieving Long-Term Sustainability Through Strategic Partnerships</td>
<td>2010</td>
<td>SLR</td>
<td>Case study</td>
</tr>
<tr>
<td>65</td>
<td>(Jiang et al. 2010) : Four requirements for digital case study libraries</td>
<td>2010</td>
<td>SLR</td>
<td>Case study</td>
</tr>
<tr>
<td>66</td>
<td>(Sridharan et al. 2010) : Critical success factors in elearning ecosystems: a qualitative study</td>
<td>2010</td>
<td>NSR</td>
<td>Survey</td>
</tr>
<tr>
<td>67</td>
<td>(Trajkovik et al. 2010) : Establishing a videoconferencing infrastructure in the republic of Macedonia as an engineering educational service</td>
<td>2010</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>68</td>
<td>(Bourn and Shiel 2009) : Global perspectives: aligning agendas?</td>
<td>2009</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>69</td>
<td>(Dyson et al. 2009) : Advancing the m-learning research agenda for active, experiential learning: Four case studies</td>
<td>2009</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>70</td>
<td>(Friesen 2009) : Open educational resources: New possibilities for change and sustainability</td>
<td>2009</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>71</td>
<td>(Garrison and Akyol 2009) : Role of instructional technology in the transformation of higher education</td>
<td>2009</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>72</td>
<td>(Fisler and Schneider 2009) : Creating, handling and implementing e-learning courses using the Open source tools OLAT and eLML at the University of Zurich</td>
<td>2009</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>No</td>
<td>Paper</td>
<td>Year</td>
<td>Step</td>
<td>Characteristics of paper</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------------------------------------------------</td>
<td>------</td>
<td>------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>73</td>
<td>(Cheung and Lee 2009) : Understanding the sustainability of a virtual community: model development and empirical test</td>
<td>2009</td>
<td>SP</td>
<td>empirical</td>
</tr>
<tr>
<td>74</td>
<td>(Dong et al. 2009) : An E-learning Ecosystem Based on Cloud Computing Infrastructure</td>
<td>2009</td>
<td>NSR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>75</td>
<td>(Gustavsson et al. 2009) : On Objectives of Instructional Laboratories, Individual Assessment, and Use of Collaborative Remote Laboratories</td>
<td>2009</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>77</td>
<td>(Shehabat and Mahdi 2009) : E-Learning and its Impact to the Educational System in the Arab World</td>
<td>2009</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>78</td>
<td>(Park et al. 2009) : Adaptive open mobile learning device for the underserved</td>
<td>2009</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>79</td>
<td>(Jin and Law 2009) : Lifelong learning to advance the engineer's career</td>
<td>2009</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>80</td>
<td>(Robertson 2008) : Sustainable e-learning, activity theory and professional development</td>
<td>2008</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>81</td>
<td>(Roy et al. 2008) : Designing low carbon higher education systems: Environmental impacts of campus and distance learning systems</td>
<td>2008</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>82</td>
<td>(Mason 2008) : What is complexity theory and what are its implications for educational change?</td>
<td>2008</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>83</td>
<td>(Dinevski 2008) : Open educational resources and lifelong learning</td>
<td>2008</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>84</td>
<td>(O’Neil 2008) : The current status of instructional design theories in relation to today's authoring systems</td>
<td>2008</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>86</td>
<td>(Kim et al. 2008) : Pocket school: Exploring mobile technology as a sustainable literacy education option for underserved indigenous children in Latin America</td>
<td>2008</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>87</td>
<td>(Franceschi et al. 2008) : Engaging E-Learning in Virtual Worlds: Supporting Group Collaboration</td>
<td>2008</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>89</td>
<td>(Berge and Giles 2008) : Strategic Planning for E-Learning in the Workplace</td>
<td>2008</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>90</td>
<td>(Laurillard 2007) : Modelling benefits-oriented costs for technology enhanced learning</td>
<td>2007</td>
<td>SP</td>
<td>Conceptual</td>
</tr>
<tr>
<td>91</td>
<td>(Uden et al. 2007) : The future of E-learning: E-learning ecosystem</td>
<td>2007</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>92</td>
<td>(Chang and Guetl 2007) : E-learning ecosystem (eles)-a holistic approach for the development of more effective learning environment for small-and-medium sized enterprises (smes)</td>
<td>2007</td>
<td>SP</td>
<td>Conceptual</td>
</tr>
<tr>
<td>93</td>
<td>(Thomas and Trapp 2007) : Building re-configurable blended learning arrangements</td>
<td>2007</td>
<td>SP</td>
<td>Conceptual</td>
</tr>
<tr>
<td>94</td>
<td>(Stiles and Yorke 2007) : Technology supported learning – Tensions between innovation, and control and organisational and professional cultures</td>
<td>2007</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>No.</td>
<td>Paper</td>
<td>Year</td>
<td>Step</td>
<td>Characteristics of paper</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
<td>------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>95</td>
<td>(Motiwalla 2007) : Mobile learning: A framework and evaluation</td>
<td>2007</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>96</td>
<td>(Lee and Chan 2007) : Pervasive, lifestyle-integrated mobile learning for distance learners: an analysis and unexpected results from a podcasting study</td>
<td>2007</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>97</td>
<td>(Chen 2007) : The factors influencing members’ continuance intentions in professional virtual communities — a longitudinal study</td>
<td>2007</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>98</td>
<td>(Müller et al. 2007) : The socio-economic dimensions of ICT-driven educational change</td>
<td>2007</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>99</td>
<td>(Müller and Siebenhüner 2007) : Policy instruments for sustainability-oriented organizational learning</td>
<td>2007</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>100</td>
<td>(Bottino 2007) : On-line learning networks: Framework and scenarios</td>
<td>2007</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>102</td>
<td>(Downes 2007) : Models for sustainable open educational resources</td>
<td>2007</td>
<td>NSR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>103</td>
<td>(Farooq et al. 2007) : Sustaining a community computing infrastructure for online teacher professional development: A case study of designing tapped in</td>
<td>2007</td>
<td>SLR</td>
<td>Case study</td>
</tr>
<tr>
<td>104</td>
<td>(Pullen and Snow 2007) : Integrating synchronous and asynchronous internet distributed education for maximum effectiveness</td>
<td>2007</td>
<td>SLR</td>
<td>Empirical</td>
</tr>
<tr>
<td>105</td>
<td>(Koohang and Harman 2007) : Advancing sustainability of open educational resources</td>
<td>2007</td>
<td>NSR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>106</td>
<td>(Georgiadou and Siakas 2006) : Distance learning: Technologies; Enabling learning at own place, own pace, own time</td>
<td>2006</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>107</td>
<td>(Hylén 2006) : Open educational resources: Opportunities and challenges</td>
<td>2006</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>108</td>
<td>(Chiu et al. 2006) : Understanding knowledge sharing in virtual communities: An integration of social capital and social cognitive theories</td>
<td>2006</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>109</td>
<td>(Sharpe et al. 2006) : Implementing a university e-learning strategy: levers for change within academic schools</td>
<td>2006</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>110</td>
<td>(Dholakia et al. 2006) : What makes an open education program sustainable? The case of Connexions</td>
<td>2006</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>111</td>
<td>(Fisler and Bleisch 2006) : eLML, the eLesson Markup Language: Developing Sustainable e-Learning Content Using an Open Source XML Framework</td>
<td>2006</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>112</td>
<td>(Berge and Giles 2006) : Implementing and sustaining e-learning in the workplace</td>
<td>2006</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>113</td>
<td>(Olofsson and Lindberg 2006) : Whatever Happened to the Social Dimension?&quot; Aspects of Learning in a Distance-based Teacher Training Programme&quot;</td>
<td>2006</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>114</td>
<td>(Steichert 2006) : Informatics system comprehension: A learner-centred cognitive approach to networked thinking</td>
<td>2006</td>
<td>SLR</td>
<td>Conceptual</td>
</tr>
<tr>
<td>115</td>
<td>(Chen et al. 2005) : Personalized e-learning system using item response theory</td>
<td>2005</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>116</td>
<td>(Gunn et al. 2005) : Repurposing learning objects: a sustainable alternative?</td>
<td>2005</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>117</td>
<td>(Salmon 2005) : Flying not flapping: a strategic framework for e-learning and pedagogical innovation in higher education institutions</td>
<td>2005</td>
<td>SP</td>
<td>Conceptual</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>No</th>
<th>Paper</th>
<th>Year</th>
<th>Step</th>
<th>Characteristics of paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>119</td>
<td>(Bell and Bell 2005) : It's installed... now get on with it! Looking beyond the software to the cultural change</td>
<td>2005</td>
<td>SP</td>
<td>Empirical</td>
</tr>
<tr>
<td>120</td>
<td>(Hoffman et al. 2005) : Social capital, knowledge management, and sustained superior performance</td>
<td>2005</td>
<td>SP</td>
<td>Theoretical</td>
</tr>
<tr>
<td>121</td>
<td>(Kendall 2005) : Lifelong learning really matters for elementary education in the 21st century</td>
<td>2005</td>
<td>SLR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>122</td>
<td>(Littlejohn and Shum 2003) : Reusing online resources: a sustainable approach to e-learning</td>
<td>2003</td>
<td>NSR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>123</td>
<td>(Littlejohn 2003) : Supporting sustainable e-learning</td>
<td>2003</td>
<td>NSR</td>
<td>Theoretical</td>
</tr>
<tr>
<td>124</td>
<td>(Schoenwald 2003) : Sustainable implementation of e-learning as a change process at universities</td>
<td>2003</td>
<td>NSR</td>
<td>Case study</td>
</tr>
</tbody>
</table>
Appendix B

Ethics approval and survey documents

This research is approved and classified as negligible or low risk by the Science Engineering and Health CHEAN (College Human Ethics Advisory Network) under ethics approval number ASEHAPP 72-15 which is valid from 30-Mar-2016 to 30-Mar-2019. Based on the rules set down by CHEAN, all data should be stored on the RMIT University network system. Thus, information technology services in the university have located a secure data storage facility in the system for this research called REeLearning.

Ethics approval
30th March 2016

Dear Dr Spichkova

ASEHAPP 72-15 SPICHKOVA-ALAHRTHI Requirements Engineering Aspects of E-Learning Systems

Thank you for submitting your amended application for review.

I am pleased to inform you that the CHEAN has approved your application for a period of **3 Years** from the date of this letter to **30th March 2019** and your research may now proceed.

The CHEAN would like to remind you that:

- All data should be stored on University Network systems. These systems provide high levels of manageable security and data integrity, can provide secure remote access, are backed up on a regular basis and can provide Disaster Recover processes should a large scale incident occur. The use of portable devices such as CDs and memory sticks is valid for archiving; data transport where necessary and for some works in progress.
- The authoritative copy of all current data should reside on appropriate network systems; and the Principal Investigator is responsible for the retention and storage of the original data pertaining to the project for a minimum period of five years.

**Please Note:** Annual reports are due on the anniversary of the commencement date for all research projects that have been approved by the CHEAN. Ongoing approval is conditional upon the submission of annual reports failure to provide an annual report may result in Ethics approval being withdrawn.

Final reports are due within six months of the project expiring or as soon as possible after your research project has concluded.

The annual/final reports forms can be found at:  
www.rmit.edu.au/staff/research-human-research-ethics

Yours faithfully,

Dr Linda Jones  
Chair, Science Engineering & Health  
College Human Ethics Advisory Network

Cc CHEAN Member: A/Prof Susana Gavidia-Payne School of Health Sciences RMIT University  
Student Investigator/s: Mr Ahmed Alahrthi Computer Science & IT RMIT University Other Investigator/s: A/Prof Margaret Hamilton Computer Science & IT RMIT University
Survey documents

In our research we have three surveys as:

1. **Survey 1** About sustainability of eLearning systems being discussed in Chapter 4,

2. **Survey 2** About analysing sustainability requirements of Canvas and Desire2Learn (D2L) as case studies of eLearning systems, see Section 6.2, and

3. **Survey 3** About SuSoftPro framework and its tool being presented in Section 6.3.

Also, each survey has

1. **Survey questions**: includes all questions,

2. **Participant Information**: include information about the research project and the survey, and

3. **Recruitment advertisements**: copy of recruitment advertisements and the used media.
Surveys Process

PARTICIPANT INFORMATION

Demography Questions

IT Support and Administration
Teacher Survey
Learner Survey

General Questions

• Participant Information

1. Watching video demonstration
2. Trying the tool (optional)
3. Demography questions
4. Evaluation questions
<table>
<thead>
<tr>
<th>Survey*</th>
<th>Purpose</th>
<th>Recruitment</th>
<th>Participants</th>
<th>Approval Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To explore the most used, requested and deficient functionalities of eLearning systems</td>
<td>Email</td>
<td>Students, instructors, Administrator and IT support in RMIT university and Umm Alqura university</td>
<td>Original</td>
</tr>
<tr>
<td>2</td>
<td>To analyse sustainability requirements of eLearning systems</td>
<td>Email</td>
<td>Students, instructors, Administrator and IT support in RMIT university and Umm Alqura university</td>
<td>Amendment</td>
</tr>
<tr>
<td>3</td>
<td>To evaluate developed SuSoftPro framework and tool for analysing sustainability in software.</td>
<td>Twitter and LinkedIn</td>
<td>Student, instructor, researcher, software developer, IT supports, and Administrator, and related.</td>
<td>Amendment</td>
</tr>
</tbody>
</table>
Surveys 1
For Requirements Engineering Aspects of eLearning Systems

Demography Questions:
DQ1. Who you are?
   - IT Support or Administration
   - Teacher
   - Learner
DQ2. Your affiliation: Country?
   - Australia
   - Saudi Arabia
   - Others (specify):
DQ3. University?
   - RMIT
   - Umm Alqura University (UQU)
   - Others (specify):

IT Support and Administration Group:
ITQ1. Where and how do you store data (physically)?
ITQ2. How long do you keep old data?
ITQ3. How easy to add new functionality or remove a function such as discussion boards or virtual class? What process do you need?
ITQ4. What problems need to be solved in the current system?
ITQ5. How much power consumed by your eLearning system?

Teacher Group:
TQ1. Gender: Male or Female
TQ2. How old are you?
TQ3. What kind of functionality are you using such as chat, discussion board, etc?
TQ4. Which functionality do you request which is not provided (by now) in your system?
TQ5. How long should the eLearning system keep your materials and data, from your point of view?

Learner Group:
LQ1. Gender: Male or Female
LQ2. How old are you?
LQ3. What kind of functionality are you using such as chat, discussion board, etc?
LQ4. Which functionality do you request which is not provided (by now) in your system?
LQ5. How long should the eLearning system keep your materials and data, from your point of view?

General Questions:
GQ1. What kind of eLearning systems and platforms are you using?
   - Blackboard (Bb)
   - Moodle (M)
   - Desire2Learn (D2L)
   - Pearson such as MyLab
   - Others (specify):
GQ2. What would you change or improve features in the current system and how important?
GQ3. Do you have anything to add?
الأسئلة الديموغرافية:
DQ1 من أنت؟
- داعم فني أو مدير نظام
- معالج
- طلب
- أستاذ
DQ2 أين تدرس؟
- المملكة العربية السعودية
- آخر(حدد):
DQ3 الجامعة؟
- RMIT
- جامعة أم القرى
- أخرى (حدد):

مجموعة الدعم الفني ومدير النظام:
ITQ1 أين يتم تخزين البيانات وكيف يتم تخزينها؟
ITQ2 إلى متى يتم تخزين البيانات القديمة؟
ITQ3 ما هي المشاكل الموجودة في نظامكم الحالي؟
ITQ4 ما هو مقدار الطاقة التي يستهلكها نظام التعليم الإلكتروني الخاص بك؟

مجموعة المعلم:
TQ1 الجنس: (ذكر أو أنثى)
- كم عمرك؟
TQ2 أي من الأدوات أو الوظائف التي تستخدمها في النظام التعليم الإلكتروني مثل الدردشة، المناقشات وغيرها؟
TQ3 ما هي الأدوات أو الوظائف التي ترغب بها وليست موجودة في نظامكم الآن؟
TQ4 لغة تعبد من وجهة نظرك أن النظام يجب أن يحتفظ ببياناتك الخاصة وملفاتك؟

مجموعة الطالب:
LQ1 الجنس: (ذكر أو أنثى)
- كم عمرك؟
LQ2 أي من الأدوات أو الوظائف التي تستخدمها في النظام التعليم الإلكتروني مثل الدردشة، المناقشات وغيرها؟
LQ3 ما هي الأدوات أو الوظائف التي ترغب بها وليست موجودة في نظامكم الآن؟
LQ4 لغة تعبد من وجهة نظرك أن النظام يجب أن يحتفظ ببياناتك الخاصة وملفاتك؟

الأسئلة العامة:
GQ1 ما هو النظام المستخدم في التعليم الإلكتروني؟
- Blackboard (Bb)
- Moodle
- Desire2Learn (D2L)
- Pearson
- أخرى (حدد):
GQ2 ما هي الأدوات أو الوظائف تريدها في نظامكم الحالي؟
- هل هناك شيء آخر تريد أن تضيف؟

(October 31, 2019)
Questions of survey 2 consist of sustainability dimension instruction and requirements in Table C.1, on Page 171, and Table C.2 on Page 181

**Surveys 2**

for analysing sustainability requirements of eLearning system

<table>
<thead>
<tr>
<th>System</th>
<th>University</th>
<th>Country</th>
<th>Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canvas</td>
<td>RMIT university</td>
<td>Australia</td>
<td>English</td>
</tr>
<tr>
<td>Desir2Learn (D2L)</td>
<td>Umm Alqura university</td>
<td>Saudi Arabia</td>
<td>Arabic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant group</th>
<th>Sustainability aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>Individual ✓ Social ✓ Technical ✓ Economic ✓ Environmental ✓</td>
</tr>
<tr>
<td>Instructor</td>
<td>✓</td>
</tr>
<tr>
<td>Admin</td>
<td>✓</td>
</tr>
<tr>
<td>IT support/developer</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sustainability aspects</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>Rate the influence of the requirement on the individual sustainability</td>
</tr>
<tr>
<td>Social</td>
<td>Rate the influence of the requirement on the social sustainability</td>
</tr>
<tr>
<td>Technical</td>
<td>Rate the influence of the requirement on the technical sustainability</td>
</tr>
<tr>
<td>Economic</td>
<td>Rate the influence of the requirement on the economic sustainability</td>
</tr>
<tr>
<td>Environmental</td>
<td>Rate the influence of the requirement on the environmental sustainability</td>
</tr>
</tbody>
</table>

**Sustainability aspects – Arabic version:**

<table>
<thead>
<tr>
<th>Sustainability aspects</th>
<th>تعليمات</th>
</tr>
</thead>
<tbody>
<tr>
<td>الفردي</td>
<td>أوجه الاستدامة على الفرد من وجهة نظرك</td>
</tr>
<tr>
<td>الاجتماعي</td>
<td>أوجه الاستدامة على المجتمع من وجهة نظرك</td>
</tr>
<tr>
<td>التقني</td>
<td>أوجه الاستدامة على التقنية من وجهة نظرك</td>
</tr>
<tr>
<td>الاقتصادي</td>
<td>أوجه الاستدامة على الاقتصاد من وجهة نظرك</td>
</tr>
<tr>
<td>البيئي</td>
<td>أوجه الاستدامة على البيئة من وجهة نظرك</td>
</tr>
</tbody>
</table>
Introduction to sustainability and the SuSoftPro framework:

We defined a new framework and developed a new tool, SuSoftPro to analyse sustainability requirements of software systems.

Our framework requires software engineers and stakeholders to complete a questionnaire about the five sustainability aspects fronting a high level of software requirements. The responses are analysed systematically via multiple criteria decision analysis. The result presented as sustainability profiling including sustainability five-star rating, visualisation of the five sustainability aspects and a bar graph for overall sustainability of each requirement. The following demo video presents the main features of the SuSoftPro tool.

The term sustainability is derived from the Latin word sustinere (sus: up; tinere: to hold) and is often used solely in the environmental sense.

Sustainability of software is defined through the following aspects:

- **Individual sustainability aspect**: Individual needs should be protected and supported with dignity;
- **Social sustainability aspect**: Relationships should be equitable, diverse, connected and democratic;
- **Technical sustainability aspect**: Technology should be able to cope with the changes and evolution efficiently and with respect for natural resources;
- **Economic sustainability aspect**: A positive economic value and capital growth should be ensured and maintained; and
- **Environmental sustainability aspect**: Natural resources have to be protected from human needs and wastes.
We require information about our framework and SuSoftPro tool.

After watching and trying the tool, to what extent do you agree or disagree with the following?

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 10 20 30 40 50 60 70 80 90 100</td>
<td></td>
</tr>
</tbody>
</table>

1. The tool has a logical flow from the start to the end for analysing the sustainability requirements and sustainability aspects of software systems.

2. The tool has a systematic procedure to generate sustainability software profiling and star rating. It also analyses the sustainability requirements and sustainability aspects of software systems.

3. The tool is easy to use for analysing the sustainability requirements and sustainability aspects of software systems.

4. The tool provides for the assignment of stakeholders to certain group that is allocated to one or more sustainability aspects.

5. The tool contributes analysing sustainability requirements for software systems.

6. I am likely to use the tool to measure sustainability aspects and sustainability requirements of software systems in future.

NOTE: when the rate scale of 6 below 50, 6.a and 6.b will appear, otherwise they will not be showed.

6.a. How do you measure and analyse sustainability requirements and sustainability aspects of software systems? ______________________________________________________

6.b. Do you use any tool to analyse the sustainability aspects and sustainability requirements of software systems?

○ No

○ Yes, what are these tools? ____________________________________________________________

Would you have any suggestions on how can we improve the tool and/or the framework?

__________________________________________________________________________________
المراجعات

SuSoftPro

تقييم منهجية وآداة SuSoftPro

مقدمة

قد عرفنا منهجية جديدة وطورنا نظاماً استناداً إلى أداة SuSoftPro ليساعد في تحليل وقياس متطلبات الاستدامة للنظم البرمجية في المرحلة المبكرة من تطوير البرمجيات:

منهجيتنا تتضمن تحليل القواعد المتعددة المعمول بها وتقييم مستوى الاستدامة، وذلك عن طريق تصنيف الاستدامة خمس نجوم، وعرض جانب الاستدامة الخمسة على شكل رسم بياني فقي، ورسم بياني شريطي آخر للعامة العامة لكل متطلب رئيسي للبرمجيات.

مصطلح الاستدامة (Sustainability) مشتق من الكلمة اللاتينية (sustinere (sus: up; tinere: to hold) وغالباً ما يستخدم الاستدامة مع الاستدامة الطبيعية والبيئة.

ولن تعرف الاستدامة للبرامج من خلال الجوانب التالية:

• جانب الاستدامة الفردية ينبغي حماية الاحتياجات الفردية ودعتها;
• جانب الاستدامة الاجتماعية العلاقات ينبغي أن تكون متمنية ومعروفة ومنتظمة وتبرعات;
• جانب الاستدامة البيئية التكنولوجيا ينبغي أن تكون قادرة على التكيف مع التغيرات وتتطور بفضل تعاونًا مع المحافظة على الموارد الطبيعية;
• جانب الاستدامة الاقتصادية ينبغي ضمان القيمة الاقتصادية الإيجابية تم رأس المال والمحافظة عليها;
• جانب الاستدامة البيئية الموارد الطبيعية يجب أن تكون محمية من الاحتياجات الزائدة للبرامج والموارد المضرة.

• جانب الاستدامة البيئية
تحتاج لجمع معلومات عن المنهجية والنظام

5. بعد مشاهدتك للفيديو وكذلك تجربتك للنظام، ألى أي مدى توافق أو لا توافق مع الجمل التالية

لا اتفق بشدة

أتفق بشدة

عمل النظام يُبذل بشكل منطقي من البداية إلى النهاية.

عمل النظام يُبذل بناءً على دمجات منهجية لإعداد وراي عن معايير الاستدامة التي تتعلق على مثل معايير الاستدامة والقواعد في البرنامج.

عمل النظام يُبذل بناءً على معايير الاستدامة والقواعد في البرنامج.

يتم تحليل متطلبات الاستدامة وحاجات الاستدامة في البرنامج.

يتم تحليل متطلبات الاستدامة وحاجات الاستدامة في البرنامج.

يمكن تحليل نظرة المستخدم لكل البرمجيات و객ب المصلحة في مجموعة معينة والتي يمكن تخصيصه لأحد أو أكثر من جوانب الاستدامة.

يمكن تحليل نظرة المستخدم لكل البرمجيات وقيلب المصلحة في مجموعة معينة والتي يمكن تخصيصه لأحد أو أكثر من جوانب الاستدامة.

6. كيف يمكنك قياس وتحليل متطلبات الاستدامة وحاجات الاستدامة للبرمجيات؟

هل تستخدم أي أداة لتحليل جوانب الاستدامة ومتعلقات الاستدامة للبرمجيات؟

لا

tعلم باذى الطرق أو الأداة المستخدمة

هل تشير إجابة التحسين المنهجية والأداة؟

150 (October 31, 2019)
Participant Information (PI)

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

PARTICIPANT INFORMATION

Project Title: Requirements Engineering Aspects of eLearning Systems

Investigators:
- Principal Research Student: Ahmed Alharthi
- Chief Investigator: Dr. Maria Spichkova
- Co-investigator: Dr. Margaret Hamilton

Dear …………,

You are invited to participate in a research project being conducted by RMIT University. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate. If you have any questions about the project, please ask one of the investigators.

Who is involved in this research project? Why is it being conducted?
- Students, teachers, IT supporters and administrators who use eLearning system and their answers will help us identify the requirements aspects of eLearning systems.
- This research is being conducted as part of a Ph.D. Computer Science degree.
- The project has been approved by the RMIT Human Research Ethics Committee.
- This study is sponsored by Umm Al-Qura University in Saudi Arabia.

Why have you been approached?
The reason we are recruiting you for this survey is that you are student, or teacher, or IT supporter or administrator in an eLearning system and your answers will help us identify the requirements aspects of eLearning systems. You have been selected by your school or department.

What is the project about? What are the questions being addressed?
- The aims of this ongoing research are: (1) to identify country- and/or culture-specific as well as common requirements for eLearning systems, and (2) to construct a framework for analysis of the diversity aspects such as culture and technical as well as sustainability aspects (environmental, technical, educational, social, etc.). The framework will contribute to the requirement engineering (RE) process for development and improvement of eLearning systems, which might improve the overall sustainability of online and on-campus teaching and learning activities.
- This work aims to answer the following research questions:
  - RQ1: How can we deal with the diversity (technical, cultural, etc.) aspects while developing or improving a global eLearning system?
  - RQ2: What is specific in RE for eLearning systems (in comparison to other development domain, e.g. automotive)?
  - RQ3: How can we cover sustainability aspects while developing or extending an eLearning system? How can we model them as a part of RE process?
  - RQ4: How can we improve the RE process for an eLearning system?
- We are expecting 100 participates.
If I agree to participate, what will I be required to do?

In requesting your participation in this survey, anonymity will be assured. Your participation in the online survey is completely voluntary, and you can withdraw from the process at any time by closing the browser. The survey would take around 10-15 minutes of your time to be completed. If you agree to participate, you need to choose agree at the end of this page which indicating your agreement to participation.

This will take you to the survey pages. First part is demographic questions which include question who you are and you country. The second part is more specific question regarding your selection in the first part. For example if you choose you are student in the first part, the second part will include question such as What kind of functionality are you using such as chat, discussion board, etc.? Last part has general questions such as what kind of eLearning systems and platforms are you using? Once you have responded to all the questions, you need to click on the submit button. By clicking the submit button, you are implying your consent to participate in this research.

What are the possible risks or disadvantages?

- There are no perceived risks outside the participant’s normal day-to-day activities. “If you are unduly concerned about your responses to any of the questionnaire items or if you find participation in the project distressing, you should contact Chief Investigator as soon as convenient. Dr. Maria Spichkova will discuss your concerns with you confidentially and suggest appropriate follow-up, if necessary”.

What are the benefits associated with participation?

One of the benefits that may accrue to you as a result of your participation is the improvement of quality requirements in eLearning system such as sustainability, availability, performance, portability, reliability, safety and security.

What will happen to the information I provide?

- Anonymity will be assured; so, you cannot be identified at any stage of the research.
- The research findings may be published in the PhD thesis in the RMIT Repository, or in academic journals, or report, or be presented at conferences.
- Because of the nature of data collection, we are not obtaining written informed consent from you. Instead, we assume that you have given consent by your completion and submitting the questionnaire.

What are my rights as a participant?

- The right to withdraw from participation at any time before submitting.

Whom should I contact if I have any questions?

- Chief Investigator: Dr. Maria Spichkova
- Co-investigator: Dr. Margaret Hamilton
- Principal Research Student: Ahmed Alharthi

What other issues should I be aware of before deciding whether to participate?

- If you submit you survey, you cannot withdraw your participation because of anonymity.
SECTION B.0:

Participant Information (PI)

Security of the website

Users should be aware that the World Wide Web is an insecure public network that gives rise to the potential risk that a user’s transactions are being viewed, intercepted or modified by third parties or that data which the user downloads may contain computer viruses or other defects.

Security of the data:
This project will use an external site to create, collect and analyse data collected in a survey format. The site we are using is Google Forms. If you agree to participate in this survey, the responses you provide to the survey will be stored on a host server that is used by Google. No personal information will be collected in the survey so none will be stored as data. Once we have completed our data collection and analysis, we will import the data we collect to the RMIT server where it will be stored securely for five (5) years. The data on the Google host server will then be deleted and expunged.

Thank you so much for your support of conducting our research.

Dr. Maria Spichkova

Dr. Margaret Hamilton

Ahmed Alharthi, MS
Ph.D student, Computer Science
The School of Computer Science and Information Technology
RMIT University

If you have any concerns about your participation in this project, which you do not wish to discuss with the researchers, then you can contact the Ethics Officer, Research Integrity, Governance and Systems, RMIT University, GPO Box 2476V VIC 3001. Tel: (03) 9925 2251 or email human.ethics@rmit.edu.au
المعلومات المشاركة
عنوان البحث: جوانب متطلبات بناء نظم التعليم الإلكتروني
الباحثون:
اﻟﺑﺎﺣث اﻟرﺋﯾﺳﻲ: اﺣﻣد اﻟﺣﺎرﺛﻲ
thedoctora maria sabitkova
marshrएn unforgettable
marshrكلم: أساتذة مشترك ماري غريغ هاتون

سنوولنعراء،
السلام عليك ورحمة الله وبركاته
أما بعد:
أنت مدعو للمشاركة في بحث يتم عمله في جامعة RMIT. فضلا اقرأ هذه المعلومات جيدا وكن واثقا انك فهمت المحتوى قبل اتخاذ القرار للمشاركة. اذا كان لديك اي سؤال حول البحث لا تتردد بسؤال احد الباحثين.

من هم المشاركون في هذا البحث؟ ولماذا يتم عمل هذا البحث؟
• الطلاب والمعلمين والمحاضرين والمدربين الذين يتعلمون نظم التعليم الإلكتروني. وجموعهم سوف يساعد في تحديد
• جوانب المتطلبات الخاصة بلغة التعليم الإلكتروني. وجموعهم سوف يساعد في تحديد
• البحث يتم الموافقة عليه من قبل لجنة أخلاقيات البحث الإنسانية بجامعة RMIT.
• هذا البحث تم تمويله من قبل جامعة أم القرى في المملكة العربية السعودية.

لماذا تم اختيارك للبحث؟
المسبب لاختيارك هو أنك طالب أو معلم أو محاضر أو داعم فني أو مدير نظم تستخدم نظام التعليم الإلكتروني. واجبتك على هذا الاستطلاع سوف

ما هو البحث؟ وما هي الاستفسارات الذي يعالجه؟
• الأهداف الأساسية لهذا البحث هو 1) تحديد المتطلبات الخاصة بدولة أو ثقافة خاصة وكذلك المتطلبات العامة لبناء نظم التعليم الإلكتروني.
• البحث مثل بيئة التنورر مثل لتوجيع التنافسية واللغة، ومعا جوانب الاستماع (اللغة، الثقافة، التعليمية، الاجتماعية، التكنولوجيا)
• البحث سوف يساعد في تحديد المتطلبات لبناء نظم التعليم الإلكتروني. واجبتك على هذا الاستطلاع سوف

ما هي الفوائد لتنفيذ هذا الاستطلاع؟
أحد الفوائد المتوقع الحصول عليها من خلال مشاركتك هو

ما هي المخاطر المحتملة لتنفيذ هذا الاستطلاع؟
• ليس هناك أي مخاطر محتملة
• إذا كنت غير متأكد من إعادة الاتصال خلال مشترك يمكن التواصل مع رئيسة البحث دكتورة ماريا وهي سوف
• تناقش تلك التطبيقات المشتركة معك وسوف تكون هناك خصوصية للمعلومات ومتاح حلو إذا احتاج الأمر.
• ما هي الفوائد لهذا الاستطلاع؟

هناك 100 مشترك على الأقل.

ما هي المشاكل المحتملة لتنفيذ هذا الاستطلاع؟
• ليس هناك أي مخاطر محتملة
• إذا كنت غير متأكد من إعادة الاتصال خلال مشترك يمكن التواصل مع رئيسة البحث دكتورة ماريا وهي سوف
• تناقش تلك التطبيقات المشتركة معك وسوف تكون هناك خصوصية للمعلومات ومتاح حلو إذا احتاج الأمر.
• ما هي الفوائد لهذا الاستطلاع؟

154 (October 31, 2019)
ماذا سيحدث للاجابت الذي سوف أقدمها؟

• ضمانية عدم كشف الهوية. ولذا لن يتم التعرف على هويتك في أي مرحلة من مراحل البحث.

على الرغم من أن نتائج الاستطلاع قد تنشر في أطرافه الدوران مثل مكتبة RMIT، أو في المجلات الأكاديمية أو كتابة تقرير أو عرضها في المؤتمرات، فإننا لن نتمكن من التعرف على هويتك في أي مرحلة من مراحل البحث.

• ما هي حقوقك كمشارك؟

ما هي القضايا الأخرى التي يجب أن تكون على علم بها؟

• إذا كنت مشاركًا، لا يمكنك الغاء أي إجابة.

• إذا كان لديك أي مخاوف حول مشاركتك في هذا البحث، والتي لا ترغب في مناقشتها مع الباحثين، يمكنك التواصل مع مسئول إخلاق البحوث والنزاهة والحوكمة في جامعة RMIT، RMIT University, GPO Box 2476V VIC 3001. Tel: (03) 9925 2251 or email human.ethics@rmit.edu.au

• يمكن أن تحدث الهوية عبر الشبكات العامة في الشبكات العامة، والتي غالبا تكون خطيرة من حيث نقل البيانات مثل مشاركتها أو تعديلها، من قبل طرف ثالث.

• إذا استخدمت Google Forms، فإن فئة البيانات الموجودة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدمة في جمع البيانات مصممة لتضمن أن البيانات المستخدم
PARTICIPANT INFORMATION

Project Title: Requirements Engineering Aspects of eLearning Systems

Investigators:

- Principal Research Student: Ahmed Alharthi
- Chief Investigator: Dr. Maria Spichkova
- Co-investigator: Dr. Margaret Hamilton

Dear ………….,

You are invited to participate in a research project being conducted by RMIT University. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate. If you have any questions about the project, please ask one of the investigators.

Who is involved in this research project? Why is it being conducted?

- Students, teachers, IT supporters and administrators who use eLearning system and their answers will help us identify the requirements aspects of eLearning systems.
- This research is being conducted as part of a Ph.D. Computer Science degree.
- The project has been approved by the RMIT Human Research Ethics Committee.
- This study is sponsored by Umm Al-Qura University in Saudi Arabia.

Why have you been approached?

The reason we are recruiting you for this survey is that you are student, or teacher, or IT supporter or administrator in an eLearning system and your answers will help us identify the requirements aspects of eLearning systems. You have been selected by your school or department.

What is the project about? What are the questions being addressed?

- The aims of this ongoing research are: (1) to identify country- and/or culture-specific as well as common requirements for eLearning systems, and (2) to construct a framework for analysis of the diversity aspects such as culture and technical as well as sustainability aspects (environmental, technical, educational, social, etc.). The framework will contribute to the requirement engineering (RE) process for development and improvement of eLearning systems, which might improve the overall sustainability of online and on-campus teaching and learning activities.
- This work aims to answer the following research questions:
  - RQ1: How can we deal with the diversity (technical, cultural, etc.) aspects while developing or improving a global eLearning system?
  - RQ2: What is specific in RE for eLearning systems (in comparison to other development domain, e.g. automotive)?
  - RQ3: How can we cover sustainability aspects while developing or extending an eLearning system? How can we model them as a part of RE process?
  - RQ4: How can we improve the RE process for an eLearning system?
- We are expecting 100 participates.
If I agree to participate, what will I be required to do?

In requesting your participation in this survey, anonymity will be assured. Your participation in the online survey is completely voluntary, and you can withdraw from the process at any time by closing the browser. The survey would take around 15-20 minutes of your time to be completed. If you agree to participate, you need to choose “I agree” button at the end of this page which indicates your agreement to participate.

If you agree, you will need to select your role as a stakeholder in your eLearning system (instructor, learner, administrator and IT support). In the portal, you will be asked to rate a list of requirements (features) in the eLearning system at your institution. You need to give your stakeholder perspective on the sustainability of the system by rating the influence of requirements on the individual, social, technical, economic and environmental aspects.

For example, you will be presented with a requirement such as “Profile and User Settings requirement” and then asked to rate its influence on the individual sustainability of your eLearning system.

You can ignore a question that you may not be familiar with. Once you have responded to all the questions, you need to click on the submit button.

What are the possible risks or disadvantages?

- There are no perceived risks outside your normal day-to-day activities.
- If you are unduly concerned about your responses to any of the questionnaire items or if you find participation in the project distressing, you should contact Chief Investigator as soon as convenient. Dr. Maria Spichkova will discuss your concerns with you confidentially and suggest appropriate follow-up, if necessary.

What are the benefits associated with participation?

One of the benefits that may accrue to you as a result of your participation is the improvement of quality requirements in eLearning system such as sustainability, availability, performance, portability, reliability, safety and security.

What will happen to the information I provide?

- Anonymity will be assured; so, you cannot be identified at any stage of the research.
- The research findings may be published in the PhD thesis in the RMIT Repository, or in academic journals, or report, or be presented at conferences.
- Because of the nature of data collection, we are not obtaining written informed consent from you. Instead, we assume that you have given consent by your completion and submitting the questionnaire.

What are my rights as a participant?

- The right to withdraw from participation at any time before submitting.

Whom should I contact if I have any questions?

- Chief Investigator: Dr. Maria Spichkova
- Co-investigator: Dr. Margaret Hamilton
- Principal Research Student: Ahmed Alharthi

What other issues should I be aware of before deciding whether to participate?
Participant Information (PI)

- If you submit your survey, you cannot withdraw your participation.

Security of the website

Users should be aware that the World Wide Web is an insecure public network that gives rise to the potential risk that a user’s transactions are being viewed, intercepted or modified by third parties or that data which the user downloads may contain computer viruses or other defects.

Security of the data:

This project will use an external site to create, collect and analyse data collected in a scale-based questionnaire format. The site we are using is SuSoftPro. If you agree to participate in this survey, the responses you provide to the survey will be stored on a host server that is used by SuSoftPro. No personal information will be collected in the survey, so none will be stored as data. Once we have completed our data collection and analysis, we will import the data we collect to the RMIT server where it will be stored securely for five (5) years. The data on SuSoftPro will then be deleted and expunged.

Thank you so much for your support of conducting our research.

Dr. Maria Spichkova

Dr. Margaret Hamilton

Ahmed Alharthi, MS
Ph.D student, Computer Science
The School of Computer Science and Information Technology
RMIT University

If you have any concerns about your participation in this project, which you do not wish to discuss with the researchers, then you can contact the Ethics Officer, Research Integrity, Governance and Systems, RMIT University, GPO Box 2476V VIC 3001. Tel: (03) 9925 2251 or email human.ethics@rmit.edu.au
 salud de los participantes:

- Participantes:
  - Participante principal: Ahmed Alharthy
  - Doctora Maria Sibayoka
  - Supervisor de la investigación:
    - Profesor Maragret Hameen
  - Supervisor secundario:
    - Esta el respeto}

Pío

- Saludo:
  - Su Excelencia
  - Señor

Bienvenidos:

- Participantes:
  - Estudiantes y profesores
  - Directores de sistemas de aprendizaje electrónicos que utilizan el sistema de aprendizaje electrónico.
  - Sus respuestas ayudarán a determinar aspectos de las necesidades para la construcción de sistemas de aprendizaje electrónicos.

- El estudio es parte de una tesis de doctorado en Ciencias de la Información.
- El estudio fue aprobado por la comisión de ética de la investigación de la Universidad RMIT.
- Este estudio fue financiado por la Universidad Am Qura en Arabia Saudita.

- ¿Por qué te elegimos para participar en este estudio?
  - El motivo de tu elección es porque eres estudiante, profesor, docente, ingeniero de soporte o director de sistemas que utiliza el sistema de aprendizaje electrónico. Tus respuestas ayudarán a determinar aspectos de las necesidades para la construcción de sistemas de aprendizaje electrónicos.
  - Fueron elegidos de manera aleatoria en la universidad.

- ¿Qué es este estudio y cuáles son las preguntas que aborda?
  - Los objetivos principales de este estudio son:
    1. Determinar las necesidades específicas de una cultura o un país, así como las necesidades generales para la construcción de sistemas de aprendizaje electrónicos.
    2. Desarrollar un marco de organización para analizar la diversidad, como la diversidad cultural y tecnológica, y aspectos de la sostenibilidad (ambiental, educativa, social, etc.).
  - Este estudio responderá a las siguientes preguntas:
    1. ¿Cómo podemos manejar la diversidad (cultural, tecnológica, etc.) cuando desarrollamos o mejoramos los sistemas de aprendizaje electrónicos?
    2. ¿Cuáles son las necesidades específicas del aprendizaje electrónico (en comparación con otras áreas de desarrollo)?
    3. ¿Cómo podemos abordar los aspectos de la sostenibilidad durante el desarrollo o mejora del aprendizaje electrónico y cómo podemos incorporarlo en las actividades de construcción de necesidades?

- Si aceptas participar, ¿qué necesitas hacer?
  - Si decides participar, nos garantizamos la confidencialidad de tus datos.
  - Tu participación es voluntaria, puedes abandonarla en cualquier momento a través de la eventualidad de la página.
  - El estudio tomará entre 10 y 15 minutos.
  - Para participar, debes aceptar el consentimiento.
  - Si dejas una pregunta sin responder, no afectará tu participación.

- ¿Qué riesgos hay en el proceso de este estudio?
  - No hay riesgos potenciales.

Si tienes alguna duda o preocupación, puedes contactar a la Dra. Maria, quien será encargada de discutir tus dudas sobre la participación y se garantizará la confidencialidad de la información y la propuesta de soluciones si se requieren.
ما هي الفوائد لتنفيذ هذا الاستطلاع؟
أحد الفوائد المتوقع الحصول عليها من خلال مشاركتك هو تحسين جودة المتطلبات في نظام التعليم الإلكتروني مثل الامان، الأمان، والأداء، الاستدامة، وامان المعلومات.

ما هو التأريخ الذي سوف أقدمه؟
• ضمان عدم كشف الهوية، وهذا يعني أن يتم التعرف على مشاركتك في أي مرحلة من مراحل البحث.
• على الرغم من أن نتائج الاستطلاع قد تنشر في أطراف النشر والمقاريب الإدارية أو كتة تقرير أو RMIT.
• عرضها في المؤتمرات، أو عندما تكون نتائج الاستطلاع مطبوعة تماما، ولن يتم تعرفك بمشتركته الشخصية أثناء وبعد الاستطلاع.
• إذا تكون تطبيق مهمة بيانات، في ذلك لا تحتاج معرفة خصية ملخص. ولكن تعبرني تبعيتك وامكاني للإسقاط هو عبارة عن الفوائد المشارك.

ما هي حقوقك كمشارك؟
• إذا كنت متواصل احترامtain في الاستطلاع.

مع من يمكن أن يكون أي سؤال في الاستطلاع؟
• الباحث: احمد الحارثي
• مشرف البحث: الدكتور ماريا أنخيل
• مشرف الثاني: أستاذ مارغريت هامتون

ما هي القضايا الأخرى التي يجب أن تكون على علم بها؟
• إذا كنت متواصل احترامtain في الاستطلاع.

إنما تخضع النتائج في محفوظات SuSoftPro للأمنية في خفاء البيانات، وستتم تثبيت البيانات في خوادم RMIT بعد أن يتم جمع البيانات.

شكراً جزيلاً.
احترام في كل شيء واحترام للأعمال.

Assistant
RMIT University, GPO Box 2476V VIC 3001. Tel: (03) 9925 2251 or email human.ethics@rmit.edu.au.
Participant Information (PI)

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

PARTICIPANT INFORMATION

Project Title: Requirements Engineering Aspects of eLearning Systems

Investigators:

- Principal Research Student: Ahmed Alharthi
- Chief Investigator: Dr. Maria Spichkova
- Co-investigator: Dr. Margaret Hamilton

Dear …………,

You are invited to participate in a research project being conducted by RMIT University. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate. If you have any questions about the project, please ask one of the investigators.

Who is involved in this research project? Why is it being conducted?

- Students, instructor, researcher, IT supporters, software developer and administrator, and related to strategy leadership, who have the interest to improve the quality of software and sustainable software and their answers will help us to evaluate our new framework and developed tool, SuSoftpro.
- This research is being conducted as part of a Ph.D. Computer Science degree.
- The project has been approved by the RMIT Human Research Ethics Committee.
- This study is sponsored by Umm Al-Qura University in Saudi Arabia.

Why have you been approached?

The reason we are recruiting you for this survey is that your answers will help us help us to evaluate our new framework and developed tool, SuSoftpro.

What is the project about? What are the questions being addressed?

- The main aim of this ongoing research is to construct a framework and tool for analysis of the sustainability requirements as well as sustainability aspects (environmental, technical, educational, social, etc.). The framework contributes to the requirement engineering (RE) process for development and improvement of sustainable software.
- This work aims to answer the following research questions:
  - RQ: How can we cover sustainability aspects while developing software systems? How can we model them as a part of RE process?
- We are expecting 50 participates.

If I agree to participate, what will I be required to do?

In requesting your participation in this survey, anonymity will be assured. Your participation in the online survey is completely voluntary, and you can withdraw from the process at any time by closing the browser. The survey would take around 10-15 minutes of your time to be completed. If you agree to participate, you need to choose “I agree” button at the end of this page which indicates your agreement to participate.
Participant Information (PI)

This will take you to the survey pages. Firstly, you need to watch a 4-minute demonstration video to explain our framework and SuSoftPro tool. Then, you need to answer 6 questions. The first part includes demographic questions which include information about who you are and where you live. The second part includes a more specific question regarding the framework and SuSoftPro tool. For example, in the second part, you will be asked about your agreement with statements such as, “to what extent do you agree or disagree with the tool’s logical flow from the start to the end for assessing the sustainability requirements and sustainability aspects of software systems?” The last part asks for your suggestions on how we can improve the tool. Once you have responded to all the questions, you need to click on the submit button. By clicking the submit button, you are implying your consent to participate in this research.

What are the possible risks or disadvantages?

- There are no perceived risks outside the participant’s normal day-to-day activities. If you are unduly concerned about your responses to any of the questionnaire items or if you find participation in the project distressing, you should contact Chief Investigator as soon as convenient. Dr. Maria Spichkova will discuss your concerns with you confidentially and suggest appropriate follow-up, if necessary.

What are the benefits associated with participation?

One of the benefits that may accrue to you as a result of your participation is the improvement of quality requirements, particularly in sustainability.

What will happen to the information I provide?

- Anonymity will be assured; so, you cannot be identified at any stage of the research.
- The research findings may be published in the PhD thesis in the RMIT Repository, or in academic journals, or report, or be presented at conferences.
- Because of the nature of data collection, we are not obtaining written informed consent from you. Instead, we assume that you have given consent by your completion and submitting the questionnaire.

What are my rights as a participant?

- The right to withdraw from participation at any time before submitting.

Whom should I contact if I have any questions?

- Chief Investigator: Dr. Maria Spichkova
- Co-Investigator: Dr. Margaret Hamilton
- Principal Research Student: Ahmed Alharthi

What other issues should I be aware of before deciding whether to participate?

- If you submit your survey, you cannot withdraw your participation because of anonymity.

Security of the website

Users should be aware that the World Wide Web is an insecure public network that gives rise to the potential risk that a user’s transactions are being viewed, intercepted or modified by third parties or that data which the user downloads may contain computer viruses or other defects.

Security of the data:
Participant Information (PI)

This project will use an external site to create, collect and analyse data collected in a survey format. The site we are using is Qualtrics Online Survey. If you agree to participate in this survey, the responses you provide to the survey will be stored on a host server that is used by Qualtrics. No personal information will be collected in the survey, so none will be stored as data. Once we have completed our data collection and analysis, we will import the data we collect to the RMIT server where it will be stored securely for five (5) years. The data on the Qualtrics host server will then be deleted and expunged.

Thank you so much for your support of conducting our research.

Dr. Maria Spichkova

Dr. Margaret Hamilton

Ahmed Alharethi, MS
Ph.D student, Computer Science
The School of Computer Science and Information Technology
RMIT University

If you have any concerns about your participation in this project, which you do not wish to discuss with the researchers, then you can contact the Ethics Officer, Research Integrity, Governance and Systems, RMIT University, GPO Box 2476V VIC 3001. Tel: (03) 9925 2251 or email human.ethics@rmit.edu.au
هل يمكنني التعامل مع التنوع (التقني، الثقافي وغيرها) عندما يتم تطوير أو تحسين نظام التعليم الالكتروني؟

• ما هي المتطلبات الخاصة بالتعليم الالكتروني (بالمقارنة مع مجالات التطوير الأخرى)?

• كيف يمكننا إضافتها كجزء من عمليات بناء المتطلبات؟

- نحن نتوقع 100مشاركة على الاقل.

• إذا قمت بالمشاركة، ماذا يتطلب مني عمله؟

- يمكنكم الانسحاب من المشاركة في أي وقت عن طريق إغلاق النافذة.

• ما هي الفوائد المتوقعة من خلال مشاركتك؟

- إحد الفوائد المتوقعة الرئيسيه هو تحسين جودة المتطلبات في نظم التعليم الالكتروني مثل الاستدامة، الأداء، الامان، وامن المعلومات.
Participant Information (PI)

What will happen to my responses?

• Confidentiality: Your identity will remain confidential. No one will be able to trace you throughout the research process.

• Research results: The results of the survey will be published in a PhD thesis, such as the Library at RMIT or in academic journals, or presented at conferences. However, I promise you that your data and information will be handled with full confidentiality and will not be stored. Your personal data will not be collected during or after the survey.

• Data collection: Due to the nature of data collection, we do not require explicit consent. However, your participation in the survey is considered your consent to participate.

What are my rights as a participant?

• The right to withdraw before submitting your responses.

• If you have any questions about the survey, you can contact the main researcher: Amr Maraghi Hameed, the research advisor: Maryam Sabit Shokaf, and the second advisor: Mohammad Al-Basit.

• What other information do I need to be aware of?

• If your responses are collected, you cannot change them.

• Be aware that internet pages are not secure in public networks that are often dangerous for data transmission, such as viewing or modifying data before a third party, and the data transferred may contain malware or viruses.

• Data security: This survey uses secure systems to create, collect, and analyze data. The location where we collect data is Qualtrics Online Survey, and if you accept to participate in the survey, the data will be stored in Qualtrics. You must be aware that personal data will not be collected and the data used for the survey will be transferred to RMIT servers and stored securely for 5 years, after which they will be deleted.

Thank you for your support.

Please accept our highest respect,
Amr Maraghi Hameed

Masters in Software Engineering and PhD student at RMIT.

If you have any concerns about your participation in this research, which you do not wish to discuss with the researchers, you can contact the Research Ethics, Integrity, and Governance Systems Coordinator at RMIT University, GPO Box 2476V VIC 3001. Tel: (03) 9925 2251 or email human.ethics@rmit.edu.au.
Recruitment advertisements

Copy of recruitment advertisements FOR SURVEY 1

Email
From: Ahmed.alharthi
BCC: [learner-list, teacher-list, ITsupport-and-admin-list]
Subject: Research Participation Invitation: Requirements Engineering Aspects of eLearning Systems survey

Dear …………,

I write to invite you to participate in my research on Requirements Engineering Aspects of eLearning Systems. I am a PhD student at the School of Computer Science and Information Technology (CSIT), RMIT University, Melbourne, Australia. My supervisors are Dr Maria Spichkova and Associate Professor Margaret Hamilton.

The reason I am recruiting you for this survey is that you are student, or teacher, or IT supporter or administrator in an eLearning system and your answers will help identify the requirements aspects of eLearning systems.

In requesting your participation in this survey, anonymity will be assured. Your participation in the online survey is completely voluntary, and you can withdraw from the process at any time by closing the browser. The survey would take around 10-15 minutes of your time to be completed. You need to click on the agree button at the end of this page which indicating your agreement to participation.

This will take you to the survey pages and once you have responded to all the questions, you need to click on the submit button. By clicking the submit button you are implying your consent to participate in this research.

……………………

Yours Sincerely,
Ahmed Alharthi, MS
Ph.D candidate, Computer Science
The School of Science
RMIT University

This project ASEHAPP 72-15 SPICHKOVA-ALHARTHI Requirements Engineering Aspects of eLearning Systems was approved by RMIT University on 30th March 2016.

This research project is subject to the Ethics policy of RMIT University. If you have any enquiries at any time about the interview or the procedures regarding your participation in the project, you can contact Ahmed Alharthi by email: ………………………..
أعزائي/ عزيزتي،

السلام عليكم ورحمة الله وبركاته،

أنا أدعوكم للمشاركة في بحث يتعلق بمهارات بناء نظام التعليم الإلكتروني. أنا طالب في مرحلة الدكتوراه في كلية علوم الحاسب في جامعة RMIT، استراليا، وتشرف على الدكتوراه ماريا سبيتشكوفا وأستاذ مشارك مارغريت هاملتون.

السبب لدعوةكم هو أنك طالب أو معلم، أو مسؤول في نظام التعليم الإلكتروني. علماً أن الاستطلاع سوف يساعدني في تحديد متطلبات تصميم وتطوير أنظمة التعليم الإلكتروني.

هذا البحث يركز على استطلاع نماذج الاستطلاع، فعندما تفاصل على المشاركة، يمكنك إلغاء المشاركة عن طريق إغلاق هذه الصفحة. ومع ذلك، يجب أن تكون موافقة على المشاركة للإجابة على الأسئلة في البحث.

يرجى الضغط على الزر الموافق عند الانتهاء من المشاركة. شكراً جزيلاً لدعمكم.

أحمد الحارثي
طالب دكتوراه في علوم الحاسب الآلي
جامعة RMIT
باستراليا

ASEQAP 72-15 SPICHKOVA-ALH ARTHI Requirements Engineering

ASEHAPP 72-15 SPICHKOVA-ALH ARTHI Requirements Engineering (October 31, 2019)
CHAPTER B: ETHICS APPROVAL AND SURVEY DOCUMENTS

Recruitment advertisements

Copy of recruitment advertisements FOR SURVEY 2

Email
From: Ahmed.alharthi
BCC: [learner-list, teacher-list, ITsupport-and-admin-list]
Subject: Research Participation Invitation: Requirements Engineering Aspects of eLearning Systems survey

Dear ............
I write to invite you to participate in my research on Requirements Engineering Aspects of eLearning Systems. I am a PhD student at the School of Computer Science and Information Technology (CSIT), RMIT University, Melbourne, Australia. My supervisors are Dr Maria Spichkova and Associate Professor Margaret Hamilton.

The reason I am recruiting you for this survey is that you are student, or teacher, or IT supporter or administrator in an eLearning system and your answers will help identify the requirements aspects of eLearning systems.

In requesting your participation in this survey, confidentiality will be assured. Your participation in the online survey is completely voluntary, and you can withdraw from the process at any time by closing the browser. The survey would take around 15-20 minutes of your time to be completed. You should agree to participate, you need to click on the agree button at the end of the Participant Information page which indicates your agreement to participation.

This will take you to the survey pages and once you have responded to all the questions, you need to click on the submit button. By clicking the submit button you are implying your consent to participate in this research.

Yours Sincerely,
Ahmed Alharthi, MS
Ph.D candidate . Computer Science
The School of Science
RMIT University

This project ASEHAPP 72-15 SPICHKOVA-ALHARTHI Requirements Engineering Aspects of eLearning Systems was approved by RMIT University on 30th March 2016. This research project is subject to the Ethics policy of RMIT University. If you have any enquiries at any time about the interview or the procedures regarding your participation in the project, you can contact Ahmed Alharthi by email:..........................
عزيزي/ عزيزتي،

السلام عليكم ورحمة الله وبركاته

أنا طالب بكلية علوم الحاسب في جامعة RMIT، أستراليا. أنا طالب دراسة الدكتوراه في كلية علوم الحاسب RMIT، أستراليا.

هذا البحث العلمي خضع لسياسة أخلاقيات المشاركة والبحث.

أنا أتلقى دعوتك للمشاركة في استطلاع صممه الباحث أحمد الحارثي، طالب دكتوراه في كلية علوم الحاسب، جامعة RMIT، في ملبورن، أستراليا.

هذا الاستطلاع يهدف إلى تحسين نظم التعليم الإلكتروني، وتحديد متطلبات في ذلك النظام.

تم تصميم الاستطلاع لتضمن خصوصية المعلومات الشخصية للمشاركين، ويمكنهم الاستماع إلى الاستطلاع في أي وقت.

الاستطلاع يحتوي على 15 أسئلة. بعد الإجابة على استطلاع، يمكنك تسليم الاستطلاع عن طريق الضغط على زر موافق في الجزء السفلي من الصفحة.

شكرا جزيلا لدعمكم.

أحمد الحارثي
طالب دكتوراه في علوم الحاسب الآلية
جامعة RMIT، أستراليا

ASEHAPP 72-15 SPICHIKOVA-ALHARTHI Requirements Engineering

هذا الاستطلاع ورغم تحمل مشاعر خلافات البيئة الحالية، تمت تدريس الاستطلاع في 30 مارس 2016، بجامعة RMIT، أستراليا.

إذا كان لديك أي استفسارات فيما يتعلق بخصوص المشاركة أو الإجراءات المتعلقة بالمشاركة، يمكنك التواصل مع أحمد الحارثي عن طريق البريد الإلكتروني:

الإلكتروني:...
Recruitment advertisements

Copy of recruitment advertisements on Twitter and LinkedIn FOR SURVEY 3

English:
Dear academic, and practitioner working with software requirements, you’re invited to participate in our survey about analysing sustainability requirements of software (10-15 mins)
Link:..........................................................

Arabic:
عزيزنا الأكاديمي، والممارس الذي يعمل مع متطلبات البرمجيات، انت مدعو للمشاركة في استبنا عن تحليل متطلبات الاستدامة في البرمجيات (10-15 دقيقة)
...........................................
Sustainable Software Profile for Case Studies

In Chapter 6, we carried out three case studies: Canvas, D2L and Skin Cancer Information System (SCIS). This appendix presents complete documentation of the sustainability profiling for Canvas, D2L and SCIS. Canvas and D2L are Learning Management System (LMS). While SCIS is clinical software to store patient health records.

C.1 Canvas sustainability profile

Table C.1: The results of Canvas requirements. The sustainability rate is the result giving by 46 stakeholders who rated between 0 and 1 where 0 the worst and 1 is the best

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Announcements</td>
<td>Announcements in Canvas shall allow instructors to broadcast information out to an entire class. Students shall be able to reply to announcements, but replies shall be not considered to be a conversation and shall not appear in the Conversations Inbox.</td>
<td>Instructors Learner IT support</td>
<td>0.554031</td>
</tr>
<tr>
<td>2</td>
<td>Assignments</td>
<td>Assignments in Canvas shall include Quizzes, graded Discussions, and online submissions (i.e., files, images, text, URLs, etc.). The Assignments page shall allow students to show all the assignments that will be expected of them and how many points each is worth. Assignments shall be assigned to everyone in the course or differentiated by section or user.</td>
<td>Instructors Learner IT support</td>
<td>0.435058</td>
</tr>
<tr>
<td>3</td>
<td>Calendar</td>
<td>Calendar in Canvas shall be a global feature, to allow users see all courses assignments and events in one place. Calendars shall be filtered by selecting or deselecting courses in the sidebar.</td>
<td>Instructors Learner IT support</td>
<td>0.333333</td>
</tr>
<tr>
<td>4</td>
<td>Chat</td>
<td>Canvas shall allow students and teachers to interact and communicate in real time.</td>
<td>Instructors Learner IT support</td>
<td>0.451972</td>
</tr>
<tr>
<td>5</td>
<td>Collaborations</td>
<td>Canvas shall leverage collaborative technology to allow multiple users to work together on the same document at the same time. Collaborative documents shall be able to save documents in real-time, when a change made by any of its users, the change shall be immediately visible to everyone.</td>
<td>Instructors Learner IT support</td>
<td>0.531258</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Conferences</td>
<td>Canvas shall provide Conferences for virtual lectures, virtual office hours, and student groups. Conferences shall be used to demonstrate technologies or troubleshoot technology issues online.</td>
<td>Instructors Learner IT support</td>
<td>0.531277</td>
</tr>
<tr>
<td>7</td>
<td>Conversations</td>
<td>Conversations in Canvas shall allow internal messaging tool used instead of email to communicate with a course, a group, an individual student, or a group of students.</td>
<td>Instructors Learner IT support</td>
<td>0.506496</td>
</tr>
<tr>
<td>8</td>
<td>Groups</td>
<td>Canvas shall allow instructors to create groups for students to collaborate on group assignments, pages, collaborations, and more. Instructors shall also allow students to create their own groups.</td>
<td>Instructors Learner IT support</td>
<td>0.505193</td>
</tr>
<tr>
<td>9</td>
<td>Discussions</td>
<td>Discussions in Canvas shall allow users for interactive communication between two or more people; Discussions shall enable users to participate in a conversation with an entire class or group. Discussions shall be created as an assignment for grading purposes (and seamlessly integrated with the Canvas Gradebook).</td>
<td>Instructors Learner IT support</td>
<td>0.537939</td>
</tr>
<tr>
<td>10</td>
<td>Pages</td>
<td>Pages store content and educational resources shall be part of a course or group but shall not necessarily belong in an assignment. Pages shall include text, video, and links to files and other course or group content. Canvas shall provide Pages to be used as a collaboration tool for a course or group wikis where only specific users shall have access.</td>
<td>Instructors Learner IT support</td>
<td>0.498566</td>
</tr>
<tr>
<td>11</td>
<td>Outcomes</td>
<td>Outcomes in Canvas shall enable the administration and faculty to track students progress as measured by pedagogical goals or desired outcomes.</td>
<td>Admins Instructors Learner IT support</td>
<td>0.50691</td>
</tr>
<tr>
<td>12</td>
<td>Roll Call Attendance Tool</td>
<td>The Attendance (Roll Call) tool in Canvas shall be an external app (LTI) used for taking attendance in courses. Canvas shall provide the Attendance tool for online or face-to-face courses.</td>
<td>Instructors Learner IT support</td>
<td>0.419432</td>
</tr>
<tr>
<td>13</td>
<td>Navigation</td>
<td>Canvas shall provide Global Navigation and Course Navigation. Global navigation links shall provide quick access to all courses collectively. Default links in Global Navigation shall include the Dashboard, Courses, Groups, Calendar, Inbox, User Account, and the Help menu. Course navigation shall be a sidebar and dashboard including course home contents having a page, the syllabus, discussions, announcements, quizzes, or imported content.</td>
<td>Instructors Students IT support</td>
<td>0.447231</td>
</tr>
<tr>
<td>14</td>
<td>Quizzes</td>
<td>The quiz tool in Canvas shall allow instructors to create and administer online quizzes and surveys. Canvas shall provide Quizzes to conduct and moderate exams and assessments, both graded and ungraded.</td>
<td>Instructors Learner IT support</td>
<td>0.514917</td>
</tr>
<tr>
<td>15</td>
<td>Question banks</td>
<td>Questions banks in Canvas shall allow Account-level roles to create institutional or departmental question repositories.</td>
<td>Admins Instructors IT support</td>
<td>0.460052</td>
</tr>
<tr>
<td>16</td>
<td>Grades and the Gradebook</td>
<td>The Gradebook in Canvas shall store all information about student progress in the course, measuring grades and course outcomes.</td>
<td>Instructors Learner IT support</td>
<td>0.497479</td>
</tr>
<tr>
<td>17</td>
<td>Grading schemes</td>
<td>Canvas shall provide a grading scheme to set criteria for measuring varying levels of achievement in a course. Grading schemes shall be built based on percentage ranges, and each percentage range shall be assigned a name value. Canvas shall allow instructors to create any grading scheme and edit the name and percentage range for each item.</td>
<td>Admins Instructors IT support</td>
<td>0.477389</td>
</tr>
<tr>
<td>18</td>
<td>What-If Grades</td>
<td>What-If Grades in Canvas shall allow students to calculate their total grade by entering hypothetical grades for assignments. Only students shall enter and view What-If scores.</td>
<td>Learner IT support</td>
<td>0.553507</td>
</tr>
<tr>
<td>19</td>
<td>Rubrics</td>
<td>Canvas shall provide Rubrics to set up custom or Outcome-based assessment criteria for scoring.</td>
<td>Instructors IT support</td>
<td>0.464301</td>
</tr>
<tr>
<td>20</td>
<td>SpeedGrader</td>
<td>SpeedGrader in Canvas shall allow instructors to view and grade student assignment submissions in one place using a simple point scale or complex rubric.</td>
<td>Instructors IT support</td>
<td>0.460397</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Course Settings</td>
<td>Settings navigation link in Canvas shall allow instructors to update and see the different users and sections, and Canvas shall allow instructors to modify the navigation of their course.</td>
<td>Instructors</td>
<td>0.376019</td>
</tr>
<tr>
<td>22</td>
<td>Modules</td>
<td>Canvas shall provide Modules to organise course content by weeks, units, or a different organisational structure. Each module in Canvas shall contain files, discussions, assignments, quizzes, and other learning materials.</td>
<td>Instructors</td>
<td>0.428617</td>
</tr>
<tr>
<td>23</td>
<td>Files</td>
<td>Files in Canvas shall house course files, assignments, syllabi, readings, or other documents, as well as profile pictures and user-specific files. Canvas shall allow instructors to lock folders and files so file shall only be viewed by direct links or only unlock on a specific date.</td>
<td>Instructors</td>
<td>0.503684</td>
</tr>
<tr>
<td>24</td>
<td>Rich Content Editor</td>
<td>Canvas shall provide Rich Content Editor with features that support the editor (Announcements, Assignments, Discussions, Pages, Quizzes, or Syllabus). It shall be integrated with LaTeX, Google Docs, and Microsoft Office.</td>
<td>Instructors</td>
<td>0.432002</td>
</tr>
<tr>
<td>25</td>
<td>Profile and User Settings</td>
<td>Profile and User Settings in Canvas shall let users control their personal information.</td>
<td>Instructors</td>
<td>0.438155</td>
</tr>
<tr>
<td>26</td>
<td>ePortfolios</td>
<td>Users in Canvas shall build an unlimited number of ePortfolios in which to collect and document their educational projects, submissions, experiences, and other work products. Users shall keep ePortfolios private or share with other students, instructors, and future employers. Canvas also shall allow users to export ePortfolios to a zip file.</td>
<td>Instructors</td>
<td>0.402836</td>
</tr>
<tr>
<td>27</td>
<td>Authentication</td>
<td>Canvas authentication shall include an option called self-registration to display a registration banner on account login page that shall allow users to create their own Canvas accounts. Canvas authentication shall be enabled for all institutions, but self-registration shall be disabled by default.</td>
<td>Admins</td>
<td>0.502108</td>
</tr>
<tr>
<td>28</td>
<td>Roles and Permissions</td>
<td>Course-level roles shall include users with permissions in the course. Account-level roles shall include permissions that shall affect the entire account as well as courses. Canvas shall provide five base roles that each shall include a set of default permissions as Students, Teachers, TAs (tutor), Designers, and Observers (mentors).</td>
<td>Admins</td>
<td>0.482754</td>
</tr>
<tr>
<td>29</td>
<td>Hierarchical structure for accounts</td>
<td>Accounts in Canvas shall include subaccounts, courses, and sections, all of which shall be added manually in Canvas, via the API, or via Student Information Systems imports.</td>
<td>Admins</td>
<td>0.442438</td>
</tr>
<tr>
<td>30</td>
<td>Analytics</td>
<td>Canvas shall provide Analytics functionality to produce the evaluation of individual components, a course and student performance.</td>
<td>Admins</td>
<td>0.51626</td>
</tr>
<tr>
<td>31</td>
<td>Mobile Features</td>
<td>Canvas shall allow users to access from any browser on Android and iOS device.</td>
<td>Instructors</td>
<td>0.455323</td>
</tr>
<tr>
<td>32</td>
<td>Integrations</td>
<td>Canvas shall provide optional integrations with a variety of third-party providers: Web Services (Twitter, LinkedIn, etc.), Collaboration (Adobe Connect, Microsoft Office 365, etc.) Educational (Turnitin, Wimba, etc.), Multimedia (Equella, Kaltura, etc.), Calendar (Google, Outlook, etc.).</td>
<td>Admins</td>
<td>0.493492</td>
</tr>
<tr>
<td>33</td>
<td>Course Export Tool</td>
<td>The Course Export Tool shall allow instructor to extract course content, assignments, and quizzes from previous terms and quickly import them into existing courses.</td>
<td>Instructors</td>
<td>0.355907</td>
</tr>
<tr>
<td>34</td>
<td>Student Information Systems Exports</td>
<td>Canvas shall allow admins to import, export and/or create users, accounts, courses, and enrolments.</td>
<td>Admins</td>
<td>0.508587</td>
</tr>
</tbody>
</table>

(Continued)
## CHAPTER C: SUSTAINABLE SOFTWARE PROFILE FOR CASE STUDIES

Continuation of Table C.1

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>External Apps</td>
<td>Canvas shall allow admins and instructors to enable apps through the App Centre, which shall be integrated directly into Canvas.</td>
<td>Admins Instructors IT support</td>
<td>0.483955</td>
</tr>
<tr>
<td>36</td>
<td>MagicMarker app</td>
<td>MagicMarker in Canvas shall help instructor to organize students into small groups for assessment in the classroom.</td>
<td>Instructors IT support</td>
<td>0.428096</td>
</tr>
<tr>
<td>37</td>
<td>Polls for Canvas app</td>
<td>Polls in Canvas shall allow instructors to request student opinion in the classroom and collect responses with ease.</td>
<td>Instructors Learner IT support</td>
<td>0.54714</td>
</tr>
<tr>
<td>38</td>
<td>Arc</td>
<td>Canvas shall provide Arc to be a video learning platform that shall turn content into conversation, connection, and collaboration. Arc’s interface shall let students and instructors engage with media content by commenting directly on the media timeline.</td>
<td>Instructors Learner IT support</td>
<td>0.420134</td>
</tr>
</tbody>
</table>
Canvas - RMIT profile:

1- Overall Sustainability:

3 Stars ★★★☆☆

Rating of sustainability dimensions:

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>0.608367</td>
</tr>
<tr>
<td>Social</td>
<td>0.44316</td>
</tr>
<tr>
<td>Technical</td>
<td>0.500632</td>
</tr>
<tr>
<td>Economic</td>
<td>0.331978</td>
</tr>
<tr>
<td>Environmental</td>
<td>0.331664</td>
</tr>
</tbody>
</table>

Key Charts

<table>
<thead>
<tr>
<th>Percentage/%</th>
<th>Colour Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-100</td>
<td>Dark brown</td>
<td>Green (Vibrant)</td>
</tr>
<tr>
<td>60-79</td>
<td>Light brown</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>40-59</td>
<td>Yellow</td>
<td>Basic</td>
</tr>
<tr>
<td>20-39</td>
<td>Orange</td>
<td>Unsatisfactory</td>
</tr>
<tr>
<td>0-19</td>
<td>blue</td>
<td>Critical</td>
</tr>
</tbody>
</table>
2- Requirement list

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Announcements</td>
<td>Announcements in Canvas shall allow instructors to broadcast information out to an entire class. Students shall be able to reply to announcements, but replies shall be not considered to be a conversation and shall not appear in the Conversations Inbox.</td>
<td>Student, Instructor</td>
<td>0.653561</td>
</tr>
<tr>
<td>2</td>
<td>Assignments</td>
<td>Assignments in Canvas shall include Quizzes, graded Discussions, and online submissions (i.e., files, images, text, URLs, etc.). The Assignments page shall allow students to show all the assignments that will be expected of them and how many points each is worth. Assignments shall be assigned to everyone in the course or differentiated by section or user.</td>
<td>Student, Instructor</td>
<td>0.610519</td>
</tr>
<tr>
<td>3</td>
<td>Calendar</td>
<td>Calendar in Canvas shall be a global feature, to allow users see all courses assignments and events in one place. Calendars shall be filtered by selecting or deselecting courses in the sidebar.</td>
<td>Student, Instructor</td>
<td>0.594229</td>
</tr>
<tr>
<td>4</td>
<td>Chat</td>
<td>Canvas shall allow students and teachers to interact and communicate in real time.</td>
<td>Student, Instructor</td>
<td>0.557077</td>
</tr>
</tbody>
</table>

Overall sustainability of each requirement

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Announcements</td>
<td>0.653561</td>
</tr>
<tr>
<td>Groups</td>
<td>0.610519</td>
</tr>
<tr>
<td>Analytics</td>
<td>0.594229</td>
</tr>
<tr>
<td>Conversations</td>
<td>0.557077</td>
</tr>
<tr>
<td>#</td>
<td>Requirement Name</td>
</tr>
<tr>
<td>----</td>
<td>--------------------------</td>
</tr>
<tr>
<td>5</td>
<td>Collaborations</td>
</tr>
<tr>
<td>6</td>
<td>Conferences</td>
</tr>
<tr>
<td>7</td>
<td>Conversations</td>
</tr>
<tr>
<td>8</td>
<td>Groups</td>
</tr>
<tr>
<td>9</td>
<td>Discussions</td>
</tr>
<tr>
<td>10</td>
<td>Pages</td>
</tr>
<tr>
<td>11</td>
<td>Outcomes</td>
</tr>
<tr>
<td>12</td>
<td>Roll Call Attendance Tool</td>
</tr>
<tr>
<td>13</td>
<td>Navigation</td>
</tr>
<tr>
<td>14</td>
<td>Quizzes</td>
</tr>
<tr>
<td>#</td>
<td>Requirement Name</td>
</tr>
<tr>
<td>---</td>
<td>---------------------------</td>
</tr>
<tr>
<td>15</td>
<td>Question banks</td>
</tr>
<tr>
<td>16</td>
<td>Grades and the Gradebook</td>
</tr>
<tr>
<td>17</td>
<td>Grading schemes</td>
</tr>
<tr>
<td>18</td>
<td>What-if Grades</td>
</tr>
<tr>
<td>19</td>
<td>Rubrics</td>
</tr>
<tr>
<td>20</td>
<td>SpeedGrader</td>
</tr>
<tr>
<td>21</td>
<td>Course Settings</td>
</tr>
<tr>
<td>22</td>
<td>Modules</td>
</tr>
<tr>
<td>23</td>
<td>Files</td>
</tr>
<tr>
<td>24</td>
<td>Rich Content Editor</td>
</tr>
<tr>
<td>#</td>
<td>Requirement Name</td>
</tr>
<tr>
<td>----</td>
<td>--------------------------</td>
</tr>
<tr>
<td>25</td>
<td>Profile and User Settings</td>
</tr>
<tr>
<td>26</td>
<td>ePortfolios</td>
</tr>
<tr>
<td>27</td>
<td>Authentication</td>
</tr>
<tr>
<td>28</td>
<td>Roles and Permissions</td>
</tr>
<tr>
<td>29</td>
<td>Hierarchical structure for accounts</td>
</tr>
<tr>
<td>30</td>
<td>Analytics</td>
</tr>
<tr>
<td>31</td>
<td>Mobile Features</td>
</tr>
<tr>
<td>32</td>
<td>Integrations</td>
</tr>
<tr>
<td>33</td>
<td>Course Import Tool</td>
</tr>
<tr>
<td>34</td>
<td>Student Information Systems Imports</td>
</tr>
</tbody>
</table>
### 3- Stakeholders

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Submitted</th>
<th>In progress</th>
<th>Not started</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>46</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
## C.2 Desire2Learn sustainability profile

Table C.2: The results of D2L requirements. The sustainability rate is the result giving by 79 stakeholders who rated between 0 and 1 where 0 the worst and 1 is the best.

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>News</td>
<td>News in D2L shall allow instructors to broadcast information out to an entire class.</td>
<td>Learner, Instructor, IT support</td>
<td>0.659925</td>
</tr>
<tr>
<td>2</td>
<td>Calendar</td>
<td>Calendar in D2L shall be a global feature, to allow users see all courses assignments and events in one place. Calendars shall be filtered by selecting or deselecting courses in the sidebar.</td>
<td>Learner, Instructor, IT support</td>
<td>0.608868</td>
</tr>
<tr>
<td>3</td>
<td>Chat</td>
<td>D2L shall allow students and teachers to interact and communicate in real time.</td>
<td>Learner, Instructor, IT support</td>
<td>0.603911</td>
</tr>
<tr>
<td>4</td>
<td>Dropbox</td>
<td>D2L shall allow students to submit assignments through uploading documents to the appropriate Dropbox folder. While instructor shall create categories to group and organise Dropbox folders that have restricted access by date and time, group membership, or special access permissions.</td>
<td>Learner, Instructor, IT support</td>
<td>0.593502</td>
</tr>
<tr>
<td>5</td>
<td>Virtual Classrooms</td>
<td>D2L shall provide Virtual Classrooms for virtual lectures, sharing screen, and white board.</td>
<td>Learner, Instructor, IT support</td>
<td>0.614835</td>
</tr>
<tr>
<td>6</td>
<td>Email</td>
<td>Email in D2L shall allow internal messaging tool used instead of email to communicate with a course, a group, an individual student, or a group of students.</td>
<td>Learner, Instructor, IT support</td>
<td>0.584962</td>
</tr>
<tr>
<td>7</td>
<td>Groups</td>
<td>D2L shall allow to set up areas for groups to submit assignments, have discussion areas, and private locker specifically for members of these Groups.</td>
<td>Learner, Instructor, IT support</td>
<td>0.533592</td>
</tr>
<tr>
<td>8</td>
<td>Discussions</td>
<td>Discussions in D2L shall allow users for interactive communication between two or more people; Discussions shall allow users to participate in a conversation with an entire class or group. Discussions shall be created as an assignment for grading purposes (and seamlessly integrated with the D2L Grades).</td>
<td>Learner, Instructor, IT support</td>
<td>0.614396</td>
</tr>
<tr>
<td>9</td>
<td>Course Layout</td>
<td>Course Layout shall allow customising the Navbar and Homepage of course. Navbar shall contain links such as Content and Grades while Homepage can feature several different widgets together, such as News, Content, and Calendar.</td>
<td>Instructor, Admin, IT support</td>
<td>0.406468</td>
</tr>
<tr>
<td>10</td>
<td>Class Progress</td>
<td>Class Progress in D2L shall enable the administration and faculty to track students' progress as measured by pedagogical objective, grades, logins or content.</td>
<td>Instructor, Admin, IT support</td>
<td>0.409156</td>
</tr>
<tr>
<td>11</td>
<td>Attendance</td>
<td>Attendance in D2L shall allow taking attendance in courses. D2L shall provide the Attendance for online or face-to-face courses.</td>
<td>Instructor, Admin, IT support</td>
<td>0.465359</td>
</tr>
<tr>
<td>12</td>
<td>Navigation</td>
<td>D2L shall provide Global Navigation (Minibar) and Course Navigation (Navbar). Minibar shall allow users to switch between courses, and personal menu with links to profile, notifications, account settings, and progress. Navbar shall be a sidebar and Course Homepage including course relevant contents having news, syllabus, discussions, quizzes, or third-party tools.</td>
<td>Instructor, Admin, IT support</td>
<td>0.459255</td>
</tr>
<tr>
<td>13</td>
<td>Quizzes</td>
<td>The quiz tool in D2L shall allow instructors to create and administer online quizzes. D2L shall provide Quizzes to conduct and moderate exams and assessments, both graded and ungraded.</td>
<td>Learner, Instructor, IT support</td>
<td>0.584821</td>
</tr>
<tr>
<td>14</td>
<td>Question Library</td>
<td>Questions Library in D2L shall allow Account-level roles to create institutional or departmental question repositories.</td>
<td>Instructor, Admin, IT support</td>
<td>0.465321</td>
</tr>
</tbody>
</table>

(Continued)
## CHAPTER C: SUSTAINABLE SOFTWARE PROFILE FOR CASE STUDIES

### Continuation of Table C.2

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Grade book</td>
<td>Grade book in D2L shall provide grading system, grade calculations, grade scheme, grade items, and view and display options. Grade book shall allow students to show all the assignments that will be expected of them and how many points each is worth.</td>
<td>Learner, Instructor, IT support</td>
<td>0.613126</td>
</tr>
<tr>
<td>16</td>
<td>Grading system</td>
<td>Grading system shall determine how the grade items in grade book contribute to students’ final grades. Grading system shall include weighted, point, and formula system</td>
<td>Instructor, IT support</td>
<td>0.531859</td>
</tr>
<tr>
<td>17</td>
<td>Grading Schemes</td>
<td>D2L shall provide a grading scheme to set criteria for measuring varying levels of achievement in a course.</td>
<td>Instructor, Admin, IT support</td>
<td>0.542706</td>
</tr>
<tr>
<td>18</td>
<td>Surveys</td>
<td>Surveys in D2L shall allow instructors to create and administer online surveys.</td>
<td>Instructor, IT support</td>
<td>0.540764</td>
</tr>
<tr>
<td>19</td>
<td>Rubrics</td>
<td>D2L shall provide Rubrics to set up custom or objective-based assessment criteria for scoring.</td>
<td>Instructor, IT support</td>
<td>0.58701</td>
</tr>
<tr>
<td>20</td>
<td>Assignment Grader app</td>
<td>Assignment Grader app in D2L shall allow instructor to view and grade student assignment submissions in one place using a simple point scale or complex rubric.</td>
<td>Instructor, IT support</td>
<td>0.594956</td>
</tr>
<tr>
<td>21</td>
<td>Learning Activity Library</td>
<td>Learning Activity Library in D2L shall allow to view, activate or deactivate, and add to the activity descriptions in the Instructional Design Wizard by creating custom activity descriptions.</td>
<td>Instructor, IT support</td>
<td>0.547762</td>
</tr>
<tr>
<td>22</td>
<td>Course Builder</td>
<td>D2L shall provide modules to organize course content by weeks, units, or a different organizational structure. Each module in D2L shall contain files, discussions, assignments, quizzes, and other learning materials.</td>
<td>Instructor, Admin, IT support</td>
<td>0.528675</td>
</tr>
<tr>
<td>23</td>
<td>Manage Files</td>
<td>Manage Files in D2L shall house course files, assignments, syllabi, readings, or other documents, as well as profile pictures and user-specific files. D2L shall allow instructors to lock folders and files so file shall only be viewed by direct links or only unlock on a specific date.</td>
<td>Instructor, IT support</td>
<td>0.50945</td>
</tr>
<tr>
<td>24</td>
<td>Rich Content Editor</td>
<td>D2L shall provide Rich Content Editor with features that support the editor (News, Assignments, Discussions, Quizzes, or Syllabus). It shall be integrated with Google Docs and Microsoft Office.</td>
<td>Learner, Instructor, IT support</td>
<td>0.514633</td>
</tr>
<tr>
<td>25</td>
<td>Profile and User Settings</td>
<td>Profile and User Settings in D2L shall let users control their personal information.</td>
<td>Learner, Instructor, IT support</td>
<td>0.535382</td>
</tr>
<tr>
<td>26</td>
<td>ePortfolios</td>
<td>Users in D2L shall build an unlimited number of ePortfolios in which to collect and document their educational projects, submissions, experiences, and other work products. Users shall keep ePortfolios private or share with other students, instructors, and future employers.</td>
<td>Learner, Instructor, IT support</td>
<td>0.497119</td>
</tr>
<tr>
<td>27</td>
<td>Self-Registration</td>
<td>D2L self-registration shall allow users to enrol themselves in courses that have the self-registration feature enabled, but self-registration shall be disabled by default.</td>
<td>Instructor, Admin, IT support</td>
<td>0.376276</td>
</tr>
<tr>
<td>28</td>
<td>Roles and Permissions</td>
<td>Course-level roles shall include users with permissions in the course. Account-level roles shall include permissions that shall affect the entire account as well as courses. D2L shall provide four base roles that each shall include a set of default permissions as Students, Instructor, Teaching Assistant, and Department Secretary.</td>
<td>Admin, IT support</td>
<td>0.464462</td>
</tr>
<tr>
<td>29</td>
<td>Organizational Unit Structure</td>
<td>Accounts in D2L shall include six default org unit types: semester, department, course template, course offering, group, and section, all of which shall be added manually in D2L, via the API, or via Student Information Systems imports.</td>
<td>Admin, IT support</td>
<td>0.420019</td>
</tr>
<tr>
<td>30</td>
<td>Analytics</td>
<td>D2L shall provide analytics functionality to produce the evaluation of individual components, completion rates, course, program and student performance.</td>
<td>Instructor, Admin, IT support</td>
<td>0.581382</td>
</tr>
</tbody>
</table>

(Continued)
### SECTION C.2: DESIRE2LEARN SUSTAINABILITY PROFILE

Continuation of Table C.2

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>Mobile Features</td>
<td>D2L shall allow users to access from any browser on Android and iOS device.</td>
<td>Learner Instrctor IT support</td>
<td>0.602226</td>
</tr>
<tr>
<td>32</td>
<td>Integrations</td>
<td>D2L shall provide optional integrations with a variety of third-party providers: Web Services (Twitter, LinkedIn, etc.), Collaboration (Adobe Connect, Microsoft Office 365, etc.), Educational (Turnitin, Wimba, etc.), Multimedia (Equella, Kaltura, etc.), Calendar (Google, Outlook, etc.).</td>
<td>Learner Instructor Admin IT support</td>
<td>0.560076</td>
</tr>
<tr>
<td>33</td>
<td>Importing course components</td>
<td>The importing course components shall allow instructors to extract course content, assignments, and quizzes from previous terms and quickly import them into existing courses.</td>
<td>Instructor Admin IT support</td>
<td>0.395206</td>
</tr>
<tr>
<td>34</td>
<td>Student Information Systems Imports</td>
<td>D2L shall allow admins to import, export and create users, accounts, courses, and enrolments.</td>
<td>Learner Instructor Admin IT support</td>
<td>0.507362</td>
</tr>
<tr>
<td>35</td>
<td>Blog</td>
<td>Blog tool in D2L shall allow user to post and respond to questions, engage in discussions, and share opinions and comments with other users.</td>
<td>Learner Instructor IT support</td>
<td>0.619709</td>
</tr>
<tr>
<td>36</td>
<td>Binder app</td>
<td>Binder in D2L shall allow student and instructor to view, annotate and organise their documents from anywhere.</td>
<td>Learner Instructor IT support</td>
<td>0.580759</td>
</tr>
</tbody>
</table>
Desir2Learn (D2L) -UQU profile:

1- Overall Sustainability:

3 Stars ★★★☆☆

Rating of sustainability dimensions:

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual dimension</td>
<td>0.634079</td>
</tr>
<tr>
<td>Social dimension</td>
<td>0.546945</td>
</tr>
<tr>
<td>Technical dimension</td>
<td>0.489619</td>
</tr>
<tr>
<td>Economic dimension</td>
<td>0.359917</td>
</tr>
<tr>
<td>Environmental dimension</td>
<td>0.314414</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage/%</th>
<th>Colour Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-100</td>
<td>Dark green</td>
<td>Green (Vibrant)</td>
</tr>
<tr>
<td>60-79</td>
<td>Light green</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>40-59</td>
<td>Yellow</td>
<td>Basic</td>
</tr>
<tr>
<td>20-39</td>
<td>Orange</td>
<td>Unsatisfactory</td>
</tr>
<tr>
<td>0-19</td>
<td>Red</td>
<td>Critical</td>
</tr>
</tbody>
</table>
## Overall sustainability of each requirement

<table>
<thead>
<tr>
<th>Requirement Name</th>
<th>Description</th>
<th>Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>News</td>
<td>News in D2L shall allow instructors to broadcast information out to an entire class.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
<td>0.520927</td>
</tr>
<tr>
<td>Calendar</td>
<td>Calendar in D2L shall be a global feature, to allow users see all courses assignments and events in one place. Calendars shall be filtered by selecting or deselecting courses in the sidebar.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
<td>0.50317</td>
</tr>
<tr>
<td>Chat</td>
<td>D2L shall allows students and teachers to interact and communicate in real time.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
<td>0.490526</td>
</tr>
<tr>
<td>#</td>
<td>Requirement Name</td>
<td>Description</td>
<td>Group</td>
</tr>
<tr>
<td>----</td>
<td>------------------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>4</td>
<td>Dropbox</td>
<td>D2L shall allow students to submit assignments through uploading documents to the appropriate Dropbox folder. While instructor shall create categories to group and organise Dropbox folders that have restricted access by date and time, group membership, or special access permissions.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
</tr>
<tr>
<td>5</td>
<td>Virtual Classrooms</td>
<td>D2L shall provide Virtual Classrooms for virtual lectures, sharing screen, and white board.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
</tr>
<tr>
<td>6</td>
<td>Email</td>
<td>Email in D2L shall allow internal messaging tool used instead of email to communicate with a course, a group, an individual student, or a group of students.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
</tr>
<tr>
<td>7</td>
<td>Groups</td>
<td>D2L shall allow to set up areas for groups to submit assignments, have discussion areas, and private locker specifically for members of these Groups.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
</tr>
<tr>
<td>8</td>
<td>Discussions</td>
<td>Discussions in D2L shall allow users for interactive communication between two or more people; Discussions shall allow users to participate in a conversation with an entire class or group. Discussions shall be created as an assignment for grading purposes (and seamlessly integrated with the D2L Grades).</td>
<td>Student, Instructor, Admin, IT support/developer</td>
</tr>
<tr>
<td>9</td>
<td>Course Layout</td>
<td>Course Layout shall allow customising the Navbar and Homepage of course. Navbar shall contain links such as Content and Grades while Homepage can feature several different widgets together, such as News, Content, and Calendar.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
</tr>
<tr>
<td>10</td>
<td>Class Progress</td>
<td>Class Progress in D2L shall enable the administration and faculty to track students' progress as measured by pedagogical objective, grades, logins or content.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
</tr>
<tr>
<td>11</td>
<td>Attendance</td>
<td>Attendance in D2L shall allow taking attendance in courses. D2L shall provide the Attendance for online or face-to-face courses.</td>
<td>Student, Instructor, Admin, IT support/developer</td>
</tr>
<tr>
<td>#</td>
<td>Requirement Name</td>
<td>Description</td>
<td>Group</td>
</tr>
<tr>
<td>---</td>
<td>------------------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>12</td>
<td>Navigation</td>
<td>D2L shall provide Global Navigation (Minibar) and Course Navigation (Navbar). Minibar shall allow users to switch between courses, and personal menu with links to profile, notifications, account settings, and progress. Navbar shall be a side bar and Course Homepage including course relevant contents having news, syllabus, discussions, quizzes, or third-party tools.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
<tr>
<td>13</td>
<td>Quizzes</td>
<td>The quiz tool in D2L shall allow instructors to create and administer online quizzes. D2L shall provide Quizzes to conduct and moderate exams and assessments, both graded and ungraded.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
<tr>
<td>14</td>
<td>Question Library</td>
<td>Questions Library in D2L shall allow Account-level roles to create institutional or departmental question repositories.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
<tr>
<td>15</td>
<td>Grade book</td>
<td>Grade book in D2L shall provide grading system, grade calculations, grade scheme, grade items, and view and display options. Grade book shall allow students to show all the assignments that will be expected of them and how many points each is worth.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
<tr>
<td>16</td>
<td>Grading system</td>
<td>Grading system shall determine how the grade items in grade book contribute to students' final grades. Grading system shall include weighted, point, and formula system.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
<tr>
<td>17</td>
<td>Grading Schemes</td>
<td>D2L shall provide a grading scheme to set criteria for measuring varying levels of achievement in a course.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
<tr>
<td>18</td>
<td>Surveys</td>
<td>Surveys in D2L shall allow instructors to create and administer online surveys.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
<tr>
<td>19</td>
<td>Rubrics</td>
<td>D2L shall provide Rubrics to set up custom or objective-based assessment criteria for scoring.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
<tr>
<td>20</td>
<td>Assignment Grader app</td>
<td>Assignment Grader app in D2L shall allow instructor to view and grade student assignment submissions in one place using a simple point scale or complex rubric.</td>
<td>Student, Instructor, Admin, IT support/ developer</td>
</tr>
</tbody>
</table>
# Requirement Name | Description | Group | Sustainability
--- | --- | --- | ---
21 Learning Activity Library | Learning Activity Library in D2L shall allow to view, activate or deactivate, and add to the activity descriptions in the Instructional Design Wizard by creating custom activity descriptions. | Student, Instructor, Admin | 0.536788
22 Course Builder | D2L shall provide modules to organize course content by weeks, units, or a different organizational structure. Each module in D2L shall contain files, discussions, assignments, quizzes, and other learning materials. | Student, Instructor, Admin | 0.475953
23 Manage Files | Manage Files in D2L shall house course files, assignments, syllabi, readings, or other documents, as well as profile pictures and user-specific files. D2L shall allow instructors to lock folders and files so file shall only be viewed by direct links or only unlock on a specific date. | Student, Instructor, Admin | 0.518723
24 Rich Content Editor | D2L shall provide Rich Content Editor with features that support the editor (News, Assignments, Discussions, Quizzes, or Syllabus). It shall be integrated with Google Docs and Microsoft Office. | Student, Instructor, Admin | 0.447157
25 Profile and User Settings | Profile and User Settings in D2L shall let users control their personal information. | Student, Instructor, Admin | 0.476575
26 ePortfolios | Users in D2L shall build an unlimited number of ePortfolios in which to collect and document their educational projects, submissions, experiences, and other work products. Users shall keep ePortfolios private or share with other students, instructors, and future employers. | Student, Instructor, Admin | 0.434032
27 Self-Registration | D2L self-registration shall allow users to enrol themselves in courses that have the self-registration feature enabled, but self-registration shall be disabled by default. | Student, Instructor, Admin | 0.609854
28 Roles and Permissions | Course-level roles shall include permissions that shall affect the entire account as well as courses. D2L shall provide four base roles that each shall include a set of default permissions as Students, Instructor, Teaching Assistant, and Department Secretary. | Student, Instructor, Admin | 0.545384
## Requirement Name Description Group Sustainability

### 29 Organizational Unit Structure

Accounts in D2L shall include six default org unit types: semester, department, course template, course offering, group, and section, all of which shall be added manually in D2L, via the API, or via Student Information Systems imports.

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Organizational Unit Structure</td>
<td>Accounts in D2L shall include six default org unit types: semester, department, course template, course offering, group, and section, all of which shall be added manually in D2L, via the API, or via Student Information Systems imports.</td>
<td>Student, Instructor, Admin</td>
<td>0.545297</td>
</tr>
<tr>
<td>30</td>
<td>Analytics</td>
<td>D2L shall provide analytics functionality to produce the evaluation of individual components, completion rates, course, program and student performance.</td>
<td>Student, Instructor, Admin</td>
<td>0.466342</td>
</tr>
<tr>
<td>31</td>
<td>Mobile Features</td>
<td>D2L shall allow users to access from any browser on Android and iOS device.</td>
<td>Student, Instructor, Admin</td>
<td>0.498376</td>
</tr>
<tr>
<td>32</td>
<td>Integrations</td>
<td>D2L shall provide optional integrations with a variety of third-party providers: Web Services (Twitter, LinkedIn, etc.), Collaboration (Adobe Connect, Microsoft Office 365, etc.) Educational (Turnitin, Wimba, etc.), Multimedia (Equella, Kaltura, etc.), Calendar (Google, Outlook, etc.).</td>
<td>Student, Instructor, Admin</td>
<td>0.452653</td>
</tr>
<tr>
<td>33</td>
<td>Importing course components</td>
<td>The importing course components shall allow instructors to extract course content, assignments, and quizzes from previous terms and quickly import them into existing courses.</td>
<td>Student, Instructor, Admin</td>
<td>0.417786</td>
</tr>
<tr>
<td>34</td>
<td>Student Information Systems Imports</td>
<td>D2L shall allow admins to import, export and create users, accounts, courses, and enrolments.</td>
<td>Student, Instructor, Admin</td>
<td>0.491317</td>
</tr>
<tr>
<td>35</td>
<td>Blog</td>
<td>Blog tool in D2L shall allow user to post and respond to questions, engage in discussions, and share opinions and comments with other users</td>
<td>Student, Instructor, Admin</td>
<td>0.590016</td>
</tr>
<tr>
<td>36</td>
<td>Binder app - Binder</td>
<td>Binder in D2L shall allow student and instructor to view, annotate and organise their documents from anywhere.</td>
<td>Student, Instructor, Admin</td>
<td>0.594171</td>
</tr>
</tbody>
</table>

### 3- Stakeholders

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Submitted</th>
<th>In progress</th>
<th>Not started</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>79</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
C.3 SCIS sustainability profile

SCIS is a web-based software system to register the diagnoses of skin cancer along with the treatments. SCIS has five stakeholder roles (Physician, Nurses, Receptionist, Administrator and manager, and IT support and developer). The system has 23 high-level software requirements. Table C.3 shows the overall impact on sustainability of each requirement. The sustainability is calculated vis SuSoftPro tool. As demonstrated in Figure C.5 and Figure 6.8, SuSoftPro enables requirements engineers to manage stakeholders as well as provide an immediate update for sustainability profiling in the dashboard when stakeholders submit their questionnaire.

Table C.3: The results of SCIS requirements. The sustainability rate is the result giving by 13 stakeholders who rated between 0 and 1 where 0 the worst and 1 is the best.

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Login system</td>
<td>The SCIS shall provide system access having suitable security services. This access will have various levels that depend on user authorization.</td>
<td>Physician Nurse Receptionist Administrator and manager IT support and developer</td>
<td>0.618686</td>
</tr>
<tr>
<td>2</td>
<td>Create new record</td>
<td>The SCIS shall provide physicians and nurses with the ability to create a new record for patients for the first time.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.495698</td>
</tr>
<tr>
<td>3</td>
<td>Create new problems</td>
<td>The SCIS shall provide physicians and nurses with the ability to create a problem in a patients' record. When patients have a problem, the problem will be described and diagnosed.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.611013</td>
</tr>
<tr>
<td>4</td>
<td>Create visit</td>
<td>The SCIS shall enable physicians and nurses to record each visit that may have various problems and different procedures.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.55784</td>
</tr>
<tr>
<td>5</td>
<td>Edit record</td>
<td>The SCIS shall enable physicians and nurses to edit records by updating or adding more information.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.542436</td>
</tr>
<tr>
<td>6</td>
<td>Insert procedure</td>
<td>The SCIS shall enable physicians and nurses to select appropriate procedures for one problem or more than one.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.410874</td>
</tr>
<tr>
<td>7</td>
<td>Finalise procedure</td>
<td>The SCIS shall enable physicians and nurses to complete record and finalise the procedure.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.613918</td>
</tr>
<tr>
<td>8</td>
<td>Access patients' record</td>
<td>The SCIS shall enable physicians and nurses to view record and previous problems with their procedures and any previous history that was recorded.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.473612</td>
</tr>
<tr>
<td>9</td>
<td>Allocate pathology report to procedure</td>
<td>The SCIS shall enable physicians and nurses to allocate any pathology report to its procedure in a patients' record.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.406329</td>
</tr>
<tr>
<td>10</td>
<td>Upload documents and image</td>
<td>The SCIS shall enable physicians and nurses to upload documents and images to a patients' record.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.489118</td>
</tr>
<tr>
<td>11</td>
<td>Generate and print form</td>
<td>The SCIS shall enable physicians and nurses to generate forms such as, taking a test and printing it.</td>
<td>Physician Nurse IT support and developer</td>
<td>0.432951</td>
</tr>
<tr>
<td>12</td>
<td>Generate bill</td>
<td>The SCIS shall enable physicians and nurses to generate bills and print them.</td>
<td>Receptionist Administrator and manager IT support and developer</td>
<td>0.525928</td>
</tr>
</tbody>
</table>

(Continued)
### Section C.3: SCIS Sustainability Profile

**Continuation of Table A.1**

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Assigned Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Hold or un-hold bill</td>
<td>The SCIS shall enable physicians and nurses to hold bills until the result appear, then un-hold them to continue the process.</td>
<td>Physician, Receptionist, Administrator and manager, IT support and developer</td>
<td>0.467628</td>
</tr>
<tr>
<td>14</td>
<td>Print bill</td>
<td>The SCIS shall enable physicians, nurses and receptionist to print bills.</td>
<td>Nurse, Receptionist, Administrator and manager, IT support and developer</td>
<td>0.418866</td>
</tr>
<tr>
<td>15</td>
<td>Create patients’ information</td>
<td>The SCIS shall enable physicians, nurses and receptionist to create patients’ information.</td>
<td>Physician, Nurse, Receptionist, Administrator and manager, IT support and developer</td>
<td>0.638787</td>
</tr>
<tr>
<td>16</td>
<td>Edit patients’ details</td>
<td>The SCIS shall enable physicians, nurses and receptionist to update patients’ information.</td>
<td>Physician, Nurse, Receptionist, Administrator and manager, IT support and developer</td>
<td>0.624384</td>
</tr>
<tr>
<td>17</td>
<td>Search feature</td>
<td>The SCIS shall enable all users who have authorization to look at different information via a search feature, including patient and staff information.</td>
<td>Physician, Nurse, Receptionist, Administrator and manager, IT support and developer</td>
<td>0.49455</td>
</tr>
<tr>
<td>18</td>
<td>Generate and print Financial and business reports</td>
<td>The SCIS shall enable administrators and managers to print various reports.</td>
<td>Administrator and manager, IT support and developer</td>
<td>0.565542</td>
</tr>
<tr>
<td>19</td>
<td>Generate and print Financial and business reports</td>
<td>The SCIS shall enable administrators and managers to print various reports.</td>
<td>Administrator and manager, IT support and developer</td>
<td>0.487618</td>
</tr>
<tr>
<td>20</td>
<td>Create new staff account</td>
<td>The SCIS shall enable administrators and managers to create new staff account and enter their details.</td>
<td>Administrator and manager, IT support and developer</td>
<td>0.53129</td>
</tr>
<tr>
<td>21</td>
<td>Edit staff’s details</td>
<td>The SCIS shall enable administrators and managers to update staff details.</td>
<td>Administrator and manager, IT support and developer</td>
<td>0.532949</td>
</tr>
<tr>
<td>22</td>
<td>Administrator Manage role</td>
<td>The SCIS shall enable administrators to locate staff authorization.</td>
<td>Administrator and manager, IT support and developer</td>
<td>0.552101</td>
</tr>
<tr>
<td>23</td>
<td>Create centre’s information</td>
<td>The SCIS shall enable administrators to establish the centre’s information and entering important details such as connecting details.</td>
<td>Administrator and manager, IT support and developer</td>
<td>0.430374</td>
</tr>
</tbody>
</table>
SCIS - Skin Cancer Information System profile:

1- Overall Sustainability:

3 Stars ★★★☆☆

Rating of sustainability dimensions:

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual dimension</td>
<td>0.673737</td>
</tr>
<tr>
<td>Social dimension</td>
<td>0.614824</td>
</tr>
<tr>
<td>Technical dimension</td>
<td>0.543264</td>
</tr>
<tr>
<td>Economic dimension</td>
<td>0.515676</td>
</tr>
<tr>
<td>Environmental dimension</td>
<td>0.329999</td>
</tr>
</tbody>
</table>

Percentage% Colour Code Description
80-100 Dark green Green (Vibrant)
60-79 Light green Satisfactory
40-59 Yellow Basic
20-39 Orange Unsatisfactory
0-19 Red Critical
### Overall sustainability of each requirement

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finalise procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create visit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold or un-hold bill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create new record</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create centre’s information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access patients’ record</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create new problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create new staff account</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edit record</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create waiting list</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Login system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edit patients’ details</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edit staff’s details</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administrator Manage role</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Search feature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create patients’ information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insert procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generate and print Financial and business reports</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upload documents and image</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allocate pathology report to procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generate bill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generate and print form</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Print bill</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2- Requirement list

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Login system</td>
<td>The SCIS shall provide system access having suitable security services. This access will have various levels that depend on user authorization</td>
<td>Physician</td>
<td>0.558696</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nurse</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Receptionist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Administrator and Manager</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Developer and IT Support</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Create new record</td>
<td>The SCIS shall provide physicians and nurses with the ability to create a new record for patients for the first time</td>
<td>Physician</td>
<td>0.604063</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nurse</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Receptionist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Administrator and Manager</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Developer and IT Support</td>
<td></td>
</tr>
</tbody>
</table>
### CHAPTER C: SUSTAINABLE SOFTWARE PROFILE FOR CASE STUDIES

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement Name</th>
<th>Description</th>
<th>Group</th>
<th>Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Create new problems</td>
<td>The SCIS shall provide physicians and nurses with the ability to create a problem in a patients’ record. When patients have a problem, the problem will be described and diagnosed.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.599514</td>
</tr>
<tr>
<td>4</td>
<td>Create visit</td>
<td>The SCIS shall enable physicians and nurses to record each visit that may have various problems and different procedures.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.624814</td>
</tr>
<tr>
<td>5</td>
<td>Edit record</td>
<td>The SCIS shall enable physicians and nurses to edit records by updating or adding more information.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.583649</td>
</tr>
<tr>
<td>6</td>
<td>Insert procedure</td>
<td>The SCIS shall enable physicians and nurses to select appropriate procedures for one problem or more than one.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.476776</td>
</tr>
<tr>
<td>7</td>
<td>Finalise procedure</td>
<td>The SCIS shall enable physicians and nurses to complete record and finalise the procedure.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.636561</td>
</tr>
<tr>
<td>8</td>
<td>Access patients’ record</td>
<td>The SCIS shall enable physicians and nurses to view record and previous problems with their procedures and any previous history that was recorded.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.602394</td>
</tr>
<tr>
<td>9</td>
<td>Allocate pathology report to procedure</td>
<td>The SCIS shall enable physicians and nurses to allocate any pathology report to its procedure in a patients’ record.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.345824</td>
</tr>
<tr>
<td>#</td>
<td>Requirement Name</td>
<td>Description</td>
<td>Group</td>
<td>Sustainability</td>
</tr>
<tr>
<td>----</td>
<td>---------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>10</td>
<td>Upload documents and image</td>
<td>The SCIS shall enable physicians and nurses to upload documents and images to a patients' record.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.385387</td>
</tr>
<tr>
<td>11</td>
<td>Generate and print form</td>
<td>The SCIS shall enable physicians and nurses to generate forms such as, taking a test and printing it.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.34242</td>
</tr>
<tr>
<td>12</td>
<td>Generate bill</td>
<td>The SCIS shall enable physicians and nurses to generate bills and print them.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.343278</td>
</tr>
<tr>
<td>13</td>
<td>Hold or un-hold bill</td>
<td>The SCIS shall enable physicians and nurses to hold bills until the result appear, then un-hold them to continue the process.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.609793</td>
</tr>
<tr>
<td>14</td>
<td>Print bill</td>
<td>The SCIS shall enable physicians, nurses and receptionist to print bills.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.338953</td>
</tr>
<tr>
<td>15</td>
<td>Create patients' information</td>
<td>The SCIS shall enable physicians, nurses and receptionist to create patients' information.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.510435</td>
</tr>
<tr>
<td>#</td>
<td>Requirement Name</td>
<td>Description</td>
<td>Group</td>
<td>Sustainability</td>
</tr>
<tr>
<td>----</td>
<td>-----------------</td>
<td>-------------</td>
<td>-------</td>
<td>----------------</td>
</tr>
<tr>
<td>16</td>
<td>Edit patients’ details</td>
<td>The SCIS shall enable physicians, nurses and receptionist to update patients’ information.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.553727</td>
</tr>
<tr>
<td>17</td>
<td>Create waiting list</td>
<td>The SCIS shall enable receptionists to create waiting lists and update them</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.561173</td>
</tr>
<tr>
<td>18</td>
<td>Search feature</td>
<td>The SCIS shall enable all users who have authorisation to look at different information via a search feature, including patient and staff information.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.533224</td>
</tr>
<tr>
<td>19</td>
<td>Generate and print Financial and business reports</td>
<td>The SCIS shall enable administrators and managers to print various reports.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.470714</td>
</tr>
<tr>
<td>20</td>
<td>Create new staff account</td>
<td>The SCIS shall enable administrators and managers to create new staff account and enter their details.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.587723</td>
</tr>
<tr>
<td>21</td>
<td>Edit staff’s details</td>
<td>The SCIS shall enable administrators and managers to update staff details.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.550823</td>
</tr>
<tr>
<td>22</td>
<td>Administrator Manage role</td>
<td>The SCIS shall enable administrators to locate staff authorization.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.540712</td>
</tr>
<tr>
<td>#</td>
<td>Requirement Name</td>
<td>Description</td>
<td>Group</td>
<td>Sustainability</td>
</tr>
<tr>
<td>----</td>
<td>---------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>23</td>
<td>Create centre’s information</td>
<td>The shall enable administrators to establish the centre’s information and entering important details such as connecting details.</td>
<td>Physician, Nurse, Receptionist, Administrator and Manager, Developer and IT Support</td>
<td>0.602745</td>
</tr>
</tbody>
</table>

### 3- Stakeholders

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Submitted</th>
<th>In progress</th>
<th>Not started</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Made by Ahmed Alharthi (http://ahmedalharthi.net)
Based on Bootstrap (http://twitter.github.com/bootstrap/) and Bootswatch (http://bootswatch.com).
[@alharth_ahmed](https://twitter.com/alharth_ahmed)

(October 31, 2019)
CHAPTER C: SUSTAINABLE SOFTWARE PROFILE FOR CASE STUDIES

C.4 Screen shot of SuSoftPro tool-support

![SuSoftPro Dashboard](image)

Figure C.1: SuSoftPro: Dashboard (Skin Cancer Information System Project)
SECTION C.4: SCREEN SHOT OF SUSOFTPRO TOOL-SUPPORT

Figure C.2: SuSoftPro: Creating and assigning group to sustainability (Skin Cancer Information System Project)

Figure C.3: SuSoftPro: Defining questions for each sustainability dimension (Skin Cancer Information System Project)
Figure C.4: SuSoftPro: Requirements management (Skin Cancer Information System Project)
Figure C.5: SuSoftPro: Stakeholder management (example, the names and the email addresses are blacked-out)

Figure C.6: SuSoftPro: Profile details