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 Unversity

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

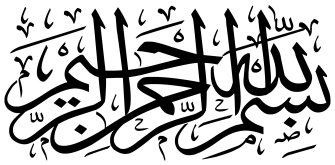
Declaration

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:

1. **Ahmed D. Alharthi**, Tawfeeq Alsanoosy, Maria Spichkova, and Margaret Hamilton. Social position and gender perspectives of elearning systems: A study of social sustainability. In *Advances in Information Systems Development*, volume 34. Springer, 2019. doi: 10.1007/978-3-030-22993-1_10
   This book chapter is presented in **Chapter 4**.

Peer-reviewed journal:

2. **Ahmed D. Alharthi**, Maria Spichkova, and Margaret Hamilton. Sustainability requirements for elearning systems: A systematic literature review and analysis. *Requirements Engineering*, 2018a. doi: 10.1007/s00766-018-0299-9
   Q2 journal according to 2017 SCImago journal rankings[1] and this work is presented in **Chapter 3**.

Conferences:

3. **Ahmed D. Alharthi**, Maria Spichkova, Margaret Hamilton, and Tawfeeq Alsanoosy. Gender-based perspectives of elearning systems: An empirical study of social sustainability. In *the 27th International Conference on Information Systems Development (ISD2018)*. AIS, 2018d
   According to CORE 2018 conference rankings[2], 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-*

[1] https://www.scimagojr.com
[2] http://www.core.edu.au/

neering Conference (RE'18). IEEE, 2018c. doi: 10.1109/RE.2018.00072
According to CORE 2018 conference rankings[2], RE is an **A-ranked** conference and this work is presented in **Chapter 5**.

5. **Ahmed D. Alharthi** and Maria Spichkova. Individual and social requirement aspects of sustainable elearning systems. In *International Conference on Engineering Education and Research (ICEER 2016)*. Western Sydney University, 2016
This paper is presented in **Chapter 3**.

6. Maria Spichkova, James Harland, and **Ahmed D. Alharthi**. Online support system for transnational education. In *International Conference on Engineering Education and Research (ICEER 2016)*. Western Sydney University, 2016
This paper presents in **Chapter 3**.

7. **Ahmed D. Alharthi**, Maria Spichkova, and Margaret Hamilton. Requirements engineering aspects of elearning systems. In *Proceedings of the ASWEC 2015 24th Australasian Software Engineering Conference*, ASWEC ' 15 Vol. II, pages 132–133. ACM, 2015. ISBN 978-1-4503-3796-0. doi: 10.1145/2811681.2817756
According to CORE 2018 conference rankings[3], ASWEC is ranked as **Australasian** conference this paper is presented in **Chapter 1**.

Workshops:

8. **Ahmed D. Alharthi**, Maria Spichkova, and Margaret Hamilton. Towards tool-support for sustainability profiling. In *Proceedings of the 7th International Workshop on Requirements Engineering for Sustainable Systems, RE4SuSy 2018, co-located with the 26th IEEE International Requirements Engineering Conference (RE 2018)*. CEUR-WS, 2018b
This paper presents in **Chapter 6**. Workshop at a CORE 2018 **A-ranked** conference.

9. **Ahmed D. Alharthi** and Maria Spichkova. Green architecture for sustainable elearning systems. In *Proceedings of the 11th European Conference on Software Architecture: Companion Proceedings*, ECSA'17, pages 199–204. ACM, 2017. ISBN 978-1-4503-5217-8. doi: 10.1145/3129790.3129817
According to CORE 2018 conference rankings[3], ECSA is an **A-ranked** conference. This paper presents in **Chapter 7**.

10. **Ahmed D. Alharthi**, Maria Spichkova, and Margaret Hamilton. Sustainability profiling of long-living software systems. In *Proceedings of 4th International Workshop on Quantitative Approaches to Software Quality*, volume 1771, pages 12–19. CEUR–WS, 2016
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 2_ε document preparation system.
All trademarks are the property of their respective owners.

Contents

List of Figures

List of Tables

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;

- **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:

- 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.

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:

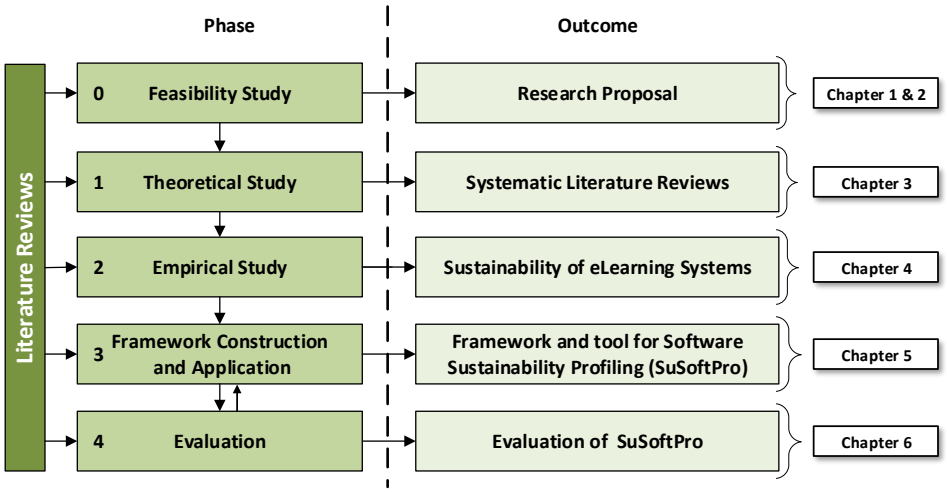


Figure 1.1: Research methodology overview

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.

Chapter 2

Background

"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

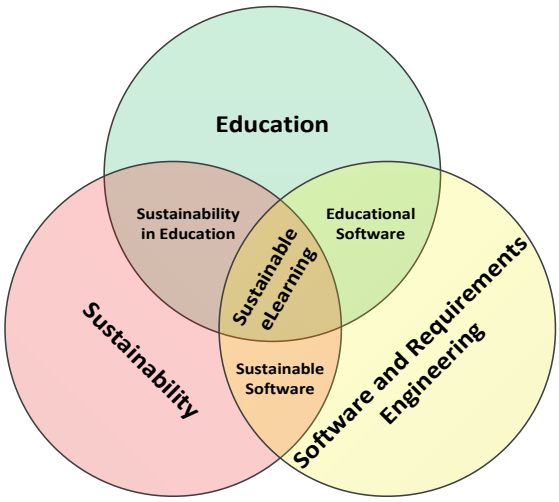


Figure 2.1: Research field

each domain. 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, Figure2.2 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.

4. Nonfunctional Requirements
4.3 Quality requirements specification
4.3.1 Sustainability

SUS-1 eLearning systems shall run on green data centre,

SUS-2 eLearning systems shall share learning content with other eLearning systems and social networks,

SUS-3 eLearning systems shall provide extension for Massive Open Online Courses (MOOCs) for anyone to enrol,

SUS-4 eLearning systems shall allow collaboration on a document to use real-time co-authoring, and

SUS-5 eLearning systems shall calculate the return on investment formula for curriculum development and implementation, and power consumption per business transaction.

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

- **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

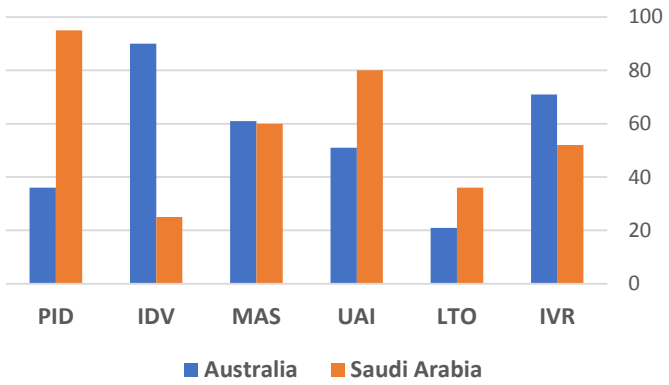


Figure 2.3: Comparison of Australia and Saudi Arabia using Hofstede's cultural dimensions: Power Distance Index (PDI), Individualism versus collectivism (IDV), Masculinity versus femininity (MAS), Uncertainty Avoidance Index (UAI), Long-Term versus short-term Orientation (LTO), and Indulgence Versus 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 2.1: Comparison of rating scale classifications

Likert	**Linguistic**	**Fuzzy**	
		Triangular	*Trapezoidal*
1	Critical	(0,0,1)	(0,0,1,1.5)
2	Unsatisfactory	(1,2,3)	(1,1.5,2.5,3)
3	Basic	(2,3,4)	(2,2.5,3.5,4)
4	Satisfactory	(3,4,5)	(3,3.5,4.5,5)
5	Green (Vibrant)	(4,5,5)	(4,4.5,5,5)

The fuzzy rating scale

The FRS, also called visual analogue or continuous rating scale, allows capturing the diversity and unambiguousness 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 $Tra(a, b, c, d)$, 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

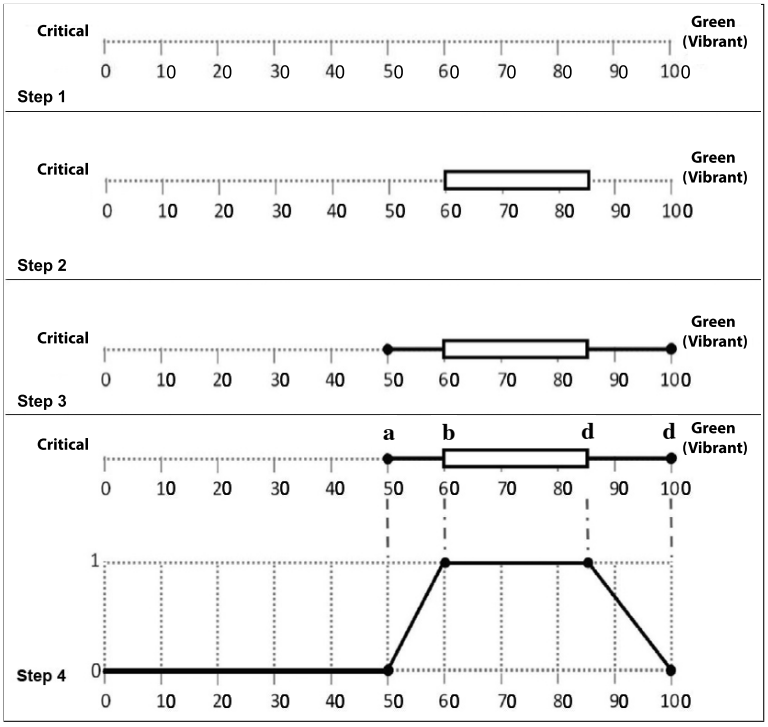


Figure 2.4: Fuzzy rating scale for sustainability profiling

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 realité (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}

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad for\ i = 1, \cdots, m, \quad j = 1, \cdots, n \tag{2.1}$$

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}

$$v_{ij} = w_i r_{ij} \tag{2.2}$$

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

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

Negative ideal solutions

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

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

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

Similarly, the separation from negative ideal is

$$S^{'} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_i^{'})^2}, \quad i = \{1, \cdots, m\} \tag{2.6}$$

Step 5: Calculate the relative closeness to the ideal solution C_i^*

$$C_i^* = \frac{S'}{(S^* + S')}, \quad 0 < C_i^* < 1, \quad i = \{1, \cdots, m\} \tag{2.7}$$

$C_i^* = 1$ 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

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 3.1: Primary sources

Automated search	Manual searches
IEEExplore Digital Library[1]	Springer Link[2]
ACM Digital Library[3]	Wiley[4]
Scopus[5]	—

[1] http://ieeexplore.ieee.org
[2] http://springerlink.com
[3] http://dl.acm.org
[4] http://onlinelibrary.wiley.com
[5] http://scopus.com

For the automated search, the following search string was used over the title, abstract and keywords fields of the papers in the digital libraries:
(sustainability OR sustainable OR sustain) AND (requirement OR requirements OR requirements engineering) AND (learning OR e-learning OR eLearning OR (distance AND education) OR (electronic AND Learning)) AND (system OR systems OR environment OR ecosystem)

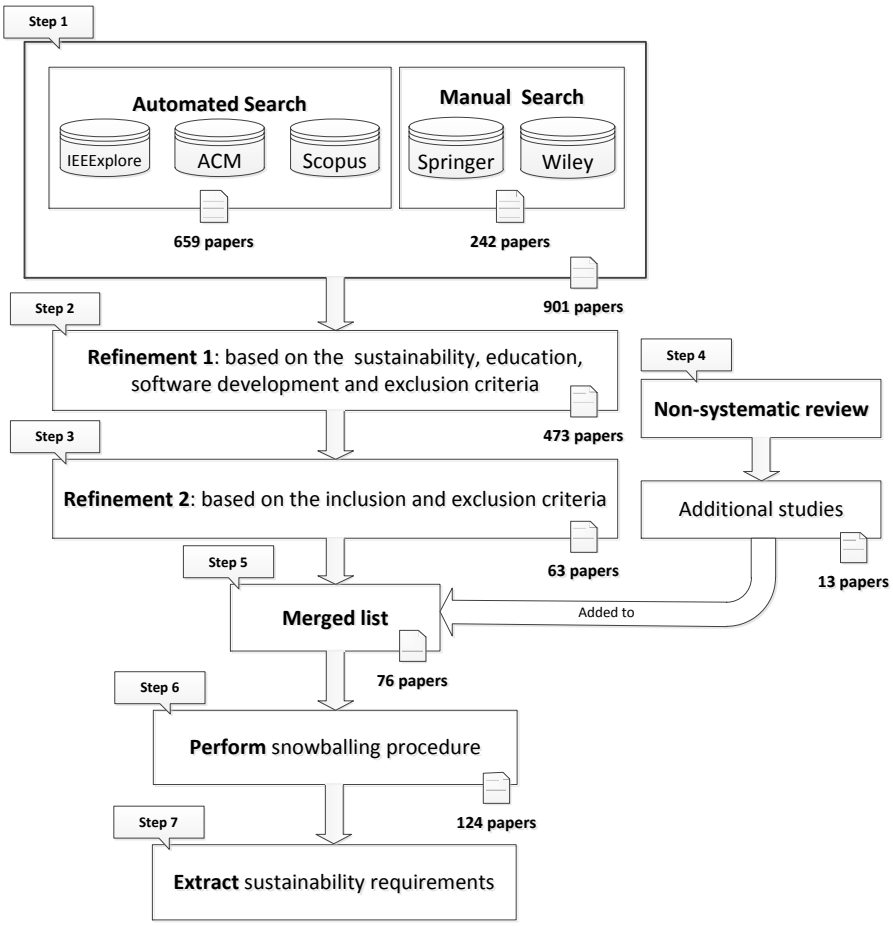


Figure 3.1: Review process and outcomes

Table 3.2: Primary sources and number of papers

Primary Sources	**Papers**
IEEExplore	87
ACM	113
Scopus	459
Springer: Requirements Engineering Journal	26
Springer: Empirical Software Engineering	39
Springer: Education and Information Technologies	77
Wiley: Software Practice and Experience	29
Wiley: Journal of Software: Evolution and Process	71
Total	**901**

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.

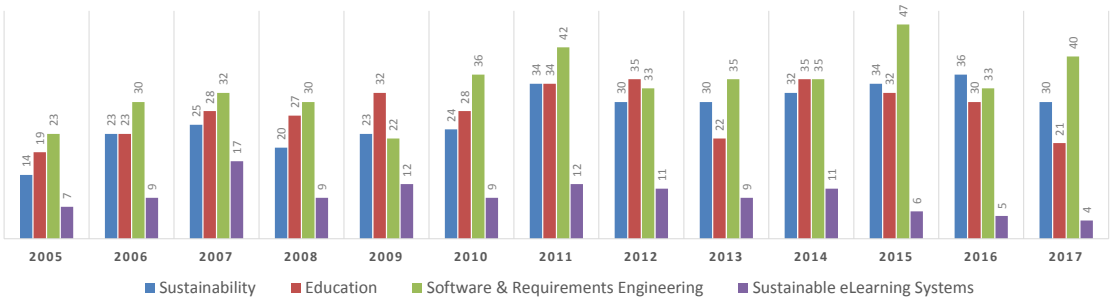


Figure 3.2: Distribution of the number of studies over the years (2005–2017)

Table 3.3: Sustainability meta-requirements for eLearning systems

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

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.

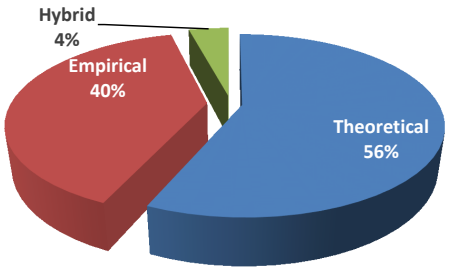


Figure 3.3: The classifications of studies in percentage

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 reasons 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.

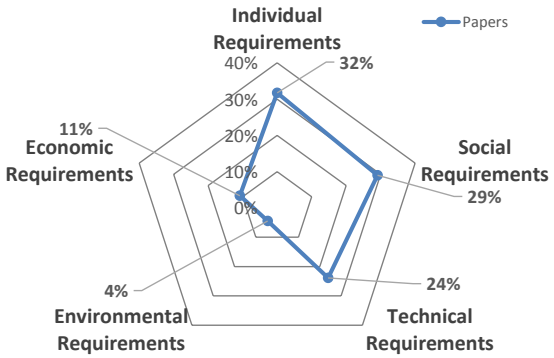


Figure 3.4: Dimensions of sustainable eLearning systems (2005–2017)

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, Pellas 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.

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 martial (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 (Vovides 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.

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

Dimension	Sustainability meta-requirements	G/S	Software product quality	References
Individual and Social	R1.1 Personalisation	G	Usability	Attwell (2007), Burton et al. (2014), Chen et al. (2005), Dyson et al. (2009), Gunn (2010; 2011), Jiang et al. (2010), Liu et al. (2009), Memmel (2011), Meneses (2011), Ossiannilsson and Landgren (2012), Park et al. (2009), Pettersson and Vogel (2012), Rajasingham (2011), Randelin et al. (2013), Sun et al. (2008), Tikhomirova et al. (2012), Toppin and Toppin (2016), Winfree et al. (2017)
	R1.2 Learner-centred features	**S**	Usability, greenability	Attwell (2007), Breslow et al. (2013), Cápay et al. (2011), Dinevski (2008), Georgiadou and Siakas (2006), Halimi (2005), Hylén (2006), Iatagan (2012), Jin and Law (2009), Kendall (2005), Kruchten (2015), Liu et al. (2009), Lizhong et al. (2011), Mason (2008), Miliszewska and Sztendur (2011), Nunes et al. (2016), Ossiannilsson and Landgren (2012), Pellas (2014; 2016), Pettersson and Vogel (2012), Rahanu et al. (2015), Secundo et al. (2013), Tikhomirova et al. (2012), Wang et al. (2014)
	R1.3 Collaboration	G	Functional suitability, compatibility	Allen et al. (2010), Bottino (2007), Breslow et al. (2013), Buchan (2010), Cheung and Lee (2009), Demirkan et al. (2010), Ellis (2016), Farooq et al. (2007), Franceschi et al. (2008), Hoffman et al. (2005), Hylén (2006), Jiang et al. (2010), Koshkin et al. (2016), Liu et al. (2009), Mocigemba (2006), Mohan et al. (2017), Mridha et al. (2013), Ossiannilsson and Landgren (2012), Pardo et al. (2012), Pellas (2016), Rovai and Downey (2010), Secundo et al. (2012), Sridharan et al. (2010), Stiles and Yorke (2007), Suhonen and Sutinen (2014), Thomas and Trapp (2007), Vogel et al. (2014), Zon et al. (2012)
	R1.4 Leadership development	G	Usability	Bell and Bell (2005), Berge and Giles (2006; 2008), Garrison and Akyol (2009), Gunn (2010; 2011), Iatagan (2012), Ko (2012), Lago and Jansen (2011), Robertson (2008), Ruyters et al. (2012), Salmon (2005), Secundo et al. (2012; 2013), Shen and LeClair (2013), Stepanyan et al. (2013), Törngren et al. (2015), Winfree et al. (2017)
	R1.5 Privacy and security	G	Security	Fisler and Bleisch (2006), Neila and Rabai (2014), Sridharan et al. (2010), Stewart and Khare (2015), Törngren et al. (2015)
	R1.6 Analysis of learning progress	**S**	Functional suitability, usability	Cápay et al. (2011), Ossiannilsson and Landgren (2012), Shehabat and Mahdi (2009), Zheng et al. (2014)
	R1.7 Reuse of learning materials	**S**	Maintainability	Chiu et al. (2006), Farooq et al. (2007), Friesen (2009), Gunn (2010), Koohang and Harman (2007), O'Neil (2008), Scoppio and Luyt (2017), Shehabat and Mahdi (2009), Sowe et al. (2013), Sridharan et al. (2010), Stepanyan et al. (2013), Vovides et al. (2014)
	R1.8 Integration with social networks	G	Compatibility, portability, usability	Attwell (2007), Chiu et al. (2006), Colasante (2010), Koshkin et al. (2016), Lee and Chan (2007), Manca and Ranieri (2017), Secundo et al. (2013), Wang et al. (2014)
	R1.9 Standardisation of the LORs	**S**	Compatibility, maintainability	Dinevski (2008), Friesen (2009), Hylén (2006), Littlejohn (2003), Scoppio and Luyt (2017), Shehabat and Mahdi (2009), Stepanyan et al. (2013), Vovides et al. (2014)
Technical	R2.1 Support of LORs	**S**	Maintainability	Downes (2007), Gunn (2011), Gunn et al. (2005), O'Neil (2008), Robertson (2008), Shehabat and Mahdi (2009), Sridharan et al. (2010), Yigit et al. (2014)
	R2.2 Support of shared services	G	Compatibility	Memmel (2011), Mohan et al. (2017), Stepanyan et al. (2013), Stewart and Khare (2015), Vovides et al. (2014)
	R2.3 Software quality requirements	G	All qualities	Assembly (2015), Bhat (2011), Calero et al. (2013), Chen (2007), Dong et al. (2009), Fisler and Bleisch (2006), Garg and Varma (2015), Kazancoglu and Aksoy (2011), Keengwe and Malapile (2014), Mahmood and Hafeez (2013), Manuja et al. (2011), Miliszewska and Sztendur (2011), Nwokediuko (2012), Ossiannilsson and Landgren (2012), Stepanyan et al. (2013), Weichhart (2015)
	R2.4 Portability	G	Portability	Attwell (2007), Dholakia et al. (2006), Garg and Varma (2015), Kim et al. (2008), Mahmood and Hafeez (2013), Motiwalla (2007), Park et al. (2009), Scoppio and Luyt (2017), Sharpe et al. (2006), Sun et al. (2008)
	R2.5 Modularity	G	Maintainability	Dagger et al. (2005), Mahmood and Hafeez (2013), Sousa (2011), Tikhomirova et al. (2012), Tomkinson and Hutt (2012), Zon et al. (2012)
Environmental	R3.1 Cloud computing	G	Greenability	Bensch and Rager (2012), Demski (2012), Dong et al. (2009), Kumar and Buyya (2012), Lago and Jansen (2011), Mahmoud and Ahmad (2013), Sousa (2011), Sowe et al. (2013), Uden et al. (2007), Winfree et al. (2017), Zheng et al. (2014)
	PR3.2 Green and sustainable SE *	G	Greenability	Betz and Caporale (2014), Calero and Piattini (2015), Dong et al. (2009), Mahmoud and Ahmad (2013), Naumann et al. (2011), Roy et al. (2008), Stewart and Khare (2012; 2015)
Economic	R4.1 Reducing the cost	G	Greenability	Berge and Giles (2006; 2008), Castro-Schez et al. (2012), Demirkan et al. (2010), Fisler and Schneider (2009), Gustavsson et al. (2009), Laurillard (2007), Meneses (2011), Müller and Siebenhüner (2007), Sowe et al. (2013), Stefanovic (2013)
	R4.2 Ensuring the growth	G	Greenability	Alrashidi (2013), Bourn and Shiel (2009), Gunn (2010; 2011), Iatagan (2012), Konting (2012), Koshkin et al. (2016), Meneses (2011), Müller et al. (2007), Toppin and Toppin (2016)

* 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
RQ1.1: What are the requirements for eLearning systems that cover the sustainability aspects?
and
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
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: *Product Quality*, *Data Quality* and *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;

- **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[6]; 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.

[6]http://www.scimagojr.com/

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

Journal	SJR Quartile
Springer: Requirements Engineering	Q2
Springer: Empirical Software Engineering	Q1
Springer: Education and Information Technologies	Q2
Wiley: Software Practice and Experience	Q2
Wiley: Journal of Software: Evolution and Process	Q3

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.

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.

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.

4.1 Survey scheme

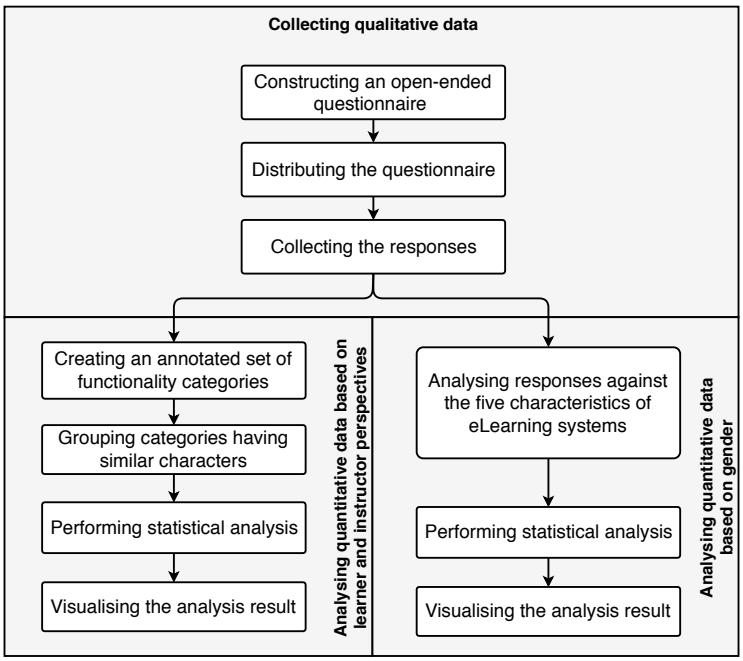


Figure 4.1: Design for data collection and analysis

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

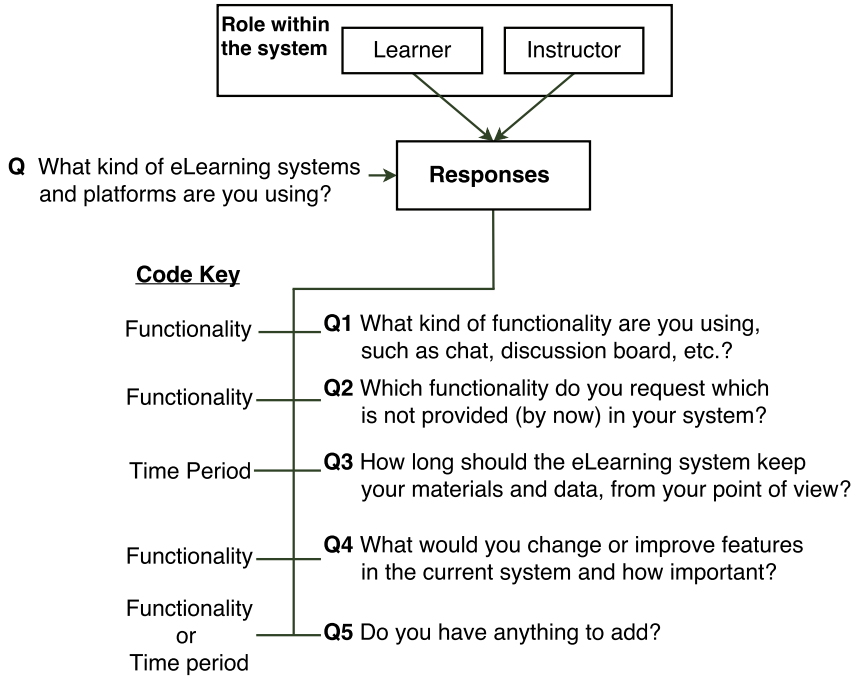


Figure 4.2: Coding process for extracting values from responses

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 $\sim$3% IT support personnel and administrators. To address the research questions, we analysed three aspects of the

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

Role	**eLearning systems**	**Responses of 'What kind of functionality are you using?'**	**Category**	**Annotation**					
				Course Contents	Discussion board	Email	Grade book	Tests and Quizzes	Assignment management
Instructor	Bb	'Email, discussion board, quizzes'	1- Discussion board 2- Email 3- Tests and Quizzes	-	1	1	-	1	-
Instructor	D2L	'Quizzes / content / discussions / grade book / delivery folder'	1- Course Contents 2- Discussion board 3- Grade book 4- Tests and Quizzes 5- Assignment management	1	1	-	1	1	1
Learner	Bb	'Discussion boards, looking up learning content'	1- Course Contents 2- Discussion board	1	1	-	-	-	-
Learner	D2L	'Submitting assignments, downloading slides'	1- Course Contents 2- Assignment management	1	-	-	-	-	1

data:

- 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

System / Role	**Blackboard**	**Desire2Learn**	**Total**
Learner	69	58	127
Instructor	20	27	47
IT support personnel and administrator	2	3	5
Total	91	88	**179**

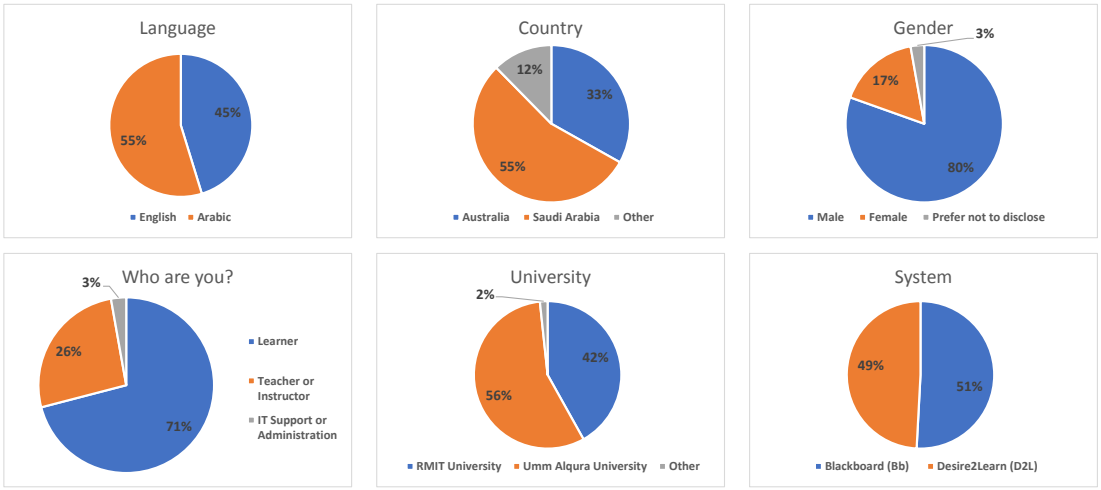


Figure 4.3: Overall participant demographics

Table 4.3: Functionality categories

ID	Functionality category	Provided and used	Requested	Needs improvement
F1	Discussion board	Yes	Yes	Yes
F2	Text and video chat	Yes	Yes	Yes
F3	Course content	Yes	Yes	-
F4	Tests and quizzes	Yes	Yes	Yes
F5	Email	Yes	Yes	Yes
F6	Social media	Yes	Yes	-
F7	Assignment management	Yes	Yes	-
F8	Collaborative tools	Yes	Yes	Yes
F9	Grade book	Yes	Yes	-
F10	Lecture recordings	Yes	Yes	Yes
F11	Cloud storage service	Yes	Yes	-
F12	Virtual classrooms	Yes	Yes	Yes
F13	Calendar and schedule	Yes	Yes	Yes
F14	Notifications	Yes	Yes	-
F15	Survey	Yes	Yes	-
F16	Remote service	Yes	-	-
F17	Announcement board	Yes	-	-
F18	Mobile version	-	Yes	Yes
F19	Improve performance	-	Yes	Yes
F20	Availability	-	Yes	Yes
F21	Improve usability	-	Yes	Yes
F22	Integrating with university community and resource	-	Yes	Yes
F23	Progress analysis	-	Yes	-
F24	Customisation	-	Yes	Yes
F25	Mind mapping	-	Yes	-
F26	Providing maths editor	-	Yes	-
F27	Standardised learning delivery	-	Yes	Yes
F28	Checklists of task to do	-	Yes	-

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 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

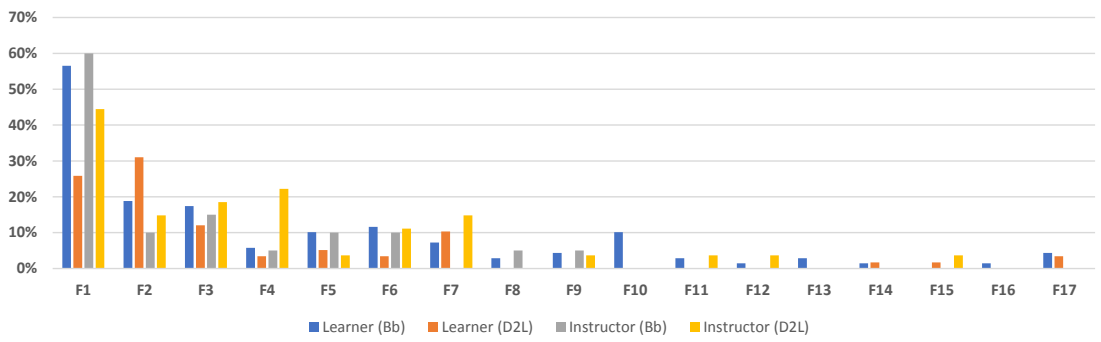


Figure 4.4: Used functionalities: learners' and instructors' responses on the Bb and D2L systems

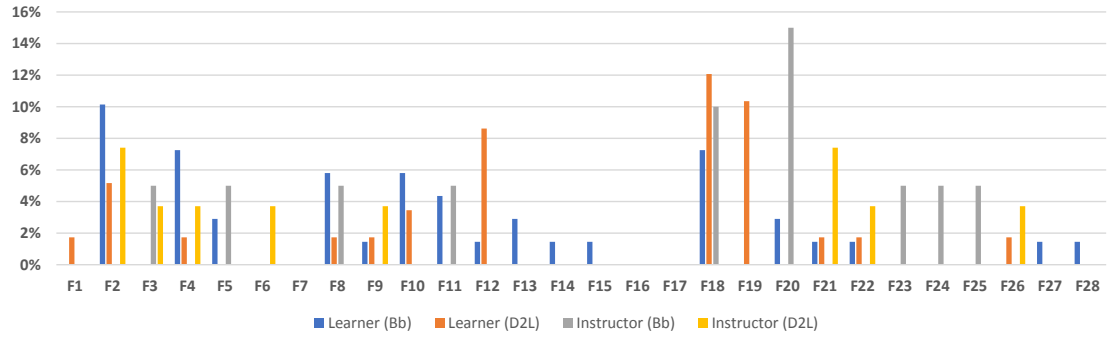


Figure 4.5: Requested functionalities: learners' and instructors' responses on the Bb and D2L systems

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.

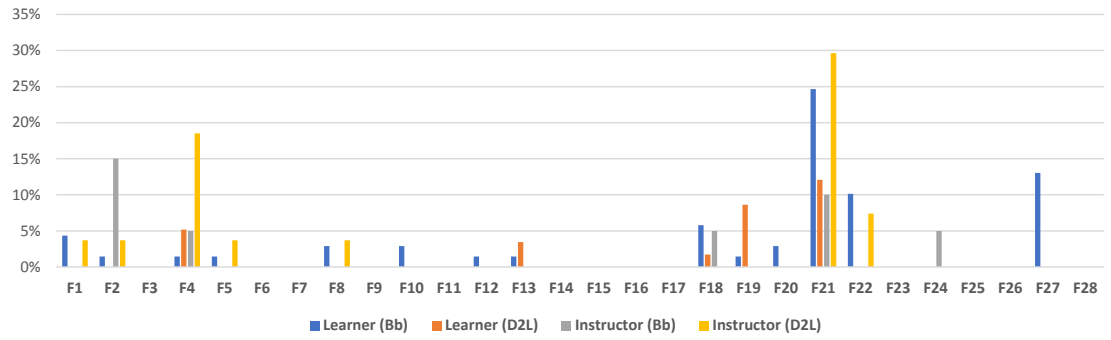


Figure 4.6: Deficient functionalities: learners' and instructors' responses on the Bb and D2L systems

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 ≥ 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 α 2, where α 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 ≤ 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 squire* 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 ≤ 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

Aspect	System Groups	Blackboard		Desire2Learn	
		Learner	Instructor	Learner	Instructor
Used functionalities	*Count*	16	8	10	11
	Sum	110	24	57	39
	Mean	6.88	3	5.7	3.55
	Standard Deviation	9.36	3.70	6.07	3.36
	Standard Error	2.34	1.31	1.92	1.01
	Variance	87.58	13.71	36.9	11.27
	t-value	1.445		0.992	
	Two-tail p-value	0.163		0.338	
Requested functionalities	*Count*	17	9	13	8
	Sum	42	12	30	10
	Mean	2.47	1.33	2.31	1.25
	Standard Deviation	1.87	0.71	2.25	0.46
	Standard Error	0.455	0.235	0.624	0.16
	Variance	3.51	0.5	5.06	0.21
	t-value	2.221		1.639	
	Two-tail p-value	**0.037**		0.123	
Deficient functionalities	*Count*	14	5	5	7
	Sum	52	8	18	19
	Mean	3.71	1.6	3.6	2.71
	Standard Deviation	4.55	0.89	2.41	2.75
	Standard Error	1.22	0.4	1.07	1.04
	Variance	20.68	0.8	5.8	7.57
	t-value	1.652		0.592	
	Two-tail p-value	0.119		0.569	

Table 4.5: ANOVA testing result

Source of Variation	SS	df	MS	F	p-**value**
Between Groups	374.2487483	11	34.02261	1.62937	0.10003
Within Groups	2317.767512	111	20.88079		
Total	2692.01626	122			

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

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

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

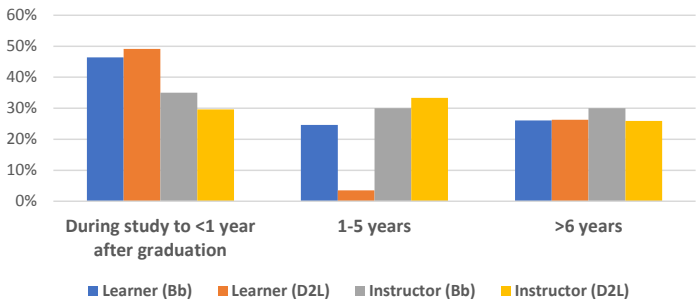


Figure 4.7: Required data retention time from learners' and instructors' perspectives on the Bb and D2L systems

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 $\sim$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 4.7: Participants: statistics by gender and country

Country / Gender	Australia	Saudi Arabia	Total
Male	69	75	144
Female	20	10	30
Total	89	85	**174**

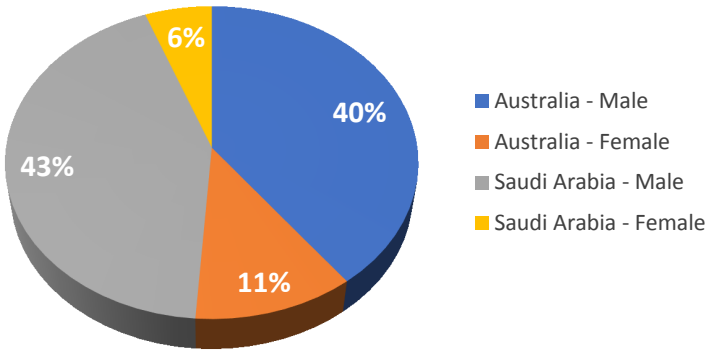


Figure 4.8: Gender percentage of participants from Australia and Saudi Arabia

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 ($p < l0.020$), 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

Aspect	**Country Groups**	**Australia**		**Saudi Arabia**	
		Male	**Female**	**Male**	**Female**
Used functionalities	*Count*	4	3	3	3
	Sum	80	25	71	14
	Mean	20	8.33	23.67	4.67
	Standard Deviation	23.19	6.66	21.13	2.08
	Standard Error	11.60	3.84	12.20	1.20
	Variance	538	44.33	446.33	4.33
	t-value	0.955		1.550	
	Two-tail p-value	0.394		0.261	
Requested functionalities	*Count*	5	5	5	2
	Sum	42	14	37	3
	Mean	8.4	2.8	7.4	1.5
	Standard Deviation	4.22	1.30	3.78	0.71
	Standard Error	1.89	0.58	1.69	0.50
	Variance	17.8	1.7	14.3	0.5
	t-value	2.836		3.346	
	Two-tail p-value	**0.036**		**0.020**	
Deficient functionalities	*Count*	5	4	4	4
	Sum	38	19	28	6
	Mean	7.6	4.75	7	1.5
	Standard Deviation	11.59	5.19	7.57	0.58
	Standard Error	5.18	2.59	3.79	0.29
	Variance	134.3	26.92	57.33	0.33
	t-value	0.492		1.449	
	Two-tail p-value	0.640		0.243	

Table 4.9: ANOVA testing result

Source of Variation	SS	df	MS	F	p-**value**
Between Groups	1784.328723	11	162.2117021	1.608035227	0.1395026
Within Groups	3530.65	35	100.8757143		
Total	5314.978723	46			

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

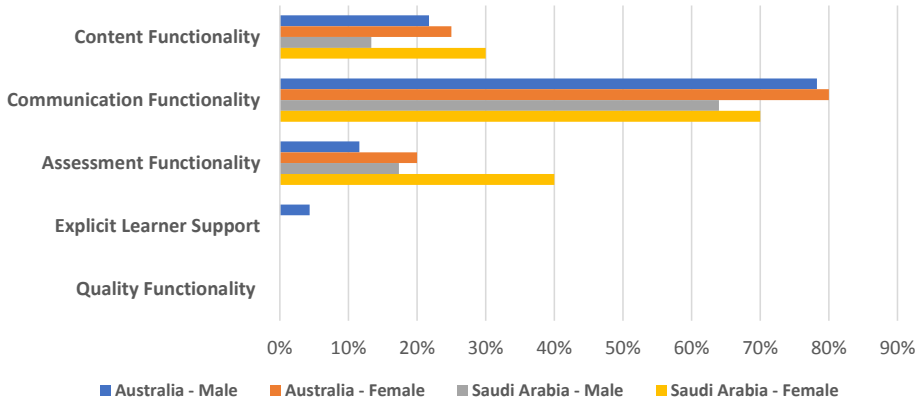


Figure 4.9: Functionality usage: comparison by gender and country

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 $\sim 5\%$ of Australian male participants.

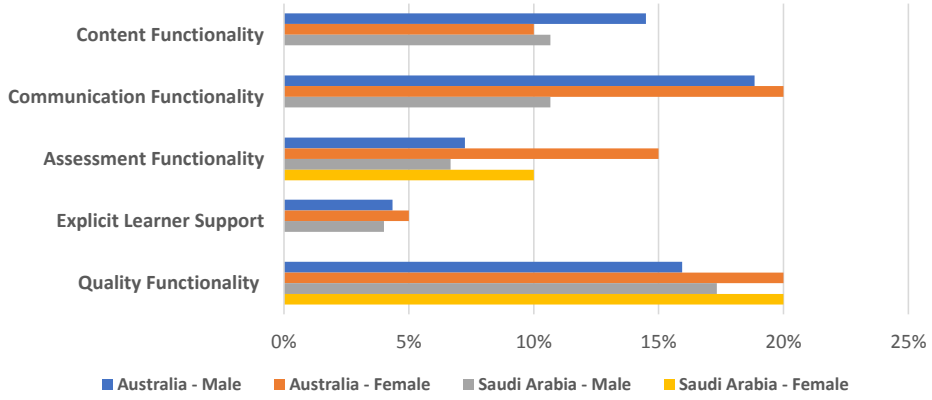


Figure 4.10: Functionalities requested: comparison by gender and country

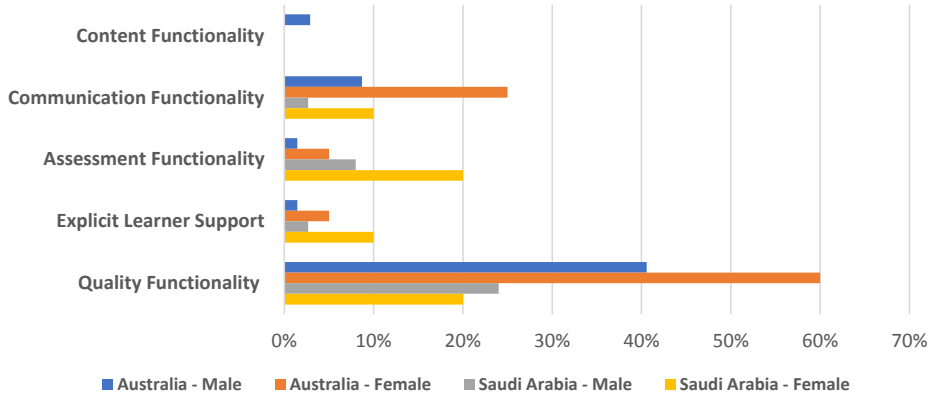


Figure 4.11: Comparison of deficient functionalities between female and male responses in Australia and Saudi Arabia

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:

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 thefirst-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.

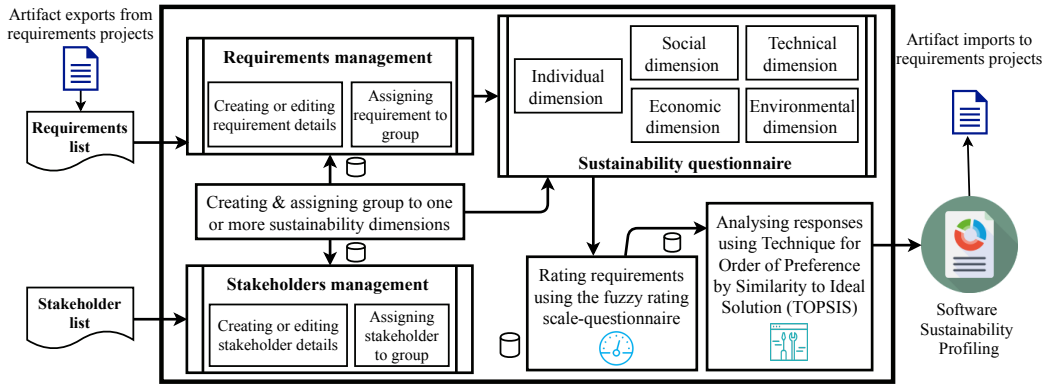


Figure 5.1: SuSoftPro: process model

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:

'*Rate the influence of the requirement on the X sustainability*',

where *X* is replaced in a concrete case by the corresponding sustainability dimension: *individual*, *social*, *technical*, *economic* and *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 *artifact type*, *primary text*, *name*, *description* and *owner*, where *name* is a requirement name, and *primary text* as the description of the requirement. An example of exported CSV file is:

ArtifactType, PrimaryText, Name, Description, Owner

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, *waiting*, *in progress* or *submitted*. If a stakeholder is allocated to a group to rate requirements, their status in the project will become *waiting* until they start answering the questionnaire. As soon as they start responding, their status will be updated to *in progress* until they finish and submit their questionnaire; then the status will be changed to *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.

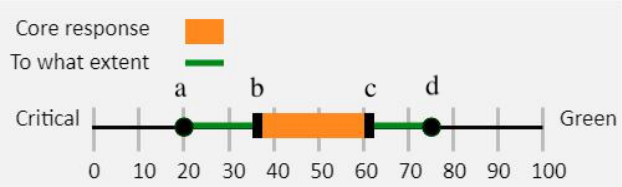


Figure 5.2: The developed fuzzy rating scale in SuSoftPro

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 digram 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

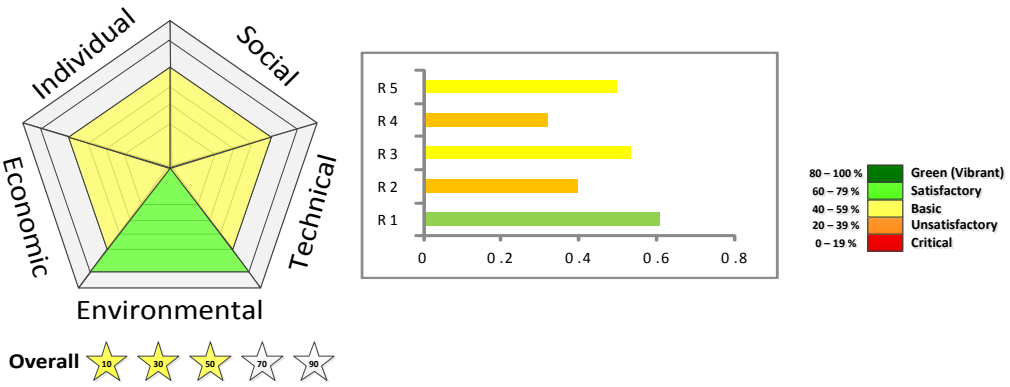


Figure 5.3: Sustainability profile of a software system using the default colour schema.

Table 5.1: Key chart in software sustainability profiling

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

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

True colour	Protanopia	Deuteranopia	Tritanopia

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

True colour	Protanopia	Deuteranopia	Tritanopia

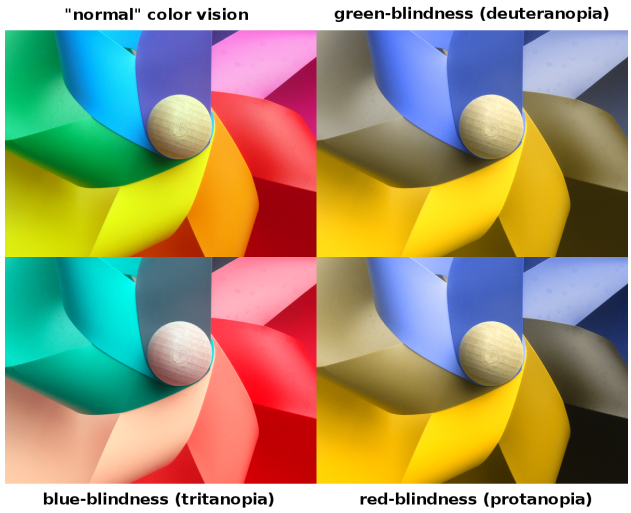


Figure 5.4: Simulation of different colour deficiencies. By Johannes Ahlmann (2011), via Flickr/Wikimedia Commons. Used under Creative Commons Attribution 2.0 Generic License.

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

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):

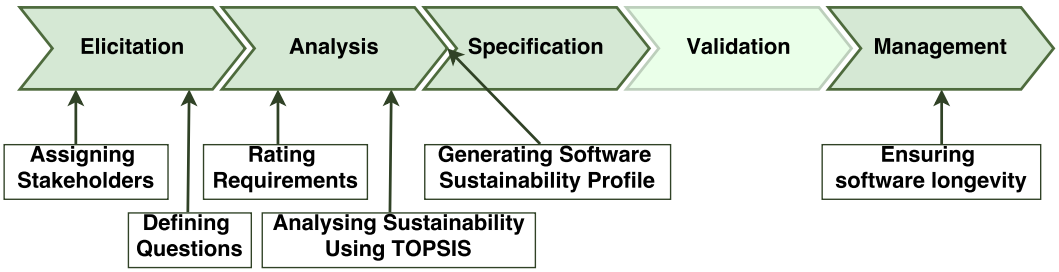


Figure 5.5: Sustainability profiling as a part of RE activities

- **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 discuses. 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.

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.

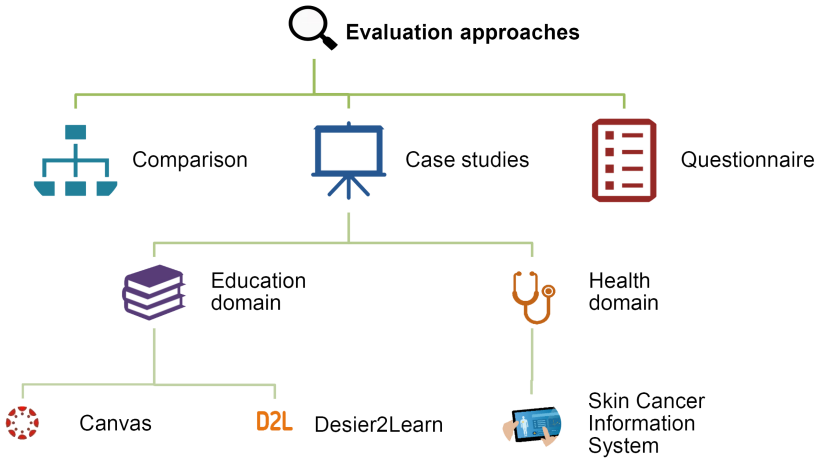


Figure 6.1: Overview of evaluation approaches

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

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

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* 23^{rd} *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 domain 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

Group	**Sustainability dimensions**				
	Individual	Social	Technical	Economic	Environmental
Learner	✓				
Instructor	✓	✓			
Admin		✓		✓	
IT support/ developer			✓		✓

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

Sustainability aspects	Instructions
Individual	Rate the influence of the requirement on the individual sustainability
Social	Rate the influence of the requirement on the social sustainability
Technical	Rate the influence of the requirement on the technical sustainability
Economic	Rate the influence of the requirement on the economic sustainability
Environmental	Rate the influence of the requirement on the environmental sustainability

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

System / Role	Canvas	Desire2Learn	Total
Learner	32	56	88
Instructor	7	14	21
Administrator and related	3	4	7
IT support and developer	4	5	9
Total	46	79	**125**

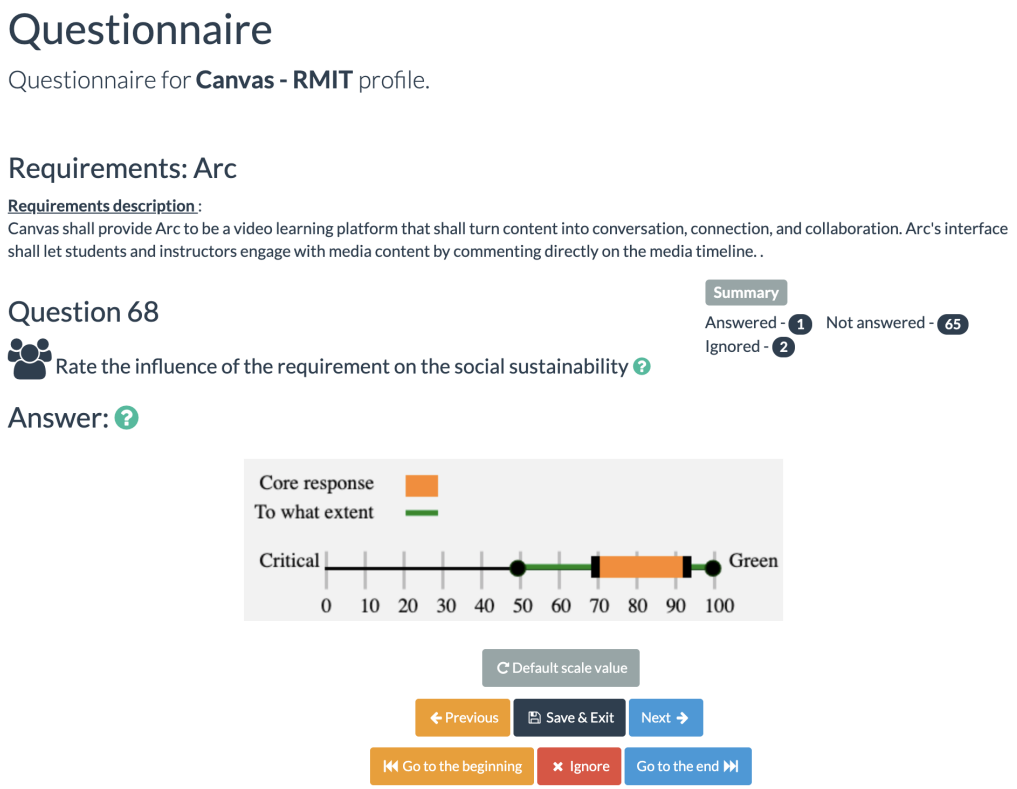


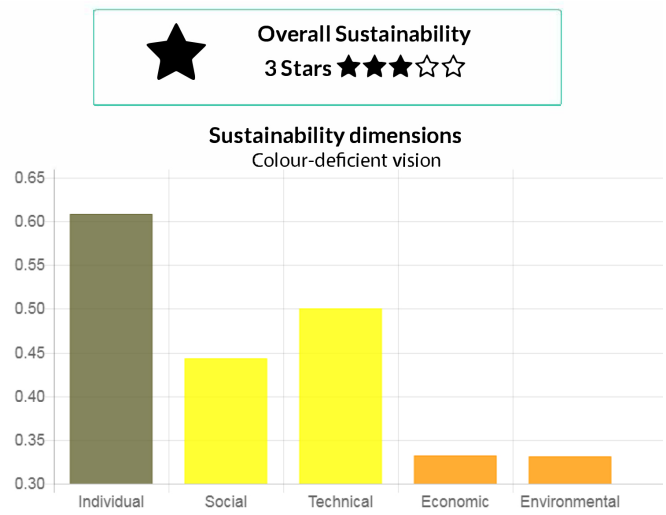
Figure 6.2: SuSoftPro: rating of one Canvas requirement's effect on social sustainability

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

System / Role	Canvas	Desire2Learn
Learner	23	18
Instructor	68	66
Administrator and related	28	30
IT support and developer	76	72

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*).



Key chart for colour-deficient vision

Percentage %	Colour Code	Description
80-100	Dark brown	Green (Vibrant)
60-79	Light brown	Satisfactory
40-59	Yellow	Basic
20-39	Orange	Unsatisfactory
0-19	Blue	Critical

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

#	Requirement name	Sustainability	#	Requirement name	Sustainability
1	Announcements	0.653561	20	SpeedGrader	0.475038
2	Assignments	0.610519	21	Course Settings	0.366096
3	Calendar	0.594229	22	Modules	0.444777
4	Chat	0.557077	23	Files	0.444393
5	Collaborations	0.52757	24	Rich Content Editor	0.476673
6	Conferences	0.594289	25	Profile and User Settings	0.431636
7	Conversations	0.581955	26	ePortfolios	0.410954
8	Groups	0.636811	27	Authentication	0.435554
9	Discussions	0.539979	28	Roles and Permissions	0.426534
10	Pages	0.489472	29	Hierarchical structure for accounts	0.415785
11	Outcomes	0.486183	30	Analytics	0.607245
12	Roll Call Attendance Tool	0.453021	31	Mobile Features	0.389086
13	Navigation	0.528323	32	Integrations	0.50601
14	Quizzes	0.489581	33	Course Import Tool	0.410846
15	Question banks	0.44508	34	Student Information Systems Imports	0.428707
16	Grades and the Gradebook	0.488973	35	External Apps	0.453915
17	Grading schemes	0.43454	36	MagicMarker app	0.438597
18	What-If Grades	0.482085	37	Polls for Canvas app	0.509167
19	Rubrics	0.472837	38	Arc	0.537273

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

#	Requirement name	Sustainability	#	Requirement name	Sustainability
1	News	0.520927	19	Rubrics	0.549669
2	Calendar	0.50317	20	Assignment Grader app	0.509498
3	Chat	0.490526	21	Learning Activity Library	0.536788
4	Dropbox	0.557709	22	Course Builder	0.475953
5	Virtual Classrooms	0.486143	23	Manage Files	0.518723
6	Email	0.51225	24	Rich Content Editor	0.447157
7	Groups	0.481093	25	Profile and User Settings	0.476575
8	Discussions	0.538938	26	ePortfolios	0.434032
9	Course Layout	0.508773	27	Self-Registration	0.609854
10	Class Progress	0.519936	28	Roles and Permissions	0.545384
11	Attendance	0.57533	29	Organizational Unit Structure	0.545297
12	Navigation	0.502819	30	Analytics	0.466342
13	Quizzes	0.506062	31	Mobile Features	0.498376
14	Question Library	0.583901	32	Integrations	0.452653
15	Grade book	0.554914	33	Importing course components	0.417786
16	Grading system	0.495104	34	Student Information Systems Imports	0.491317
17	Grading Schemes	0.567044	35	Blog	0.590016
18	Surveys	0.532029	36	Binder app	0.594171

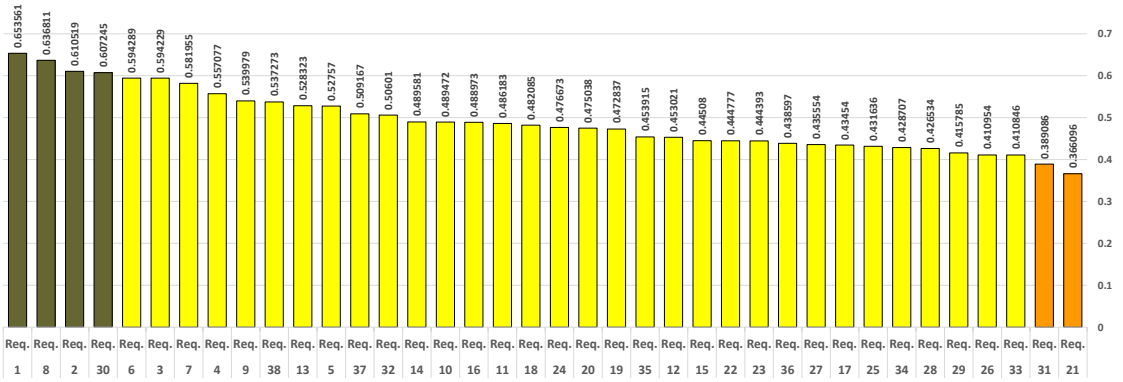
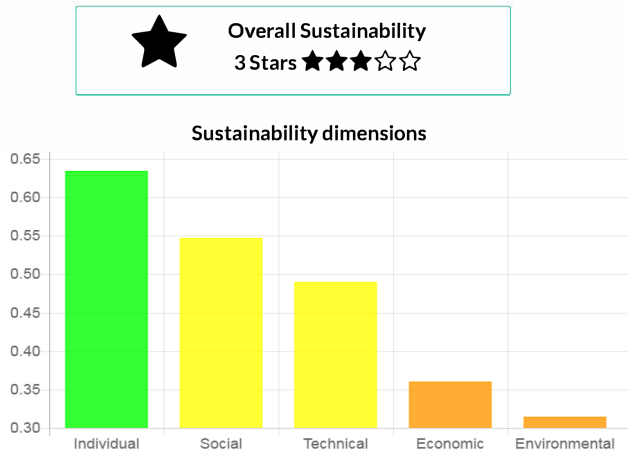


Figure 6.4: The result of sustainability for each requirement in Canvas systems, requrements definded in Table 6.6



Regular vision key chart

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

Figure 6.6: Generated result for D2L sustainability profile

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

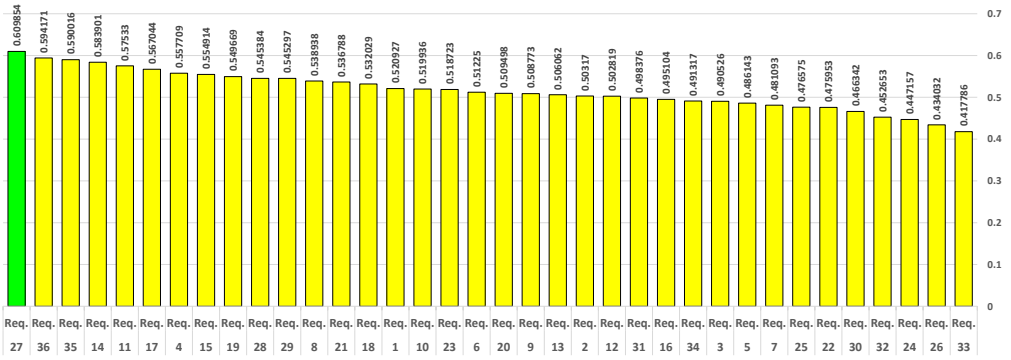


Figure 6.5: The result of sustainability for each requirement in D2L systems, requrements definded in Table 6.7

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

Group	**Sustainability Dimensions**				
	Individual	Social	Technical	Economic	Environmental
Physician	✓	✓		✓	
Nurse	✓	✓			
Receptionist	✓	✓		✓	
Administrator and manager		✓	✓	✓	✓
Developer and IT support	✓		✓	✓	✓

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.

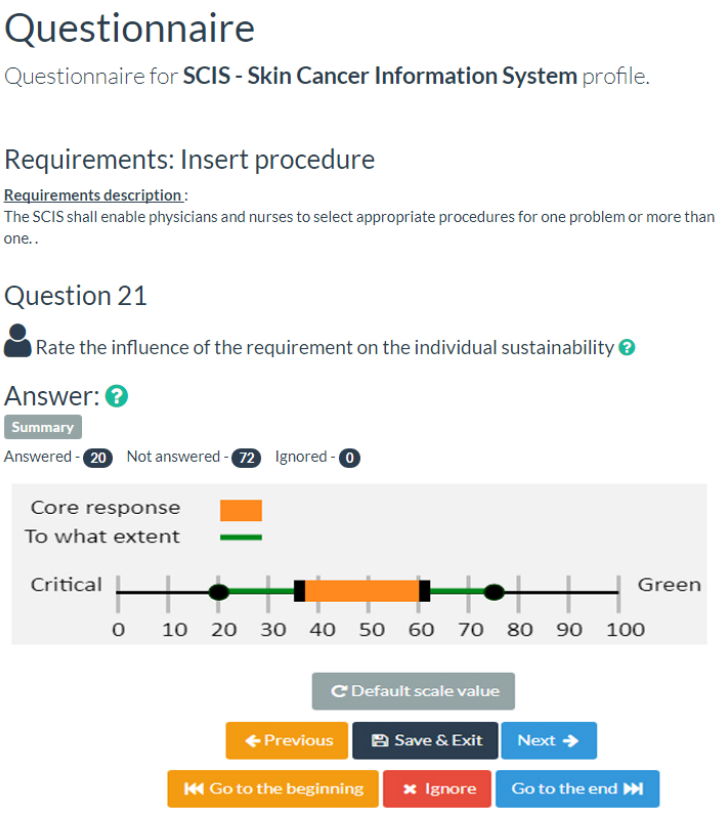


Figure 6.7: SuSoftPro: rating of one requirement's effect on individual sustainability

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

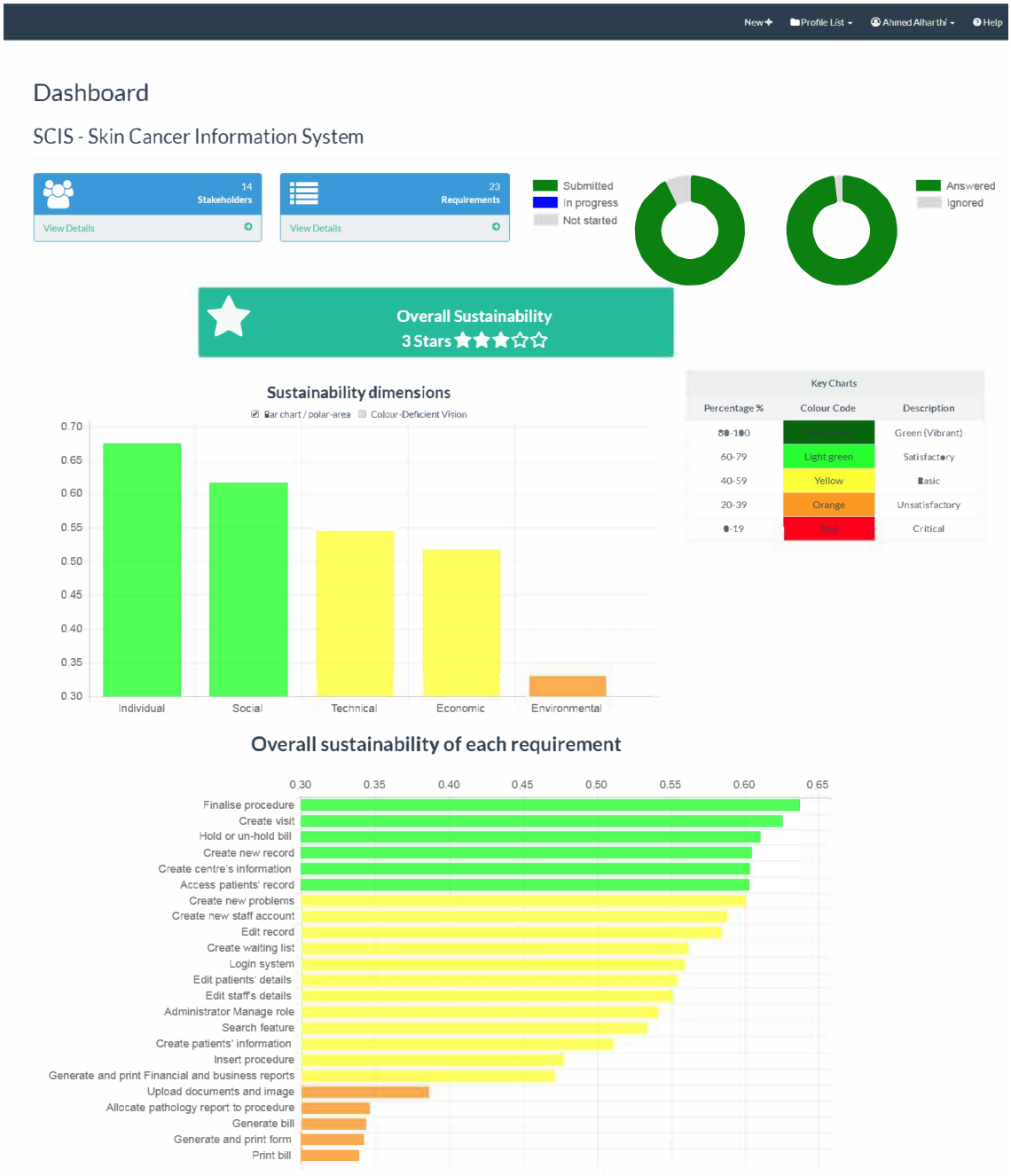


Figure 6.8: SuSoftPro: Dashboard (Skin Cancer Information System Project)

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

#	Requirement name	Sustainability	#	Requirement name	Sustainability
1	Login system	0.558696	13	Hold or un-hold bill	0.609793
2	Create new record	0.604063	14	Print bill	0.338953
3	Create new problems	0.599514	15	Create patients' information	0.510435
4	Create visit	0.624814	16	Edit patients' details	0.553727
5	Edit record	0.583649	17	Create waiting list	0.561173
6	Insert procedure	0.476776	18	Search feature	0.533224
7	Finalise procedure	0.636561	19	Generate and print Financial and business reports	0.470714
8	Access patients' record	0.602394	20	Create new staff account	0.587723
9	Allocate pathology report to procedure	0.345824	21	Edit staff's details	0.550823
10	Upload documents and image	0.385387	22	Administrator Manage role	0.540712
11	Generate and print form	0.34242	23	Create centre's information	0.602745
12	Generate bill	0.343278			

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 : μ=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

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

Table 6.11: ANOVA testing result of the six statements

Source of Variation	SS	*df*	MS	F	**p-value**
Between Groups	763.9169	5	152.7834	0.6038	0.6971
Within Groups	27327.4416	108	253.0319		
Total	28091.3585	113			

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 $\sim$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 $\sim$77% and $\sim$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 $\sim$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

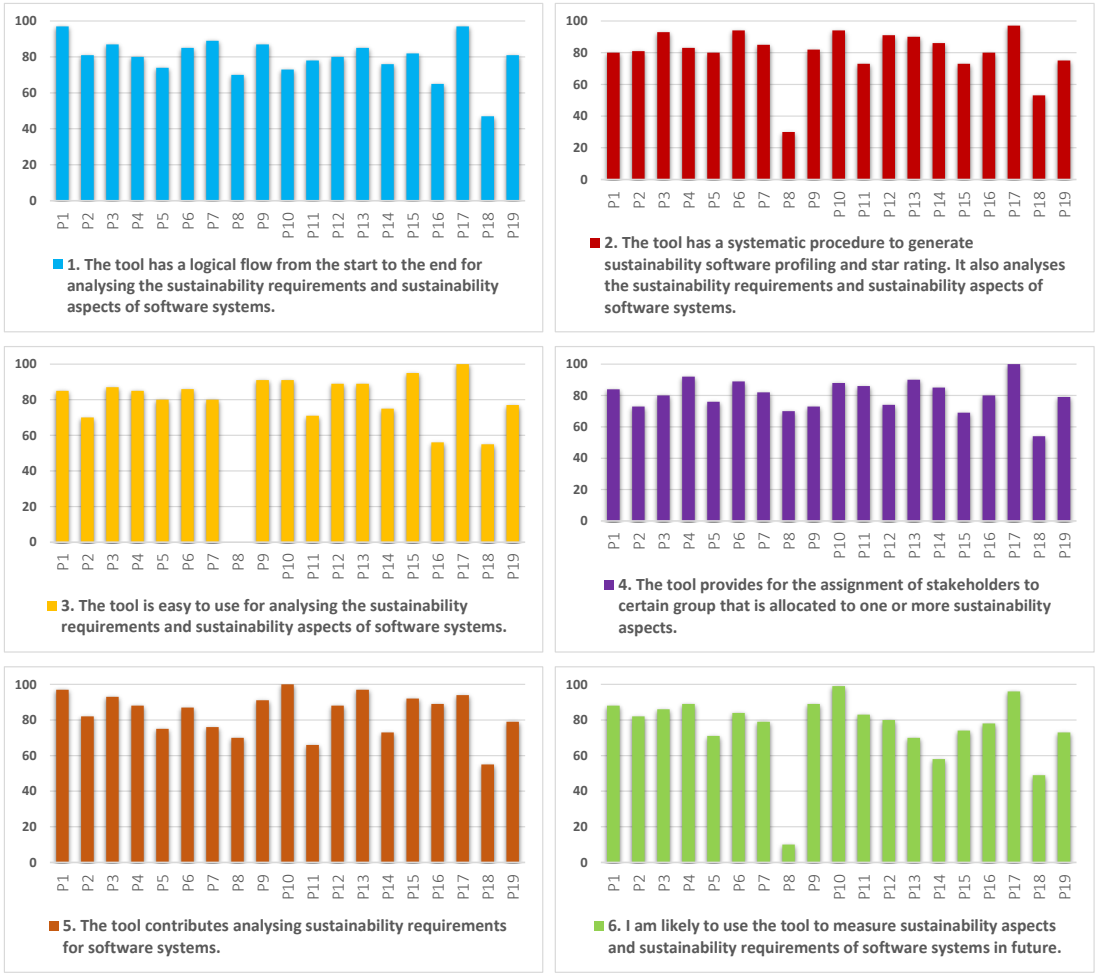


Figure 6.10: Comparing 19 participants (P) responses with regard to the six evaluation statements

Figure 6.11: Comparing the average rate of participant 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.

Chapter 7

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. Alharthi** 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[1] and Sustainable Tourism Certification (Scarlat and Dallemand 2011) are examples of such certification.

[1] http://wearealbert.org/certification

Bibliography

S. Abbasbandy and T. Hajjari. A new approach for ranking of trapezoidal fuzzy numbers. *Computers & Mathematics with Applications*, 57(3):413–419, 2009.

P. Achimugu, A. Selamat, R. Ibrahim, and M. N. Mahrin. A systematic literature review of software requirements prioritization research. *Information and Software Technology*, 56(6):568–585, 2014.

P. Achimugu, A. Selamat, and R. Ibrahim. Reprotizer: A fully implemented software requirements prioritization tool. *Trans. Computational Collective Intelligence*, 22:80–105, 2016.

M. Al Hinai. Quantification of social sustainability in software. In *22nd International Requirements Engineering Conference (RE'14)*, pages 456–460. IEEE, 2014.

M. Al Hinai and R. Chitchyan. Social sustainability indicators for software: Initial review. In *Proceedings of the Third International Workshop on Requirements Engineering for Sustainable Systems, RE4SuSy 2014, co-located with 22nd International Conference on Requirements Engineering (RE'14)*. CEUR-WS.org, 2014.

M. Al Hinai and R. Chitchyan. Engineering requirements for social sustainability. 2016.

A. Alhabeeb, A. Alhabeeb, J. Rowley, and J. Rowley. Critical success factors for elearning in saudi arabian universities. *International Journal of Educational Management*, 31(2):131–147, 2017.

A. D. Alharthi, P. Busch, and S. Smith. A prototypical skin cancer information system. In *the 24th Australasian Conference on Information Systems (ACIS)*, pages 1–11. RMIT University, 2013.

D. B. Allen, R. A. Gould, L. A. Littrell, and J. E. Schillie. K-state's distributed learning commons: Achieving long-term sustainability through strategic partnerships. *College and Undergraduate Libraries*, 17(2):160–176, 2010.

A. Alrashidi. *An exploration of e-learning benefits for Saudi Arabia: Toward policy reform*. PhD thesis, College of Business and Public Management, 2013.

F. Amador and C. P. Oliveira. Integrating sustainability into the university: Past, present, and future. In *Sustainability Assessment Tools in Higher Education Institutions: Mapping Trends and Good Practices Around the World*, pages 65–78. Springer, 2013.

C. H. Antunes and C. O. Henriques. Multi-objective optimization and multi-criteria analysis models and methods for problems in the energy sector. In *Multiple Criteria Decision Analysis*, pages 1067–1165. Springer, 2016.

U. G. Assembly. Transforming our world: the 2030 Agenda for sustainable development. *The Global Initiative Against Transnational Organized Crime*, 2015.

G. Attwell. Personal learning environments-the future of e-learning? *eLearning Papers*, 2(1), 2007. ISSN 1887-1542.

P. Bartalos, M. B. Blake, and S. Remy. Green web services: Models for energy-aware web services and applications. In *2011 IEEE International Conference on Service-Oriented Computing and Applications (SOCA)*, pages 1–8, 12 2011.

C. Becker, S. Betz, R. Chitchyan, L. Duboc, S. M. Easterbrook, B. Penzenstadler, N. Seyff, and C. C. Venters. Requirements: The key to sustainability. *IEEE Software*, 33(1):56–65, 01 2016. ISSN 0740-7459.

M. Behzadian, S. K. Otaghsara, M. Yazdani, and J. Ignatius. A state-of the-art survey of TOPSIS applications. *Expert Systems with Applications*, 39(17):13051–13069, 2012. ISSN 0957-4174.

M. Bell and W. Bell. It's installed... now get on with it! looking beyond the software to the cultural change. *British Journal of Educational Technology*, 36(4):643–656, 2005.

S. Bensch and M. Rager. Cloud-based online learning platforms. In *Business Information Systems Workshops*, volume 127 LNBIP, pages 165–176, 2012.

Z. L. Berge and L. Giles. Implementing and sustaining e-learning in the workplace. *International Journal of Information and Communication Technology Education (IJICTE)*, 2(4):64–75, 2006.

Z. L. Berge and L. Giles. Strategic planning for e-learning in the workplace. In *Adapting Information and Communication Technologies for Effective Education*, pages 257–270. IGI Global, 2008.

F. Berkhout and J. Hertin. Impacts of information and communication technologies on environmental sustainability: Speculations and evidence. *Report to the OECD, Brighton*, 21, 2001.

K. R. Berntsen, M. R. Olsen, N. Limbu, A. T. Tran, and R. Colomo-Palacios. Sustainability in software engineering-a systematic mapping. In *International Conference on Software Process Improvement*, pages 23–32. Springer, 2016.

S. Betz and T. Caporale. Sustainable software system engineering. In *The Fourth International Conference on Big Data and Cloud Computing (BdCloud)*, pages 612–619. IEEE, 12 2014.

N. Bevan and M. Azuma. Quality in use: Incorporating human factors into the software engineering lifecycle. In *Proceedings of IEEE International Symposium on Software Engineering Standards*, pages 169–179. IEEE, 1997.

J. S. Bhat. Technological ambidexterity in the management of national infrastructure programmes. *Journal of Asian Public Policy*, 4(3):350–356, 2011.

Z. Bogdanović, D. Barać, B. Jovanić, S. Popović, and B. Radenković. Evaluation of mobile assessment in a learning management system. *British Journal of Educational Technology*, 45(2):231–244, 2014.

G. Borchers. The software engineering impacts of cultural factors on multi-cultural software development teams. In *Proceedings of the 25th International Conference on Software Engineering*, ICSE '03, pages 540–545. IEEE Computer Society, 2003.

R. M. Bottino. On-line learning networks: Framework and scenarios. *Education and Information Technologies*, 12(2), 2007.

D. Bourn and C. Shiel. Global perspectives: aligning agendas? *Environmental Education Research*, 15(6):661–677, 2009.

M. Bovea and V. Pérez-Belis. A taxonomy of ecodesign tools for integrating environmental requirements into the product design process. *Journal of Cleaner Production*, 20(1):61–71, 2012. ISSN 0959-6526.

R. H. Boyer, N. D. Peterson, P. Arora, and K. Caldwell. Five approaches to social sustainability and an integrated way forward. *Sustainability*, 8(9):878, 2016.

J.-P. Brans and Y. De Smet. Promethee methods. In *Multiple Criteria Decision Analysis*, pages 187–219. Springer, 2016.

P. Brereton, B. A. Kitchenham, D. Budgen, M. Turner, and M. Khalil. Lessons from applying the systematic literature review process within the software engineering domain. *Journal of Systems and Software*, 80(4):571–583, 2007. ISSN 0164-1212.

L. Breslow, D. E. Pritchard, J. DeBoer, G. S. Stump, A. D. Ho, and D. T. Seaton. Studying learning in the worldwide classroom: Research into edx's first mooc. *Research & Practice in Assessment*, 8, 2013.

J. Buchan. Putting ourselves in the big picture: A sustainable approach to project management for e-learning. *International Journal of E-Learning & Distance Education*, 24(1):55–76, 2010.

S. L. Burton, H. R. Harris, D. N. Burrell, K. L. Brown-Jackson, D. Bessette, R. McClintock, S. Lu, and Y. W. White. Educational edifices need a mobile strategy to fully engage in learning activities. *Implications of Social Media Use in Personal and Professional Settings*, pages 284–309, 2014.

C. Calero and M. Piattini. *Green in software engineering*. Springer, 2015. doi: 10.1007/978-3-319-08581-4.

C. Calero and M. Piattini. Puzzling out software sustainability. *Sustainable Computing: Informatics and Systems*, 16: 117–124, 2017.

C. Calero, M. F. Bertoa, and M. Á. Moraga. Sustainability and quality: Icing on the cake. In *Proceedings of the 2nd International Workshop on Requirements Engineering for Sustainable Systems*. CEUR-WS.org, 2013.

M. Cápay, M. Mesárošová, and Z. Balogh. Analysis of students' behaviour in e-learning system. In *EAEEIE Annual Conference (EAEEIE), 2011 Proceedings of the 22nd*, pages 1–6. IEEE, 2011.

O. Casquero, J. Portillo, R. Ovelar, M. Benito, and J. Romo. iPLE Network: an integrated eLearning 2.0 architecture from a university's perspective. *Interactive Learning Environments*, 18(3):293–308, 2010.

J. J. Castro-Schez, M. A. Redondo, J. Gallardo, F. Jurado, et al. Designing and developing software for educative virtual laboratories with language processing techniques: Lessons learned in practical experiments. *Journal of Research and Practice in Information Technology*, 44(3):289–308, 2012.

V. Chang and C. Guetl. E-learning ecosystem (eles)-a holistic approach for the development of more effective learning environment for small-and-medium sized enterprises (SMES). In *Digital EcoSystems and Technologies Conference, 2007. DEST'07. Inaugural IEEE-IES*, pages 420–425. IEEE, 2007.

A. Chaparro and M. Chaparro. Applications of color in design for color-deficient users. *Ergonomics in Design*, 25(1): 23–30, 2017.

C.-h. Chen. The implementation and evaluation of a mobile self-and peer-assessment system. *Computers & Education*, 55(1):229–236, 2010.

C.-M. Chen, H.-M. Lee, and Y.-H. Chen. Personalized e-learning system using item response theory. *Computers & Education*, 44(3):237–255, 2005.

H.-R. Chen and H.-L. Huang. User acceptance of mobile knowledge management learning system: Design and analysis. *Educational Technology & Society*, 13(3):70–77, 2010.

I. Y. Chen. The factors influencing members' continuance intentions in professional virtual communities—a longitudinal study. *Journal of Information science*, 33(4):451–467, 2007.

Y. Chen, K. W. Li, D. M. Kilgour, and K. W. Hipel. A case-based distance model for multiple criteria abc analysis. *Computers & Operations Research*, 35(3):776–796, 2008.

C. M. Cheung and M. K. Lee. Understanding the sustainability of a virtual community: model development and empirical test. *Journal of Information Science*, 35(3):279–298, 2009.

R. Chitchyan, C. Becker, S. Betz, L. Duboc, B. Penzenstadler, N. Seyff, and C. C. Venters. Sustainability design in requirements engineering: state of practice. In *Proceedings of the 38th International Conference on Software Engineering Companion*, pages 533–542. ACM, 2016.

C.-M. Chiu, M.-H. Hsu, S.-Y. Sun, T.-C. Lin, and P.-C. Sun. Usability, quality, value and e-learning continuance decisions. *Computers & Education*, 45(4):399–416, 2005.

C.-M. Chiu, M.-H. Hsu, and E. T. Wang. Understanding knowledge sharing in virtual communities: An integration of social capital and social cognitive theories. *Decision support systems*, 42(3):1872–1888, 2006.

M. Colasante. Future-focused learning via online anchored discussion, connecting learners with digital artefacts, other learners, and teachers. In *Ascilite 2010*, pages 211–221. Ascilite, 2010.

R. Colomo-Palacios, R. Messnarz, K. Siakas, D. Palosi, and D. Coakley. Using social media as a tool for business improvement and certification of knowledge workers. *Journal of Software: Evolution and Process*, 26(9):791–798, 2014. ISSN 2047-7481.

W. W. Cooper, L. M. Seiford, and J. Zhu. Data envelopment analysis. In *Handbook on data envelopment analysis*, pages 1–39. Springer, 2004.

J. W. Creswell. *Educational research: Planning, conducting, and evaluating quantitative*. Prentice Hall Upper Saddle River, NJ, 2002.

J. W. Creswell. *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications, Incorporated, 3rd edition, 2009.

D. Dagger, O. Conlan, and V. Wade. Fundamental requirements of personalised elearning development environments. In G. Richards, editor, *E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2005*, pages 2746–2754. Association for the Advancement of Computing in Education (AACE), 2005.

D. Dagger, A. O'Connor, S. Lawless, E. Walsh, and V. Wade. Service-oriented e-learning platforms: From monolithic systems to flexible services. *Internet Computing, IEEE*, 11(3):28–35, 05 2007. ISSN 1089-7801. doi: 10.1109/MIC.2007.70.

J. M. C. De Gea, J. Nicolás, J. L. F. Alemán, A. Toval, C. Ebert, and A. Vizcaíno. Requirements engineering tools: Capabilities, survey and assessment. *Information and Software Technology*, 54(10):1142–1157, 2012. ISSN 0950-5849.

S. d. l. R. de Sáa, M. Á. Gil, G. González-Rodríguez, M. T. López, and M. A. Lubiano. Fuzzy rating scale-based questionnaires and their statistical analysis. *IEEE Transactions on Fuzzy Systems*, 23(1):111–126, 02 2015. ISSN 1063-6706.

H. Demirkan, M. Goul, and M. Gros. A reference model for sustainable e-learning service systems: Experiences with the joint university/teradata consortium. *Decision Sciences Journal of Innovative Education*, 8(1):151–189, 2010.

J. Demski. Rebuilding the lms for the 21st century. *Campus Technology*, 25(8):34, 2012.

U. Dholakia, J. King, and R. Baraniuk. What makes an open education program sustainable? the case of connexions. In *Open Education Conference*, volume 2340, 2006.

D. Dinevski. Open educational resources and lifelong learning. In *Information Technology Interfaces, 2008. ITI 2008. 30th International Conference on*, pages 117–122. IEEE, 2008.

B. Dong, Q. Zheng, J. Yang, H. Li, and M. Qiao. An e-learning ecosystem based on cloud computing infrastructure. In *IEEE International Conference on Advanced Learning Technologies*, pages 125–127. IEEE, 2009.

S. Downes. Models for sustainable open educational resources. *Interdisciplinary Journal of E-Learning and Learning Objects*, 3(1):29–44, 2007.

V. G. Duffy. Improving sustainability through usability. In A. Marcus, editor, *Design, User Experience, and Usability*, pages 507–519. Springer International Publishing, 2014. ISBN 978-3-319-07635-5.

J. S. Dyer. Multiattribute utility theory (maut). In *Multiple Criteria Decision Analysis*, pages 285–314. Springer, 2016.

L. E. Dyson, A. Litchfield, E. Lawrence, R. Raban, and P. Leijdekkers. Advancing the m-learning research agenda for active, experiential learning: Four case studies. *Australasian Journal of Educational Technology*, 2009.

S. Easterbrook, J. Singer, M.-A. Storey, and D. Damian. Selecting empirical methods for software engineering research. In *Guide to advanced empirical software engineering*, pages 285–311. Springer, 2008.

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.

U. Farooq, P. Schank, A. Harris, J. Fusco, and M. Schlager. Sustaining a community computing infrastructure for online teacher professional development: A case study of designing tapped in. *Computer Supported Cooperative Work*, 16 (4-5):397–429, 2007.

F. Febrero, M. A. Moraga, and C. Calero. Software reliability as user perception: Application of the fuzzy analytic hierarchy process to software reliability analysis. In *2017 IEEE International Conference on Software Quality, Reliability and Security (QRS)*, pages 224–231. IEEE, 2017.

J. R. Figueira, V. Mousseau, and B. Roy. Electre methods. In *Multiple Criteria Decision Analysis*, pages 155–185. Springer, 2016.

J. Fisler and S. Bleisch. elml, the elesson markup language: Developing ustainable e-learning content using an open source xml framework. In *In WEBIST 2006-International Conference on Web Information Systems and Technologies, April 11th-13th 2006 (Setubal*. Citeseer, 2006.

J. Fisler and F. Schneider. Creating, handling and implementing e-learning courses using the open source tools olat and elml at the university of zurich. In *Proceedings of the World Congress on Engineering and Computer Science*, volume 1, 2009.

K. G. Franceschi, R. M. Lee, and D. Hinds. Engaging e-learning in virtual worlds: Supporting group collaboration. In *Hawaii International Conference on System Sciences, Proceedings of the 41st Annual*, pages 7–7. IEEE, 2008.

S. I. Freitas, J. Morgan, and D. Gibson. Will moocs transform learning and teaching in higher education? engagement and course retention in online learning provision. *British Journal of Educational Technology*, 46(3):455–471, 2015.

B. Friedman, P. H. Kahn, and A. Borning. Value sensitive design and information systems. *The handbook of information and computer ethics*, pages 69–101, 2008.

N. Friesen. Open educational resources: New possibilities for change and sustainability. *The International Review of Research in Open and Distributed Learning*, 10(5), 2009.

G. A. García-Mireles, M. Á. Moraga, F. García, C. Calero, and M. Piattini. Interactions between environmental sustainability goals and software product quality: A mapping study. *Information and Software Technology*, 95: 108–129, 2018.

K. Garg and V. Varma. Systemic requirements of a software engineering learning environment. In *Proceedings of the 8th India Software Engineering Conference*, ISEC '15, pages 147–155. ACM, 2015.

D. R. Garrison and Z. Akyol. Role of instructional technology in the transformation of higher education. *Journal of Computing in Higher Education*, 21(1):19, 2009.

E. Georgiadou and K. V. Siakas. Distance learning: Technologies; enabling learning at own place, own pace, own time. In *Learning and Teaching Issues in Software Quality, Proceedings of the 11th INternational Conference on Software Process Improvement-Research into Education and Training,(INSPIRE 2006), April, Southampton, UK*, pages 29–40, 2006.

B. Ghirardini. *E-learning methodologies A guide for designing and developing e-learning courses*. Food and Agriculture Organization of the United Nations, 2011.

M. L. Gibson, C. Venters, L. Duboc, S. Betz, R. Chitchyan, V. P. Silva, B. Penzenstadler, and N. Seyff. Mind the chasm: A uk fisheye lens view of sustainable software engineering. In *the 6th International Workshop on Requirements Engineering for Sustainable Systems (RE4SuSy@RE'17)*, pages 15–24, July 2017.

D. Gmach, Y. Chen, A. Shah, J. Rolia, C. Bash, T. Christian, and R. Sharma. Profiling sustainability of data centers. In *Proceedings of the 2010 IEEE International Symposium on Sustainable Systems and Technology*, pages 1–6, May 2010.

K. Goldsworthy and L. Rankine. Identifying the characteristics of e-learning environments used to support large units. In *Proceedings Australasian Society for Computers in Learning in Tertiary Education*, pages 338–345. ASCILITE, 2009.

R. Goodland. Sustainability: human, social, economic and environmental. *Encyclopedia of Global Environmental Change. John Wiley & Sons*, 5:481–491, 2002.

C. Gunn. Sustainability factors for e-learning initiatives. *ALT-J*, 18(2):89–103, 2010.

C. Gunn. Sustaining elearning innovations. *Changing demands, changing directions. Proc. ascilite Hobart 2011*, pages 509–519, 2011.

C. Gunn, S. Woodgate, and W. O'Grady. Repurposing learning objects: a sustainable alternative? *ALT-J*, 13(3):189–200, 2005.

I. Gustavsson, K. Nilsson, J. Zackrisson, J. Garcia-Zubia, U. Hernandez-Jayo, A. Nafalski, Z. Nedic, O. Gol, J. Machotka, M. Pettersson, T. Lago, and L. Hkansson. On objectives of instructional laboratories, individual assessment, and use of collaborative remote laboratories. *IEEE Transactions on Learning Technologies*, 2(4):263–274, 10 2009. ISSN 1939-1382.

S. Halimi. Lifelong learning for equity and social cohesion: A new challenge for higher education. *Lifelong Learning & Distance Higher Education. Commonwealth of Learning/UNESCO*, 2005:11–22, 2005.

N. Harrati, I. Bouchrika, A. Tari, and A. Ladjailia. Exploring user satisfaction for e-learning systems via usage-based metrics and system usability scale analysis. *Computers in Human Behavior*, 61:463–471, 2016.

L. M. Hilty, P. Arnfalk, L. Erdmann, J. Goodman, M. Lehmann, and P. A. Wäger. The relevance of information and communication technologies for environmental sustainability. a prospective simulation study. *Environmental Modelling & Software*, 21(11):1618–1629, 2006. ISSN 1364-8152.

N. Hine, F. Petersen, M. Pluke, and T. Sund. Standardization work on personalized ehealth systems. In *Proccedings of the 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pages 1518–1520. IEEE, 2008.

M. J. Hjermstad, P. M. Fayers, D. F. Haugen, A. Caraceni, G. W. Hanks, J. H. Loge, R. Fainsinger, N. Aass, and S. Kaasa. Studies comparing numerical rating scales, verbal rating scales, and visual analogue scales for assessment of pain intensity in adults: a systematic literature review. *Journal of pain and symptom management*, 41(6):1073–1093, 2011.

J. J. Hoffman, M. L. Hoelscher, and K. Sherif. Social capital, knowledge management, and sustained superior performance. *Journal of knowledge management*, 9(3):93–100, 2005.

G. Hofstede, G. J. Hofstede, and M. Minkov. *Cultures and Organizations - Software of the Mind*. McGraw-Hill Education Ltd, 07 2010. ISBN 0071664181.

J. Horkoff and E. Yu. Analyzing goal models: Different approaches and how to choose among them. In *Proceedings of the 2011 ACM Symposium on Applied Computing*, SAC '11, pages 675–682. ACM, 2011. ISBN 978-1-4503-0113-8.

E. Hull, K. Jackson, and J. Dick. *Requirements engineering*. Springer Science & Business Media, 2010.

J. Hylén. Open educational resources: Opportunities and challenges. In *Proceedings of Open Education*, Sept. 2006.

M. Iatagan. Strategies for ongoing professional training of human resources in a globalized economy. *Human Capital and Resources: Developments, Management and Strategies*, 2012.

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

E. Jagroep, J. Broekman, J. M. E. M. van der Werf, S. Brinkkemper, P. Lago, L. Blom, and R. van Vliet. Awakening awareness on energy consumption in software engineering. In *Proceedings of the 39th International Conference on Software Engineering: Software Engineering in Society Track*, ICSE-SEIS '17, pages 76–85. IEEE Press, 2017. ISBN 978-1-5386-2673-3.

E. A. Jagroep, J. M. van der Werf, S. Brinkkemper, G. Procaccianti, P. Lago, L. Blom, and R. van Vliet. Software energy profiling: Comparing releases of a software product. In *Proceedings of the 38th International Conference on Software Engineering Companion*, ICSE '16, pages 523–532. ACM, 2016. ISBN 978-1-4503-4205-6.

P. James. *Urban sustainability in theory and practice: circles of sustainability*. Routledge, 2014. ISBN 978-1-315-76574-7.

Jazz-Platform. IBM Rational DOORS ® Next Generation, 2017. URL https://jazz.net/help-dev/clm/topic/com.ibm.rational.rrm.help.doc/topics/r_csv_format.html.

H. Jiang, C. Ganoe, and J. M. Carroll. Four requirements for digital case study libraries. *Education and Information Technologies*, 15(3), 2010.

G. Jin and R. Law. Lifelong learning to advance the engineer's career. *Annual Conference - Canadian Society for Civil Engineering*, 1:50–59, 2009.

D. Jones and M. Tamiz. A review of goal programming. In *Multiple Criteria Decision Analysis*, pages 903–926. Springer, 2016.

S. Jones, C. Johnson-Yale, S. Millermaier, and F. S. Pérez. Us college students' internet use: Race, gender and digital divides. *Journal of Computer-Mediated Communication*, 14(2):244–264, 2009.

A. Kanwar, B. Kodhandaraman, and A. Umar. Toward sustainable open education resources: A perspective from the global south. *American Journal of Distance Education*, 24(2):65–80, 2010.

Y. Kazancoglu and M. Aksoy. A fuzzy logic-based qfd to identify key factors of e-learning design. *Procedia - Social and Behavioral Sciences*, 28:322–327, 2011.

S. Keele. Guidelines for performing systematic literature reviews in software engineering. Technical report, Department of Computer Science, University of Durham, 2007.

J. Keengwe and S. Malapile. Factors influencing technology planning in developing countries: A literature review. *Education and Information Technologies*, 19(4), 2014.

M. Kendall. Lifelong learning really matters for elementary education in the 21st century. *Education and Information Technologies*, 10(3), 2005.

P. Kim, T. Miranda, and C. Olaciregui. Pocket school: Exploring mobile technology as a sustainable literacy education option for underserved indigenous children in latin america. *International Journal of Educational Development*, 28 (4):435–445, 2008.

B. Kitchenham and S. L. Pfleeger. Software quality: the elusive target [special issues section]. *IEEE Software*, 13(1): 12–21, Jan 1996. doi: 10.1109/52.476281.

B. Kitchenham, T. Dyba, and M. Jorgensen. Evidence-based software engineering. In *26th International Conference on Software Engineering*, pages 273–281. ACM, 2004.

H.-M. Ko. Soft power: A critical factor for the effectiveness and development of a school. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 7513 LNCS:414–420, 2012.

S. A. Koçak, G. G. Calienes, G. I. Alptekin, and A. B. Bener. Requirements prioritization framework for developing green and sustainable software using anp-based decision making. In *the 27th International Conference on Environmental Informatics for Environmental Protection, Sustainable Development and Risk Management, (EnviroInfo)*, pages 327–335, 2013.

S. A. Koçak, G. I. Alptekin, and A. B. Bener. Integrating environmental sustainability in software product quality. In *Proceedings of the Fourth International Workshop on Requirements Engineering for Sustainable Systems, RE4SuSy 2015, co-located with the 23rd IEEE International Requirements Engineering Conference (RE 2015)*, pages 17–24. CEUR-WS.org, 2015.

P. Konidari and D. Mavrakis. A multi-criteria evaluation method for climate change mitigation policy instruments. *Energy Policy*, 35(12):6235–6257, 2007.

M. M. Konting. Leadership development for sustainability of e-learning. *Procedia - Social and Behavioral Sciences*, 67: 312–321, 12 2012. ISSN 1877-0428.

A. Koohang and K. Harman. Advancing sustainability of open educational resources. *Issues in Informing Science and Information Technology*, 4:535–544, 2007.

A. Koohang and J. Paliszkiewicz. E-learning courseware usability: building a theoretical model. *Journal of Computer Information Systems*, 56(1):55–61, 2016.

A. P. Koshkin, I. M. Rassolov, and A. V. Novikov. Monitoring social media: Students satisfaction with university administration activities. *Education and Information Technologies*, 2016.

P. Kruchten. Lifelong learning for lifelong employment. *IEEE Software*, 32(4):85–87, 2015.

S. Kumar and R. Buyya. Green cloud computing and environmental sustainability. *Harnessing Green It: Principles and Practices*, pages 315–339, 2012.

P. Lago and T. Jansen. Creating environmental awareness in service oriented software engineering. In *International conference on service-oriented computing*, pages 181–186. Springer, 2010.

P. Lago and T. Jansen. Creating environmental awareness in service oriented software engineering. In *Service-Oriented Computing*, pages 181–186. Springer, 2011.

P. Lago, S. A. Koçak, I. Crnkovic, and B. Penzenstadler. Framing sustainability as a property of software quality. *Communications of the ACM*, 58(10):70–78, 2015.

G. Lami, F. Fabbrini, and M. Fusani. Software sustainability from a process-centric perspective. In D. Winkler, R. V. O'Connor, and R. Messnarz, editors, *Systems, Software and Services Process Improvement*, volume 301 of *Communications in Computer and Information Science*, chapter Systems, Software and Services Process Improvement, pages 97–108. Springer, 2012. ISBN 978-3-642-31198-7.

D. Laurillard. Modelling benefits-oriented costs for technology enhanced learning. *Higher Education*, 54(1):21–39, 2007.

M. J. Lee and A. Chan. Pervasive, lifestyle-integrated mobile learning for distance learners: an analysis and unexpected results from a podcasting study. *Open Learning*, 22(3):201–218, 2007.

A. Littlejohn. Supporting sustainable e-learning. *Association for Learning Technology Journal*, 11(3):88–102, 2003.

A. Littlejohn and S. B. Shum. Reusing online resources: A sustainable approach to elearning. *Journal of Interactive Media in Education*, 2003(1), 2003.

C.-C. Liu, C.-W. Chung, and S.-Y. Tao. Making classrooms socio-technical environments for supporting collaborative learning: the role of personal devices and boundary objects. In *Proceedings of the 9th International Conference on Computer Supported Collaborative Learning*, CSCL'09, pages 320–324. International Society of the Learning Sciences, 2009.

T. Lizhong, Z. Aichen, and S. Yongjie. The function of the university libraries in constructing lifelong education system. *Advances in Intelligent and Soft Computing*, 109:341–346, 2011.

M. A. Lubiano, S. de la Rosa de Sáa, M. Montenegro, B. Sinova, and M. A. Gil. Descriptive analysis of responses to items in questionnaires. why not using a fuzzy rating scale? *Inf. Sci.*, 360:131–148, 2016.

M. A. Lubiano, A. Salas, C. Carleos, S. d. l. R. de Sáa, and M. Á. Gil. Hypothesis testing-based comparative analysis between rating scales for intrinsically imprecise data. *International Journal of Approximate Reasoning*, 88:128–147, 2017.

M. Mahaux. Could participation support sustainability in requirements engineering? In *the 2nd International Workshop on Requirements Engineering for Sustainable Systems (RE4SuSy)*. CEUR-WS.org, 2013.

T. Mahmood and K. Hafeez. Performance assessment of an e-learning software system for sustainability. *International Journal of Quality and Service Sciences*, 5(2):208–229, 2013.

S. S. Mahmoud and I. Ahmad. A green model for sustainable software engineering. *International Journal of Software Engineering and Its Applications*, 7(4):1738–9984, 2013.

D. Mairiza, D. Zowghi, and V. Gervasi. Utilizing TOPSIS: A Multi Criteria Decision Analysis Technique for Non-Functional Requirements Conflicts. In D. Zowghi and Z. Jin, editors, *Requirements Engineering*, volume 432 of *Communications in Computer and Information Science*, pages 31–44. Springer, 2014.

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.

M. Manuja et al. Industry academia collaboration model: The design challenges. In *Software Engineering Education and Training (CSEE&T), 2011 24th IEEE-CS Conference on*, pages 111–120. IEEE, 2011.

Maria Spichkova, James Harland, and **Ahmed D. Alharthi**. Online support system for transnational education. In *International Conference on Engineering Education and Research (ICEER 2016)*. Western Sydney University, 2016.

M. Mason. What is complexity theory and what are its implications for educational change? *Educational Philosophy and Theory*, 40(1):35–49, 2008.

J. R. S. C. Mateo. *TOPSIS*, pages 43–48. Springer London, 2012.

M. Memmel. Interoperability requirements for a sustainable component to support management and sharing of digital resources. In *1st Workshop on Exploring Fitness and Evolvability of Personal Learning Environments*, pages 25–29. CEUR-WS.org, March 2011.

M. P. Menchaca and T. A. Bekele. Learner and instructor identified success factors in distance education. *Distance education*, 29(3):231–252, 2008.

G. Meneses. Design of an electronic instrumentation virtual laboratory based on free-open resources. In *Computing Congress (CCC), 2011 6th Colombian*, pages 1–6. IEEE, 05 2011.

I. Miliszewska and E. Sztendur. Critical success attributes of transnational it education programmes: The client perspective. *Journal of Information Technology Education:Research*, 10(1):123–137, 2011.

D. Mocigemba. Sustainable computing. *Poiesis & Praxis*, 4(3):163–184, 09 2006. ISSN 1615-6609.

L. Mohan, P. Raman, V. Choppella, and Y. R. Reddy. A crowdsourcing approach for quality enhancement of elearning systems. In *Proceedings of the 10th Innovations in Software Engineering Conference*, ISEC '17, pages 188–194. ACM, 2017.

L. F. Motiwalla. Mobile learning: A framework and evaluation. *Computers & education*, 49(3):581–596, 2007.

B. C. Mourão, L. Karita, and I. do Carmo Machado. Green and sustainable software engineering-a systematic mapping study. In *Proceedings of the 17th Brazilian Symposium on Software Quality*, pages 121–130. ACM, 2018.

G. Mridha, M.and Nihlen, B. Erlandsson, A. Khan, M. Islam, N. Sultana, S. Reza, and M. Srinivas. E-learning for empowering the rural people in Bangladesh opportunities and challenges. In *2nd International Conference on E-Learning and E-Technologies in Education (ICEEE)*, pages 323–328. IEEE, Sept. 2013.

P. Mtika and P. Gates. Developing learner-centred education among secondary trainee teachers in malawi: The dilemma of appropriation and application. *International Journal of Educational Development*, 30(4):396–404, 07 2010. doi: 10.1016/j.ijedudev.2009.12.004.

J. Müller, J. M. S. Gil, F. Hernández, X. Giró, and A. Bosco. The socio-economic dimensions of ict-driven educational change. *Computers and Education*, 49(4):1175–1188, 2007.

M. Müller and B. Siebenhüner. Policy instruments for sustainability-oriented organizational learning. *Business Strategy and the Environment*, 16(3):232–245, 2007.

G. Munda. Multiple criteria decision analysis and sustainable development. In *Multiple Criteria Decision Analysis*, pages 1235–1267. Springer, 2016.

S. Naumann, M. Dick, E. Kern, and T. Johann. The GREENSOFT model: A reference model for green and sustainable software and its engineering. *Sustainable Computing: Informatics and Systems*, 1(4):294–304, 2011.

R. Neila and L. B. A. Rabai. Deploying suitable countermeasures to solve the security problems within an e-learning environment. In *Proceedings of the 7th International Conference on Security of Information and Networks*, SIN '14, pages 33–38. ACM, 2014.

M. Nichols. Institutional perspectives: The challenges of e-learning diffusion. *British journal of educational technology*, 39(4):598–609, 2008.

E. P. Nunes, A. R. Luz, E. M. Lemos, C. Maciel, A. M. dos Anjos, L. C. Borges, and C. Nunes. Mobile serious game proposal for environmental awareness of children. In *the Frontiers in Education Conference (FIE)*, pages 1–8. IEEE, Oct 2016.

B. Nuseibeh and S. Easterbrook. Requirements engineering: A roadmap. In *Proceedings of the Conference on The Future of Software Engineering*, ICSE'00, pages 35–46. ACM, 2000. ISBN 1-58113-253-0.

A. Nwokediuko. Advancing e-learning in african native communities: The language factor. In *International Conference on Education and e-Learning Innovations (ICEELI)*, pages 1–4. IEEE, 07 2012.

A. D. Olofsson and J. O. Lindberg. "whatever happened to the social dimension?" aspects of learning in a distance-based teacher training programme. *Education and Information Technologies*, 11(1):7–20, 01 2006. ISSN 1360-2357.

A. F. O'Neil. The current status of instructional design theories in relation to today's authoring systems. *British Journal of Educational Technology*, 39(2):251–267, 2008.

K. Orfanou, N. Tselios, and C. Katsanos. Perceived usability evaluation of learning management systems: Empirical evaluation of the system usability scale. *The International Review of Research in Open and Distributed Learning*, 16 (2), 2015.

E. Ossiannilsson and L. Landgren. Quality in e-learning–a conceptual framework based on experiences from three international benchmarking projects. *Journal of Computer assisted learning*, 28(1):42–51, 2012.

S. Pan and M. Jordan-Marsh. Internet use intention and adoption among chinese older adults: From the expanded technology acceptance model perspective. *Computers in human behavior*, 26(5):1111–1119, 2010.

A. Pardo, J. A. Fisteus, C. D. Kloos, et al. A distributed collaborative system for flexible learning content production and management. *Journal of Research and Practice in Information Technology*, 44(2):203–221, 2012.

C. B. Park, H. Choi, and P. Kim. Adaptive open mobile learning device for the underserved. In *ICCE'09 International Conference on Consumer Electronics, Digest of Technical Papers*. IEEE, Jan 2009.

N. Pellas. The influence of computer self-efficacy, metacognitive self-regulation and self-esteem on student engagement in online learning programs: Evidence from the virtual world of second life. *Computers in Human Behavior*, 35: 157–170, jun 2014. doi: 10.1016/j.chb.2014.02.048.

N. Pellas. Bolstering the quality and integrity of online collaborative university- level courses via an open sim standalone server in conjunction with sloodle. *Education and Information Technologies*, 21(5):1007–1032, 2016.

B. Penzenstadler. Infusing green: Requirements engineering for green in and through software systems. In *Proceedings of the Third International Workshop on Requirements Engineering for Sustainable Systems, (RE4SuSy)*. CEUR-WS.org, 2014.

B. Penzenstadler. From requirements engineering to green requirements engineering. In C. Calero and M. Piattini, editors, *Green in Software Engineering*, pages 157–186. Springer, 2015. ISBN 978-3-319-08581-4.

B. Penzenstadler and H. Femmer. A generic model for sustainability with process- and product-specific instances. In *Proc. of the Workshop on Green in/by Software Engineering*, GIBSE '13, pages 3–8. ACM, 2013.

B. Penzenstadler, V. Bauer, C. Calero, and X. Franch. Sustainability in software engineering: A systematic literature review. In *16th International Conference on Evaluation Assessment in Software Engineering*, pages 32–41. IET, 2012.

B. Penzenstadler, H. Femmer, and D. Richardson. Who is the advocate? stakeholders for sustainability. In *2nd International Workshop on Green and Sustainable Software (GREENS)*, pages 70–77. IEEE, 05 2013.

B. Penzenstadler, A. Raturi, D. Richardson, C. Calero, H. Femmer, and X. Franch. Systematic mapping study on software engineering for sustainability (se4S). In *Proc. of the 18th International Conference on Evaluation and Assessment in Software Engineering*, EASE '14, pages 14:1–14:14. ACM, 2014a. ISBN 978-1-4503-2476-2.

B. Penzenstadler, A. Raturi, D. Richardson, and B. Tomlinson. Safety, security, now sustainability: The nonfunctional requirement for the 21st century. *IEEE Software*, 31(3):40–47, 2014b.

D. E. Perry, A. A. Porter, and L. G. Votta. Empirical studies of software engineering: a roadmap. In *Proceedings of the conference on The future of Software engineering*, pages 345–355. ACM, 2000.

O. Pettersson and B. Vogel. Reusability and interoperability in mobile learning: A study of current practices. In *The Seventh International Conference on Wireless, Mobile and Ubiquitous Technology in Education*, pages 306–310. IEEE, March 2012.

K. A. Pituch and Y.-k. Lee. The influence of system characteristics on e-learning use. *Computers & Education*, 47(2): 222–244, 2006.

J. Porras, M. Palacin-Silva, O. Drögehorn, and B. Penzenstadler. Developing a model for evaluation of sustainability perspectives and effects in ict projects. In *International conference on Sustainable, Ecological Engineering Design for Society (SEEDS)*, September 2017.

J. M. Pullen and C. Snow. Integrating synchronous and asynchronous internet distributed education for maximum effectiveness. *Education and Information Technologies*, 12(3), 2007.

H. Rahanu, E. Georgiadou, K. Siakas, D. Ekert, R. Messanarz, and G. Abeysinghe. Towards relating delivery methods and examination success: lessons learned from the valo llp project case study. *Journal of Software: Evolution and Process*, 27(8):555–564, 2015. ISSN 2047-7481.

L. Rajasingham. Will mobile learning bring a paradigm shift in higher education? *Education Research International*, 2011, 2011.

M. Randelin, T. Saaranen, P. Naumanen, and V. Louhevaara. Towards sustainable well-being in smes through the web-based learning program of ergonomics. *Education and Information Technologies*, 18(1), 2013. doi: 10.1007/s10639-011-9177-5.

M. Razavian, G. Procaccianti, D. A. Tamburri, et al. Four-dimensional sustainable e-services. In *Proceedings of the 28th EnviroInfo*. Shaker-Verlag AG, 2014.

J. A. Rice. *Mathematical statistics and data analysis*. Cengage Learning, 2006.

R. C. Richey. Reflections on the 2008 Aect definitions of the field. *TechTrends*, 52(1):24–25, 2008.

M. M. Richter and R. O. Weber. Basic cbr elements. In *Case-Based Reasoning*, pages 17–40. Springer, 2013.

I. Robertson. Sustainable e-learning, activity theory and professional development. In *Ascilite*, pages 819–826. ASCILITE (Melbourne, Australia), 2008.

K. Roher and D. Richardson. Sustainability requirement patterns. In *the Third International Workshop on Requirements Patterns (RePa)*, pages 8–11. IEEE, 07 2013.

A. P. Rovai. Facilitating online discussions effectively. *The Internet and Higher Education*, 10(1):77–88, 2007.

A. P. Rovai and J. R. Downey. Why some distance education programs fail while others succeed in a global environment. *The Internet and Higher Education*, 13(3):141–147, 2010.

A. Roy. elearning: Tool to ensure growth and sustainability of SMEs. *Proceedings of the 11th European Confernece on e-Learning: ECEL*, page 480, 2012.

R. Roy, S. Potter, and K. Yarrow. Designing low carbon higher education systems: Environmental impacts of campus and distance learning systems. *International journal of sustainability in higher education*, 9(2):116–130, 2008.

P. Runeson and M. Höst. Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering*, 14(2):131–164, 2009.

M. Ruyters, M. Colasante, K. Douglas, and G. Mandarano. Sustainability of a university designed and developed media annotation tool to prepare learners with skills needed for future employment. *ASCILITE - Annual conference of the Australian Society for Computers in Tertiary Education*, 2012.

T. L. Saaty. The analytic hierarchy and analytic network processes for the measurement of intangible criteria and for decision-making. In *Multiple Criteria Decision Analysis*, pages 363–419. Springer, 2016.

G. Salmon. Flying not flapping: a strategic framework for e-learning and pedagogical innovation in higher education institutions. *ALT-J*, 13(3):201–218, 2005.

A. Sangrà, D. Vlachopoulos, and N. Cabrera. Building an inclusive definition of e-learning: An approach to the conceptual framework. *The International Review of Research in Open and Distributed Learning*, 13(2):145–159, 2012.

P. Sawyer, I. Sommerville, and S. Viller. Requirements process improvement through the phased introduction of good practice. *Software Process: Improvement and Practice*, 3(1):19–34, 1997. ISSN 1099-1670.

N. Scarlat and J.-F. Dallemand. Recent developments of biofuels/bioenergy sustainability certification: A global overview. *Energy Policy*, 39(3):1630–1646, 2011.

I. Schoenwald. Sustainable implementation of e-learning as a change process at universities. *Online Educa*, 1:1–6, 2003.

G. Scoppio and I. Luyt. Mind the gap: Enabling online faculty and instructional designers in mapping new models for quality online courses. *Education and Information Technologies*, 2017.

C. B. Seaman. Qualitative methods in empirical studies of software engineering. *IEEE Trans. Software Eng.*, 25(4): 557–572, 1999.

G. Secundo, G. Passiante, and A. Romano. Industry-university learning network to create competences for intelligent and sustainable manufacturing: A case study. In *International Conference on Information Technology Based Higher Education and Training (ITHET)*, pages 1–8. IEEE, June 2012.

G. Secundo, G. Passiante, A. Romano, and P. Moliterni. Developing the next generation of engineers for intelligent and sustainable manufacturing: A case study. *International Journal of Engineering Education*, 29(1):248–262, 2013.

H. M. Selim. Critical success factors for e-learning acceptance: Confirmatory factor models. *Computers & Education*, 49(2):396–413, 2007.

R. Sharpe, G. Benfield, and R. Francis. Implementing a university e-learning strategy: levers for change within academic schools. *Research in Learning Technology*, 14(2):135–151, 2006.

I. M. Shehabat and S. A. Mahdi. E-learning and its impact to the educational system in the arab world. In *International Conference on Information Management and Engineering*, pages 220–225. IEEE, April 2009.

L. Shen and J. LeClair. Use of sustainable and systematic plan to assess student learning outcomes for non-traditional it students. In *ASEE Annual Conference and Exposition*. American Society for Engineering Education, 2013.

I. Sommerville. *Software Engineering*. Addison-Wesley Publishing Company, 9th edition, 2010.

J. L. Sousa. Information systems architecture modeling based on loosely coupled structures: An e-learning use case. In *9th International Conference on Emerging eLearning Technologies and Applications (ICETA)*, pages 195–198. IEEE, 10 2011. doi: 10.1109/ICETA.2011.6112614.

S. K. Sowe, K. Zettsu, and Y. Murakami. A model for creating and sustaining information services platform communities: Lessons learnt from open source software. In *Proceedings of ITU Kaleidoscope: Building Sustainable Communities (K-2013)*, pages 1–8. IEEE, 04 2013.

B. Sridharan, H. Deng, and B. Corbitt. Critical success factors in elearning ecosystems: a qualitative study. *Journal of Systems and Information Technology*, 12(4):263–288, 2010.

P. Stechert. Informatics system comprehension: A learner-centred cognitive approach to networked thinking. *Education and Information Technologies*, 11(3-Apr), 2006.

M. Stefanovic. The objectives, architectures and effects of distance learning laboratories for industrial engineering education. *Computers & Education*, 69:250–262, 2013.

K. Stepanyan, A. Littlejohn, and A. Margaryan. Sustainable e-learning: toward a coherent body of knowledge. *Journal of Educational Technology & Society*, 16(2):91–102, 2013.

B. Stewart and A. Khare. Athabasca university reduces ict carbon footprint. *GSTF Journal on Computing*, 1(4), 2012.

B. Stewart and A. Khare. elearning and the sustainable campus. In *Transformative Approaches to Sustainable Development at Universities*, pages 291–305. Springer, 2015.

M. Stiles and J. Yorke. Technology supported learning tensions between innovation, and control and organisational and professional cultures. *Journal of Organisational Transformation & Social Change*, 3(3):251–267, 2007.

J. Suhonen and E. Sutinen. The four pillar model-analysing the sustainability of online doctoral programmes. *TechTrends*, 58(4):81–88, 2014.

P.-C. Sun, R. J. Tsai, G. Finger, Y.-Y. Chen, and D. Yeh. What drives a successful e-learning? an empirical investigation of the critical factors influencing learner satisfaction. *Computers & education*, 50(4):1183–1202, 2008.

Ahmed D. Alharthi and Maria Spichkova. Individual and social requirement aspects of sustainable elearning systems. In *International Conference on Engineering Education and Research (ICEER 2016)*. Western Sydney University, 2016.

Ahmed D. Alharthi and Maria Spichkova. Green architecture for sustainable elearning systems. In *Proceedings of the 11th European Conference on Software Architecture: Companion Proceedings*, ECSA'17, pages 199–204. ACM, 2017. ISBN 978-1-4503-5217-8. doi: 10.1145/3129790.3129817.

Ahmed D. Alharthi, Maria Spichkova, and Margaret Hamilton. Requirements engineering aspects of elearning systems. In *Proceedings of the ASWEC 2015 24th Australasian Software Engineering Conference*, ASWEC ' 15 Vol. II, pages 132–133. ACM, 2015. ISBN 978-1-4503-3796-0. doi: 10.1145/2811681.2817756.

Ahmed D. Alharthi, Maria Spichkova, and Margaret Hamilton. Sustainability profiling of long-living software systems. In *Proceedings of 4th International Workshop on Quantitative Approaches to Software Quality*, volume 1771, pages 12–19. CEUR–WS, 2016.

Ahmed D. Alharthi, Maria Spichkova, and Margaret Hamilton. Sustainability requirements for elearning systems: A systematic literature review and analysis. *Requirements Engineering*, 2018a. doi: 10.1007/s00766-018-0299-9.

Ahmed D. Alharthi, Maria Spichkova, and Margaret Hamilton. Towards tool-support for sustainability profiling. In *Proceedings of the 7th International Workshop on Requirements Engineering for Sustainable Systems, RE4SuSy 2018, co-located with the 26th IEEE International Requirements Engineering Conference (RE 2018)*. CEUR-WS, 2018b.

Ahmed D. Alharthi, Maria Spichkova, and Margaret Hamilton. Susoftpro: Sustainability profiling for software. In *Proceedings of the 26th IEEE International Requirements Engineering Conference (RE'18)*. IEEE, 2018c. doi: 10.1109/RE.2018.00072.

Ahmed D. Alharthi, Maria Spichkova, Margaret Hamilton, and Tawfeeq Alsanoosy. Gender-based perspectives of elearning systems: An empirical study of social sustainability. In *the 27th International Conference on Information Systems Development (ISD2018)*. AIS, 2018d.

Ahmed D. Alharthi, Tawfeeq Alsanoosy, Maria Spichkova, and Margaret Hamilton. Social position and gender perspectives of elearning systems: A study of social sustainability. In *Advances in Information Systems Development*, volume 34. Springer, 2019. doi: 10.1007/978-3-030-22993-1_10.

R. H. Thayer and M. Dorfman. *Software Requirements Engineering*, chapter Introductions, Issues, and Terminology, pages 3–40. Wiley-IEEE Press, 2000. ISBN 9781118156674.

S. Thew and A. Sutcliffe. Value-based requirements engineering: method and experience. *Requirements Engineering*, 23(4):443–464, 2018.

L. Thomas and S. Trapp. Building re-configurable blendedlearning arrangements. In *Balkan Conference in Informatics (BCI 2007)*, pages 271–280, 2007.

N. Tikhomirova, V. Tikhomirov, V. Maksimova, and Y. Telnov. Knowledge management in the smart university. *Proceedings of the European Conference on Knowledge Management, ECKM*, 2:1172–1178, 2012.

B. Tomkinson and I. Hutt. Online pbl: A route to sustainability education? *Campus-Wide Information Systems*, 29(4): 291–303, 2012.

I. N. Toppin and S. M. Toppin. Virtual schools: The changing landscape of k-12 education in the us. *Education and Information Technologies*, 21(6), 2016.

M. Törngren, S. Bensalem, J. McDermid, R. Passerone, A. Sangiovanni-Vincentelli, and B. Schätz. Education and training challenges in the era of cyber-physical systems: beyond traditional engineering. In *Proceedings of the WESE'15: Workshop on Embedded and Cyber-Physical Systems Education*, WESE'15, pages 8:1–8:5. ACM, 2015.

V. Trajkovik, E. Caporali, E. Palmisano, and J. Valdiserri. Establishing a videoconferencing infrastructure in the republic of Macedonia as an engineering educational service. In *Joint International IGIP-SEFI Annual Conference*. SEFI, 2010.

T. Tullis and B. Albert. *Measuring the User Experience*. Interactive Technologies. Morgan Kaufmann, 2nd edition edition, 2013.

G. Tuparov, H. Kostadinova, D. Tuparova, and M. Raykova. Approaches for competencies assessment in open source e-learning environments. In *Global Engineering Education Conference (EDUCON)*, pages 529–532. IEEE, 04 2014.

T. Tuunanen and I.-T. Kuo. The effect of culture on requirements: a value-based view of prioritization. *European Journal of Information Systems*, 24(3):295–313, 2015.

L. Uden, I. T. Wangsa, and E. Damiani. The future of e-learning: E-learning ecosystem. In *2007 Inaugural IEEE-IES Digital EcoSystems and Technologies Conference*, pages 113–117, Feb 2007. doi: 10.1109/DEST.2007.371955.

M. Velasquez and P. T. Hester. An analysis of multi-criteria decision making methods. *International Journal of Operations Research*, 10(2):56–66, 2013.

C. Verly and Y. De Smet. Some results about rank reversal instances in the promethee methods. *International Journal of Multicriteria Decision Making 71*, 3(4):325–345, 2013.

B. Vogel, A. Kurti, M. Milrad, E. Johansson, and M. Müller. Mobile inquiry learning in Sweden: Development insights on interoperability, extensibility and sustainability of the lets go software system. *Educational Technology and Society*, 17(2):43–57, 2014.

Y. Vovides, S. B. Chale, R. Gadhula, M. B. Kebaetse, N. A. Nigussie, F. Suleman, D. Tibyampansha, G. R. Ibrahim, M. Ntabaye, S. Frehywot, et al. A systems approach to implementation of elearning in medical education: Five mepi schools' journeys. *Academic Medicine*, 89(8):S102–S106, 2014.

J.-J. Wang, Y.-Y. Jing, C.-F. Zhang, and J.-H. Zhao. Review on multi-criteria decision analysis aid in sustainable energy decision-making. *Renewable and Sustainable Energy Reviews*, 13(9):2263–2278, 2009.

R. Wang, P. Scown, C. Urquhart, and J. Hardman. Tapping the educational potential of facebook: Guidelines for use in higher education. *Education and Information Technologies*, 19(1), 2014.

G. Weichhart. Supporting the evolution and interoperability of organisational models with e-learning technologies. *Annual Reviews in Control*, 39:118–127, 2015.

P. Willis, S. McKenzie, and R. Harris. Introduction: Challenges in adult and vocational education for social sustainability. In *Rethinking Work and Learning*, pages 1–9. Springer, 2009.

T. Winfree, P. Goldacre, M. Sherkat, P. Graham, A. Mendoza, and T. Miller. Learning for low carbon living: The potential of mobile learning applications for built environment trades and professionals in australia. *Procedia Engineering*, 180:1773–1783, 2017.

C. Wohlin. Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*, EASE '14, pages 38:1–38:10. ACM, 2014.

C. Wohlin, P. Runeson, M. Höst, M. C. Ohlsson, and B. Regnell. *Experimentation in Software Engineering*. Springer, 2012. ISBN 978-3-642-29043-5.

B. Wong. Color blindness. *Nature methods*, 8(6), 2011.

K. B. Wright. Researching internet-based populations: Advantages and disadvantages of online survey research, online questionnaire authoring software packages, and web survey services. *Journal of computer-mediated communication*, 10(3), 2005.

J.-H. Wu, R. D. Tennyson, and T.-L. Hsia. A study of student satisfaction in a blended e-learning system environment. *Computers & Education*, 55(1):155–164, 2010.

T. Yigit, A. H. Isik, and M. Ince. Web-based learning object selection software using analytical hierarchy process. *Software, IET*, 8(4):174–183, 08 2014. ISSN 1751-8806.

S. Yos and C. Chua. Requirements engineering tools for global software engineering - a feature analysis study. In *13th International Conference on Evaluation of Novel Approaches to Software Engineering ENASE*, pages 291–298. SciTePress, 2018. ISBN 978-989-758-300-1. doi: 10.5220/0006760102910298.

Q. Zheng, H. He, T. Ma, N. Xue, B. Li, and B. Dong. Big log analysis for e-learning ecosystem. In *IEEE 11th International Conference on e-Business Engineering (ICEBE)*, pages 258–263. IEEE, 11 2014. doi: 10.1109/ICEBE.2014.51.

G. Zon, S. Corrigan, N. McDonald, and A. Maij. A learning, training & mentoring framework (ltm) & the role of serious games to facilitate sustainable change in the aviation industry. *11th International Probabilistic Safety Assessment and Management Conference and the Annual European Safety and Reliability Conference*, 6:5044–5051, 2012.

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

No	Paper	Year	Step	Characteristics of paper
1	(Mohan et al. 2017) : A Crowdsourcing Approach for Quality Enhancement of eLearning Systems	2017	SLR	Case study
2	(Winfree et al. 2017) : Learning for Low Carbon Living: The Potential of Mobile Learning Applications for Built Environment Trades and Professionals in Australia	2017	SLR	Empirical
3	(Manca and Ranieri 2017) : Implications of social network sites for teaching and learning. Where we are and where we want to go	2017	SLR	Literature review
4	(Scoppio and Luyt 2017) : Mind the gap: Enabling online faculty and instructional designers in mapping new models for quality online courses	2017	SLR	Comparative
5	(Nunes et al. 2016) : Mobile serious game proposal for environmental awareness of children	2016	SLR	Experimental
6	(Toppin and Toppin 2016) : Virtual schools: The changing landscape of K-12 education in the US	2016	SLR	Theoretical
7	(Ellis 2016) : Students' approaches to groupwork in a blended course, associations with perceptions of the online environment and academic achievement–when is learning engaged?	2016	SLR	Empirical

(Continued)

Continuation of Table A.1

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

(Continued)

Continuation of Table A.1

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

(Continued)

Continuation of Table A.1

No	Paper	Year	Step	Characteristics of paper
51	(Gunn 2011) : Sustaining e-learning innovations	2011	SP	Theoretical
52	(Sousa 2011) : Information systems architecture modeling based on loosely coupled structures: An e-learning use case	2011	SLR	Conceptual
53	(Kazancoglu and Aksoy 2011) : A fuzzy logic-based QFD to identify key factors of e-learning design	2011	SLR	Theoretical
54	(Miliszewska and Sztendur 2011) : Critical success attributes of transnational IT education programmes: The client perspective	2011	SLR	Empirical
55	(Lizhong et al. 2011) : The Function of the University Libraries in Constructing Lifelong Education System	2011	SLR	Theoretical
56	(Bhat 2011) : Technological ambidexterity in the management of national infrastructure programmes	2011	SLR	Theoretical
57	(Memmel 2011) : Interoperability Requirements for a Sustainable Component to Support Management and Sharing of Digital Resources	2011	SLR	Theoretical
58	(Meneses 2011) : Design of an electronic instrumentation virtual laboratory based on free-open resources	2011	SLR	Conceptual
59	(Gunn 2010) : Sustainability factors for e-learning initiatives	2010	SP	Empirical
60	(Colasante 2010) : Future-focused learning via online anchored discussion, connecting learners with digital artefacts, other learners, and teachers	2010	SP	Empirical
61	(Rovai and Downey 2010) : Why some distance education programs fail while others succeed in a global environment	2010	SP	Empirical
62	(Buchan 2010) : Putting ourselves in the big picture: A sustainable approach to project management for e-learning	2010	SP	Case study
63	(Demirkan et al. 2010) : A Reference Model for Sustainable E-Learning Service Systems: Experiences with the Joint University/Teradata Consortium	2010	SP	Case study
64	(Allen et al. 2010) : K-State's Distributed Learning Commons: Achieving Long-Term Sustainability Through Strategic Partnerships	2010	SLR	Case study
65	(Jiang et al. 2010) : Four requirements for digital case study libraries	2010	SLR	Case study
66	(Sridharan et al. 2010) : Critical success factors in elearning ecosystems: a qualitative study	2010	NSR	Survey
67	(Trajkovik et al. 2010) : Establishing a videoconferencing infrastructure in the republic of Macedonia as an engineering educational service	2010	SLR	Empirical
68	(Bourn and Shiel 2009) : Global perspectives: aligning agendas?	2009	SP	Theoretical
69	(Dyson et al. 2009) : Advancing the m-learning research agenda for active, experiential learning: Four case studies	2009	SP	Empirical
70	(Friesen 2009) : Open educational resources: New possibilities for change and sustainability	2009	SP	Empirical
71	(Garrison and Akyol 2009) : Role of instructional technology in the transformation of higher education	2009	SP	Theoretical
72	(Fisler and Schneider 2009) : Creating, handling and implementing e-learning courses using the Open source tools OLAT and eLML at the University of Zurich	2009	SP	Theoretical

(Continued)

Continuation of Table A.1

No	Paper	Year	Step	Characteristics of paper
73	(Cheung and Lee 2009) : Understanding the sustainability of a virtual community: model development and empirical test	2009	SP	empirical
74	(Dong et al. 2009) : An E-learning Ecosystem Based on Cloud Computing Infrastructure	2009	NSR	Conceptual
75	(Gustavsson et al. 2009) : On Objectives of Instructional Laboratories, Individual Assessment, and Use of Collaborative Remote Laboratories	2009	SLR	Empirical
76	(Liu et al. 2009) : Making classrooms socio-technical environments for supporting collaborative learning: the role of personal devices and boundary objects	2009	SLR	Empirical
77	(Shehabat and Mahdi 2009) : E-Learning and its Impact to the Educational System in the Arab World	2009	SLR	Theoretical
78	(Park et al. 2009) : Adaptive open mobile learning device for the underserved	2009	SLR	Conceptual
79	(Jin and Law 2009) : Lifelong learning to advance the engineer's career	2009	SLR	Theoretical
80	(Robertson 2008) : Sustainable e-learning, activity theory and professional development	2008	SP	Theoretical
81	(Roy et al. 2008) : Designing low carbon higher education systems: Environmental impacts of campus and distance learning systems	2008	SP	Empirical
82	(Mason 2008) : What is complexity theory and what are its implications for educational change?	2008	SP	Theoretical
83	(Dinevski 2008) : Open educational resources and lifelong learning	2008	SP	Theoretical
84	(O'Neil 2008) : The current status of instructional design theories in relation to today's authoring systems	2008	SP	Theoretical
85	(Sun et al. 2008) : What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction	2008	SP	Empirical
86	(Kim et al. 2008) : Pocket school: Exploring mobile technology as a sustainable literacy education option for underserved indigenous children in Latin America	2008	SP	Theoretical
87	(Franceschi et al. 2008) : Engaging E-Learning in Virtual Worlds: Supporting Group Collaboration	2008	SP	Theoretical
88	(Nichols 2008) : Institutional perspectives: The challenges of e-learning diffusion	2008	SP	Empirical
89	(Berge and Giles 2008) : Strategic Planning for E-Learning in the Workplace	2008	SLR	Conceptual
90	(Laurillard 2007) : Modelling benefits-oriented costs for technology enhanced learning	2007	SP	Conceptual
91	(Uden et al. 2007) : The future of E-learning: E-learning ecosystem	2007	SP	Theoretical
92	(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)	2007	SP	Conceptual
93	(Thomas and Trapp 2007) : Building re-configurable blendedlearning arrangements	2007	SP	Conceptual
94	(Stiles and Yorke 2007) : Technology supported learning – Tensions between innovation, and control and organisational and professional cultures	2007	SP	Theoretical

(Continued)

Continuation of Table A.1

No	Paper	Year	Step	Characteristics of paper
95	(Motiwalla 2007) : Mobile learning: A framework and evaluation	2007	SP	Empirical
96	(Lee and Chan 2007) : Pervasive, lifestyle-integrated mobile learning for distance learners: an analysis and unexpected results from a podcasting study	2007	SP	Empirical
97	(Chen 2007) : The factors influencing members' continuance intentions in professional virtual communities — a longitudinal study	2007	SP	Empirical
98	(Müller et al. 2007) : The socio-economic dimensions of ICT-driven educational change	2007	SLR	Theoretical
99	(Müller and Siebenhüner 2007) : Policy instruments for sustainability-oriented organizational learning	2007	SLR	Theoretical
100	(Bottino 2007) : On-line learning networks: Framework and scenarios	2007	SLR	Conceptual
101	(Attwell 2007) : Personal Learning Environments-the future of e-Learning?	2007	NSR	Commentary
102	(Downes 2007) : Models for sustainable open educational resources	2007	NSR	Theoretical
103	(Farooq et al. 2007) : Sustaining a community computing infrastructure for online teacher professional development: A case study of designing tapped in	2007	SLR	Case study
104	(Pullen and Snow 2007) : Integrating synchronous and asynchronous internet distributed education for maximum effectiveness	2007	SLR	Empirical
105	(Koohang and Harman 2007) : Advancing sustainability of open educational resources	2007	NSR	Conceptual
106	(Georgiadou and Siakas 2006) : Distance learning: Technologies; Enabling learning at own place, own pace, own time	2006	SP	Theoretical
107	(Hylén 2006) : Open educational resources: Opportunities and challenges	2006	SP	Theoretical
108	(Chiu et al. 2006) : Understanding knowledge sharing in virtual communities: An integration of social capital and social cognitive theories	2006	SP	Empirical
109	(Sharpe et al. 2006) : Implementing a university e-learning strategy: levers for change within academic schools	2006	SP	Empirical
110	(Dholakia et al. 2006) : What makes an open education program sustainable? The case of Connexions	2006	SP	Theoretical
111	(Fisler and Bleisch 2006) : eLML, the eLesson Markup Language: Developing Sustainable e-Learning Content Using an Open Source XML Framework	2006	SP	Theoretical
112	(Berge and Giles 2006) : Implementing and sustaining e-learning in the workplace	2006	SLR	Theoretical
113	(Olofsson and Lindberg 2006) : Whatever Happened to the Social Dimension?" Aspects of Learning in a Distance-based Teacher Training Programme"	2006	SLR	Theoretical
114	(Stechert 2006) : Informatics system comprehension: A learner-centred cognitive approach to networked thinking	2006	SLR	Conceptual
115	(Chen et al. 2005) : Personalized e-learning system using item response theory	2005	SP	Theoretical
116	(Gunn et al. 2005) : Repurposing learning objects: a sustainable alternative?	2005	SP	Theoretical
117	(Salmon 2005) : Flying not flapping: a strategic framework for e-learning and pedagogical innovation in higher education institutions	2005	SP	Conceptual

(Continued)

Continuation of Table A.1

No	Paper	Year	Step	Characteristics of paper
118	(Halimi 2005) : Lifelong learning for equity and social cohesion: A new challenge for Higher Education	2005	SP	Theoretical
119	(Bell and Bell 2005) : It's installed... now get on with it! Looking beyond the software to the cultural change	2005	SP	Empirical
120	(Hoffman et al. 2005) : Social capital, knowledge management, and sustained superior performance	2005	SP	Theoretical
121	(Kendall 2005) : Lifelong learning really matters for elementary education in the 21st century	2005	SLR	Theoretical
122	(Littlejohn and Shum 2003) : Reusing online resources: a sustainable approach to e-learning	2003	NSR	Theoretical
123	(Littlejohn 2003) : Supporting sustainable e-learning	2003	NSR	Theoretical
124	(Schoenwald 2003) : Sustainable implementation of e-learning as a change process at universities	2003	NSR	Case study

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

RMIT University

Science Engineering and Health

College Human Ethics Advisory Network (CHEAN)

Plenty Road
Bundoora VIC 3083

PO Box 71
Bundoora VIC 3083
Australia

Tel. +61 3 9925 7096
Fax +61 3 9925 6506
www.rmit.edu.au

30th March 2016

Dear Dr Spichkova

ASEHAPP 72-15 SPICHKOVA-ALAHRTHI Requirements Engineering Aspects of ELearning 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

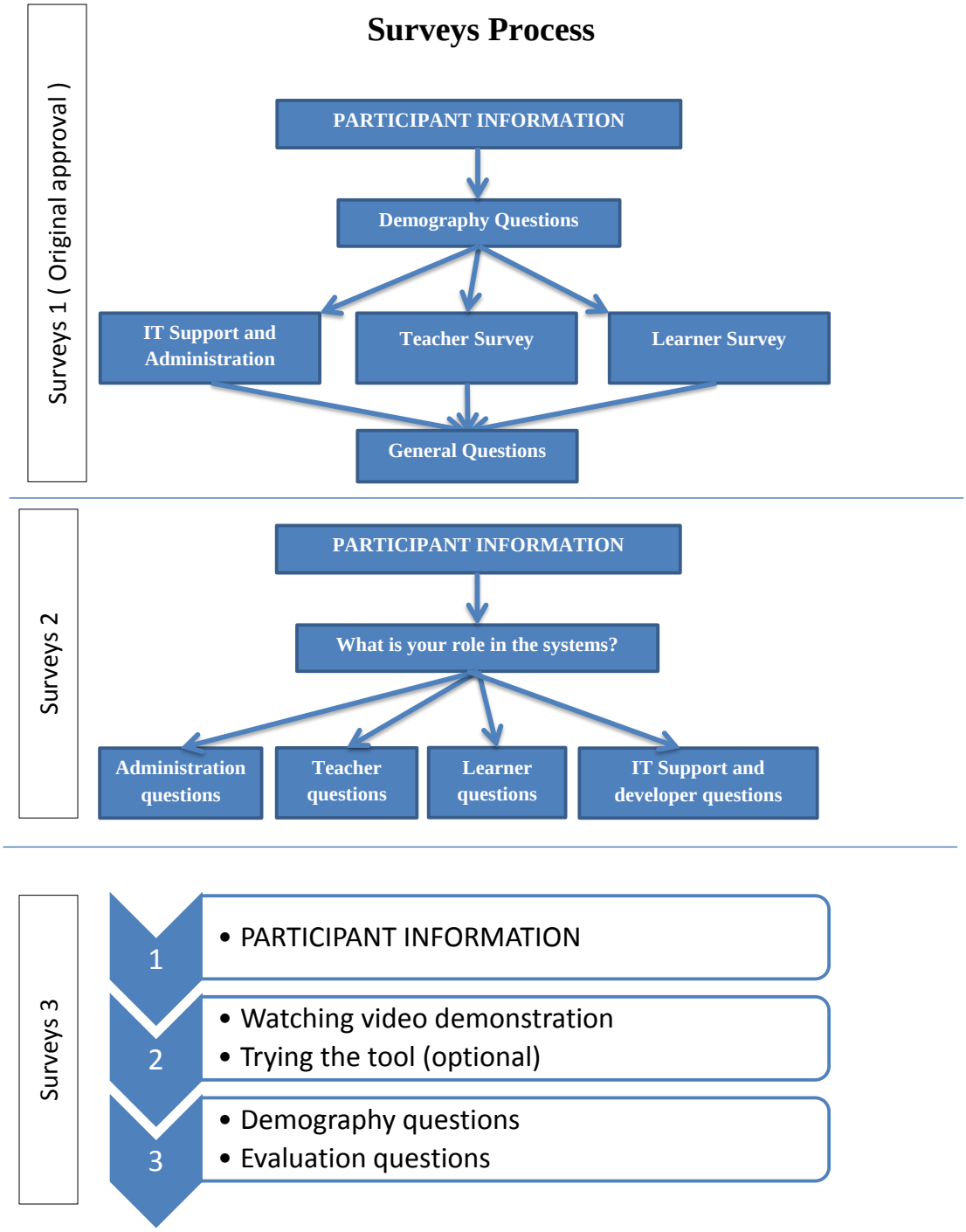
Survey documents

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
Surveys 1 (Original approval)
PARTICIPANT INFORMATION
Demography Questions
IT Support and Administration
Teacher Survey
Learner Survey
General Questions
Surveys 2
PARTICIPANT INFORMATION
What is your role in the systems?
Administration questions
Teacher questions
Learner questions
IT Support and developer questions
Surveys 3
1
• PARTICIPANT INFORMATION
2
• Watching video demonstration
• Trying the tool (optional)
3
• Demography questions
• Evaluation questions

Survey*	Purpose	Recruitment	Participants	Approval Status
1	To explore the most used, requested and deficient functionalities of eLearning systems	Email	Students, instructors, Administrator and IT support in RMIT university and Umm Alqura university	Original
2	To analyse sustainability requirements of eLearning systems	Email	Students, instructors, Administrator and IT support in RMIT university and Umm Alqura university	Amendment
3	To evaluate developed SuSoftPro framework and tool for analysing sustainability in software.	Twitter and LinkedIn	Student, instructor, researcher, software developer, IT supports, and Administrator, and related.	Amendment

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?

الاستطلاعات

جوانب متطلبات بناء نظم التعليم الإلكتروني

أسئلة الديموغرافيا:

DQ1 من أنت؟
- داعم فني أو مدير نظام
- معلم \ محاضر
- طالب

DQ2انتسابك: البلد؟
- أستراليا
- المملكة العربية السعودية
- أخرى (حدد):

DQ3الجامعة؟
- 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 إلى اي مدى السهولة لإضافة وظائف جديدة أو إزالة وظيفة مثل لوحة المناقشة "منتدى" أو الفصول الافتراضية ؟ وماهي الطريقة المستخدمه؟
ITQ4 ما هي المشاكل الموجودة في نظامكم الحالي وتحتاج إلى حل ؟
ITQ5 ما هو مقدار الطاقة التي يستهلكها نظام التعليم الالكتروني الخاص بكم ؟

مجموعة المعلم:

TQ1 الجنس: (ذكر أو أنثى)
TQ2 كم عمرك؟
TQ3 أي من الادوات او الوظائف التي تستخدمها في النظام التعليم الالكتروني مثلا الدردشة, المناقشات وغيرها؟
TQ4 ماهي الأدوات او الوظائف التي ترغبها وليست موجوده في نظامكم الان؟
TQ5 ألى متى تعتقد من وجهة نظرك أن النظام يجب ان يحتفظ ببياناتك الخاصة وملفاتك؟

مجموعة الطالب:

LQ1 الجنس: (ذكر أو أنثى)
LQ2 كم عمرك؟
LQ3 أي من الادوات او الوظائف التي تستخدمها في النظام التعليم الالكتروني مثلا الدردشة, المناقشات وغيرها؟
LQ4 ماهي الأدوات او الوظائف التي ترغبها وليست موجوده في نظامكم الان؟
LQ5 ألى متى تعتقد من وجهة نظرك أن النظام يجب ان يحتفظ ببياناتك الخاصة وملفاتك؟

اسئلة عامة:

GQ1 ماهو النظام المستخدم في التعليم الالكتروني؟
- Blackboard (Bb) بلاك بورد
- Moodle (M) مودل
- Desire2Learn (D2L)
- Pearson بيرسون
- أخرى (حدد):

GQ2 ماهي الادوات او الوظائف تريد تحسينها في نظامكم الحالي؟ والى أي مدى هذا التحسين مهم؟
GQ3 هل عندك شيء أخر تريد أن تضيفه؟

Questions of survey 2 consist of sustainability dimesntion 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

System	University	Country	Language
Canvas	RMIT university	Australia	English
Desir2Learn (D2L)	Umm Alqura university	Saudi Arabia	Arabic

Participant group	Sustainability aspects				
	Individual	**Social**	**Technical**	**Economic**	**Environmental**
Student	✓				
Instructor	✓	✓			
Admin		✓		✓	
IT support/ developer			✓	✓	✓

Sustainability aspects	Instructions
Individual	Rate the influence of the requirement on the **individual** sustainability
Social	Rate the influence of the requirement on the **social** sustainability
Technical	Rate the influence of the requirement on the **technical** sustainability
Economic	Rate the influence of the requirement on the **economic** sustainability
Environmental	Rate the influence of the requirement on the **environmental** sustainability

Sustainability aspects – Arabic version:

أوجه الاستدامة	التعليمات
الفردي	قيم تأثير الاستدامة على **الفرد** من وجهة نظرك
الاجتماعي	قيم تأثير الاستدامة على **المجتمع** من وجهة نظرك
التقني	قيم تأثير الاستدامة على **التقنية** من وجهة نظرك
الاقتصادي	قيم تأثير الاستدامة على **الاقتصاد** من وجهة نظرك
البيني	قيم تأثير الاستدامة على **البيئة** من وجهة نظرك

Surveys 3
for evaluating SuSoftPro framework and tool

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?

	Strongly disagree 0 10 20 30 40 50 60 70 80 90 100 **Strongly agree**
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?

_____

الاستطلاعات

تقيم منهجية وأداة SuSoftPro

مقدمه عن الاستدامة ومنهجية SuSoftPro

لقد عرفنا منهجية جديدة وطورنا نظام اسميناها SuSoftPro ليساعد في تحليل وقياس متطلبات الاستدامة للنظم البرمجيات في المرحلة المبكرة من تطوير البرمجيات:

منهجيتنا SuSoftPro يتضمن انشاء استبيانا حول الجوانب الخمسة للاستدامة مع متطلبات البرمجيات الرئيسية .وتحلل الاجابات باستخدام منهجيه تحليل القرارات متعددة المعايير .والنتيجة تعرض مستوى للاستدامة للبرمجيات، وتحتوي على تصنيف الاستدامة بخمس نجوم ، وعرض جوانب الاستدامة الخمسة على شكل رسم بياني افقي، ورسم بياني شريطي اخر للاستدامة العامة لكل متطلب رئيسي للبرمجيات.

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

يتم تعريف الاستدامة للبرامج من خلال الجوانب التالية :

- **جانب الاستدامة الفردية :**ينبغي حماية الاحتياجات الفردية ودعمها؛
- **جانب الاستدامة الاجتماعية** :العلاقات ينبغي أن تكون منصفة ومتنوعة ومتصلة وديمقراطي؛
- **جانب الاستدامة التقنية والتكنولوجيا :**ينبغي أن تكون قادرة على التكيف مع التغيرات وتطور بكفاءة مع المحافضة على الموارد الطبيعية؛
- **جانب الاستدامة الاقتصادية** :ينبغي ضمان القيمة الاقتصادية الإيجابية ونمو رأس المال والمحافظة عليها؛
- **جانب الاستدامة البيئية :**الموارد الطبيعية يجب أن تكون محمية من الاحتياجات الزائدة البشرية والنفايات المضرة .

نحتاج لجمع معلومات عن المنهجية والنظام SuSoftPro

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

اتفق بشدة **لا اتفق بشدة**

0 10 20 30 40 50 60 70 80 90 100

	1- النظام يعمل بشكل منطقي من البداية إلى النهاية لتحليل متطلبات الاستدامة وجوانب الاستدامة في البرمجيات.
	2- النظام يعمل بإجراء منهجي لإعداد وانشاء تقرير عن استدامة البرمجيات التي تحتوي على تحلل متطلبات الاستدامة وجوانب الاستدامة للبرمجيات.
	3- النظام سهل الاستخدام لتحليل متطلبات الاستدامة وجوانب الاستدامة في البرمجيات.
	4- يمكن للنظام تعيين المستخدمين للبرمجيات واصحاب المصلحة في مجموعه معينه والتي يمكن تخصصيه لواحد أو أكثر من جوانب الاستدامة.
	5- يسهم النظام في تحقيق النتائج المرجوة من تحليل متطلبات استدامة البرمجيات
	6- ومن المرجح ان استخدم النظام لقياس جوانب الاستدامة ومتطلبات استدامة للبرمجيات.

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

_____

7. هل تستخدم اي أداة لتحليل جوانب الاستدامة ومتطلبات الاستدامة للبرمجيات ؟

○ لا

○ نعم ,ماهي الطرق او الأداة المستخدمة_____

8. هل لديك اقتراح للتحسين المنهجية والأداة؟

_____

Participant Information (PI)

PI for **Surveys 1**

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.

Participant Information (PI)

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.

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

Participant Information (PI)

Translated PI for **Surveys 1**

معلومات المشاركة

عنوان البحث: جوانب متطلبات بناء نظم التعليم الإلكتروني
الباحثون:
الباحث الرئيسي: احمد الحارثي
مشرف البحث: الدكتورة ماريا سبيتشكوفا
مشرف ثاني: أستاذ مشارك مارغريت هاملتون

سيدي|تي العزيز|ة

السلام عليكم ورحمة الله وبركاته أما بعد:

أنت مدعو للمشاركة في بحث يتم عمله في جامعة *RMIT*. فضلا اقراء هذه المعلومات جيدا وكن واثقا انك فهمت المحتوى قبل اتخاذ القرار بالمشاركة. اذا كان لديك اي سؤال حول البحث لا تتردد بسؤال احد الباحثين.

من هم المشاركين في هذا البحث؟ ولماذا يتم عمل هذا البحث؟

- الطلاب والمعلمين والمحاضرين والدعمين الفنين مدراء النظم الذين يستخدمون نظام التعلم الالكتروني. واجوبتهم سوف يساعد في تحديد جوانب متطلبات بناء نظم التعليم الالكتروني.
- البحث يعتبر جزء من بحث درجة الدكتوراة في علوم الحاسب الالي.
- البحث تم الموافقة عليه من قبل لجنة اخلاقيات البحوث الانسانية بجامعة RMIT.
- هذا البحث تم تمويلة من قبل جامعة ام القرى في المملكة العربية السعودية.

لماذا تم اختيارك للبحث؟

السبب لاختيارك هو انك طالب أو معلم أو محاضر أو داعم فني أو مدير نظم تستخدم نظام التعلم الالكتروني. واجابتك على هذا الاستطلاع سوف يساعد في تحديد جوانب متطالبات نظم التعليم الالكتروني. تم اختيارك عشوائيا أو من قبل جامعتك.

ما هو البحث؟ وماهي الاسئلة الذي يعالجه البحث؟

- الاهداف الاساسية لهذا البحث هو 1) تحديد المتطلبات الخاصة بدولة أو ثقافة خاصة وكذلك المتطلبات العامة لبناء نظم التعليم الالكتروني. 2) بناء هيكل تنظيمي لتحليل التنوع مثل تنوع الثقافات والتقنية وايضا جوانب الاستدامة.(البيئية, التقنية, التعليمية, الاجتماعية..) الهيكل التنظيمي سوف يساعد عمليات بناء المتطلبات لتطوير وتحسين نظم التعليم الالكتروني والذي بشكل عام سوف يطور الاستدامة التعليمية على الانترنت أو في الفصول الدراسية والتعليم التفاعلي.
- هذا البحث سوف يجواب على الاسئلة التالية:
  - كيف يمكننا التعامل مع التنوع(التقنية, الثقافية وغيرها) عندما يتم تطوير أوتحسين نظم التعليم الالكتروني؟
  - ما هي المتطلبات الخاصة بالتعليم الاكتروني(بالمقارنة مع مجالات التطوير الاخرى)؟
  - كيف يمكننا تغطية جوانب الاستدامة مع تطوير أو تحسين أو توسع نطاق التعلم الالكتروني؟ وكيف يمكننا اضافتة كجزء من عمليات بناء المتطالبات؟
- نحن نتوقع 100 مشاركة على الاقل.

أذا قبلت المشاركة ماذا يتطلب مني عمله؟

بمشاركتكم في هذا البحث، اضمن لكم عدم الكشف عن هويتكم. ومشاركتكم في الاستطلاع تطوعي تماما، ويمكنكم الانسحاب من المشاركة في أي وقت عن طريق إغلاق النافذة. علما ان الاستطلاع يأخذ 10-15 دقيقة من وقتك. ويجب أن توافق على المشاركة، وللموافقة تحتاج ان تضغط على زر موافق في الجزء السفلي من هذه الصفحة والذي يدل على موافقتك على المشاركة.

وبعدها سوف يأخذك المتصفح إلى صفحات الاستطلاع وسوف يكون هناك ثلاثة اجزاء. في الجزء الاول سوف يسألك مثلا دولتك وعن مجالك هل انت طالب أو محاضر أو داعم فني لتحديد مسارك في الجزء الثاني الذي يتعلق بالتعليم الالكتروني. أما الجزء الاخير هو عبارة عن اسئلة عامة مثلا ما هو النظام المستخدم. وعندما تجاوب على جميع الأسئلة، تحتاج إلى الضغط على زر تسليم.علما بان الضغط على زر تسليم يعني تأكيد موافقتكم على المشاركة في هذا البحث.

ما هي المخاطر المحتملة لتنفيذ هذا الاستطلاع؟

- ليس هناك اي مخاطر محتملة.

"اذا كنت قلق من اجابتك على اي من الاسئلة أو تخشى الاكتئاب خلال مشاركتك يمكن التواصل مع رئيسة البحث دكتورة ماريا. وهي سوف تناقش قلقك المتعلق بالمشاركة وسوف تكون هناك خصوصية للمعلومات واقتراح حلول اذا احتاج الامر"

ما هي الفوائد لتنفيذ هذا الاستطلاع؟

أحد الفوائد المتوقع الحصول عليها من خلال مشاركتك هو تحسين جودة المتطلبات في نظم التعليم الالكتروني مثل الاستدامة, الأداء, الامان, وامن المعلومات.

Participant Information (PI)

ماذا سيحدث للاجابت الذي سوف اقدمها؟

- ضمانية عدم كشف الهوية, ولهذا لن يتم التعرف على هويتك في اي مرحلة من مراحل البحث.
- على الرغم من أن نتائج الاستطلاع قد تنشر في أطروحة الدكتوراه مثل مكتبة RMITأو في المجلات الأكاديمية أو كتابة تقرير أو عرضها في المؤتمرات ، اضمن لكم أن البيانات والمعلومات ستعامل بسرية كاملة ولن يتم تخزين بياناتك الشخصية اثناء وبعد الاستطلاع.
- نظرا لطبيعة جمع البيانات, نحن لا نحتاج موافقة خطية منك, ولكن نعتبر تعبيتك واكمالك للاستطلاع هو عبارة عن الموافقة للمشاركة.

ماهي حقوقي كمشارك؟

- لك الحق بالانسحاب قبل تسليم الاجابات.

مع من بامكانني التواصل بخصوص أي سؤال في الاستطلاع؟

الباحث الرئيسي: احمد الحارثي
مشرف البحث: الدكتورة ماريا سبيتشكوفا
مشرف ثاني: أستاذ مشارك مارغريت هاملتون

ما هي القضايا الاخرى التي يجب أن كون على علم بها؟

- اذا سملت اجابتك, لا يمكنك الغاءه

آمان تصفح الانترنت:
يجب ان تعلم ان صفحات الانترنت غير آمنه في الشبكات العامة التي غالبا تكون خطيرة من حيث نقل البيانات مثل مشاهدتها أو تعديلها من قبل طرف ثالث كذلك البيانات التي يتم تمزيلها من قبل المستخدم ربما تحتوي على برامج خبيثة أو فيروسات.

آمن البيانات:
هذا الاستطلاع يستخدم أنظمة آمنة في انشاء وجمع وتحليل البيانات. الموقع الذي نستخدمه في جمع البيانات هوGoogle Froms فإذا وفقت على المشاركة في الاستبيان سوف يتم تخزين البيانات في Google . ويجب أن تعلم بيانات الشخصية لن يتم جمعها والبينات المستخدمه للاستبيان سوف يتم نقلها إلى خوادم RMIT وسيتم تخزين البيانات التي تم جمعها بشكل آمن لمدة خمس (5) سنوات، وسيتم بعد ذلك حذف البيانات الموجودة في Google نهائيا.

شكرا جزيلا لدعمكم.
تفضلوا بقبول فائق الاحترام،
أحمد الحارثي
ماجستير في هندسة البرمجيات وطالب دكتوراه في جامعة RMIT

اذا كان لديك أي مخاوف حول مشاركتكم في هذا البحث, والتي لا ترغب في مناقشتها مع الباحثين يمكنك التواصل مع مسئول اخلاقيات البحوث والنزاهة والحوكمة والانظمة بجامعة أر ام اي تي

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

Participant Information (PI)

RMIT UNIVERSITY

PI for **Surveys 2**

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.

Participant Information (PI)

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 you 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

Participant Information (PI)

Translated PI
for **Surveys 2**

معلومات المشاركة

عنوان البحث: جوانب متطلبات بناء نظم التعليم الإلكتروني
الباحثون:
الباحث الرئيسي: احمد الحارثي
مشرف البحث: الدكتورة ماريا سبيتشكوفا
مشرف ثاني: أستاذ مشارك مارغريت هاملتون

سيدي|تي العزيز|ة

السلام عليكم ورحمة الله وبركاته أما بعد:

أنت مدعو للمشاركة في بحث يتم عمله في جامعة *RMIT*. فضلا اقراء هذه المعلومات جيدا وكن واثقا انك فهمت المحتوى قبل اتخاذ القرار بالمشاركة. اذا كان لديك اي سؤال حول البحث لا تتردد بسؤال احد الباحثين.

من هم المشاركين في هذا البحث؟ ولماذا يتم عمل هذا البحث؟

- الطلاب والمعلمين والمحاضرين والدعمين الفنين مدراء النظم الذين يستخدمون نظام التعلم الالكتروني. واجوبتهم سوف يساعد في تحديد جوانب متطلبات بناء نظم التعليم الالكتروني.
- البحث يعتبر جزء من بحث درجة الدكتوراه في علوم الحاسب الالي.
- البحث تم الموافقة عليه من قبل لجنة اخلاقيات البحوث الانسانية بجامعة RMIT.
- هذا البحث تم تمويله من قبل جامعة ام القرى في المملكة العربية السعودية.

لماذا تم اختيارك للبحث؟

السبب لاختيارك هو انك طالب أو معلم أو محاضر أو داعم فني أو مدير نظم تستخدم نظام التعلم الالكتروني. واجابتك على هذا الاستطلاع سوف يساعد في تحديد جوانب متطلبات نظم التعليم الالكتروني. تم اختيارك عشوائيا أو من قبل جامعتك.

ما هو البحث؟ وماهي الاسئلة الذي يعالجه البحث؟

- الاهداف الاساسية لهذا البحث هو 1) تحديد المتطلبات الخاصة بدولة أو ثقافة خاصة وكذلك المتطلبات العامة لبناء نظم التعليم الالكتروني. 2) بناء هيكل تنظيمي لتحليل التنوع مثل تنوع الثقافات والتقنية وايضا جوانب الاستدامة.(البيئية, التقنية, التعليمية, الاجتماعية..) الهيكل التنظيمي سوف يساعد عمليات بناء المتطلبات لتطوير وتحسين نظم التعليم الالكتروني والذي بشكل عام سوف يطور الاستدامة التعليمية على الانترنت أو في الفصول الدراسية والتعليم التفاعلي.
- هذا البحث سوف يجاوب على الاسئلة التالية:
  - كيف يمكننا التعامل مع التنوع (التقنية, الثقافية وغيرها) عندما يتم تطوير أو تحسين نظم التعليم الالكتروني؟
  - ما هي المتطلبات الخاصة بالتعليم الإلكتروني (بالمقارنة مع مجالات التطوير الاخرى)؟
  - كيف يمكننا تغطية جوانب الاستدامة مع تطوير أو تحسين أو توسع نطاق التعلم الالكتروني؟ وكيف يمكننا إضافته كجزء من عمليات بناء المتطلبات؟
- نحن نتوقع 100 مشاركة على الاقل.

أذا قبلت المشاركة ماذا يتطلب مني عمله؟

بمشاركتكم في هذا البحث، اضمن لكم سرية بياناتكم. ومشاركتكم في الاستطلاع تطوعي تماما، ويمكنكم الانسحاب من المشاركة في أي وقت عن طريق إغلاق النافذة. علما ان الاستطلاع يأخذ 10-15 دقيقة من وقتك. ويجب أن توافق على المشاركة، وللموافقة تحتاج ان تضغط على زر موافق في الجزء السفلي من هذه الصفحة والذي يدل على موافقتك على المشاركة.

إذا وافقت، فستحتاج إلى تحديد دورك كمستخدم في نظام التعليم الإلكتروني (طالب، معلم ، مسئول اداري أو داعم فني). في البوابة ، سيُطلب منك تقييم قائمة من المتطلبات (الميزات) في نظام التعليم الإلكتروني في جامعتك. تحتاج إلى إعطاء وجهة نظرك كمستخدم حول استدامة النظام من خلال تقييم تأثير المتطلبات على الجوانب الفردية والاجتماعية والتقنية والاقتصادية والبيئية.

على سبيل المثال، سيتم تقديمك لمتطلبات مثل "متطلبات الملف الشخصي وإعدادات المستخدم" ثم يطلب منك تقييم تأثيره على الاستدامة الفردية لنظام التعليم الإلكتروني الخاص بك.

يمكنك تجاهل سؤال إذا لم تكون على دراية به. وعندما تجاوب على جميع الأسئلة، تحتاج إلى الضغط على زر تسليم.

ما هي المخاطر المحتملة لتنفيذ هذا الاستطلاع؟

- ليس هناك اي مخاطر محتملة.

"إذا كنت قلق من اجابتك على اي من الاسئلة أو تخشى الاكتئاب خلال مشاركتك يمكن التواصل مع رئيسة البحث دكتورة ماريا. وهي سوف تناقش قلقك المتعلق بالمشاركة وسوف تكون هناك خصوصية للمعلومات واقتراح حلول اذا احتاج الامر"

Participant Information (PI)

.ما هي الفوائد لتنفيذ هذا الاستطلاع؟

أحد الفوائد المتوقع الحصول عليها من خلال مشاركتك هو تحسين جودة المتطلبات في نظم التعليم الالكتروني مثل الاستدامة، الأداء, الامان, وامن المعلومات.

ماذا سيحدث للإجابات الذي سوف اقدمها؟

- ضمانيه عدم كشف الهوية, ولهذا لن يتم التعرف على هويتك في اي مرحلة من مراحل البحث.
- على الرغم من أن نتائج الاستطلاع قد تنشر في أطروحة الدكتوراه مثل مكتبة RMITأو في المجلات الأكاديمية أو كتابة تقرير أو عرضها في المؤتمرات ، اضمن لكم أن البيانات والمعلومات ستعامل بسرية كاملة ولن يتم تخزين بياناتك الشخصية اثناء وبعد الاستطلاع.
- نظرا لطبيعة جمع البيانات, نحن لا نحتاج موافقة خطية منك, ولكن نعتبر تعبيتك واكمالك للاستطلاع هو عبارة عن الموافقة للمشاركة.

ماهي حقوقي كمشارك؟

- لك الحق بالانسحاب قبل تسليم الاجابات.

مع من بإمكاني التواصل بخصوص أي سؤال في الاستطلاع؟

الباحث الرئيسي: احمد الحارثي
مشرف البحث: الدكتورة ماريا سبيتشكوفا
مشرف ثاني: أستاذ مشارك مارغريت هاملتون

ما هي القضايا الاخرى التي يجب أن كون على علم بها؟

- اذا سملت اجابتك، لا يمكنك الغاءه

آمان تصفح الانترنت:
يجب ان تعلم ان صفحات الانترنت غير آمنه في الشبكات العامة التي غالبا تكون خطيرة من حيث نقل البيانات مثل مشاهدتها أو تعديلها من قبل طرف ثالث كذلك البيانات التي يتم تنزيلها من قبل المستخدم ربما تحتوي على برامج خبيثة أو فيروسات.

آمن البيانات:
هذا الاستطلاع يستخدم أنظمة آمنة في انشاء وجمع وتحليل البيانات. الموقع الذي نستخدمه في جمع البيانات هو موقع **SuSoftPro** فإذا وفقت على المشاركة في الاستبيان سوف يتم تخزين البيانات في **SuSoftPro**. ويجب أن تعلم بيانات الشخصية لن يتم جمعها والبينات المستخدمة للاستبيان سوف يتم نقلها إلى خوادم **RMIT** وسيتم تخزين البيانات التي تم جمعها بشكل آمن لمدة خمس (5) سنوات، وسيتم بعد ذلك حذف البيانات الموجودة في موقع **SuSoftPr** نهائيا.

شكرا جزيلا لدعمكم.
تفضلوا بقبول فائق الاحترام،
أحمد الحارثي
ماجستير في هندسة البرمجيات وطالب دكتوراه في جامعة RMIT

اذا كان لديك أي مخاوف حول مشاركتكم في هذا البحث, والتي لا ترغب في مناقشتها مع الباحثين يمكنك التواصل مع مسئول اخلاقيات البحوث والنزاهة والحوكمة والانظمة بجامعة أر ام اي تي

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

Participant Information (PI)

RMIT UNIVERSITY

PI for **Surveys 3**

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 4 minutes a demonstration video explain our framework and SuSoftPro tool. Then, you need to answer 6 questions. First part is demographic questions which include question who you are and where do live. The second part is more specific question regarding the framework and SuSoftPro tool. For example, the second part will include question such as **to what extent do you agree or disagree with the tool has a logical flow from the start to the end for analysing the sustainability requirements and sustainability aspects of software systems?** Last part has a question as **would you have any 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 you 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 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

Participant Information (PI)

Translated PI for **Surveys 3**

معلومات المشاركة

عنوان البحث: جوانب متطلبات بناء نظم التعليم الإلكتروني
الباحثون:
الباحث الرئيسي: احمد الحارثي
مشرف البحث: الدكتورة ماريا سبيتشكوفا
مشرف ثاني: أستاذ مشارك مارغريت هاملتون

سيدي|تي العزيز|ة

السلام عليكم ورحمة الله وبركاته أما بعد:

أنت مدعو للمشاركة في بحث يتم عمله في جامعة *RMIT*. فضلا اقراء هذه المعلومات جيدا وكن واثقا انك فهمت المحتوى قبل اتخاذ القرار بالمشاركة. إذا كان لديك اي سؤال حول البحث لا تتردد بسؤال احد الباحثين.

من هم المشاركين في هذا البحث؟ ولماذا يتم عمل هذا البحث؟

- الطلاب والمعلمين والمحاضرين والدعمين الفنين مدراء النظم الذين يستخدمون نظام التعلم الالكتروني. واجوبتهم سوف يساعد في تحديد جوانب متطلبات بناء نظم التعليم الالكتروني.
- البحث يعتبر جزء من بحث درجة الدكتوراه في علوم الحاسب الالي.
- البحث تم الموافقة عليه من قبل لجنة اخلاقيات البحوث الانسانية بجامعة RMIT.
- هذا البحث تم تمويله من قبل جامعة ام القرى في المملكة العربية السعودية.

لماذا تم اختيارك للبحث؟

السبب لاختيارك هو أنك طالب أو معلم أو محاضر أو داعم فني أو مدير نظم تستخدم نظام التعلم الالكتروني. واجابتك على هذا الاستطلاع سوف يساعد في تحديد جوانب متطلبات نظم التعليم الالكتروني. تم اختيارك عشوائيا أو من قبل جامعتك.

ما هو البحث؟ وماهي الاسئلة الذي يعالجه البحث؟

- الاهداف الاساسية لهذا البحث هو 1) تحديد المتطلبات الخاصة بدولة أو ثقافة خاصة وكذلك المتطلبات العامة لبناء نظم التعليم الالكتروني. 2) بناء هيكل تنظيمي لتحليل التنوع مثل تنوع الثقافات والتقنية وايضا جوانب الاستدامة. (البيئية، التقنية, التعليمية, الاجتماعية..) الهيكل التنظيمي سوف يساعد عمليات بناء المتطلبات لتطوير وتحسين نظم التعليم الالكتروني والذي بشكل عام سوف يطور الاستدامة التعليمية على الانترنت أو في الفصول الدراسية والتعليم التفاعلي.
- هذا البحث سوف يجاوب على الاسئلة التالية:
  - كيف يمكننا التعامل مع التنوع (التقنية، الثقافية وغيرها) عندما يتم تطوير أو تحسين نظم التعليم الالكتروني؟
  - ما هي المتطلبات الخاصة بالتعليم الإلكتروني (بالمقارنة مع مجالات التطوير الاخرى)؟
  - كيف يمكننا تغطية جوانب الاستدامة مع تطوير أو تحسين أو توسع نطاق التعلم الالكتروني؟ وكيف يمكننا إضافته كجزء من عمليات بناء المتطلبات؟
- نحن نتوقع 100 مشاركة على الاقل.

أذا قبلت المشاركة ماذا يتطلب مني عمله؟

بمشاركتكم في هذا البحث، اضمن لكم عدم الكشف عن هويتكم. ومشاركتكم في الاستطلاع تطوعي تماما، ويمكنكم الانسحاب من المشاركة في أي وقت عن طريق إغلاق النافذة. علما ان الاستطلاع يأخذ 10-15 دقيقة من وقتك. ويجب أن توافق على المشاركة، وللموافقة تحتاج ان تضغط على زر موافق في الجزء السفلي من هذه الصفحة والذي يدل على موافقتك على المشاركة.

وبعدها سوف يأخذك المتصفح إلى صفحات الاستطلاع وسوف يكون هناك ثلاثة اجزاء. في الجزء الاول سوف يسألك مثلا دولتك وعن مجالك هل انت طالب أو محاضر أو داعم فني لتحديد مسارك في الجزء الثاني الذي يتعلق بالتعليم الالكتروني. أما الجزء الاخير هو عبارة عن اسئلة عامة مثلا ما هو النظام المستخدم. وعندما تجاوب على جميع الأسئلة، تحتاج إلى الضغط على زر تسليم علما بان الضغط على زر تسليم يعني تأكيد موافقتكم على المشاركة في هذا البحث.

ما هي المخاطر المحتملة لتنفيذ هذا الاستطلاع؟

- ليس هناك اي مخاطر محتملة.

"إذا كنت قلق من اجابتك على اي من الاسئلة أو تخشى الاكتئاب خلال مشاركتك يمكن التواصل مع رئيسة البحث دكتورة ماريا. وهي سوف تناقش قلقك المتعلق بالمشاركة وسوف تكون هناك خصوصية للمعلومات واقتراح حلول إذا احتاج الامر"

ما هي الفوائد لتنفيذ هذا الاستطلاع؟

أحد الفوائد المتوقع الحصول عليها من خلال مشاركتك هو تحسين جودة المتطلبات في نظم التعليم الالكتروني مثل الاستدامة، الأداء، الامان, وامن المعلومات.

Participant Information (PI)

ماذا سيحدث للإجابات الذي سوف اقدمها؟

- ضمانيه عدم كشف الهوية، ولهذا لن يتم التعرف على هويتك في اي مرحلة من مراحل البحث.
- على الرغم من أن نتائج الاستطلاع قد تنشر في أطروحة الدكتوراه مثل مكتبة RMIT أو في المجلات الأكاديمية أو كتابة تقرير أو عرضها في المؤتمرات ، اضمن لكم أن البيانات والمعلومات ستعامل بسرية كاملة ولن يتم تخزين بياناتك الشخصية اثناء وبعد الاستطلاع.
- نظرا لطبيعة جمع البيانات، نحن لا نحتاج موافقة خطية منك، ولكن نعتبر تعبيتك واكمالك للاستطلاع هو عبارة عن الموافقة للمشاركة.

ماهي حقوقي كمشارك؟

- لك الحق بالانسحاب قبل تسليم الاجابات.

مع من بإمكاني التواصل بخصوص أي سؤال في الاستطلاع؟

الباحث الرئيسي: احمد الحارثي
مشرف البحث: الدكتورة ماريا سبيتشكوفا
مشرف ثاني: أستاذ مشارك مارغريت هاملتون

ما هي القضايا الاخرى التي يجب أن كون على علم بها؟

- إذا سلمت اجابتك، لا يمكنك الغاءه

آمنا تصفح الانترنت:
يجب ان تعلم ان صفحات الانترنت غير آمنه في الشبكات العامة التي غالبا تكون خطيرة من حيث نقل البيانات مثل مشاهدتها أو تعديلها من قبل طرف ثالث كذلك البيانات التي يتم تخزينها من قبل المستخدم ربما تحتوي على برامج خبيثة أو فيروسات.

آمن البيانات:
هذا الاستطلاع يستخدم أنظمة آمنة في انشاء وجمع وتحليل البيانات. الموقع الذي نستخدمه في جمع البيانات هو Qualtrics Online Surveyفإذا وافقت على المشاركة في الاستبيان سوف يتم تخزين البيانات في Qualtrics. ويجب أن تعلم بيانات الشخصية لن يتم جمعها والبينات المستخدمة للاستبيان سوف يتم نقلها إلى خوادم RMIT وسيتم تخزين البيانات التي تم جمعها بشكل آمن لمدة خمس (5) سنوات، وسيتم بعد ذلك حذف البيانات الموجودة في Qualtrics نهائيا.

شكرا جزيلا لدعمكم.
تفضلوا بقبول فائق الاحترام،
أحمد الحارثي
ماجستير في هندسة البرمجيات وطالب دكتوراه في جامعة RMIT

اذا كان لديك أي مخاوف حول مشاركتكم في هذا البحث, والتي لا ترغب في مناقشتها مع الباحثين يمكنك التواصل مع مسئول اخلاقيات البحوث والنزاهة والحوكمة والانظمة بجامعة أر ام اي تي

, 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 should agree to participate, 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: .....

Recruitment advertisements

عزيزي/ عزيزتي ،

السلام عليكم ورحمة الله وبركاته أما بعد:

أنا ادعوك للمشاركة في بحثي بشأن **جوانب متطلبات بناء نظم التعليم الإلكتروني**. أنا طالب في مرحلة الدكتوراه في كلية علوم الحاسب وتقنية المعلومات (CSIT)، جامعة RMIT في ملبورن، أستراليا. ومشرفي الدكتورة ماريا سبيتشكوفا وأستاذ مشارك مارغريت هاملتون.

السبب لدعوتك هو أنك طالب أو معلم، أو داعم فني أو مسؤول في نظام التعليم الالكتروني وإجاباتك سوف يساعدني في تحديد متطلبات تصميم وتطوير أنظمة التعليم الإلكتروني.

بمشاركتكم في هذا البحث، اضمن لكم عدم الكشف عن هويتكم. ومشاركتكم في الاستطلاع تطوعي تماما، ويمكنكم الانسحاب من المشاركة في أي وقت عن طريق إغلاق النافذة. علما ان الاستطلاع يأخذ 10-15 دقيقة من وقتك. ويجب أن توافق على المشاركة، وللموافقة تحتاج ان تضغط على زر موافق في الجزء السفلي من هذه الصفحة والذي يدل على موافقتك على المشاركة.

وبعدها سوف يأخذك المتصفح إلى صفحات الاستطلاع وعندما تجاوب على جميع الأسئلة، تحتاج إلى الضغط على زر تسليم. علما بان الضغط على زر تسليم يعني تأكيد موافقتكم على المشاركة في هذا البحث

.....

شكرا جزيلا لدعمكم.
تفضلوا بقبول فائق الاحترام،

أحمد الحارثي
طالب دكتوراه في علوم الحاسب الآلي
بجامعة RMIT بأستراليا

هذه المشاركة والبحث تخضع لسياسة أخلاقيات البحث العلمي (**ASEHAPP 72-15 SPICHKOVA-ALHARTHI Requirements Engineering Aspects of eLearning Systems**) فى 30 مارس 2016 بجامعة RMIT استراليا.
إذا كان لديك أي استفسارات فى أي وقت بخصوص المشاركة أو الإجراءات المتعلقة بمشاركتكم فى الاستطلاع، يمكنك الاتصال بى أحمد الحارثى عن طريق البريد الإلكتروني:.....

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:.....

Recruitment advertisements

عزيزي/ عزيزتي،

السلام عليكم ورحمة الله وبركاته أما بعد:

أنا أدعوك للمشاركة في بحثي بشأن **جوانب متطلبات بناء نظم التعليم الإلكتروني**. أنا طالب في مرحلة الدكتوراه في كلية علوم الحاسب وتقنية المعلومات (CSIT)، جامعة RMIT في ملبورن، أستراليا. ومشرفي الدكتورة ماريا سبيتشكوفا وأستاذ مشارك مارغريت هاملتون.

السبب لدعوتك هو أنك طالب أو معلم، أو داعم فني أو مسؤول في نظام التعليم الالكتروني وإجاباتك سوف يساعدني في تحديد متطلبات تصميم وتطوير أنظمة التعليم الإلكتروني.

بمشاركتكم فى هذا البحث، اضمن لكم سرية بياناتكم الشخصية. ومشاركتكم فى الاستطلاع تطوعى تماما، ويمكنكم الانسحاب من المشاركة في أي وقت عن طريق إغلاق النافذة. علما ان الاستطلاع يأخذ 15-20 دقيقة من وقتك. ويجب أن توافق على المشاركة، وللموافقة تحتاج ان تضغط على زر موافق في الجزء السفلي من هذه الصفحة والذي يدل على موافقتك على المشاركة.

وبعدها سوف يأخذك المتصفح إلى صفحات الاستطلاع وعندما تجاوب على جميع الأسئلة، تحتاج إلى الضغط على زر تسليم. علما بان الضغط على زر تسليم يعني تأكيد موافقتكم على المشاركة في هذا البحث

.....

شكرا جزيلا لدعمكم.
تفضلوا بقبول فائق الاحترام،

أحمد الحارثي
طالب دكتوراه في علوم الحاسب الآلي
بجامعة RMITبأستراليا

هذه المشاركة والبحث تخضع لسياسة أخلاقيات البحث العلمي (**ASEHAPP 72-15 SPICHKOVA-ALHARTHI Requirements Engineering Aspects of eLearning Systems**) في 30 مارس 2016 بجامعة RMIT استراليا.
إذا كان لديك أي استفسارات فى أي وقت بخصوص المشاركة أو الإجراءات المتعلقة بمشاركتكم فى الاستطلاع، يمكنك الاتصال بى أحمد الحارثى عن طريق البريد 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 الذين يعملون مع متطلبات البرمجيات، انت مدعو للمشاركة في استبياننا عن تحليل متطلبات الاستدامة في البرمجيات (15-10 دقيقة)
الرابط .....

Appendix C

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

#	Requirement Name	Description	Assigned Group	Sustainability
1	Announcements	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.	Instructors Learner IT support	0.554031
2	Assignments	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.	Instructors Learner IT support	0.435058
3	Calendar	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.	Instructors Learner IT support	0.333333
4	Chat	Canvas shall allow students and teachers to interact and communicate in real time.	Instructors Learner IT support	0.451972
5	Collaborations	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.	Instructors Learner IT support	0.531258

(Continued)

Continuation of Table C.1

#	Requirement Name	Description	Assigned Group	Sustainability
6	Conferences	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.	Instructors Learner IT support	0.531277
7	Conversations	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.	Instructors Learner IT support	0.506496
8	Groups	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.	Instructors Learner IT support	0.505193
9	Discussions	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).	Instructors Learner IT support	0.537939
10	Pages	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.	Instructors Learner IT support	0.498566
11	Outcomes	Outcomes in Canvas shall enable the administration and faculty to track students progress as measured by pedagogical goals or desired outcomes.	Admins Instructors Learner IT support	0.50691
12	Roll Call Attendance Tool	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.	Instructors Learner IT support	0.419432
13	Navigation	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.	Instructors Students IT support	0.447231
14	Quizzes	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.	Instructors Learner IT support	0.514917
15	Question banks	Questions banks in Canvas shall allow Account-level roles to create institutional or departmental question repositories.	Admins Instructors IT support	0.460052
16	Grades and the Gradebook	The Gradebook in Canvas shall store all information about student progress in the course, measuring grades and course outcomes.	Instructors Learner IT support	0.497479
17	Grading schemes	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.	Admins Instructors IT support	0.477389
18	What-If Grades	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.	Learner IT support	0.553507
19	Rubrics	Canvas shall provide Rubrics to set up custom or Outcome-based assessment criteria for scoring.	Instructors IT support	0.464301
20	SpeedGrader	SpeedGrader in Canvas shall allow instructors to view and grade student assignment submissions in one place using a simple point scale or complex rubric.	Instructors IT support	0.460397

(Continued)

Continuation of Table C.1

#	Requirement Name	Description	Assigned Group	Sustainability
21	Course Settings	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.	Instructors IT support	0.376019
22	Modules	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.	Instructors IT support	0.428617
23	Files	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.	Instructors Learner IT support	0.503684
24	Rich Content Editor	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.	Instructors Learner IT support	0.432002
25	Profile and User Settings	Profile and User Settings in Canvas shall let users control their personal information.	Instructors Learner IT support	0.438155
26	ePortfolios	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.	Instructors Learner IT support	0.402836
27	Authentication	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.	Admins IT support	0.502108
28	Roles and Permissions	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).	Admins Instructors IT support	0.482754
29	Hierarchical structure for accounts	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.	Admins IT support	0.442438
30	Analytics	Canvas shall provide Analytics functionality to produce the evaluation of individual components, a course and student performance.	Admins Instructors IT support	0.51626
31	Mobile Features	Canvas shall allow users to access from any browser on Android and iOS device.	Instructors Learner IT support	0.455323
32	Integrations	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.).	Admins Instructors Learner IT support	0.493492
33	Course Import Tool	The Course Import Tool shall allow instructor to extract course content, assignments, and quizzes from previous terms and quickly import them into existing courses.	Instructors IT support	0.355907
34	Student Information Systems Imports	Canvas shall allow admins to import, export and/or create users, accounts, courses, and enrolments.	Admins Instructors IT support	0.508587

(Continued)

Continuation of Table C.1

#	Requirement Name	Description	Assigned Group	Sustainability
35	External Apps	Canvas shall allow admins and instructors to enable apps through the App Centre, which shall be integrated directly into Canvas.	Admins Instructors IT support	0.483955
36	MagicMarker app	MagicMarker in Canvas shall help instructor to organize students into small groups for assessment in the classroom.	Instructors IT suppor	0.428096
37	Polls for Canvas app	Polls in Canvas shall allow instructors to request student opinion in the classroom and collect responses with ease.	Instructors Learner IT support	0.54714
38	Arc	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.	Instructors Learner IT support	0.420134

The current timezone is: Australia/Melbourne : 10/10/2018 06:36:10 pm

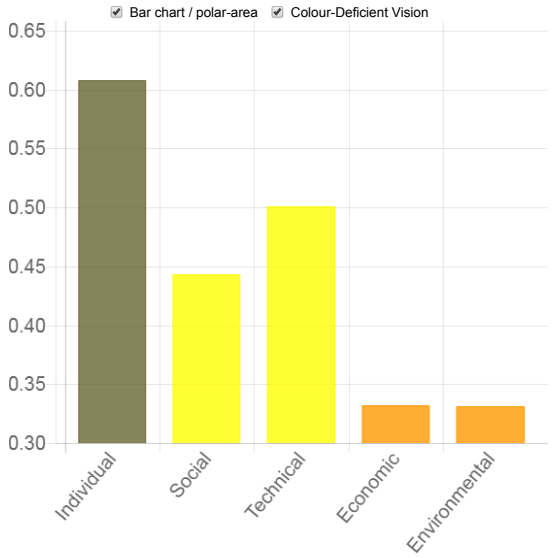
Canvas - RMIT profile:

1- Overall Sustainability:

3 Stars ★★★☆☆

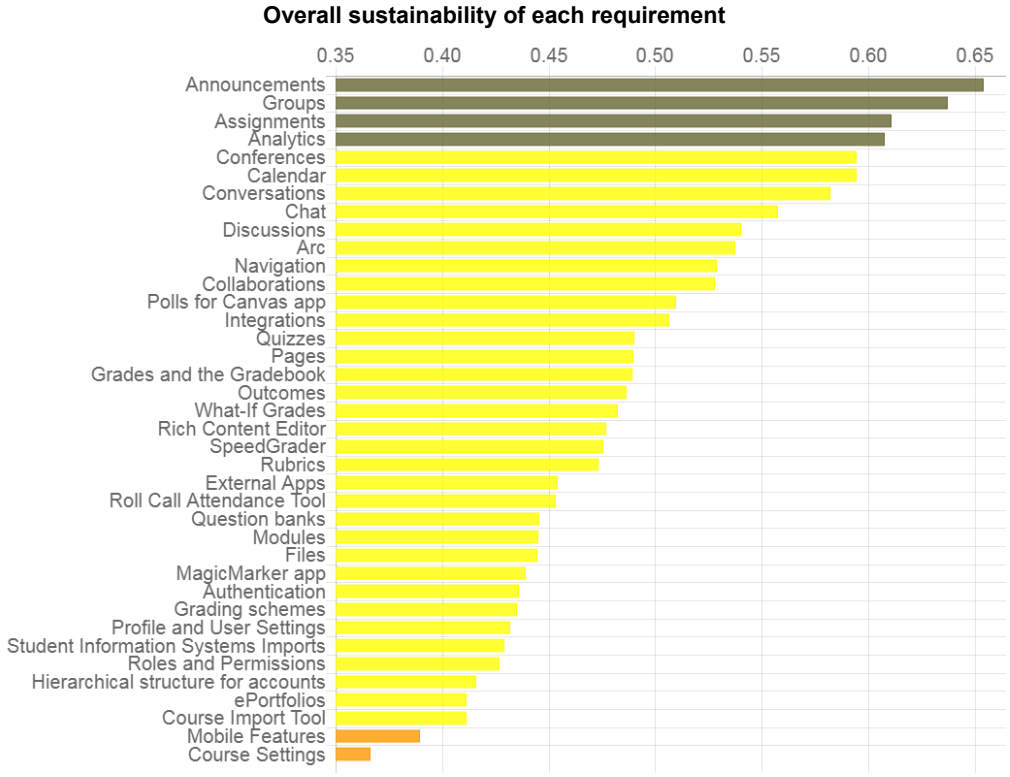
Rating of sustainability dimensions:

	Dimensions	Rate
	Individual dimension	0.608367
	Social dimension	0.44316
	Technical dimension	0.500632
	Economic dimension	0.331978
	Environmental dimension	0.331664



Key Charts

Percentage%	Colour Code	Description
80-100	Dark brown	Green (Vibrant)
60-79	Light brown	Satisfactory
40-59	Yellow	Basic
20-39	Orange	Unsatisfactory
0-19	blue	Critical



2- Requirement list

#	Requirement Name	Description	Group	Sustainability
1	**Announcements**	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.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.653561**
2	**Assignments**	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.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.610519**
3	**Calendar**	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.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.594229**
4	**Chat**	Canvas shall allow students and teachers to interact and communicate in real time.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.557077**

#	Requirement Name	Description	Group	Sustainability
5	**Collaborations**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.52757**
6	**Conferences**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.594289**
7	**Conversations**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.581955**
8	**Groups**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.636811**
9	**Discussions**	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).	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.539979**
10	**Pages**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.489472**
11	**Outcomes**	Outcomes in Canvas shall enable the administration and faculty to track students progress as measured by pedagogical goals or desired outcomes.	☑ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.486183**
12	**Roll Call Attendance Tool**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.453021**
13	**Navigation**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.528323**
14	**Quizzes**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.489581**

#	Requirement Name	Description	Group	Sustainability
15	**Question banks**	Questions banks in Canvas shall allow Account-level roles to create institutional or departmental question repositories.	☐ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.44508**
16	**Grades and the Gradebook**	The Gradebook in Canvas shall store all information about student progress in the course, measuring grades and course outcomes.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.488973**
17	**Grading schemes**	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.	☐ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.43454**
18	**What-If Grades**	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.	☑ Student ☐ Instructor ☑ Admin ☑ IT support/ developer	**0.482085**
19	**Rubrics**	Canvas shall provide Rubrics to set up custom or Outcome-based assessment criteria for scoring.	☐ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.472837**
20	**SpeedGrader**	SpeedGrader in Canvas shall allow instructors to view and grade student assignment submissions in one place using a simple point scale or complex rubric.	☐ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.475038**
21	**Course Settings**	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.	☐ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.366096**
22	**Modules**	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.	☐ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.444777**
23	**Files**	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.	☐ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.444393**
24	**Rich Content Editor**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.476673**

#	Requirement Name	Description	Group	Sustainability
25	**Profile and User Settings**	Profile and User Settings in Canvas shall let users control their personal information.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.431636**
26	**ePortfolios**	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.	☑ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.410954**
27	**Authentication**	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.	☐ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.435554**
28	**Roles and Permissions**	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).	☐ Student ☐ Instructor ☑ Admin ☑ IT support/ developer	**0.426534**
29	**Hierarchical structure for accounts**	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.	☐ Student ☐ Instructor ☑ Admin ☑ IT support/ developer	**0.415785**
30	**Analytics**	Canvas shall provide Analytics functionality to produce the evaluation of individual components, a course and student performance.	☐ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.607245**
31	**Mobile Features**	Canvas shall allow users to access from any browser on Android and iOS device.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.389086**
32	**Integrations**	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.).	☑ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.50601**
33	**Course Import Tool**	The Course Import Tool shall allow instructor to extract course content, assignments, and quizzes from previous terms and quickly import them into existing courses.	☐ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.410846**
34	**Student Information Systems Imports**	Canvas shall allow admins to import, export and/or create users, accounts, courses, and enrolments.	☐ Student ☐ Instructor ☑ Admin ☑ IT support/ developer	**0.428707**

#	Requirement Name	Description	Group	Sustainability
35	**External Apps**	Canvas shall allow admins and instructors to enable apps through the App Centre, which shall be integrated directly into Canvas.	☐ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.453915**
36	**MagicMarker app**	MagicMarker in Canvas shall help instructor to organize students into small groups for assessment in the classroom.	☐ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.438597**
37	**Polls for Canvas app**	Polls in Canvas shall allow instructors to request student opinion in the classroom and collect responses with ease.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.509167**
38	**Arc**	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.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.537273**

3- Stakeholders

Stakeholders	Submitted	In progress	Not started
46	46	0	**0**

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

#	Requirement Name	Description	Assigned Group	Sustainability
1	News	News in D2L shall allow instructors to broadcast information out to an entire class.	Learner Instructor IT support	0.650925
2	Calendar	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.	Learner Instructor IT support	0.608868
3	Chat	D2L shall allow students and teachers to interact and communicate in real time.	Learner Instructor IT support	0.603911
4	Dropbox	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.	Learner Instructor IT support	0.593502
5	Virtual Classrooms	D2L shall provide Virtual Classrooms for virtual lectures, sharing screen, and white board.	Learner Instructor IT support	0.614835
6	Email	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.	Learner Instructor IT support	0.584962
7	Groups	D2L shall allow to set up areas for groups to submit assignments, have discussion areas, and private locker specifically for members of these Groups.	Learner Instructor IT support	0.533592
8	Discussions	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).	Learner Instructor IT support	0.614396
9	Course Layout	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.	Instructor Admin IT support	0.406468
10	Class Progress	Class Progress in D2L shall enable the administration and faculty to track students' progress as measured by pedagogical objective, grades, logins or content.	Instructor Admin IT support	0.409156
11	Attendance	Attendance in D2L shall allow taking attendance in courses. D2L shall provide the Attendance for online or face-to-face courses.	Instructor Admin IT support	0.465359
12	Navigation	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.	Learner Instructor Admin IT support	0.459255
13	Quizzes	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.	Learner Instructor IT support	0.584821
14	Question Library	Questions Library in D2L shall allow Account-level roles to create institutional or departmental question repositories.	Instructor Admin IT support	0.465321

(Continued)

Continuation of Table C.2

#	Requirement Name	Description	Assigned Group	Sustainability
15	Grade book	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.	Learner Instructor IT support	0.613126
16	Grading system	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	Instructor Admin IT support	0.531859
17	Grading Schemes	D2L shall provide a grading scheme to set criteria for measuring varying levels of achievement in a course.	Instructor Admin IT support	0.542706
18	Surveys	Surveys in D2L shall allow instructors to create and administer online surveys.	Instructor IT support	0.540764
19	Rubrics	D2L shall provide Rubrics to set up custom or objective-based assessment criteria for scoring.	Instructor IT support	0.58701
20	Assignment Grader app	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.	Instructor IT support	0.594956
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.	Instructor IT support	0.547762
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.	Instructor Admin IT support	0.528675
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.	Instructor IT support	0.50945
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.	Learner Instructor IT support	0.514633
25	Profile and User Settings	Profile and User Settings in D2L shall let users control their personal information.	Learner Instructor IT support	0.535382
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.	Learner Instructor IT support	0.497119
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.	Instructor Admin IT support	0.376276
28	Roles and Permissions	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.	Admin IT support	0.464462
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.	Admin IT support	0.420019
30	Analytics	D2L shall provide analytics functionality to produce the evaluation of individual components, completion rates, course, program and student performance.	Instructor Admin IT support	0.581382

(Continued)

Continuation of Table C.2

#	Requirement Name	Description	Assigned Group	Sustainability
31	Mobile Features	D2L shall allow users to access from any browser on Android and iOS device.	Learner Instructor IT support	0.602226
32	Integrations	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.).	Learner Instructor Admin IT support	0.56076
33	Importing course components	The importing course components shall allow instructors to extract course content, assignments, and quizzes from previous terms and quickly import them into existing courses.	Instructor Admin IT support	0.395206
34	Student Information Systems Imports	D2L shall allow admins to import, export and create users, accounts, courses, and enrolments.	Learner Instructor Admin IT support	0.507362
35	Blog	Blog tool in D2L shall allow user to post and respond to questions, engage in discussions, and share opinions and comments with other users	Learner Instructor IT support	0.619709
36	Binder app	Binder in D2L shall allow student and instructor to view, annotate and organise their documents from anywhere.	Learner Instructor IT support	0.580759

The current timezone is: Australia/Melbourne : 10/10/2018 06:36:41 pm

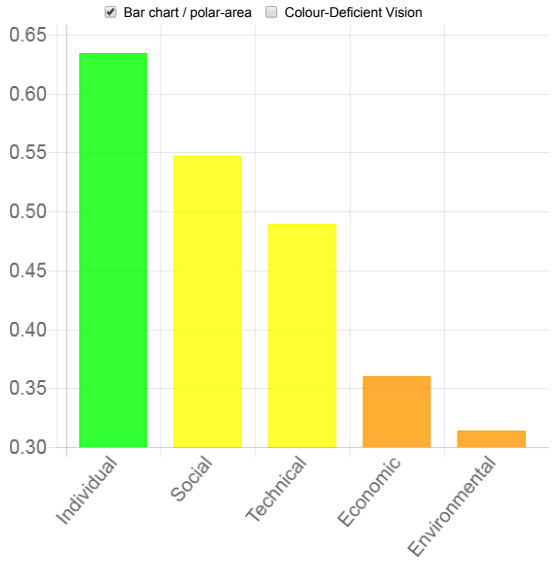
Desir2Learn (D2L) -UQU profile:

1- Overall Sustainability:

3 Stars ★★★☆☆

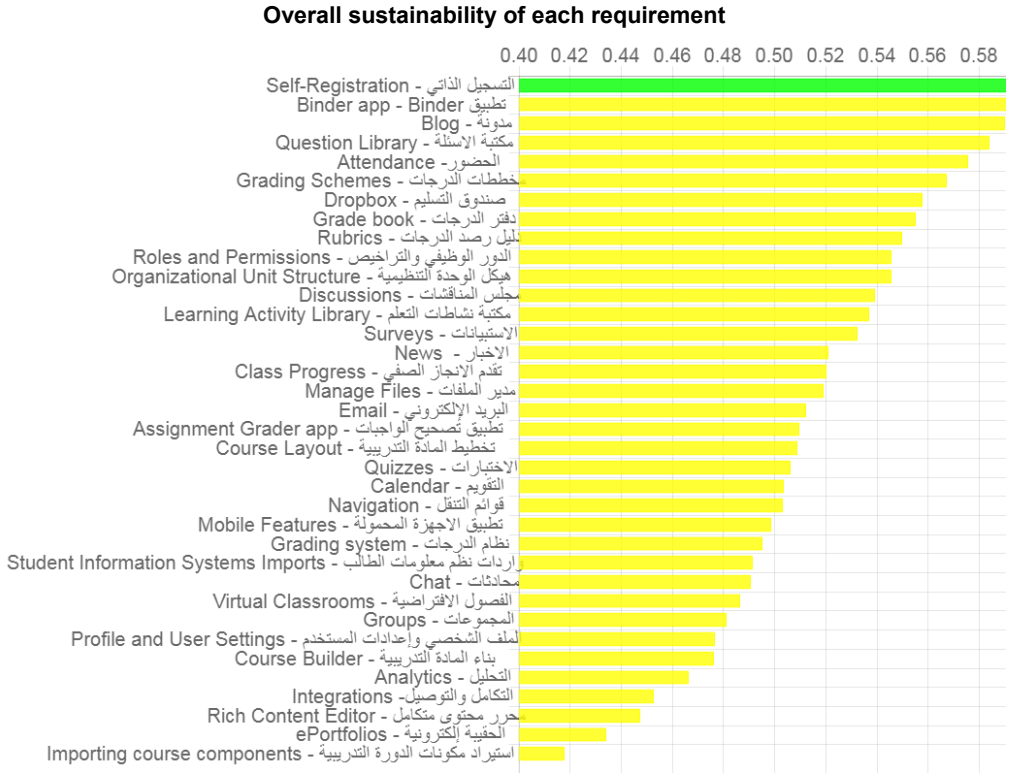
Rating of sustainability dimensions:

	Dimensions	Rate
	Individual dimension	0.634079
	Social dimension	0.546945
	Technical dimension	0.489619
	Economic dimension	0.359917
	Environmental dimension	0.31414



Key Charts

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



2- Requirement list

#	Requirement Name	Description	Group	Sustainability
1	**News - الاخبار**	News in D2L shall allow instructors to broadcast information out to an entire class. يجب أن تسمح الأخبار في التعليم الإلكتروني للمدربين ببث المعلومات إلى فئة كاملة.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.520927**
2	**Calendar - التقويم**	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. يجب أن يكون التقويم في التعليم الإلكتروني يسمح للمستخدمين رؤية جميع الواجبات والأحداث في مكان واحد. تتم تصنيف التقويم عن طريق تحديد أو إلغاء تحديد المقرر التدريبية في الشريط الجانبي.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.50317**
3	**Chat - محادثات**	D2L shall allow students and teachers to interact and communicate in real time. التعليم الإلكتروني يجب ان يسمح للطلاب والمعلمين للتفاعل والتواصل في الوقت الحقيقي.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.490526**

#	Requirement Name	Description	Group	Sustainability
4	**Dropbox - صندوق التسليم**	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. التعليم الإلكتروني يجب ان يسمح للطلاب لتقديم الواجبات من خلال تحميل الوثائق إلى مجلد صندوق التسليم المناسب. في حين أن المعلم يجب إنشاء فئات لتجميع وتنظيم مجلدات صندوق التسليم التي قد تقييد الوصول حسب التاريخ والوقت، عضوية المجموعة، أو الوصول الخاصة.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.557709**
5	**Virtual Classrooms - الفصول الافتراضية**	D2L shall provide Virtual Classrooms for virtual lectures, sharing screen, and white board. يجب على التعليم الإلكتروني توفير الفصول الافتراضية للمحاضرات ، وشاشة المشاركة، و السبورة.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.486143**
6	**Email - البريد الإلكتروني**	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. البريد الإلكتروني في نظام تعلم يسمح أداة الرسائل الداخلية المستخدمة بدلا من البريد الإلكتروني للتواصل اعضاء المقرر التدريبي، مجموعة، طالب ، أو مجموعة من الطلاب.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.51225**
7	**Groups - المجموعات**	D2L shall allow to set up areas for groups to submit assignments, have discussion areas, and private locker specifically for members of these Groups. التعليم الإلكتروني يجب ان يسمح بإنشاء مناطق خاصة للمجموعات لتقديم الواجبات، ومجالات المناقشة، ومجلد خاص مخصص لأعضاء هذه المجموعات.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.481093**
8	**Discussions - مجلس المناقشات**	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). مجلس المناقشات في التعليم الإلكتروني تسمح للمستخدمين التواصل التفاعلي بين شخصين أو أكثر. تسمح المناقشات للمستخدمين بالمشاركة في محادثة مع فئة أو مجموعة كاملة. يتم إنشاء المناقشات كحالة لأغراض التقيم (وتتكامل بسلاسة مع دفتر الدرجات في النظام).	**Student** **Instructor** **Admin** **IT support/ developer**	**0.538938**
9	**Course Layout - تخطيط المادة التدريبية**	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. يجب أن يسمح تخطيط المادة وتخصيص قائمة تنقل و الصفحة الرئيسية. يجب أن يحتوي شريط التنقل على روابط مثل المحتوى والدرجات بينما يمكن للصفحة الرئيسية أن تعرض العديد من الأدوات المختلفة معا، مثل الأخبار والمحتوى والتقويم.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.508773**
10	**Class Progress - تقدم الانجاز الصفي**	Class Progress in D2L shall enable the administration and faculty to track students' progress as measured by pedagogical objective, grades, logins or content. يجب اظهار التقدم الانجاز الصفي في التعليم الإلكتروني وتمكين الإدارة وأعضاء هيئة التدريس لمتابعة تقدم الطلاب من خلال قياس الاهداف التربوية والدرجات وعمليات تسجيل الدخول أو المحتوى.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.519936**
11	**Attendance -الحضور**	Attendance in D2L shall allow taking attendance in courses. D2L shall provide the Attendance for online or face-to-face courses. يجب متابعة الحضور في التعليم الإلكتروني وتسمح أخذ الحضور في الدورات ويمكن متابعة الحضور للدورات على شبكة الإنترنت أو وجها لوجه.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.57533**

#	Requirement Name	Description	Group	Sustainability
12	**Navigation - قوائم التنقل**	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. التعليم الإلكتروني يجب ان يوفر قائمة تنقل عامة (عام) قائمة للمقرر (خاص). العام تسمح للمستخدمين التبديل بين المقررات، والقائمة الشخصية مع وصلات إلى ملف التعريف، والإشعارات، وإعدادات الحساب، والتقدم. يجب أن يكون الشريط التنقل الخاص والصفحة الرئيسية لمقرر بما في ذلك محتويات المقرر ذات الصلة مثل وجود الأخبار، المنهج، المناقشات، مسابقات، أو أدوات اخرى.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.502819**
13	**Quizzes - الاختبارات**	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. تقوم أداة الاختبارات في التعليم الإلكتروني بالسماح للمدربين لإنشاء وإدارة الاختبارات على الانترنت. التعليم الإلكتروني يقدم الاختبارات لإجراء الامتحانات والتقييمات، سواء بدرجات أو بدون درجات.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.506062**
14	**Question Library - مكتبة الاسئلة**	Questions Library in D2L shall allow Account-level roles to create institutional or departmental question repositories. مكتبة الأسئلة في التعليم الإلكتروني يسمح الأدوار على مستوى الحساب لإنشاء مكتبات أسئلة على المستوى المؤسسية التعليمية أو الإدارات .	**Student** **Instructor** **Admin** **IT support/ developer**	**0.583901**
15	**Grade book - دفتر الدرجات**	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. دفتر الدرجات في التعليم الإلكتروني يوفر نظام الدرجات، وحساب درجات المقرر، مخطط درجات المقرر، وعرض وخيارات العرض. ويسمح دفتر الدرجات للطلاب لإظهار كافة الواجبات المستقبلية وتوزيع الدرجات.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.554914**
16	**Grading system - نظام الدرجات**	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 يحدد نظام الدرجات كيف تساهم درجات المقرر في الصفوف الدراسية وفي الدرجات النهائية للطالب. يجب أن يشتمل نظام الدرجات على نظام النسبة المئوية، نقاط، وصيغة معادلة	**Student** **Instructor** **Admin** **IT support/ developer**	**0.495104**
17	**Grading Schemes - مخططات الدرجات**	D2L shall provide a grading scheme to set criteria for measuring varying levels of achievement in a course. يجب أن توفر التعليم الإلكتروني نظام الدرجات لوضع معايير لقياس مستويات متفاوتة من الإنجاز في مقرر. يجب أن يتم بناء مخططات الدرجات استنادا إلى النطاقات المئوية، ويتم تعيين اسم لكل قيمة ونطاق مئوي.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.567044**
18	**Surveys - الاستبيانات**	Surveys in D2L shall allow instructors to create and administer online surveys. الاستطلاعات في التعليم الإلكتروني يسمح للمدربين لإنشاء وإدارة الدراسات الاستبيانات على الإنترنت.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.532029**
19	**Rubrics - دليل رصد الدرجات**	D2L shall provide Rubrics to set up custom or objective-based assessment criteria for scoring. يجب أن توفر التعليم الإلكتروني خاصية لوضع قواعد التقييم من خلال معايير تقييم مخصصة أو موضوعية لتسجيل النقاط والدرجات.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.549669**
20	**Assignment Grader app - تطبيق تصحيح الواجبات**	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. يجب على تطبيق تصحيح الوجبات في التعليم الإلكتروني أن يسمح لأعضاء هيئة التدريس لعرض وتصنيف الوجبات المسلمة واختيار الطالب في مكان واحد بوضع الدرجات أو من خلال استخدام خاصية دليل رصد الدرجات.	**Student** **Instructor** **Admin** **IT support/ developer**	**0.509498**

#	Requirement Name	Description	Group	Sustainability
21	**Learning Activity Library - مكتبة نشاطات التعلم**	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. مكتبة نشاطات التعلم في التعليم الإلكتروني يسمح بعرض أو تفعيل أو إلغاء التفعيل وإضافة إلى وصف النشاط في "معالج التصميم التعليمي" عن طريق إنشاء اهداف المقرر و النشاط المخصص	☐ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.536788**
22	**Course Builder - بناء المادة التدريبية**	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. يجب على التعليم الإلكتروني توفير وحدات تعليمية لتنظيم محتوى المقرر بأسابيع أو وحدات أو بشكل تنظيمية مختلفة. يجب أن تحتوي كل وحدة في التعليم الإلكتروني على ملفات ومناقشات واجبات واختبارات ومواد تعليمية أخرى.	☐ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.475953**
23	**Manage Files - مدير الملفات**	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. إدارة الملفات في التعليم الإلكتروني يجب أن يحتوي على ملفات المقرر، الواجبات، المحتوى الدراسية أو غيرها من الوثائق، أيضا الصور الشخصية والملفات الخاصة بالمستخدم. التعليم الإلكتروني يسمح لاعضاء هيئة التدريس لغلق المجلدات والملفات بحيث لا ينظر اليه إلا من خلال وصلات مباشرة أو فتحه فقط في تاريخ محدد.	☐ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.518723**
24	**Rich Content Editor - محرر محتوى متكامل**	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. يجب أن توفر التعليم الإلكتروني محرر المحتوى مع الميزات التي تدعم التحرير النصي (أخبار، الواجبات، مناقشات، الاختبارات). وسيتم دمجها مع محرر مستندات جوجل ومايكروسوفت أوفيس.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.447157**
25	**Profile and User Settings - الملف الشخصي وإعدادات المستخدم**	Profile and User Settings in D2L shall let users control their personal information. الملف الشخصي وإعدادات المستخدم في التعليم الإلكتروني يسمح للمستخدمين التحكم في المعلومات الشخصية الخاصة بهم.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.476575**
26	**ePortfolios - الحقيبة إلكترونية**	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. المستخدمين في التعليم الإلكتروني يمكنهم بناء عدد غير محدود من الحقائب الإلكترونية لجمع وتوثيق مشاريعهم التعليمية، والتقارير، والخبرات، وغيرها من منتجات العمل. السماح للمستخدمين بالاحتفاظ بالحقائب الخاصة أو المشاركة مع الطلاب الآخرين، أعضاء هيئة التدريس، واصحاب العمل في المستقبل.	☑ Student ☑ Instructor ☐ Admin ☑ IT support/ developer	**0.434032**
27	**Self-Registration - التسجيل الذاتي**	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. يسمح التسجيل الذاتي في التعليم الإلكتروني للمستخدمين بتسجيل أنفسهم في الدورات التي تم تتمتع بميزة التسجيل الذاتي، ولكن سيتم تعطيل التسجيل الذاتي بشكل افتراضي في المقررات.	☐ Student ☑ Instructor ☑ Admin ☑ IT support/ developer	**0.609854**
28	**Roles and Permissions - الدور الوظيفي والتراخيص**	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. يجب أن تتضمن الأدوار على مستوى المقرر للمستخدمين الذين لديهم تصريح لدخول المقرر. يجب أن تشمل الأدوار على مستوى الحساب تصاريح التي يجب أن تؤثر على الحساب بأكمله وكذلك المقررات. يجب أن توفر التعليم الإلكتروني أربعة أدوار وظيفية أساسية تتضمن كل منها مجموعة من التصاريح بشكل افتراضية مثل الطلاب وأعضاء هيئة التدريس ومساعد التدريس وأمين القسم.	☐ Student ☐ Instructor ☑ Admin ☑ IT support/ developer	**0.545384**

#	Requirement Name	Description	Group	Sustainability
29	**Organizational Unit Structure - هيكل الوحدة التنظيمية**	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. يجب أن تتضمن الحسابات في التعليم الإلكتروني ستة أنواع الوحدات التنظيمية الافتراضية: الفصل الدراسي، الإدارة، نموذج المقرر، المقرر التدريبية، المجموعة، والقسم، والتي ستضاف يدويا، عبر استيراده من نظم معلومات الطالب.	Student Instructor Admin IT support/ developer	**0.545297**
30	**Analytics - التحليل**	D2L shall provide analytics functionality to produce the evaluation of individual components, completion rates, course, program and student performance. التعليم الإلكتروني يوفر وظائف تحليلية لإنتاج وتقييم المكونات الفردية، ومعدلات الانتهاء من الواجبات والاختبارات، المقرر، وتقيم المنهج والطلاب.	Student Instructor Admin IT support/ developer	**0.466342**
31	**Mobile Features - تطبيق الاجهزة المحمولة**	D2L shall allow users to access from any browser on Android and iOS device. يسمح التعليم الإلكتروني للمستخدمين بالوصول من أي متصفح أو تطبيق على جهاز Android أوiOS.	Student Instructor Admin IT support/ developer	**0.498376**
32	**Integrations -التكامل والتوصيل**	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.). يجب أن توفر التعليم الإلكتروني عمليات تكاملية اختيارية مع مجموعة متنوعة من موفري الخدمات الخارجية: خدمات ويب (Twitter, LinkedIn)، التعاون (برنامج Adobe Connect، مايكروسوفت أوفيس 365، الخ) تعليمية (Turnitin، Wimba، الخ)، والوسائط المتعددة (Equella، Kaltura، وما إلى ذلك)، والتقويم (Google, Outlook، الخ).	Student Instructor Admin IT support/ developer	**0.452653**
33	**Importing course components - استيراد مكونات الدورة التدريبية**	The importing course components shall allow instructors to extract course content, assignments, and quizzes from previous terms and quickly import them into existing courses. يجب أن تسمح مكونات المقرر التدريبية أعضاء هيئة التدريس باستخراج محتوى المقرر، والواجبات، والاختبارات من المقررات السابقة، واستيرادها بسرعة إلى مقررات تدريبية مستحدثة.	Student Instructor Admin IT support/ developer	**0.417786**
34	**Student Information Systems Imports - واردات نظم معلومات الطالب**	D2L shall allow admins to import, export and create users, accounts, courses, and enrolments. يجب أن تسمح التعليم الإلكتروني للمشرفين باستيراد وتصدير وحساب المستخدمين والحسابات والمقررات وتسجيل المقررات.	Student Instructor Admin IT support/ developer	**0.491317**
35	**Blog - مدونة**	Blog tool in D2L shall allow user to post and respond to questions, engage in discussions, and share opinions and comments with other users المدونة في التعليم الإلكتروني تسمح للمستخدم للنشر والرد على الأسئلة، والمشاركة في المناقشات، وتبادل الآراء والتعليقات مع المستخدمين الآخرين	Student Instructor Admin IT support/ developer	**0.590016**
36	**Binder app - Binder تطبيق**	Binder in D2L shall allow student and instructor to view, annotate and organise their documents from anywhere. Binder في التعليم الإلكتروني يسمح للطالب وأعضاء هيئة التدريس لعرض، وكتابة تعليق وتنظيم وثائقهم من أي مكان.	Student Instructor Admin IT support/ developer	**0.594171**

3- Stakeholders

Stakeholders	Submitted	In progress	Not started
79	79	0	**0**

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

#	Requirement Name	Description	Assigned Group	Sustainability
1	Login system	The SCIS shall provide system access having suitable security services. This access will have various levels that depend on user authorization.	Physician Nurse Receptionist Administrator and manager IT support and developer	0.618686
2	Create new record	The SCIS shall provide physicians and nurses with the ability to create a new record for patients for the first time.	Physician Nurse IT support and developer	0.495698
3	Create new problems	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.	Physician Nurse IT support and developer	0.611013
4	Create visit	The SCIS shall enable physicians and nurses to record each visit that may have various problems and different procedures.	Physician Nurse IT support and developer	0.55784
5	Edit record	The SCIS shall enable physicians and nurses to edit records by updating or adding more information.	Physician Nurse IT support and developer	0.542436
6	Insert procedure	The SCIS shall enable physicians and nurses to select appropriate procedures for one problem or more than one.	Physician Nurse IT support and developer	0.410874
7	Finalise procedure	The SCIS shall enable physicians and nurses to complete record and finalise the procedure.	Physician Nurse IT support and developer	0.613918
8	Access patients' record	The SCIS shall enable physicians and nurses to view record and previous problems with their procedures and any previous history that was recorded.	Physician Nurse IT support and developer	0.473612
9	Allocate pathology report to procedure	The SCIS shall enable physicians and nurses to allocate any pathology report to its procedure in a patients' record.	Physician Nurse IT support and developer	0.406329
10	Upload documents and image	The SCIS shall enable physicians and nurses to upload documents and images to a patients' record.	Physician Nurse IT support and developer	0.489118
11	Generate and print form	The SCIS shall enable physicians and nurses to generate forms such as, taking a test and printing it.	Physician Nurse IT support and developer	0.432951
12	Generate bill	The SCIS shall enable physicians and nurses to generate bills and print them.	Receptionist Administrator and manager IT support and developer	0.525928

(Continued)

Continuation of Table A.1

#	Requirement Name	Description	Assigned Group	Sustainability
13	Hold or un-hold bill	The SCIS shall enable physicians and nurses to hold bills until the result appear, then un-hold them to continue the process.	Physician Receptionist Administrator and manager IT support and developer	0.467628
14	Print bill	The SCIS shall enable physicians, nurses and receptionist to print bills.	Nurse Receptionist Administrator and manager IT support and developer	0.418866
15	Create patients' information	The SCIS shall enable physicians, nurses and receptionist to create patients' information.	Physician Nurse Receptionist Administrator and manager IT support and developer	0.638787
16	Edit patients' details	The SCIS shall enable physicians, nurses and receptionist to update patients' information.	Physician Nurse Receptionist Administrator and manager IT support and developer	0.624384
17	Search feature	The SCIS shall enable all users who have authorisation to look at different information via a search feature, including patient and staff information.	Physician Nurse Receptionist Administrator and manager IT support and developer	0.49455
18	Generate and print Financial and business reports	The SCIS shall enable administrators and managers to print various reports.	Administrator and manager IT support and developer	0.565542
19	Generate and print Financial and business reports	The SCIS shall enable administrators and managers to print various reports.	Administrator and manager IT support and developer	0.487618
20	Create new staff account	The SCIS shall enable administrators and managers to create new staff account and enter their details.	Administrator and manager IT support and developer	0.5329
21	Edit staff's details	The SCIS shall enable administrators and managers to update staff details.	Administrator and manager IT support and developer	0.532949
22	Administrator Manage role	The SCIS shall enable administrators to locate staff authorization	Administrator and manager IT support and developer	0.552101
23	Create centre's information	The shall enable administrators to establish the centre's information and entering important details such as connecting details.	Administrator and manager IT support and developer	0.430374

The current timezone is: Australia/Melbourne : 10/10/2018 07:13:59 pm

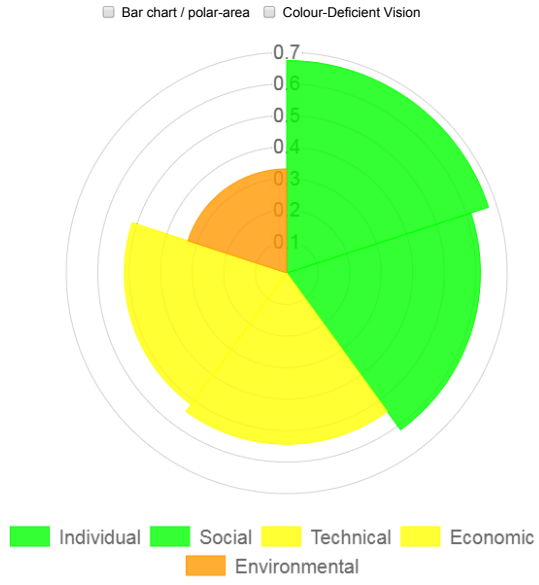
SCIS - Skin Cancer Information System profile:

1- Overall Sustainability:

3 Stars ★★★☆☆

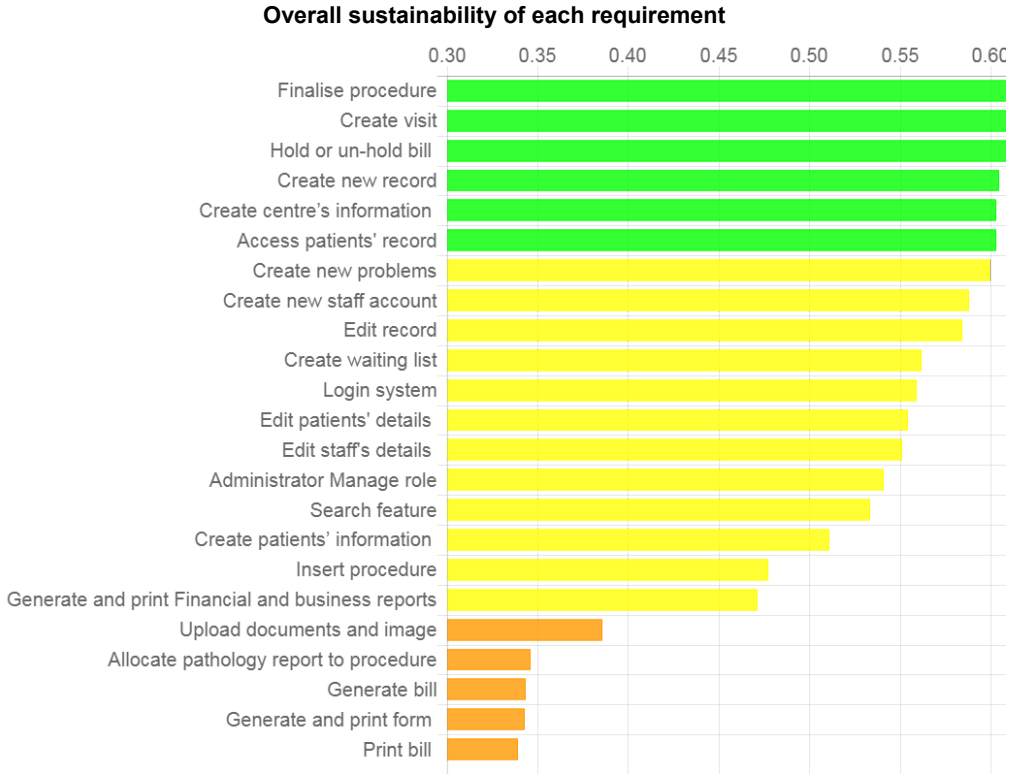
Rating of sustainability dimensions:

	Dimensions	Rate
	Individual dimension	0.673737
	Social dimension	0.614824
	Technical dimension	0.543264
	Economic dimension	0.515676
	Environmental dimension	0.329999



Key Charts

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



2- Requirement list

#	Requirement Name	Description	Group	Sustainability
1	**Login system**	The SCIS shall provide system access having suitable security services. This access will have various levels that depend on user authorization	**Physician** **Nurse** **Receptionist** **Administrator and Manager** **Developer and IT Support**	**0.558696**
2	**Create new record**	The SCIS shall provide physicians and nurses with the ability to create a new record for patients for the first time	**Physician** **Nurse** **Receptionist** **Administrator and Manager** **Developer and IT Support**	**0.604063**

#	Requirement Name	Description	Group	Sustainability
3	**Create new problems**	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.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.599514**
4	**Create visit**	The SCIS shall enable physicians and nurses to record each visit that may have various problems and different procedures.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.624814**
5	**Edit record**	The SCIS shall enable physicians and nurses to edit records by updating or adding more information.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.583649**
6	**Insert procedure**	The SCIS shall enable physicians and nurses to select appropriate procedures for one problem or more than one.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.476776**
7	**Finalise procedure**	The SCIS shall enable physicians and nurses to complete record and finalise the procedure.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.636561**
8	**Access patients' record**	The SCIS shall enable physicians and nurses to view record and previous problems with their procedures and any previous history that was recorded.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.602394**
9	**Allocate pathology report to procedure**	The SCIS shall enable physicians and nurses to allocate any pathology report to its procedure in a patients' record.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.345824**

#	Requirement Name	Description	Group	Sustainability
10	**Upload documents and image**	The SCIS shall enable physicians and nurses to upload documents and images to a patients' record.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.385387**
11	**Generate and print form**	The SCIS shall enable physicians and nurses to generate forms such as, taking a test and printing it.	☑ Physician ☑ Nurse ☐ Receptionist ☐ Administrator and Manager ☑ Developer and IT Support	**0.34242**
12	**Generate bill**	The SCIS shall enable physicians and nurses to generate bills and print them.	☐ Physician ☐ Nurse ☑ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.343278**
13	**Hold or un-hold bill**	The SCIS shall enable physicians and nurses to hold bills until the result appear, then un-hold them to continue the process.	☑ Physician ☐ Nurse ☑ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.609793**
14	**Print bill**	The SCIS shall enable physicians, nurses and receptionist to print bills.	☐ Physician ☑ Nurse ☑ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.338953**
15	**Create patients' information**	The SCIS shall enable physicians, nurses and receptionist to create patients' information.	☑ Physician ☑ Nurse ☑ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.510435**

#	Requirement Name	Description	Group	Sustainability
16	**Edit patients' details**	The SCIS shall enable physicians, nurses and receptionist to update patients' information.	☑ Physician ☑ Nurse ☑ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.553727**
17	**Create waiting list**	The SCIS shall enable receptionists to create waiting lists and update them	☐ Physician ☐ Nurse ☑ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.561173**
18	**Search feature**	The SCIS shall enable all users who have authorisation to look at different information via a search feature, including patient and staff information.	☑ Physician ☑ Nurse ☑ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.533224**
19	**Generate and print Financial and business reports**	The SCIS shall enable administrators and managers to print various reports.	☐ Physician ☐ Nurse ☐ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.470714**
20	**Create new staff account**	The SCIS shall enable administrators and managers to create new staff account and enter their details.	☐ Physician ☐ Nurse ☐ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.587723**
21	**Edit staff's details**	The SCIS shall enable administrators and managers to update staff details.	☐ Physician ☐ Nurse ☐ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.550823**
22	**Administrator Manage role**	The SCIS shall enable administrators to locate staff authorization.	☐ Physician ☐ Nurse ☐ Receptionist ☑ Administrator and Manager ☑ Developer and IT Support	**0.540712**

#	Requirement Name	Description	Group	Sustainability
23	**Create centre's information**	The shall enable administrators to establish the centre's information and entering important details such as connecting details.	☐ **Physician** ☐ **Nurse** ☐ **Receptionist** ☑ **Administrator and Manager** ☑ **Developer and IT Support**	**0.602745**

3- Stakeholders

Stakeholders	Submitted	In progress	Not started
14	13	0	**1**

C.4 Screen shot of SuSoftPro tool-support

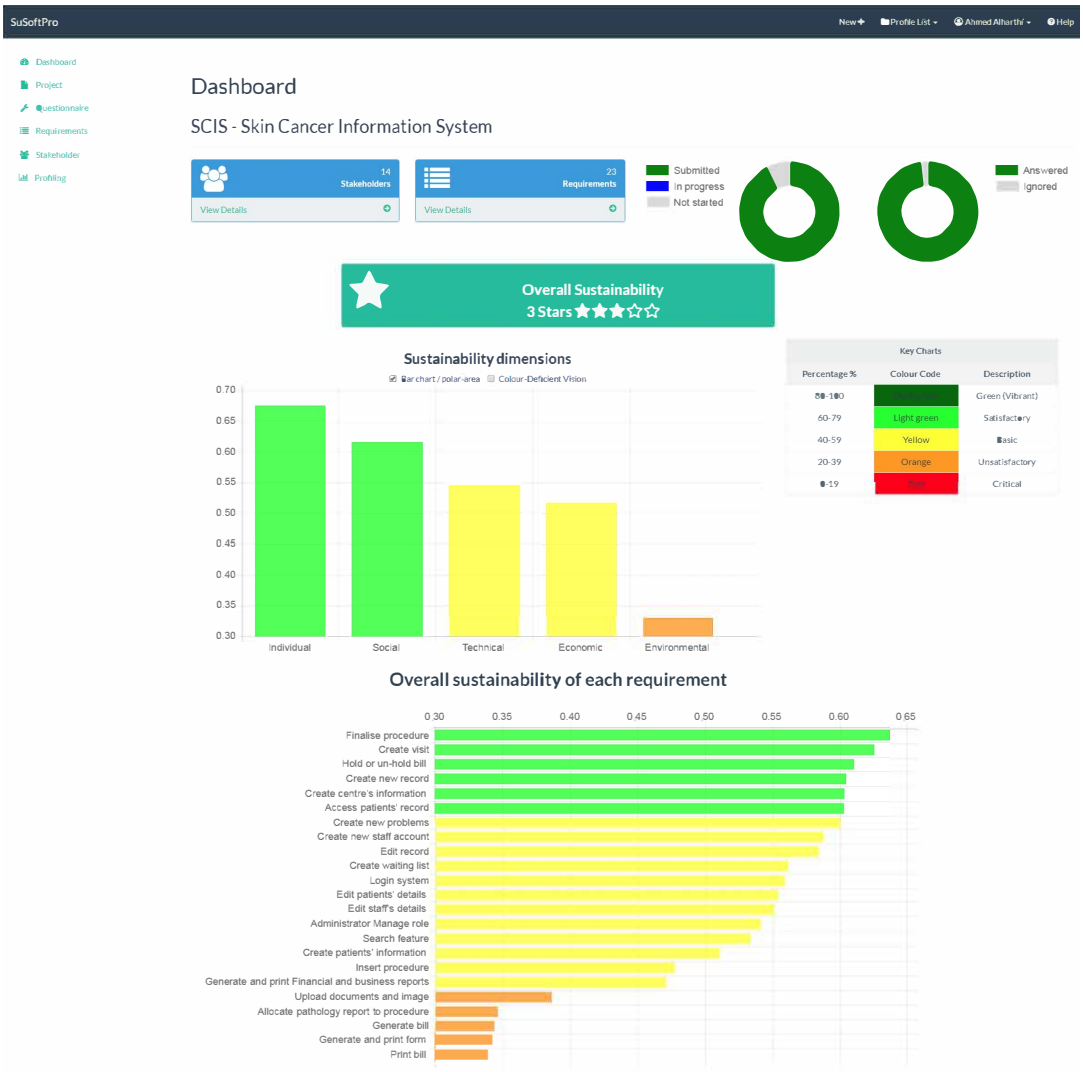


Figure C.1: SuSoftPro: Dashboard (Skin Cancer Information System Project)

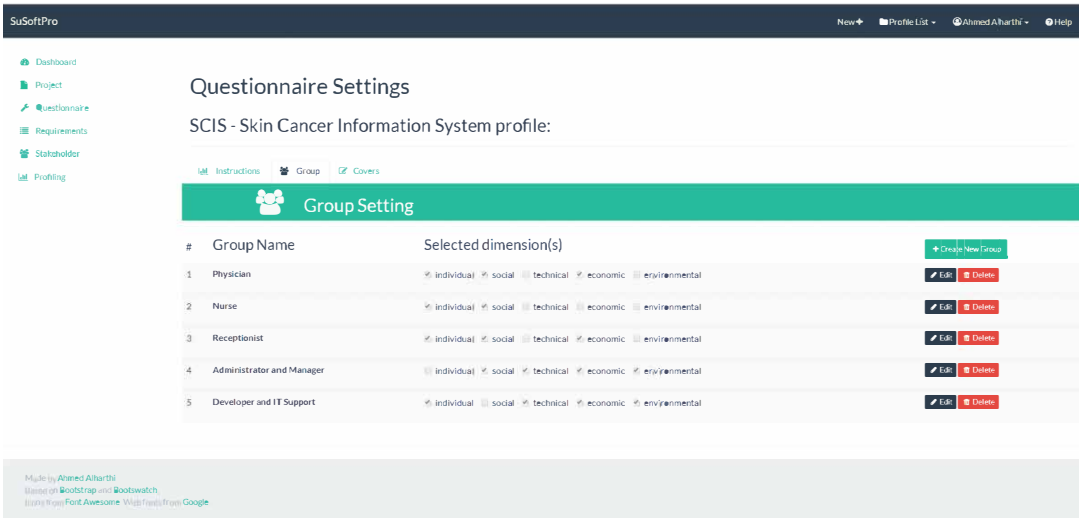


Figure C.2: SuSoftPro: Creating and assigning group to sustainability (Skin Cancer Information System Project)

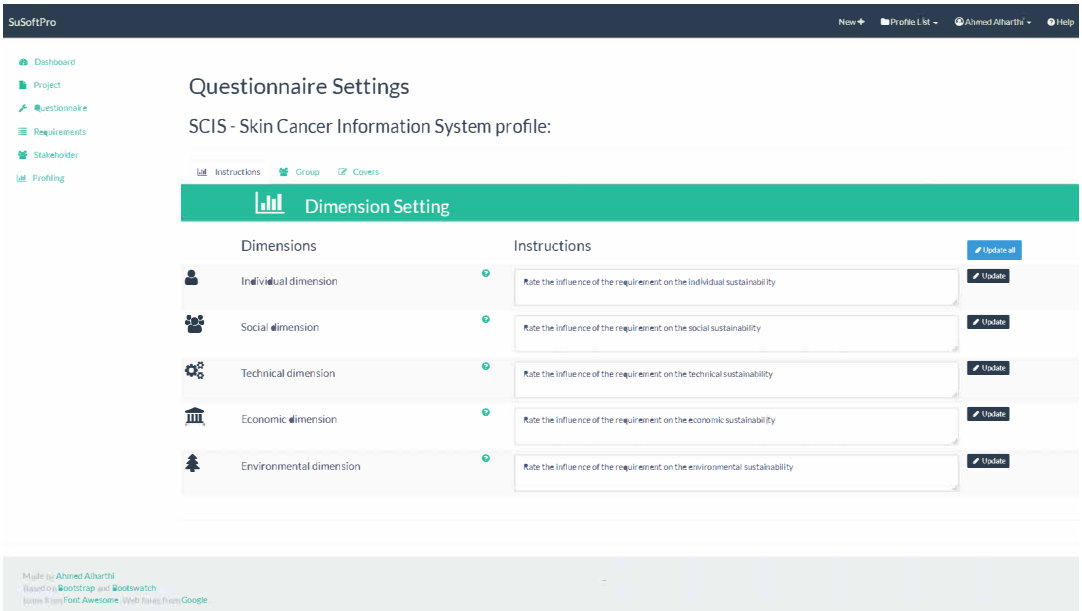


Figure C.3: SuSoftPro: Defining questions for each sustainability dimension (Skin Cancer Information System Project)

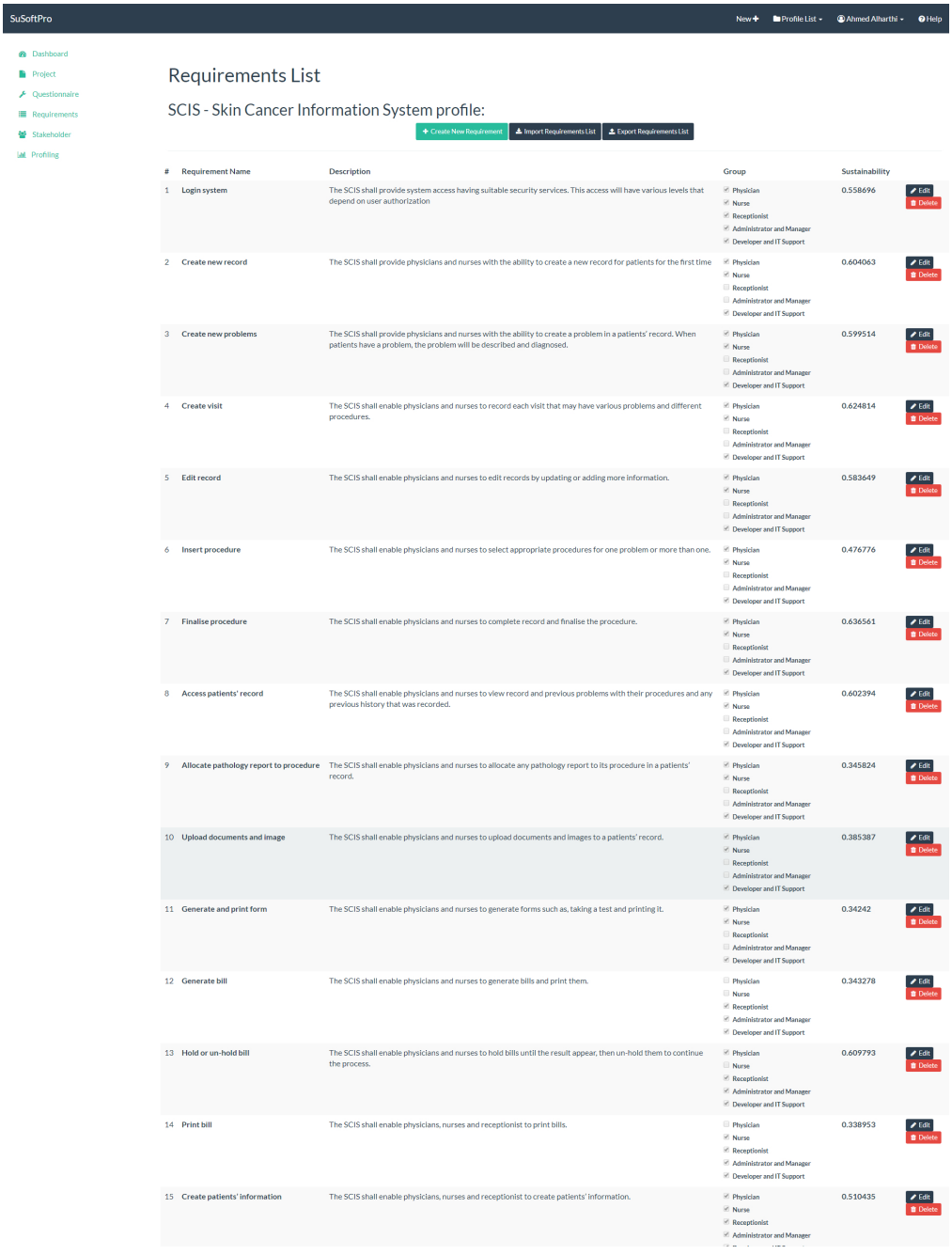


Figure C.4: SuSoftPro: Requirements management (Skin Cancer Information System Project)

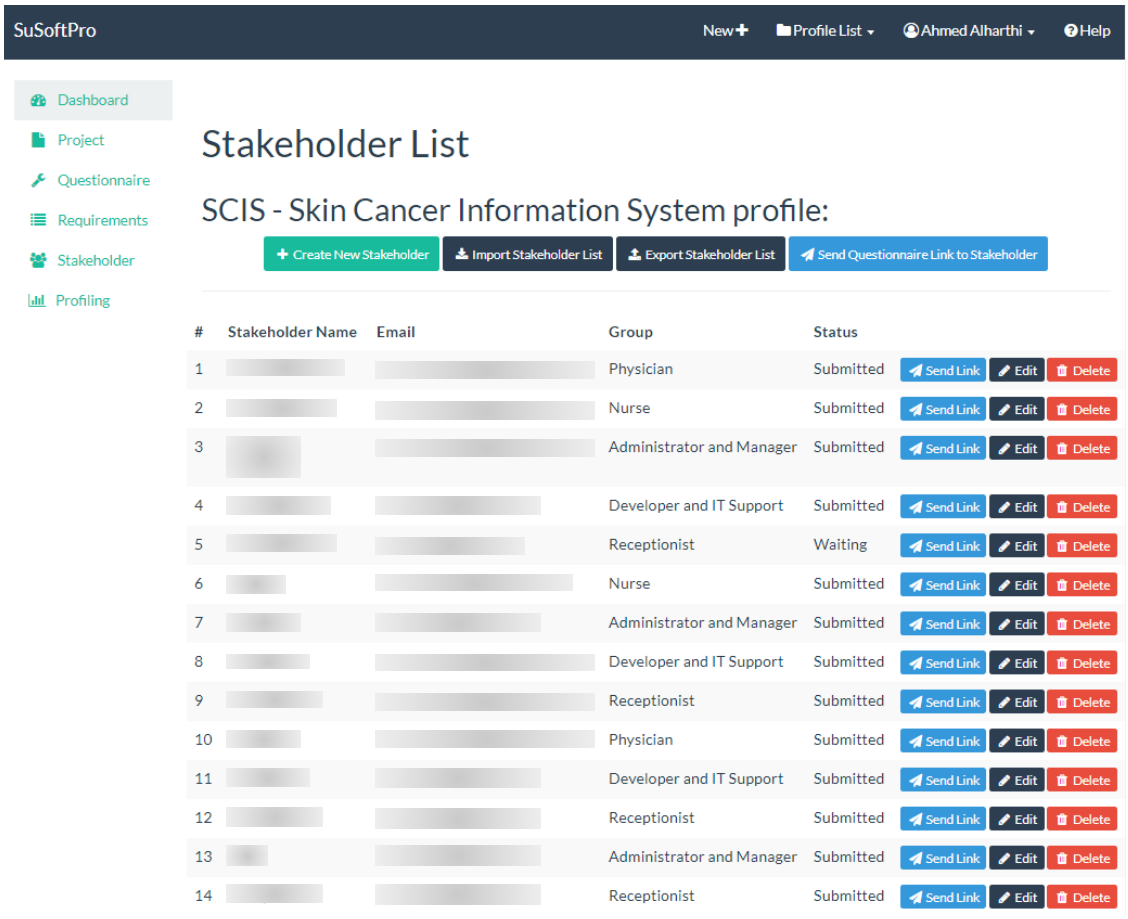


Figure C.5: SuSoftPro: Stakeholder management (example, the names and the email addresses are blacked-out)

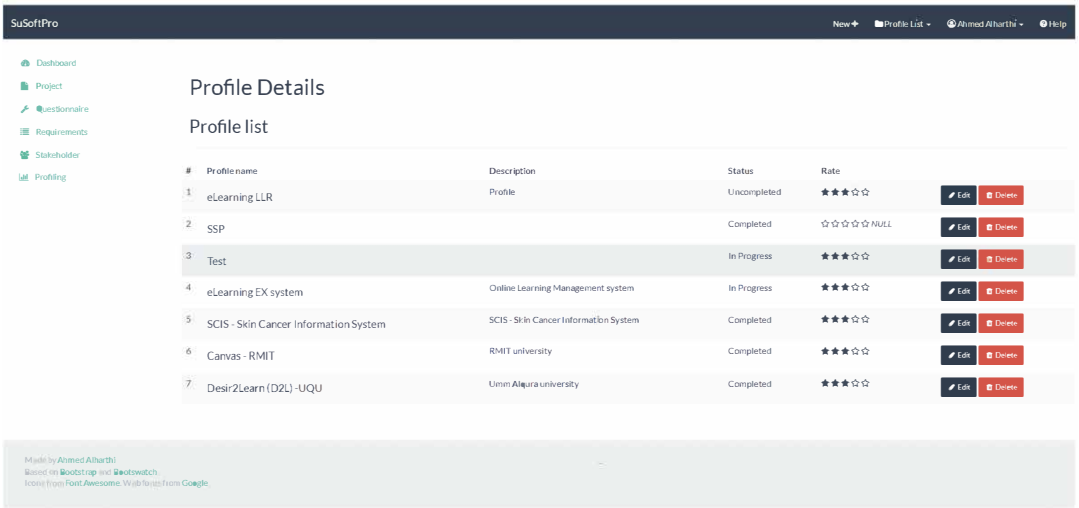


Figure C.6: SuSoftPro: Profile details


PERITA MANUS
MENS EXCULTA