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ENHANCING PROFESSIONAL COMPETENCIES OF SOFTWARE ENGINEERING STUDENTS IN A DEVELOPING COUNTRY CONTEXT:
A Design Science Approach

Maria Ndapewa Ntinda

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The originality of this publication has been checked in accordance with the University of Turku quality assurance system using the Turnitin OriginalityCheck service.

ISBN 978-952-02-0060-2 (PRINT)
ISBN 978-952-02-0061-9 (PDF)
ISSN 2736-9390 (Print)
ISSN 2736-9684 (Online)
Painosalama, Turku, Finland 2025

I dedicate my dissertation to my four nephews: Ntinda Julius Nangombe, Vilho Martin Kotokeni, Ntinda Nelson Namene, Tironenn Natangwe Vilho and my nieces, Mary Ndapewa Vilho and Mennesia Ntinda.

UNIVERSITY OF TURKU
Faculty of Technology
Department of Computing
Computer Science
MARIA NDAPEWA NTINDA: Enhancing Professional Competencies of Software Engineering Students in A Developing Country Context: A Design Science Approach
Doctoral Dissertation, 147 pp.
Doctoral Programme in Technology
February 2025

ABSTRACT

Technology advancement, the shift toward greener practices, and broader economic trends are causing significant changes in industries, leading to a fast-paced transformation of the global job market. As a result, universities are transitioning from traditional knowledge-based to competency-based learning paradigms to equip students to apply their education for societal benefit. However, many institutions in the Global South, including the University of Namibia, still follow the traditional knowledge-based approaches in computing programs. A growing consensus advocates for project-based learning, industry and academic collaboration, and integrating emerging technologies to enhance student engagement and preparedness for the workforce. This dissertation presents a conceptual model for a software engineering ecosystem to enhance student competencies in this region. Utilising the Design Science Research methodology, the study was conducted in two iterative phases. The first phase examined the potential for reshaping computing education through collaboration with the satellite campus of the University of Turku (Finland) in Namibia. The second phase concentrated on fostering partnerships with the local software engineering industry to enhance learning outcomes. Findings from this study show significant gaps in hard and soft skills among students, indicating a pressing need for competency-based learning that emphasises real-world problem-solving. The study highlights the need for a reformed curriculum that aligns with local industry requirements, enabling students to develop relevant applications. These insights are critical in addressing the high unemployment rates in Namibia, suggesting that a strategic plan focused on skills development is essential. The research advocates for establishing robust partnerships between universities and industries to ensure educational programs are tailored to meet the specific needs of key sectors within the country. Additionally, it emphasises the importance of integrating entrepreneurship skills into the curriculum to empower students to launch their startups. Future research directions include a focus on a new stream of practically oriented computing education research to experiment with new pedagogical innovation. In addition, exploring strategies for aligning the educational offerings at the University of Namibia with the Computing Curriculum 2020. This dissertation also recommends exploring how Namibian students can be prepared for the international space (offshoring).

KEYWORDS: Software Engineering Education, University-Industry collaboration, Competencies, Design Science Research, Employability, Global South, Design-Reality Gap

TURUN YLIOPISTO
Teknillinen tiedekunta
Tietojenkäsittelytieteiden laitos
Tietojenkäsittelytiede
MARIA NDAPEWA NTINDA: Ohjelmistotekniikan opiskelijoiden ammatillisten valmiuksien parantaminen kehitysmaaympäristössä: A Design Science Approach
Tohtorinväitöskirja, 147 s.
Tekniikan tohtoriohjelma
Helmikuu 2025

TIIVISTELMÄ

Teknologian kehitys, siirtyminen ympäristöystävällisempiin käytäntöihin ja laajemmat taloudelliset suuntaukset aiheuttavat merkittäviä muutoksia toimialoilla, mikä johtaa maailmanlaajuisten työmarkkinoiden nopeaan muutokseen. Tämän seurauksena yliopistot ovat siirtymässä perinteisestä tietoon perustuvasta oppimisesta osaamiseen perustuvaan oppimiseen, jotta opiskelijat voivat soveltaa koulutustaan yhteiskunnalliseen hyötyyn. Monet etelän laitokset, kuten Namibian yliopisto, noudattavat kuitenkin edelleen perinteistä tietopohjaista lähestymistapaa tietojenkäsittelyohjelmissa. Yhä useammat ovat sitä mieltä, että opiskelijoiden sitoutumista ja työelämävalmiuksia voidaan parantaa projektipohjaisella oppimisella, teollisuuden ja korkeakoulujen välisellä yhteistyöllä ja uusien teknologioiden integroinnilla. Tässä väitöskirjassa esitellään käsitteellinen malli ohjelmistotekniikan ekosysteemille, jolla parannetaan opiskelijoiden osaamista tällä alueella. Tutkimus toteutettiin kahdessa iteratiivisessa vaiheessa hyödyntäen suunnittelutieteellistä tutkimusmenetelmää. Ensimmäisessä vaiheessa tarkasteltiin mahdollisuuksia muokata tietojenkäsittelyn opetusta tekemällä yhteistyötä Turun yliopiston (Suomi) Namibiassa sijaitsevan satelliittikampuksen kanssa. Toisessa vaiheessa keskityttiin edistämään kumppanuuksia paikallisen ohjelmistotekniikkateollisuuden kanssa oppimistulosten parantamiseksi. Tutkimuksen tulokset osoittavat, että opiskelijoiden kovissa ja pehmeissä taidoissa on huomattavia puutteita, mikä osoittaa, että tarvitaan kipeästi osaamispohjaista oppimista, jossa korostetaan reaalimaailman ongelmanratkaisua. Tutkimuksessa korostetaan, että tarvitaan uudistettu opetussuunnitelma, joka vastaa paikallisen teollisuuden vaatimuksia, jotta opiskelijat voivat kehittää tarkoituksenmukaisia sovelluksia. Nämä havainnot ovat ratkaisevia Namibian korkean työttömyysasteen ratkaisemiseksi, mikä viittaa siihen, että taitojen kehittämiseen keskittyvä strateginen suunnitelma on olennaisen tärkeä. Tutkimuksessa suositellaan vankkojen kumppanuuksien luomista yliopistojen ja teollisuuden välille, jotta voidaan varmistaa, että koulutusohjelmat räätälöidään vastaamaan maan keskeisten alojen erityistarpeita. Lisäksi siinä korostetaan, että yrittäjyystaitojen sisällyttäminen opetussuunnitelmaan on tärkeää, jotta opiskelijat voivat käynnistää oman yrityksensä. Tulevaisuuden tutkimussuuntauksiin kuuluu keskittyminen uuteen käytännönläheiseen tietotekniikan opetuksen tutkimukseen, jossa kokeillaan uusia pedagogisia innovaatioita. Lisäksi tutkitaan strategioita, joilla Namibian yliopiston koulutustarjonta voidaan sovittaa yhteen tietotekniikan opetussuunnitelma 2020:n kanssa. Tässä väitöskirjassa suositellaan myös sen tutkimista, miten namibialaisia opiskelijoita voidaan valmistaa kansainväliseen tilaan (offshoring).

AVAINSANAT: Ohjelmistotekniikan koulutus, yliopiston ja teollisuuden yhteistyö, osaaminen, muotoilutieteellinen tutkimus, työllistettävyys, globaali etelä, muotoilun ja todellisuuden välinen kuilu.

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Illustrations

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Abbreviations

AI	Artificial Intelligence
CBE	Competency-based education
CDIO	Conceive, Design, Implement, Operate
CE	Computing Education
CEng	Computer Engineering
CS	Computer Science
CSPI	Conceive Solve Practice Implement
DRG	Design-Reality Gap
DSR	Design Science Research
FTLab	Future Technology Laboratory
GN	Global North
GS	Global South
HPP	Harambee Prosperity Plan
IS	Information Systems
IT	Information Technology
O-CDIO	Operate- Conceive, Design, Implement, Operate
PBL	Problem-Based Learning
PjBL	Project-Based Learning
RDI	Research, Development, and Innovation
SDP	Software Development
SE	Software Engineering
SEE	Software Engineering
UIC	University-Industry Collaboration
UUC	University-University Collaboration
UNAM	University of Namibia
3IR	Third Industrial Revolution
4IR	Fourth Industrial Revolution

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Ntinda, Maria, Mikko Apiola, and Erkki Sutinen. Mind the Gap: Aligning Software Engineering Education and Industry in Namibia. In 2021 IST-Africa Conference (IST-Africa), pp. 1-8. IEEE, 2021.
https://ieeexplore.ieee.org/document/9576977

II Ntinda, Maria N., Tulimevava K. Mufeti, and Erkki Sutinen. Plug-in campus for accelerating and catalysing software engineering education in the Global South. In 2020 IEEE Frontiers in Education Conference (FIE), pp. 1-4. IEEE, 2020.
https://ieeexplore.ieee.org/document/9274200

III Ntinda, Maria, Mikko Apiola, and Erkki Sutinen. Future Technology Lab: A Plug-in Campus as an Agent of Change for Computing Education Research in the Global South. In Past, Present and Future of Computing Education Research: A Global Perspective, pp. 259-278. Cham: Springer International Publishing, 2023.
https://link.springer.com/chapter/10.1007/978-3-031-25336-2_13

IV Ntinda, Maria Ndapewa, Carolina Islas Sedano, Mikko Apiola, and Erkki Sutinen. Aligning Academic Efforts with Key Industries: A Case of Computing at the University of Namibia. In 2023 IEEE Frontiers in Education Conference (FIE), pp. 1-8. IEEE, 2023.
https://ieeexplore.ieee.org/document/10343344

V Unpublished Journal at the time of publication------Submitted for Review – Paper 5: Refer to the appendix. Ntinda, M. N., Apiola, M., & Sutinen, E. Re-designing Software Engineering Education in the Global South by Project-Based Industry Collaboration

1 Introduction

Globalisation, the knowledge economy, and technological advancement have triggered profound transformations across different sectors, simultaneously creating new possibilities and presenting challenges (Mgaiwa, 2021,Tran, 2019). The rapid evolution of technology fuels the demand for new expertise, shifting work cultures and introducing uncertainties concerning the nature of jobs awaiting graduates after their studies (Tran, 2019). As a result, many companies are sourcing different talents, embracing remote work setups and offshoring, acknowledging the limitations of the skills-led agenda, which is predominantly based on the assumption that a 'skill gap' exists between what students acquire in universities and what is required in the industry (Jackson, 2013, p. 778). This agenda prioritises the development of competencies to drive economic growth and innovation (Tran, 2019).

The latest Computing curriculum model, the Computing Curricula 2020 (CC2020), articulates competency as a practical educational goal (CC2020 Task Force, 2020). The ACM/IEEE CC2020 report recommends that institutions of higher learning shift from traditional knowledge-based approaches to competency-based learning in computing programs (CC2020 Task Force, 2020).

Competency commonly embodies three essential elements: knowledge, representing “know-what;” skills, signifying “know-how;” and Dispositions, reflecting “know-why,” as depicted in Figure 1 (CC2020 Task Force, 2020, p.48). A comprehensive definition of competency integrates these dimensions within a specific context or task (CC2020 Task Force, 2020).

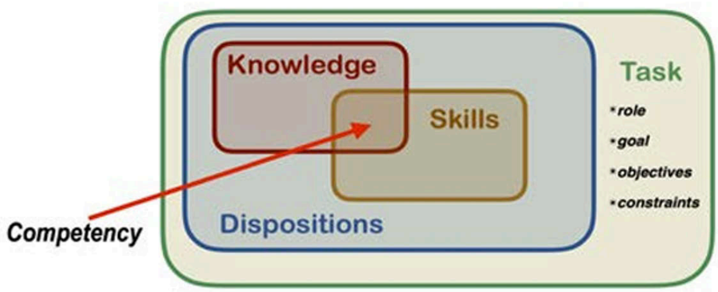

Figure 1. Conceptual Structure of the CC2020 Competency Model (CC2020 Task Force, 2020).

Competency reflects an individual's ability to apply their education to benefit society effectively. For career success, university curricula and practices must be adjusted to bridge the disparity between industry requirements and higher education provision. The literature outlines these limitations, and alternative frameworks are proposed to address such constraints (Guimon, 2013).

Despite these frameworks, Computing Education (CE), especially Software Engineering (SE), continues to fall behind in the Global South (GS) compared to its counterparts in the Global North (GN)(Ntinda et al., 2023). Therefore, universities in the Global South need to adopt open innovation strategies to access and integrate external knowledge sources to enhance opportunities in SE (Ntinda et al., 2021). Acknowledging this imperative, it becomes essential to establish synergies to facilitate the integration of active learning methodologies that emulate real-world experiences, preparing students for their professional careers (Szynkiewicz et al., 2020). These synergies involve partnerships among universities and external stakeholders, including the public sector or government, private sector, start-up community, and non-governmental organisations or civil society (Ntinda et al., 2023).

1.1 Background and Motivation

Through the Harambee Prosperity Plan (HPP) II, the Namibian government strategically addresses service delivery improvements and economic recovery, aiming to strengthen Namibia's resilience amidst socioeconomic challenges and global shifts brought on by the COVID-19 pandemic (Russmann, 2021). Anchored on five pillars: effective governance, economic advancement, social progress, infrastructure development, and international collaboration, HPP II continues to shape a more inclusive, prosperous and united Namibia (Russmann, 2021). In line with the HPP II goals, universities in Namibia aim to train software engineers to transform ideas into tangible products.

The Namibian government's investment in higher education is underscored by the support offered to three universities: the University of Namibia (UNAM), Namibia University of Science and Technology (NUST), and the International University of Management (IUM) (Team, 2022) to graduate students from different disciplines, including computing. Theoretically, these graduates are prepared for a smooth integration into the industry.

Namibia has four key industries: Agriculture, Fisheries, Mining, and Tourism. With a relatively small population of 2.5 million (The World Bank in Namibia, 2024), graduates are expected to integrate into these industries or establish start-ups. However, reality contrasts sharply as unemployment among graduates escalates persistently. Youth unemployment rates have soared to 43.4%, with projections indicating a potential escalation (Mulama and Nambinga, 2020).

While employability is a priority for universities globally, there is no universally accepted formula for achieving it (Tran, 2019). Despite this, the prevailing approach in universities for enhancing graduate employability continues to emphasise the skills agenda. Universities must, therefore, re-strategise to actively decrease unemployment rates and nurture a more robust and productive society that thrives on educated individuals' skills, talents, and contributions (Tran, 2019).

In 2018, the University of Turku (UTU) sought to adapt to the challenges of a distinct geographical and demographic environment (Ntinda et al., 2020). Simultaneously, UNAM aimed to revitalise its education, research, and societal impact (Ntinda et al., 2020). Hence, a bidirectional and mutually advantageous relationship was established between the two universities through the plug-in campus (Ntinda et al., 2020). The plug-in campus refers to a satellite extension of a university from the Global North (GN) located within the premises of a university in the Global South (GS) (Ntinda et al., 2020). In this instance, UTU is the former, while UNAM is the latter. Plug-in campuses and satellite campuses share commonalities. However, the plug-in campus sets itself apart through its dynamic and resilient character, acting as a catalyst and accelerator for both the host and base university (Ntinda et al., 2020). It is built upon collaborative, growth-oriented, and cross-inspiration principles rather than competition or one-sided support (Ntinda et al., 2020).

1.2 Research Domain

This dissertation explored the domain of computing, encompassing Computer Science (CS), Information Systems (IS), Information Technology (IT), Software Engineering (SE), and Computer Engineering (ACM, 2023). It focused specifically on SE as an emerging discipline in Namibia, where graduates from diverse computing backgrounds can be employed as software engineers.

1.3 Research Context

Namibia is located in the southwestern part of sub-Saharan Africa with an economy supported by exports, notably mining, tourism, fishing, and agriculture (“Economy,” n.d.). Additionally, emerging sectors such as green hydrogen, renewable energy, oil and gas, chemicals, transport, and logistics offer new avenues for investment and development (“Economy,” n.d.). Namibia's population growth rate was 1.44% in 2023, remaining nearly unchanged (O’Neill, 2024). Despite these opportunities, Namibia faces challenges with a high unemployment rate of 46% (Trading

Economics, 2024). Addressing this challenge necessitates strengthening UIC to enhance student's career prospects. Despite Namibia having three universities, this study focuses on UNAM.

Previously, students at UNAM, particularly in computing fields, were not mandated to pursue internships or engage with industry partners during their studies (Tjipura, 2023). Recognising the value of industry exposure as one outcome of this research, more industrial intervention is required. Currently, computing students are only exposed to industry through capstone projects, which are suggested to be aligned with guidelines set out by the ACM/IEEE. Table 1 presents the ACM/IEEE guidelines for capstone courses, as outlined in the research by Tenhunen et al. (2023), vs the guidelines implemented in the capstone course at UNAM. In Table 1, it can be seen that only two recommendations are implemented.

Table 1. The ACM/IEEE guidelines for capstone courses (Tenhunen et al., 2023) vs. Capstone Projects guidelines at the University of Namibia.

ACM Recommendations for Capstone Projects	University of Namibia Capstone Projects
The project's duration should cover an entire academic year, allowing students ample time to contemplate their experiences and make necessary adjustments to their solutions.	Recommendation implemented
Undertake the capstone project in a group where possible. In cases where assessment makes this difficult, introduce a separate group project of substantial size.	Students undertake the capstone project individually.
Whenever possible, include a customer other than the supervisor to provide students with a more comprehensive experience of product development life-cycle activities.	Customers are hardly involved; students work mostly with academic supervisors.
The final deliverable of a project should include some type of implementation. Theory-based projects, like developing formal specifications, are not enough for meeting this requirement.	End deliverable of the projects does not always involve any form of implementation.
Evaluating project outcomes should go beyond simply implementing concepts. It should include using walkthroughs, interviews, or basic experiments to assess the effectiveness and limitations of the deliverables.	The evaluation of project outcomes rarely extend beyond mere concept implementation.

Based on the comparisons in Table 1, students at UNAM only sometimes conduct their capstone courses in collaboration with industry. Furthermore, the old curriculum at UNAM does not include a work-integrated course, though such a course was introduced in the new curriculum, which will be offered in 2025. The old curriculum is being offered in parallel with the new one and will only phase out in 2025. This means that students following the old curriculum will graduate without gaining work-integrated experience unless they choose to collaborate with industry partners for their research projects, which is optional (Tjipura, 2023). Additionally, alternative approaches must be considered to expose students to workplace practices since the work-integrated course in the new curriculum will only last for three weeks annually, a period too short for students to fully engage in the workplace or experience the complete lifecycle of a project.

1.4 Research Questions

This study sought to answer two main research questions:

1. What professional competencies are lacking in SE graduates from Namibian universities?
2. What strategies can UNAM employ to cultivate synergistic relationships that enhance SE students' preparation for industry demands?

In doing so, the following Sub-Research Questions (SQ) conducted in different articles were investigated, as presented below:

Paper (P)I

1. What professional skills are lacking in SE graduates from Namibian universities?
2. What is the role of industry-academia collaboration in narrowing the knowledge gap from the university's perspective?
3. What is the role of industry-academia collaboration in narrowing the knowledge gap from the industry's perspective?

PII

1. How can the four sustainability pillars be integrated to establish the viability of the plug-in campus?

PIII

1. What initiatives were implemented at the FTLab, Plug-in Campus to reshape CE and CER in Namibia?

2. How can the Design-Reality Gap (DRG) model be used to identify gaps between FTLab's design expectations and its actual implementation reality?

PIV

1. What are the current UIC initiatives implemented in Computing-related disciplines at universities to equip students with the requisite skills for the job market?
2. How can the UNAM computing department ensure that its curriculum is aligned with local industries, thus equipping its students with relevant skills for the job market?

PV

1. Which 4Cs can be developed through PjBL with industry collaboration?
2. What guidelines should universities follow to ensure that students are effectively prepared with hands-on applications for 21st-century skills?

1.5 Conceptual Understanding

This study underwent two iterations of the Design Science Research (DSR) methodology and is structured around five articles. In the first iteration, the study was initiated with Paper 1 (PI), which focused on identifying SE students' professional competencies essential for graduates entering the Namibian industry. Subsequently, Paper 2 (PII) introduced the plug-in campus concept to foster SE competencies in Namibia. Building on the insights from PII, the proposed intervention underwent evaluation, utilising Heeks' Design-Reality Gap model in Paper 3 (PIII). Despite substantial progress highlighted in PIII, persistent challenges necessitated re-evaluating the issue, leading to the commencement of the second iteration with Paper 4 (PIV).

PIV involved a scoping review of global University-Industry Collaboration (UIC) initiatives to gain a more comprehensive perspective on the problem. Additionally, PIV ascertained whether computing students collaborated with industry in their capstone courses from 2020 to 2022 at UNAM. Drawing from the insights of PIV, this dissertation concluded with Paper 5 (PV), which integrates Project-Based Learning (PjBL) into the third-year SE course at UNAM. This initiative aimed to complement the capstone course already existing at UNAM to bridge the University-Industry gap. Figure 2 visually depicts the conceptual model guiding the discourse across these articles.

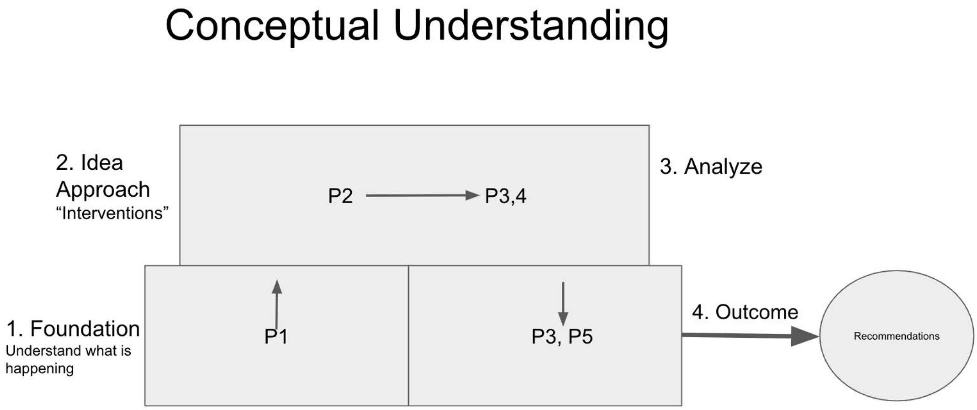

Figure 2. Concept of applying the articles used in this dissertation.

1.6 Contribution of the Study

This dissertation advances theoretical understanding and offers practical methodologies for improving Software Engineering Education (SEE) and employment prospects in Namibia, addressing educational gaps. The dissertation makes several contributions to the existing body of knowledge concerning the interaction between SEE and industry in the GS, particularly in Namibia. It focuses on shaping SE curricula and refining career development strategies to enhance students' preparedness for industry careers as listed below:

- **Interaction between SEE and Industry:** This study investigates strategies for improving students' career readiness. Results from this study provide valuable insights into how SEE can better align with the demands of Namibia's industry.
- **Innovative Concept of the Plug-in Campus:** This dissertation contributes to creating the plug-in campus as a pivotal platform for accelerating and catalysing SEE within Namibia, with potential applications in similar contexts. The experiments conducted within this research highlighted some of the pressing challenges and provided a way forward with new practical solutions. Project implementations at the plug-in campus enriched the context of Computing Education Research (CER) within Namibia. This research contributed to improving CER in Namibia via a plug-in campus, making it the first of its kind.
- **Impact on Employment Prospects:** This dissertation demonstrates a positive impact on employment prospects for students, addressing high unemployment rates in Namibia. By adopting the CDIO model, this research equips students with competitive advantages, thereby fostering Namibia's economic development.

- **Utilisation of UIC Models:** The dissertation explored the underutilised area of UIC models in GS, highlighting their importance in enhancing SEE and contributing to the broader discourse on educational strategies in the GS.
- **DSR Methodology:** This research showed the importance of combining design, development, and research efforts, highlighting the crucial need to increase DSR-based methodologies in SE.
- **Reforming the SE Course through the Conceive, Solve, Practise, implement (CSPI) Model:** A notable outcome is a reformed SE course illustrated through the CSPI model, which is tailored to Namibia's specific contextual requirements. This reformation aims to narrow the gap between academic learning and industry needs, aligning educational outcomes with the requirements of the local job market. Furthermore, it seeks to establish relationships between UNAM and local SE industries.

1.7 Scope of Research

The dissertation focuses on SE students, graduates, and professionals within the Namibian context. While SE was chosen as the primary subject for this research, the insights gained from the project could apply to other Computing disciplines across UNAM and beyond. Although the study was conducted in Namibia, the findings may have relevance beyond Namibia, yielding some limitations as the performance analysis was explicitly conducted in Namibia. In addition, the dissertation also focuses on collaboration with the plug-in campus, although the study could have collaborated with different satellite campuses.

1.8 Dissertation Structure

The remainder of the dissertation is organised as follows: Chapter 2 presents the related work. Chapter 3 presents the application of the Design Science Research (DSR) methodology within the real-life research context. Chapter 4 presents the study's results. Chapter 5 discusses the interpretation of the results and research recommendations. Chapter 6 concludes the dissertation and outlines future research.

1.9 Definitions of Key Concepts

1. The Conceive, Design, Implement, Operate model is an educational framework that supports engineering students by providing a structured approach to learning through practical application. It emphasises the four key stages: Conceiving, Designing, Implementing, and Operating (CDIO, 2023).

2. Competency-based learning aims to assist students in demonstrating their mastery of a certain discipline (Sturgis and Casey, 2018).
3. The Design Reality Gap is a framework for measuring the differences between a project's initial design expectations and its current implementation reality (Bass and Heeks, 2011).
4. Design Science Research is a problem-oriented approach focused on designing solutions to address practical problems often arising from a gap between the current and desired states in real-world settings (Johannesson and Perjons, 2014).
5. Plug-in Campus is an alternative to a satellite campus, designed as a dynamic agent of change specifically aimed at promoting Computing Education (CE) and Computing Education Research (CER) within the context of the Global South(Ntinda et al., 2020).
6. Project-based learning is a teaching approach that enables students to acquire knowledge and skills by working over an extended period to address a real, engaging, and complex question, problem, or challenge (Jumaat et al., 2017).

2 Related Work

This chapter introduces the essential frameworks and models: Competency-Based Education, Conceive Design Implement Operate (CDIO), and Design Reality Gap (DRG), as well as the methodological frame, Design Science Research (DRG) methodology, which was used in this research study. DSR was used in two roles: as a methodological frame for the dissertation and as a pedagogical frame for the teaching intervention with the SE students. The CDIO model was used to guide the implementation of student projects, and the DRG was used to determine whether the FTLab implementation, which involved teaching, research and community engagement, was successful or unsuccessful.

2.1 Frameworks and Models that Support Competency Learning

Many young professionals are motivated to address real-world challenges and require a structured platform to facilitate their efforts (Sek-yum Ngai et al., 2023). Competency-based education, also known as mastery-based, performance-based, and proficiency-based, provides an efficient and practical framework for learning while solving real-world challenges (Gallagher and Savage, 2023). The active application of knowledge encourages critical thinking, problem-solving and decision-making, thereby enabling students to solidify skills and concepts through reflection and feedback (Zabalawi, 2018). Concepts like "authentic learning" and "hands-on practice" resonate with the Project-based Learning (PjBL) approach (Jumaat et al., 2017).

PjBL emphasises a comprehensive, process-oriented approach to learning and finds its roots in constructivist learning paradigms (Lyngdorf et al., 2023). Constructivist learning paradigms perceive learning as constructing knowledge through first-hand experiences (Grant, 2002). Through PjBL, students can acquire the knowledge, skills, and dispositions essential for conceptualising, designing, implementing, and managing complex processes and systems within team-based environments (Frezza et al., 2018). The PjBL approach is typically integrated into a course through projects to form an entire course or span multiple courses (Marijan and Gotlieb, 2021). During these courses, students employ different software development processes in their projects depending on the nature of the project. In big classes, different software development processes can become challenging to assess. Hence, software development processes can be mapped onto the Conceive, Design, Implement, Operate (CDIO) framework for a holistic approach (CDIO, 2023).

The CDIO model reinforces the connections among engineering disciplines and skills. It is rooted in experiential learning theory (Zabalawi, 2018), which defines learning as an active process in which students construct knowledge (Kurt, 2020).

The CDIO model supplements the PjBL approach, as PjBL emphasises the learning process, while CDIO focuses on the outcomes (Edstrom and Kolmos, 2014). Real-life projects are, however, often ambiguous, making it hard for students to break down complex and ill-defined problems into manageable steps (Daun et al., 2016). Given the ambiguity inherent in real-world applications, utilising Design Science Research (DSR) could offer valuable insights into the given problem.

2.2 Frameworks as Intervention Strategies

Design Science Research (DSR) is a problem-oriented approach focused on designing solutions to address practical problems often arising from a gap between the current and desired states in real-world settings (Johannesson and Perjons, 2014). DSR methodology seeks to produce novel solutions specifically designed to address identified problems (Johannesson and Perjons, 2014). These solutions manifest as artefacts, forming constructs that articulate problems or solution components, models representing the problem and solution space, methods offering guidelines for performing tasks, and instantiations demonstrating the artefact's usefulness (Sonnenberg and vom Brocke, 2012).

DSR proves particularly suitable for projects where (1) the application environment (problem space) remains ambiguous and routine design is not sufficient, (2) research approaches from other scientific disciplines need to be integrated into the problem explication and requirement definition, and (3) when qualitative or mixed-methods research approaches are required (Apiola and Sutinen, 2021, Peffers et al., 2007).

DSR methodology can be utilised to guide researchers through a systematic process of defining the problem, designing solutions, building the artefact and evaluating the effectiveness of the developed artefact (Hevner, 2007). Over the years, DSR has been implemented across disciplines and has evolved into diverse frameworks varying in their sequential stages and terminologies (Peffers et al., 2006). Within DSR, a project's framework is conceptualised through an intricate interplay of three core cycles: relevance, design, and rigour, as depicted in Figure 3 (Peffers et al., 2007). The relevance cycle is responsible for pinpointing localised real-world issues, the design cycle involves a construct-evaluate process in devising solutions, and the rigour cycle ensures the application of cutting-edge methodologies during the design phase while sharing insights and outcomes of the design cycle across the broader knowledge landscape (Hevner, 2007). The rigour cycle also generalises aspects of the designed artefact or its design or relevance cycle (Hevner, 2007).

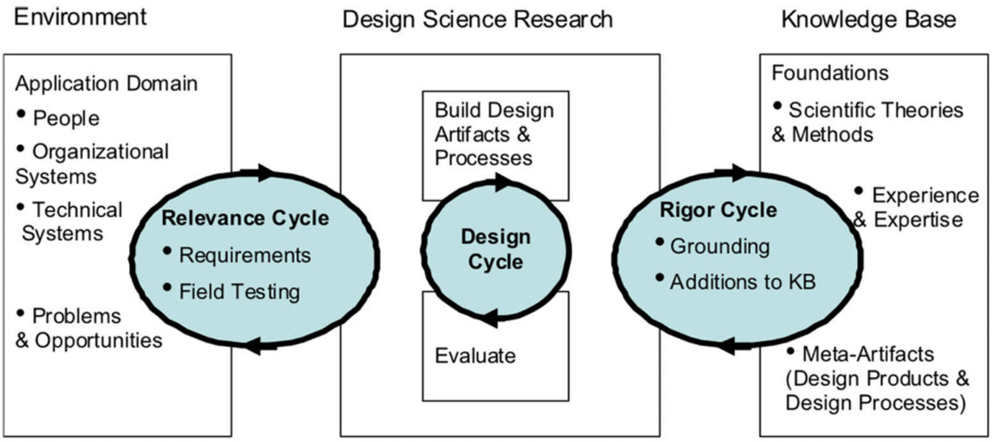

Figure 3. DSR research cycles (Hevner, 2007).

The DSR can also be presented as a process model comprising six sequential phases: Problem identification and motivation, solution objectives, Design and development, Demonstration, Evaluation, and Communication (Peffers et al., 2007), as depicted in Figure 4. When DSR is presented as a process model, the artefact's design involves a non-linear process in which uncertainty, uniqueness and conflict can emerge (Hevner et al., 2004). While the sequence maintains the structure, researchers can commence the process at different stages, guided by their initial research idea (Peffers et al., 2007). Iterations are critical, and the researchers are not confined to a strictly linear progression through activities 1 to 6.

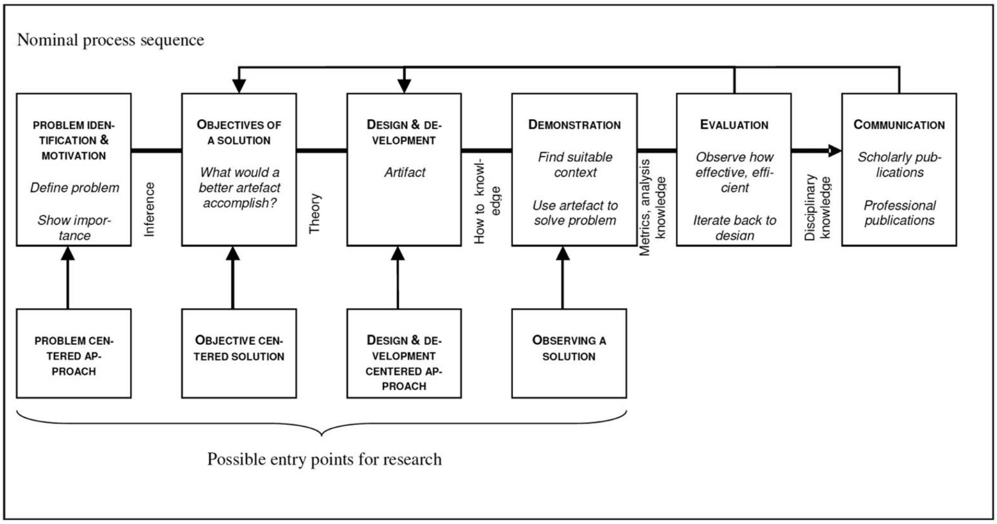

Figure 4. DSR process model (Peffers et al., 2007)

The DSR process can be initiated from any possible entry points: problem-centred approach, objective-centred solution, design and development-centred approach and observing a solution (Peffers et al., 2007). The DSR process can also be divided into two high-level activities: building and evaluating activities (Sonnenberg and vom Brocke, 2012), as depicted in Figure 5.

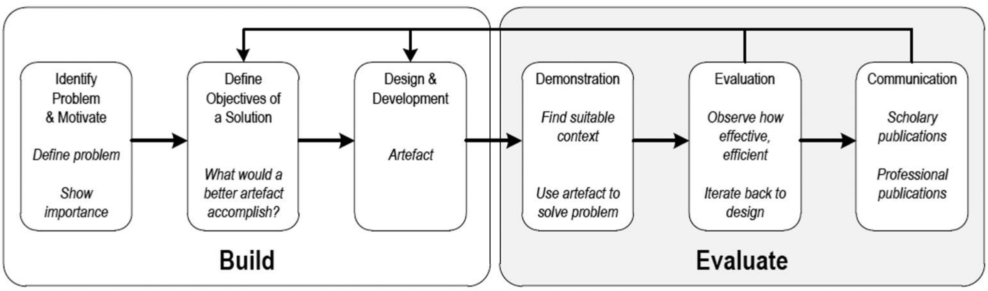

Figure 5. DSR is divided into two high-level activities (Sonnenberg and vom Brocke, 2012).

A typical DSR assumption is that evaluation activities occur only after an artefact is constructed, but this is not always the case (Pries-Heje and Baskerville, 2008). Instead, Sein et al. (2011) recommend that activities be executed, built and assessed simultaneously to track immediate progress and prompt early revisions in the artefact within the design process. In addition, an evaluation of every activity is proposed, as illustrated in Figure 6.

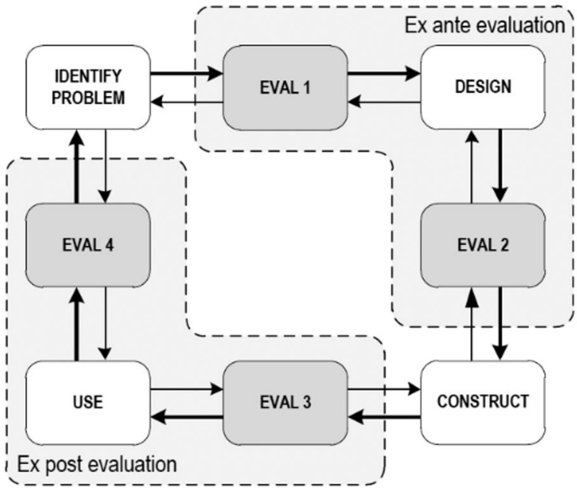

Figure 6. Evaluation activities within a DSR process adopted from Pries-Heje et al.(2008).

Depending on the activities, ex-ante or ex-post evaluations occur during evaluation. Ex-ante evaluations are conducted before the construction of any artefacts, while ex-post evaluations occur after the construction of any artefacts (Pries-Heje and Baskerville, 2008). Figure 6 depicts how feedback from each evaluation activity improves the previous design activity. These loops collectively create a feedback cycle within the DSR process. Depending on the activity, various evaluation methods or approaches may be used for each individual task; see the article by (Sonnenberg and vom Brocke, 2012) to substantiate the evaluation of each phase.

DSR can be employed in various ways depending on the artefact's utility in finding solutions to problems. In some projects, artefacts are further evaluated to see whether they fit their local realities. The developmental impacts of these investments take time to pinpoint. For example, when curricula are adopted from the GN, the GN-based curriculum design might need to be reality-checked in the GS as there are often gaps due to project beneficiaries' socio-economic and cultural contexts. In some cases, ICT4D project designers are significantly different, leading to design assumptions that do not fit local realities (Heeks, 2002). In such cases, ICT4D projects might fail, and implementers and beneficiaries need to understand why those projects fail.

In the domain of ICT4D, the Design-Reality Gap (DRG) serves as an assessment tool to measure the success of ICT4D projects, helping to explain the mismatch between ICT4D designs and local user realities. The DRG model analyses organisational change and risk and states that the design expectations of an organisation may either align with or diverge from the actual situation during implementation (Bass and Heeks, 2011).

The DRG exists across seven dimensions, abbreviated as ITPOSMO: Information, Technology, Processes, Objectives and values, Staffing and skills, Management systems and structures, and Other resources such as time and money (Bass and Heeks, 2011). The DRG model can serve as a risk analysis and project evaluation tool (Bass and Heeks, 2011). When used for risk analysis, it examines the design and reality at a specific time to pinpoint any gaps. In contrast, if used as a project evaluation tool, it contrasts the design expectations with the actual outcomes sometime after implementation, recognising that the implementation process is often continuous (Bass and Heeks, 2011).

2.3 Summary of the Application of Frameworks and Models in This Dissertation

This dissertation adopted DSR to make CE and CER relevant in the GS rather than merely adopting imported solutions. DSR was utilised as a methodological framework for this dissertation and as a pedagogical framework for the teaching intervention with SE students. This study underwent two iterations of the DSR methodology, each comprising different intervention strategies: UNAM collaborating with (1) the FTLab and (2) the SE industry, as depicted in Figure 7.

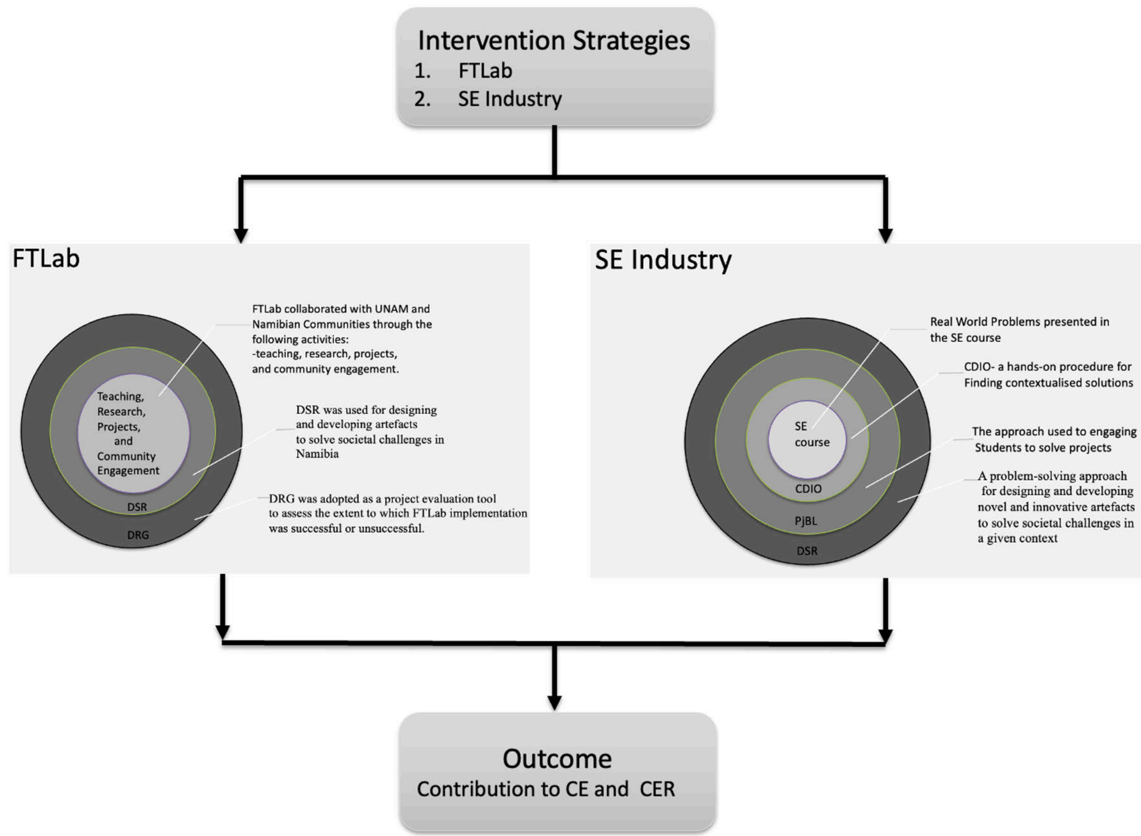

Figure 7. Summarises how the different models and frameworks were applied in this study.

The first intervention focused on fostering collaboration in teaching, research, and community engagement between the FTLab and UNAM. At the end of this intervention, the DRG framework was used to assess whether the design expectations aligned with or diverged from the real-world outcomes during its implementation (Bass and Heeks, 2011). Subsequently, the second intervention commenced, involving a collaboration between UNAM and the SE industry. This partnership integrated PjBL to encourage self-directed learning to enhance professional competencies, where students engaged in industry projects. Similarities exist between SE development models and the CDIO model (Säisä et al., 2017); thus, applying SE development models for educational purposes can be seen as aligned with the goals of the CDIO initiative (Säisä et al., 2017). The CDIO model was consequently employed to guide the implementation of student projects. Students selected their preferred software development models, which were then mapped to the CDIO framework for a more comprehensive educational approach. Figure 8 illustrates an example of this mapping process.

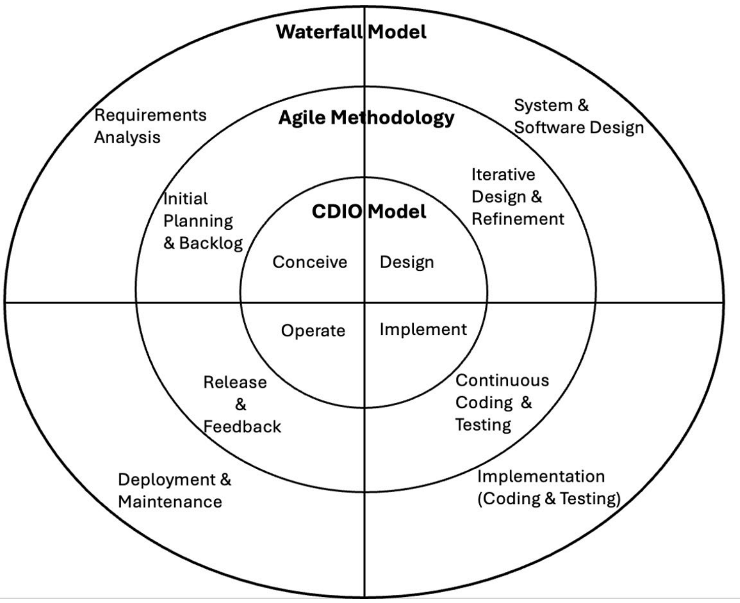

Figure 8. The CDIO model Mapped using the Agile Methodology and Waterfall model.

3 Research Design

This dissertation used the DSR as a methodological framework consisting of the seven essential phases, of which six can be repeated throughout the project life cycle until a solution is attained (Peffers et al., 2007). Two iterations of the six-step process of the DSR process, as depicted in Figure 9, were completed in this study. Since the research idea stemmed from observing a problem amongst the SE graduates in Namibia, the entry point in the creation process of this study began at the problem-centred initiation of the DSR process. The first iteration involved the plug-in campus, while the second initiative involved the local SE industry, intending to assist UNAM in enhancing the professional competencies of SE students in Namibia.

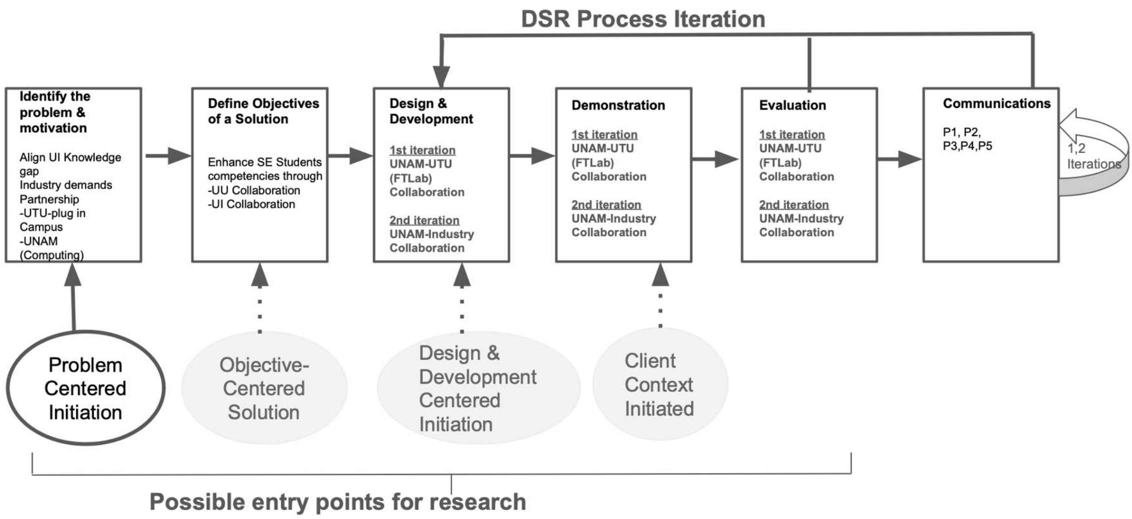

Figure 9. The DSR process as applied in this study, adapted from Peffers et al., 2006).

3.1 Problem Identification and Motivation

A key practical problem for this research has been the recurring mismatch between SE graduates' competencies and Namibia's industry requirements, as presented in PI. This study was motivated by the necessity of UNAM seeking to revitalise its educational, research, and societal impact. One of the key objectives sought by UNAM is to graduate highly skilled SE graduates. UNAM aims to train students to collaborate closely with businesses or even initiate their startups while pursuing their studies. Exposing students to the industry is significant for developing transferable employability skills within an actual workplace (Daun et al., 2016). Students with prior industry experience reflect on and put into practice what they have learned from their formal studies (Helyer and Lee, 2014). Initiatives to expose students to industrial practices through collaborations with relevant stakeholders are, therefore, paramount. In addition, employing learning practices from universities in developed countries is important, hence the partnership with the FTLab. The FTLab is a concrete example of the plug-in campus of the UTU, an alternative to a satellite (Ntinda et al., 2020). Unlike the traditional satellite campus model, the plug-in campus operates as a dynamic agent of change, specifically tailored to foster CE and CER in the context of GS.

3.2 Objectives of a Solution

The overall objective of this study was to explore interventions to enhance SE professional competencies in Namibia, specifically at UNAM. A further purpose was to provide a holistic understanding of challenges in preparing graduates for employment. The main objective was supported by different sub-objectives published in four (4) peer-reviewed articles; the fifth article is under review at the time of submission.

In PI, three objectives were presented: (1) Ascertain the software industry's expectations of SE graduates' skills, (2) Determine crucial gaps in industry-academia collaboration in educating, preparing, and nurturing SE graduates, drawing insights from Namibian lecturers and software engineers, (3) propose specific strategies to bridge these industry-academia gaps.

PII presents the concept of a "plug-in campus" as an accelerator and catalyst for both UTU and UNAM. PII also discusses the plug-in campus's sustainability, drawing insights from the four sustainability pillars: Economic, Social, Environmental, and Ethical (Suhonen and Sutinen, 2014).

PIII presents a case study illustrating how the FTLab transformed CE, research, and innovation and offering insights for enhancing CE in Namibia. Furthermore, PIII utilised the design-reality gap framework to analyse, understand, evaluate, and enhance the implementation of the FTLab initiative.

PIV explored strengthening academic efforts at UNAM with assistance from the industry. PIV analysed (1) through a scoping review of the UIC practices worldwide from 2012 to 2023, focusing on CE, and (2) the Bachelor of Science (Honours) theses in computing-related fields completed by capstone course students at UNAM between 2020 and 2022.

PV explicitly focuses on reorganising the undergraduate SE course to complement the capstone course at UNAM. As a result, the Collaborate-Solve-Practice-Iterate (CSPI) model was developed as a solution to enhance students' professional skills in the SE course in Namibia or within the context of a country similar to Namibia.

Table 2 illustrates the relationship between the research objectives presented in various articles and the main research questions of this study. Additionally, Table 2 shows how the iterations correspond to these objectives. Within the different stages of the DSR, an exploratory sequential mixed-method approach was used to leverage the strengths of both qualitative and quantitative methods. Table 3 summarises the research methods applied in each phase and the number of participants.

Table 2. The relationship between the research questions presented in various articles and the main research questions of this study.

Main Question	Sub-Research Questions	Iterations	Articles
What professional competencies are lacking in SE graduates from Namibian universities?	What professional competencies are lacking in SE graduates from Namibian universities? What is the role of industry-academia collaboration in narrowing the knowledge gap from the university's perspective? What is the role of industry-academia collaboration in narrowing the knowledge gap from the industry's perspective?	Zero	PI
What strategies can UNAM employ to cultivate synergistic relationships that enhance the preparation of SE students for the industry?	How can the four sustainability pillars be integrated to establish the viability of the plug-in campus?	First	PII
	What initiatives were implemented at the FTLab, Plug-in Campus to reshape CE and CER in Namibia? How can the Design-Reality Gap (DRG) model be used to identify gaps between FTLab's design expectations and its actual implementation reality?	First	PIII
	What are the current UIC initiatives implemented in Computing-related disciplines at universities to equip students with the requisite skills for the job market? How can the UNAM computing department ensure that its curriculum is aligned with local industries, thus equipping its students with relevant skills for the job market?	Second	PIV
	Which 4Cs can be developed through PjBL with industry collaboration? What guidelines should universities follow to ensure that students are effectively prepared with hands-on applications for 21st-century skills?	Second	PV

Table 3. Research methods and participants of the five articles.

Articles	Research Methods	No: Participants
PI	Focus Group	Seven (7) Participants
PII	Case study	FTLab
PIII	Case study	FTLab, UNAM
PIV	Scoping Review Case Study	50 Articles 49 Capstone Projects documents
PV	Case study	43 Participants

3.3 Iteration One: University-University Collaboration (UUC)

The first iteration involves UUC, a collaborative initiative between UNAM and FTLab, the plug-in campus of UTU. As discussed in PII, FTLab launched several initiatives to enhance computing education. An essential part of iteration one, these initiatives were evaluated using the DRG model to determine if the FTLab's design met local realities.

3.3.1 Design and Development

The plug-in campus concept was developed as a part of this research. The plug-in campus concept encompasses a comprehensive approach integrating learning, teaching, project work, research, and innovation, specifically designed to foster and enhance SE skills among students (Ntinda et al., 2023). Figure 10 depicts the design of the concept tree of the FTLab, which is a concrete instantiation of a plug-in campus whose foundation is rooted in values and resources, symbolising the roots of a tree. The core activities earmarked for improvement are likened to the tree trunk, while the ongoing initiatives are depicted as the branches. The tangible outcomes and accomplishments of the FTLab, such as degrees, publications, and partnerships, are analogously represented as the fruits of this metaphorical tree. More activities at the FTLab can be found on its Website (https://ftlab.utu.fi/campus/).

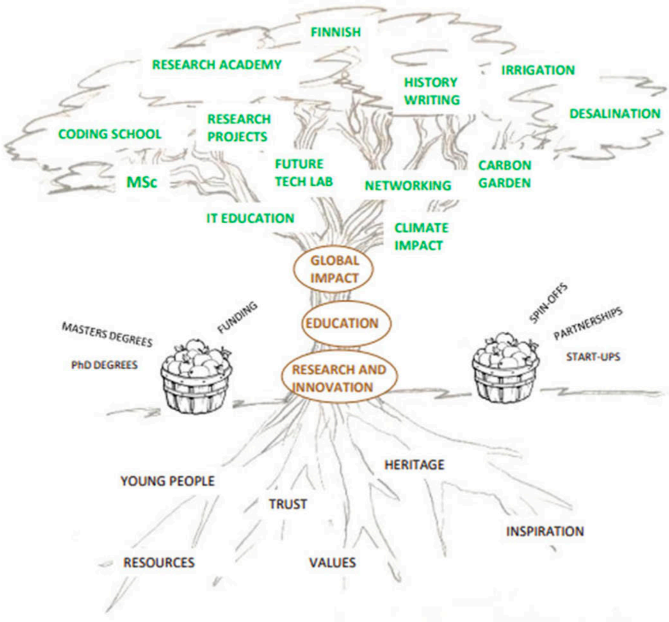

Figure 10. Concept tree of the plug-in campus, drawn by Tuula Kaisto (Ntinda et al., 2023).

3.3.2 Demonstration

The first intervention was demonstrated through initiatives undertaken at the FTLab, which were categorised into three main streams: (1) research, development, and innovation projects, (2) advancing Computing Education (CE) in Namibia through the FTLab, and (3) community outreach efforts at the FTLab as discussed in PIII.

Under the research, development, and innovation projects, a key undertaking was establishing the remote presence project (see https://ftlab.utu.fi/campus/), which aimed at conceptualising and implementing remote presence technologies to foster a greater sense of connectedness within the community (Sutinen and Uwu-khaeb, 2022). Another project involved collaborative initiatives with small-scale farmers, focusing on co-designing and co-developing climate services applications tailored to the local context (Ntinda et al., 2021).

Under projects to accelerate CE in Namibia, Namibian students were given various opportunities to enhance their skills. These included access to coding schools, micro-credential programs, short courses, and the availability of a master's degree in software engineering and a doctoral degree in Computer Science (Sutinen and Uwu-khaeb, 2022). Both degree programs provided at the FTLab were adapted from the main campus at UTU, incorporating contextual elements into projects and demonstrations to address students' needs better (Sutinen and Uwu-khaeb, 2022). Students did not register for the software engineering master's degree.

Under community outreach projects, the FTLab's efforts involved hosting robotics workshops at the UNAM main campus, in primary and secondary schools countrywide, and engaging with street engineers to promote technological education and awareness (Sutinen and Uwu-khaeb, 2022).

3.3.3 Evaluation

The Design-Reality Gap (DRG) model was employed at this stage of the study to evaluate the FTLab's implementation progress since its establishment in 2019 (Ntinda et al., 2023). This study used the DRG model for project assessment (Bass and Heeks, 2011). Since the implementation of the FTLab was ongoing and evolving at the time this study was conducted, areas requiring further changes for improvement were identified and presented in Chapter 4.

3.3.4 Communication

The findings from the first iteration were communicated through a conference article labelled PII and a book chapter labelled PIII. See the appendices for the PII and PIII.

3.4 Iteration Two: University-Industry Collaboration (UIC)

The second iteration involved the collaboration between UNAM and the SE industry in Namibia. This phase was informed by the findings obtained from the DRG model that was conducted to identify the reality gap at the plug-in campus and a re-evaluation of the consistent problem of the SE students' competencies. The second iteration began with a scoping literature review on UIC initiatives and an investigation of student capstone projects conducted between 2020 and 2022, as discussed in PIV. After that, the PjBL approach was implemented in the third-year SE course with the assistance of software engineers from local industry to reform the course and introduce students to industrial practices to prepare them for professional competencies.

3.4.1 Design and Development

The Collaborate-Solve-Practice-Iterate (CSPI) model was developed in the second iteration based on lessons learned from the first iteration and through collaborative efforts with four (4) software engineers from local industry. Competency-based learning (CBL) was employed in the second iteration using the PjBL approach. CBL is known to improve students' understanding by providing opportunities for practical application of knowledge (CC2020 Task Force, 2020). According to the CC2020

(2020) report, Computing degrees should incorporate such approaches to equip students for real-world challenges.

The goal was to enhance students' industrial exposure by complementing the fourth-year capstone course at UNAM. After acquiring essential programming and data structure skills (Apiola and Sutinen, 2021), students are better equipped to engage in capstone projects and Project-Based Learning. For this reason, this study selected third-year students enrolled in the SE course at UNAM to work on industry projects. Thirty-nine third-year students agreed to participate.

DSR served as a pedagogical framework for the intervention with SE students at this stage. As shown in Figure 11, these projects ran in parallel, initiating five concurrent design cycles. Students used agile methodologies guided by the CDIO model throughout their projects to create effective solutions. The technology requirements and related solutions continuously evolved through team collaboration and interaction with industry supervisors, following a dynamic, nonlinear, and creative process.

The designed artefacts were evaluated iteratively to incorporate feedback from software engineers throughout the study. Due to time constraints, students only developed functional artefacts and were not evaluated by the intended users.

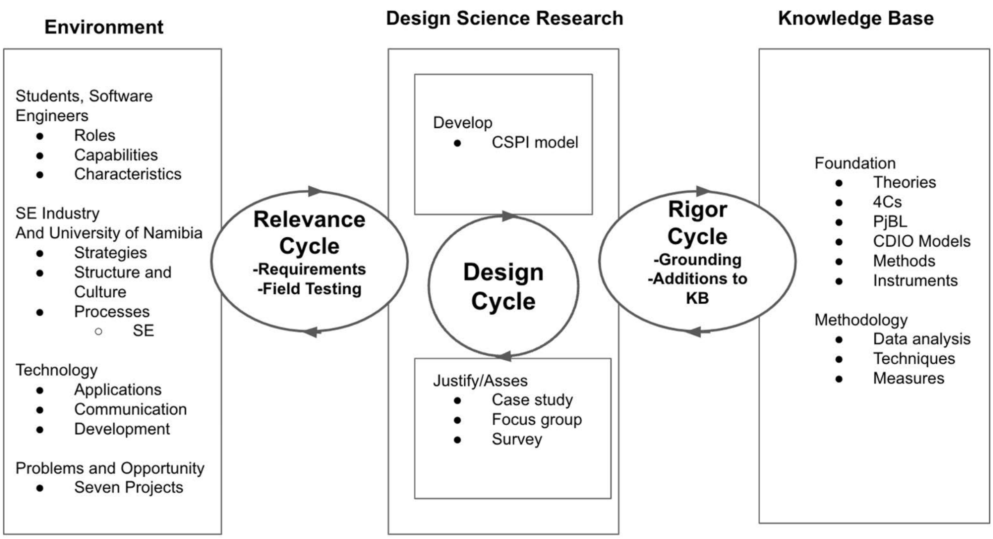

Figure 11. DSR, as applied in the 2nd iteration, was adapted from (Hevner, 2007).

As discussed in PV, students worked on five ill-defined problems with the assistance of the software engineer for a semester, a period of fourteen (14) weeks. Students brainstormed on possible solutions throughout the course. Users, technologies, methods, and software development models were identified in the environment based on the problems presented. Students used different technologies and were guided by the foundations and methodologies depicted in Figure 11. Applying the knowledge base throughout these five projects resulted in reforming the SE course. The pedagogical methodology of the SE course was continually improved through an iterative feedback loop generated from each of the five groups, which worked independently within the design cycle. Each project contributed to this feedback loop, addressing the diverse demands present in the environment. At the end of the course, a focus group discussion with the software engineers and a survey with the students further informed the course. The feedback yielded a more effective and customised educational experience and formulated the CSPI model for continuous collaboration reform to improve the curriculum.

3.4.2 Demonstration

The second intervention was demonstrated through the projects conducted throughout the course. Although seven groups were initially formed, only five participated until the end of the semester. In one group, students effectively integrated all four CDIO phases as part of their developmental methodology; three only implemented the CDI phases, and the last group implemented a non-functional prototype, implementing the CD phases only. The execution flow of the study is presented in Figure 12.

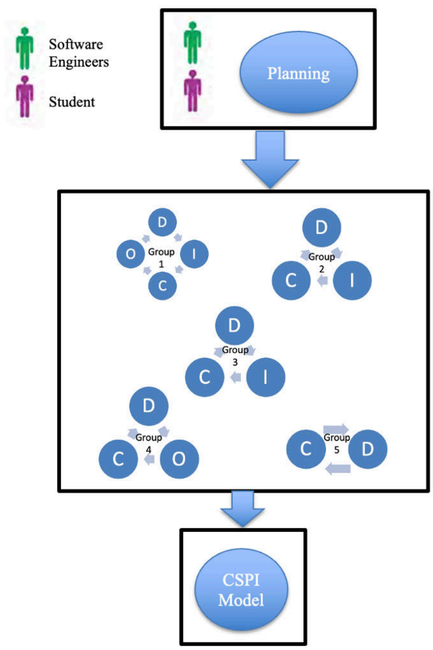

Figure 12. Execution flow of the second iteration of the study.

Group 1 collaborated with a local municipality to develop a Municipality Smart Energy Management System, as depicted in Figure 13. The project aimed to enhance energy efficiency, prevent power outages, and update users with insights into their energy consumption. This group successfully solved their assignment, completing all the phases of the CDIO model.

Figure 13. A prototype of an analysis dashboard for the municipality.

Conversely, the other three projects only managed to implement the CDI phases. While adhering to the CDIO principles, these projects didn't encompass the O-phase. Group 2 reconstructed a website for Company A, as depicted in Figure 14, focused on enhancing data management, content organisation, and service accessibility.

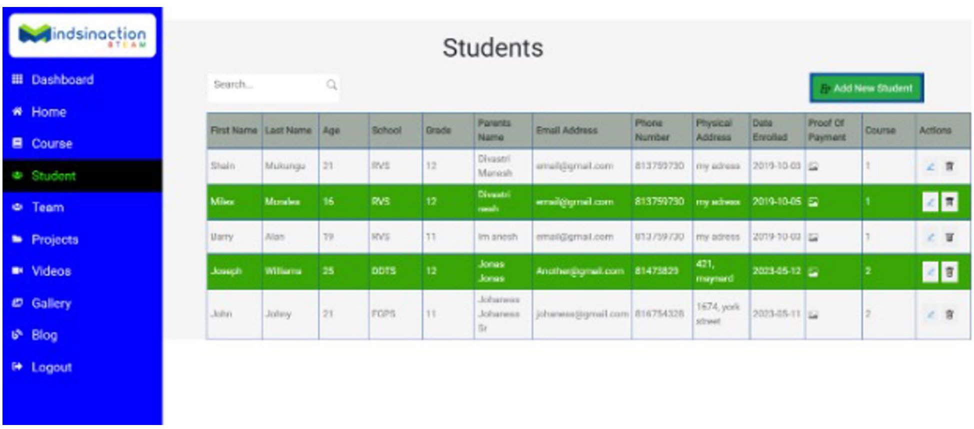

Figure 14. A prototype of the Home page of company A.

Project No. 3, "A Mobile App for Rendering Services for a Local Church," as depicted in Figure 15, involved developing a mobile application that addressed the needs of the church community.

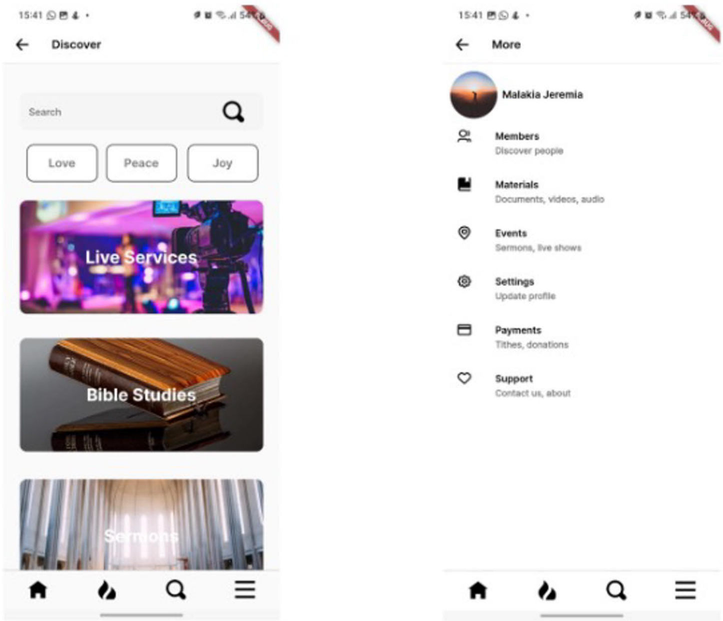

Figure 15. A prototype of the homepage and links to the church application.

Group 4 developed a "Mobile Phone Application for the Parliament." This project aimed to enhance citizen engagement and accessibility to information about Namibian parliamentary proceedings. This group also completed the CDI of the CDIO model. Unfortunately, the interfaces of the parliament application could not be published as it had yet to be launched.

Group 5 aimed to develop "a mobile application for self-learning" to assist individuals in self-learning to obtain a driver's license in Namibia. Unfortunately, this group could only complete a non-functional prototype, covering only the initial CD phase of the CDIO model. Meanwhile, Group 7 didn't present their project, and Group 6 withdrew from the course entirely.

3.4.3 Evaluation

At the end of the semester, an online hybrid questionnaire, adapted from the PBL survey (PBLSurvey, 2023), was administered to assess students' satisfaction with the study. In addition, a focus group method was used to gather qualitative data from software engineers on their experiences working with the SE students. Ex-ante and ex-post evaluations of the prototyped systems occurred throughout the project.

3.4.4 Communication

Findings from the second iteration were communicated through a conference article labelled PIV and a journal article labelled PV. The journal article is under review at the time of the dissertation submission. See the appendices for the PIV and PV.

3.5 Ethical Consideration

Before beginning the study, participants were informed about the research objectives. They were also told that participation was voluntary and confidential and that they could withdraw from it at any time. Before answering the questionnaires, participants signed a consent form. The study adhered to the ethical guidelines on research integrity established by the Finnish Advisory Board. Since the study involved computing students from UNAM, ethical clearance was obtained from UNAM.

4 Results

Chapter 4 presents results in five phases as published (PI-PV) and concludes with a summary, detailed in Table 5. The RQs of each paper contributed to the overall RQ of this dissertation.

4.1 Paper 1(PI): Webinar with Lecturers, Graduates and Professionals

This research phase, which involved a webinar with lecturers, software engineers, and a graduate programmer, focused on the essential skills for novice software engineers to succeed in the industry. Three RQs were set in P1 and are presented below, along with the results that answered those questions.

4.1.1 RQ1 was set as follows: What professional competencies are lacking in SE graduates from Namibian universities?

The webinar results indicated that students lacked both Hard and soft skills. Table 4 presents the SE industry supervisors' perspectives on the hard and soft skills required of graduates.

Table 4. Hard and soft skills recommended.

HARD-SKILLS	SOFT-SKILLS
Computational skills **Design skills, especially being able to do business processes** **Decompose and reuse code: identify a pattern, break the problem into smaller problems and reuse code**	• Good thinking and analytic skills • Problem solving skills • Effective communication skills • Domain knowledge • Management • Disposition: ability to deliver value at a given point in time • Abstraction, look at a lot of things and identify what needs to be done • Entrepreneurial mind-set • Ability to present and pitch ideas of the solution they have created

4.1.2 RQ2 was set as follows: What is the role of industry-academia collaboration in narrowing the knowledge gap from the university's perspective?

The results show that lecturers proposed several initiatives, such as competitions and collaborative projects with industry partners, to enhance students' educational experience. These suggestions emphasise the integration of real-world projects into academic curricula, facilitating a practical application of theoretical concepts. Additionally, lecturers suggested frequent communication with industry for academic programs to remain abreast of the latest industry trends and ensure that the curriculum retains relevance in the rapidly evolving sector. Lecturers also advocate for meaningful industry engagement during internships, allowing students to work on actual projects and gain firsthand experience. Further, they recommend that industry professionals be involved in innovative events, such as hackathons, to provide expert guidance to students. Despite the increasing prevalence of such competitions in Namibia, the limited capacity of these events restricts participation, leaving many students unable to engage in these valuable learning opportunities.

4.1.3 RQ3 was set as follows: What is the role of industry-academia collaboration in narrowing the knowledge gap from the industry's perspective?

The results show that software engineers recommend that students start with internships at the beginning of their academic journey rather than waiting until the end. Additionally, the software engineers recommended the establishment of a comprehensive Software Engineering (SE) body in Namibia, comprising representatives from the entire SE ecosystem, including government entities, private enterprises, universities, and educational institutions. This body would assess students' qualifications for registration as software engineers and devise initiatives beneficial to academia and industry. Furthermore, software engineers suggested that lecturers acquire practical industrial experience to better guide students, drawing on real-world expertise rather than solely theoretical knowledge. Software engineers urged universities to revise curricula and incorporate more industry-relevant exercises and programmes. Additionally, students were encouraged to pursue micro-credentials to supplement any gaps in their classroom learning. These short courses would be tailored to complement internships, ensuring students acquire skills that are directly applicable and valuable to potential employers.

4.2 Paper 2 (PII): Accelerate and Catalyse SEE in the Global South through the plug-in campus

This research phase involved the plug-in campus's design philosophy, which is not to compete with but rather collaborate with its host university. The results of this study show new perspectives for successfully integrating the four sustainability pillars into the plug-in campus model. The RQ set in PII, and the results that answered this question are presented below.

4.2.1 The RQ was set as follows: How can the four sustainability pillars be integrated to establish the viability of the plug-in campus?

The models that will ensure the plug-in campus's sustainability in terms of the sustainability pillars are implemented as follows: economy (business model), society (cultural model), environment (ecological model), and ethics (behavioural model).

First, regarding the business model, the results show that the plug-in campus must diversify its income streams from various heterogeneous and mutually independent sources rather than solely depending on one outlet, such as the base campus, to achieve financial sustainability. Income generation should depend on activities and include contributions from the base campus's industry and industries in the host and third countries. Additionally, revenue should come from grants, participation fees from workshops, summer schools, or similar events, and student enrolment fees. The plug-in campus receives income from various streams. For example, through the UNESCO Southern Summer School and SE degree programme, amongst many activities happening at the plug-in campus.

Second, regarding the culture model, the results show that the plug-in campus must foster a conducive environment for (1) the internal dynamics of its founders and (2) the socio-culturally appropriate integration of the campus within the surrounding community to achieve societal impact. Moreover, it should ensure that community engagement within the campus contributes positively to its socio-cultural functions. For instance, collaborative projects across various disciplines, such as tourism and fashion, involving different universities, industries, and local stakeholders, such as the Katutura Fashion Week and tour adventure operators, are visible at the plug-in campus. Additionally, the plug-in campus welcomes cultural groups beyond its boundaries, such as the local Vox Vitae Choir and the Namibia Film Commission, to use its facilities, fostering a rich exchange of ideas and experiences.

Third, regarding the ecology model, the results show that the plug-in campus can achieve environmental sustainability if its activities don’t harm the environment. The plug-in campus operates online, fostering a collaborative learning and research space shared by learners and educators from both the base and host universities. The online nature of the plug-in campus promotes the use of electronic services, further reducing environmental impact. The plug-in campus also contributes to ecologically friendly agriculture through initiatives such as the Carbon Garden project.

Fourth, regarding the behaviour model, the results show that the plug-in campus prioritises equality and transparency in all activities to achieve ethical sustainability. The campus is committed to fostering an environment where fairness is upheld, all actions are transparent, and it adheres to global standards of acceptance.

Fifth, regarding combining the sustainability models, the results show that it is essential to identify, analyse, and address any emerging compensation between these pillars to ensure their sustainability. For example, suppose the plug-in campus encounters challenges in maintaining its economic stability. In that case, a solid ethical foundation can provide support during periods of financial difficulty through innovative restructuring of human resources. In this scenario, the host university has generously offered its faculty to organise certain plug-in campus activities at no additional cost, demonstrating a collaborative approach to address sustainability challenges.

4.3 Paper 3 (PIII): A Plug-in Campus as an Agent of Change for Computing Education Research in the Global South

The results of this research present findings from an analysis of how implementing the FTLab transformed CE, research, and innovation. Two research questions (RQs) were established in Phase III, and the results answering those questions are presented below.

4.3.1 RQ1 was set as follows: What initiatives were implemented at the FTLab, Plug-in Campus to reshape CE and CER in Namibia?

The results show that the FTLab contributed to transforming CE and CER in Namibia by participating in diverse missions, including teaching, research, projects, and community engagement. The startup community was also transformed through the FTLab, providing insights for transforming Namibia's CE. These initiatives were enhanced by the support of all participating universities and external stakeholders, including public and private sector employers. Two RQs were set in PIII and are presented below, along with the corresponding results that address them.

4.3.2 RQ2 was set as follows: How can the Design Reality Gap (DRG) model be used to identify gaps between FTLab's design expectations and its actual implementation reality?

The results from applying the DRG model show that the design expectations and reality at the FTLab matched relatively well in terms of objectives and values, processes, information, and milieu. On the contrary, the design expectations and reality of the FTLab appear to be a mismatch in terms of technology, management structures and systems, and financial investment. Based on the results in PIII, new challenges and opportunities were identified, and if they are addressed through dialogue among CER communities globally, the field of CE and CER can be transformed to a new level of relevance globally. Overall results from PIII underscore the following agenda items that Namibia should adopt to reshape CE and CER.

First, the results highlight the importance of contextualisation: It is imperative to contextualise Computing education to ensure its effectiveness. Simply importing Computing curricula without considering the local context often leads to a surplus of Computing graduates who lack employable skills. Second, the results highlight the importance of Curriculum reform: UNAM should consider moving away from theory-based adaptations of universal Computing curricula and move towards competence-based approaches that can ignite students' enthusiasm by engaging them in real-life challenges. Third, the results highlight the importance of CER in informal and non-formal CE: UNAM should consider introducing micro-credentials that allow students to tailor their learning according to their interests and needs, potentially leading to highly personalised degrees. Fourth, the results highlight the importance of offshoring: Positioning Namibia as an offshoring destination for small and medium enterprises (SMEs) from the Global North could help address the issue of graduate unemployment. Fifth, the results highlight the importance of fast-tracking learning: The CER community should break free from the confines of well-funded institutions and explore innovative approaches to accelerating computing learning. Sixth, the results highlight the importance of developing future technologies: UNAM should consider embracing digital alternatives to traditional lecture rooms and physical facilities and exploring concepts like the metaverse and remote presence to facilitate innovative educational solutions. Seventh, the results highlight the importance of collaboration beyond traditional fields: To ensure relevant and meaningful CER in the GS, close collaboration with disciplines beyond computing, cognitive science, and education, such as business studies, social science, and cultural and development studies, is essential.

4.4 Paper 4 (PIV): Align University practices to key industries based on lessons learnt from the literature

The results present findings from two phases: (1) a scoping review of UIC practices worldwide from 2012 to 2023, focusing on CE, and (2) an analysis of Bachelor of Science (Honours) theses in computing-related fields completed by capstone course students at UNAM between 2020 and 2022. This analysis assesses the extent of students' exposure to relevant industries in Namibia. Two research questions (RQs) were established in PIV and are presented below, along with the results that address these questions.

4.4.1 RQ1 was set as follows: What are the current UIC initiatives implemented in Computing-related disciplines at universities to equip students with the requisite skills for the job market?

The results of this study identified six UIC categories: UIC Joint, Student Self-Sponsored, Cross Border UIC, Industry Involvement Only, Industry Visits, and Gamification (refer to PIV for a detailed discussion). The findings show that computing students at UNAM primarily engage in industrial practices through their capstone courses, culminating in the creation of a thesis document. Further analysis indicates that students' skills could improve with closer collaboration with key industries in Namibia, including agriculture, fisheries, mining, and tourism. While students addressed various societal challenges such as education, health, crime, technology, arts, transport, and languages, few focused on critical issues related to tourism and agriculture. Notably, no student research projects were conducted in mining and fisheries. Additionally, analysing the thesis content revealed that the challenges addressed in capstone projects were either chosen by students or recommended by their supervisors.

4.4.2 RQ2 was set as follows: How can the UNAM computing department ensure that its curriculum is aligned with local industries, thus equipping its students with relevant skills for the job market?

The results of this research highlight steps that UNAM should take to create a computing curriculum that aligns with the needs of Namibia's major industries. The results show the following factors crucial for contextualising the CDIO model into the computing curriculum to address some challenges in teaching computing. The CDIO model can be contextualised into the Computing programme as follows:

Conceive: First, the results from this research show a crucial need to expose students to industry in the third and fourth years of study. In the third year, students can engage in team-based projects with real clients, integrating learning design and related topics. Subsequently, students could progress to undertaking year-long independent projects with different clients to refine their skills further. Additionally, UNAM could bolster collaboration with key industries such as Agriculture, Fisheries, Mining, and Tourism by introducing Cooperative Education (Co-op) programs and internships from the outset.

Design: Second, the results from this research show a crucial need for designing pedagogies based on real-world projects.

Implement: Third, the results from this research show a crucial need to facilitate the implementation of third-year team projects and fourth-year independent capstone projects within industry settings and offer students the necessary support to complete them.

Operate: Fourth, this research's results show a crucial need to facilitate discussions between students and industry partners, allowing students to implement their projects in real-world operational contexts.

4.5 Paper 5 (PV): Work closely with industry supervisors through Project Based Learning (PjBL)

This research phase involved developing the Collaborate-Solve-Practice-Iterate (CSPI) model to enhance students' professional skills in a Software Engineering course in a developing nation. Two research questions (RQs) were established in PV and are presented below, along with the results that address these questions.

4.5.1 RQ1 was set as follows: Which 4Cs can be developed through PjBL with industry collaboration?

Students utilised agile methodologies aligned with CDIO principles to create system prototypes for industry-provided challenges throughout their projects. By the end of the course, students managed to dissect the problems and successfully developed prototypes.

The findings were categorised using a deductive approach, using the 4Cs theoretical framework: Creativity, Communication, Critical Thinking, and Collaboration. The results demonstrated that all 4Cs can be effectively developed through PjBL in collaboration with industry partners.

Creativity was evident in five of the seven groups, as students could reinterpret and adapt the problems to new contexts. In terms of **communication**, while students initially struggled to communicate with their supervisors, they became more confident over time, particularly during presentations. Communication within groups was generally sufficient, with some teams going beyond expectations by sourcing specialised software to facilitate collaboration. **Critical thinking** was showcased as students tackled real-life problems, analysed complex issues, and devised effective solutions, deepening their understanding and advancing their knowledge. **Collaboration** was evident in how students worked with peers and supervisors to complete their tasks. Groups effectively allocated responsibilities among members and coordinated their efforts to deliver functioning systems.

The study also emphasised the importance of employing complementary teaching strategies to address students' diverse attitudes and learning preferences. These results encourage educators to combine various teaching approaches instead of relying solely on one method. Student feedback highlighted the significant benefits of hands-on projects, PjBL, and collaborative activities, particularly in enhancing soft skills (e.g., teamwork, communication) and hard skills (e.g., technical expertise).

4.5.2 RQ2 was set as follows: What guidelines should universities follow to ensure students are effectively prepared with hands-on applications for 21st-century skills?

A CSPI model was developed to answer this RQ. The CSPI model is a design artefact that guides universities in preparing students for 21st-century skills. It was developed based on class observation, feedback from student surveys, focus group discussions with software engineers, and insights from existing literature. The model consists of five key components: the implementing university, external entities, industry, resources and software development.

The **Implementing University** supports students through lecturers and senior peers, addressing limited access to industry professionals, with senior students stepping in when supervisors are unavailable. **Local Industry** fosters collaboration through guest lectures, hackathons, and initiatives that promote real-world problem-solving and fundraising. Partnerships with **External Entities** include startups, government, and NGOs to broaden opportunities. The **Resources component** ensures equitable access through funding strategies like grants and resource-sharing such as devices amongst students. Lastly, **the Software Development** component recommends using the CDIO model, with flexibility for iterative or parallel execution, emphasising practical exposure through all development phases. Feedback loops integrate these components, ensuring continuous improvement and alignment with industry needs and student aspirations. In this context, feedback loops refer to a systematic process of gathering, analysing, and applying insights from each cycle of the SE course to improve its future iterations.

The results of this study show the importance of interdependent partnerships between academia and industry, where key stakeholders actively contribute to the continuous improvement of the SE course. Tables 5 summarise the different articles of this dissertation.

Table 5. A summary of the original Articles.

Titles	Research Objectives	Sample Size	Research Methods	Main result
M. Ntinda, M. Apiola and E. Sutinen, "Mind the Gap: Aligning Software Engineering Education and Industry in Namibia," 2021 IST-Africa Conference (IST-Africa), South Africa, South Africa, 2021, pp. 1-8.	-Ascertain the software industry's expectations of SE graduates' skills. -Determine crucial gaps in industry-academia collaboration in educating, preparing, and nurturing SE graduates with employable skills from lecturers and software engineers in Namibia. -Identify concrete future actions to address the industry-academia gaps.	Seven	Focus group method, qualitative research technique	**Industry-academia knowledge gap exist in Namibia. -Students lack both soft and hard skills. -The industry in Namibia expects hard and soft skills from graduates, see Table 4. -Universities should incorporate specific competencies: in their curriculum development to address the industry's expectations.**
Ntinda, M. N., Mufeti, T. K., & Sutinen, E. (2020, October). Plug-in campus for accelerating and catalyzing software engineering education in the Global South. In 2020 IEEE Frontiers in Education Conference (FIE) (pp. 1-4). IEEE	-Present the concept of the plug-in campus. -Discuss the role of the plug-in campus in promoting contextual innovation and collaboration in SEE. -Discuss how the plug-in campus can be sustainable, considering the four sustainability pillars.		Case study of FTLab	**- The FTLab focuses on software engineering education and emphasizes contextual innovation, collaboration, and sustainability. - The FTLab's offerings span from individual coding courses to a comprehensive Doctor of Philosophy program in Computer Science. - All learning activities within the FTLab are connected to research, development, and innovation (RDI) projects and are conducted in collaboration with end-users in the host country whenever feasible. - The four pillars of sustainability: economic, social, environmental, and ethical can work together to support a sustainable campus.**

M. Ntinda, M. Apiola and E. Sutinen, Future Technology Lab: A Plug-in Campus as an Agent of Change for Computing Education Research in the Global South. Past, Present and Future of Computing Education Research 2023: 259-278	-Investigate solutions through DSR methodology that better fits to contextualise CE and int turn enhance CER in the GS. -Identify discrepancy between the plug-in campus initiative and the realities in Namibia through the implementation of the DRG model.	One FTLab and Two Staff members	Case study of FTLab	**-Challenges and opportunities were observed and need to be attended to transform the CE in Namibia** **- Each of the eight dimensions of the DRG presented challenges, with a close alignment between the design expectations and the reality at the FTLab. Among the eight extensions of the DRG model, four showed a match between the design expectation and reality of the FTLab, while three presented relative mismatches in the areas of technology, management structures and systems, and financial investment.** **-Graduate employability was identified as a major challenge hence the need to move away from importing curriculum and instead reform and fast track the curriculum.** **-Replace traditional universities with metaversity and remote presence concepts**
Ntinda, M., Apiola, M., Islas Sedano., & Sutinen, E. (2023). Aligning Academic Efforts with Key Industries: A Case of Computing at the University of Namibia. In 2023 IEEE Frontiers in Education Conference (FIE). IEEE.	-Explore how to strengthen academic efforts at the University of Namibia (UNAM) with the assistance of industry in Namibia. -Analyse: (1) a scoping review of UIC practices worldwide from 2012 to 2023, focusing on CE, and (2) an analysis of Bachelor of Science (Honours) theses in computing-related fields completed by capstone course students at UNAM between 2020 and 2022.	Fifty (50) articles were reviewed, and fourteen (14) met inclusive criteria. Forty-nine (49) Students' theses were also reviewed	Scoping Review of peer reviewed articles published between 2012 and 2023. Analysed the theses for the Bachelor of Science (Honours) in Computing related disciplines between 2020-2022	**-Analysis from the scoping review found six (6) different Universities-Industry Collaboration (UIC) initiatives:** **UIC Joint Projects, Student self-sponsored projects, Cross Border UIC, Industry involvement only, Industry visits, and Gamification that are employed in universities worldwide.** **-A review of the students' theses shows that students tackled challenges addressing social issues such as education, health, crime, technology, arts, transport, and languages. However, only a small number of students worked on challenges related to two major industries: tourism and agriculture, while the mining and fisheries industries were not addressed.**

Ntinda, M. N., Apiola, M., & Sutinen, E. CSPI Model: Re-designing the Software Engineering Course in the Namibian Context. Submitted and is under review.	**-Identify which of the 4Cs (Critical Thinking, Communication, Collaboration, and Creativity) can be developed through project-based learning with industry collaboration. -Establish guidelines that universities should follow to effectively prepare students with hands-on applications for acquiring 21st-century skills.**	**Thirty-nine (39) participants**	**Case Study Online Questionnaire Focus Group**	**-PjBL help identify the 4Cs and it was evident that the students' skills were improved. -Students appreciated PjBL approach with industry-based projects. -Collaboration led to internship opportunities -Students' attitudes showed a diverse mixed bunch of students and calls for an alternative to complement the current teaching method employed in the SE course. -industrial partnerships is pivotal in financial resources and supporting students, however, strong collaboration is needed to source funding. -Recognising curriculum reform and incorporating participants feedback post-course ensure SE course is align to industry demands. -students do not always have to execute the CDIO stages, the execution of the O phase depends on the size of the project -The CSPI model was develop as a guide to reform the SE course.**

5 Discussion

This doctoral dissertation identified professional competencies that need to be improved in SE graduates from Namibian universities. Furthermore, it explored and devised strategies UNAM could use to foster synergistic relationships and enhance SE students' preparedness for industry requirements.

Literature shows how SE graduates in developed countries are advancing compared to their counterparts in developing countries (Mishra and Mishra, 2011). Examining the professional competencies of SE students at UNAM is imperative to contribute to shaping the computing curricula and refining career development strategies. Two Main(M) RQ supported by SRQ guided the implementation of this study. The discussion is presented in line with these MRQs.

5.1 MRQ1: What professional competencies are lacking in SE graduates from Namibian universities?

Results from PI and PV highlighted the deficiency of 21st-century skills identified among Namibian software engineering graduates at the beginning of their careers and during their studies. As acknowledged in the focus group discussions in PI, universities in Namibia are actively implementing interventions to better equip students for industry. These interventions include fostering partnerships to establish student networking opportunities and enabling interactions with professionals that may lead to internships or job prospects, all vital to closing the gap in the identified competencies, as noted in PV. Ultimately, these collaborations grant access to specialised resources and technologies beyond the usual university scope (Galloway et al., 2014).

Results from PI also identified the crucial need for practical solutions to foster collaboration between the software industry and academia. This partnership facilitates explicitly practical application by connecting students with real-world insights from industry, enhancing their hands-on learning experiences. In addition, the importance of collaboration with other universities, serving as a platform for knowledge exchange amongst students, was also identified in PI. PV showed that through PjBL, the 4Cs can be identified and improved if they are lacking. While SE students at UNAM could be introduced to industry through the capstone course, it needs a focus on collaborative team-based projects. Integrating team projects into undergraduate curricula becomes imperative when such experiences are missing from capstone courses (Tenhunen et al., 2023). Furthermore, a significant outcome highlighted the positive impact of teamwork on the learning process during the course. Despite perceptions that teamwork is challenging in Project-Oriented, Problem-Based, and Project courses (Taajamaa, 2017), students in this study consistently demonstrated effective teamwork, surpassing expectations.

Additionally, PV results found that students' disposition significantly influenced their learning. Participants exhibited both intrinsic and extrinsic motivation. Motivated students sought guidance, displayed perseverance in project completion, and engaged in profound learning, consistent with findings by Marshall (2014) and Trigwell et al. (1999). Throughout the course, motivated students actively conducted research, a crucial aspect of lifelong learning (Uziak, 2016). Motivated students also contributed or attended meetings compared to unmotivated students.

Results from PI and PV also emphasised the importance of continual curriculum updates to ensure students are equipped with contemporary, applicable skills for the industry, which were identified as needing improvement. The current curriculum at UNAM takes a long time to review; hence, a relook at frameworks is necessary for constant updates. In conclusion, this study identified hard and soft skills lacking among students, offering a broad reference to 21st-century skills, a typical case in many countries (Garousi et al., 2019). The findings suggest that narrowing the skill gap requires a collaborative effort among vested professionals to develop initiatives beneficial to all stakeholders.

5.2 What strategies can UNAM employ to cultivate synergistic relationships that enhance SE students' preparation for industry demands?

Results presented in PII, PIII, PIV and PV answered MRQ2. The findings of PII and PIII clearly show that UNAM can collaborate with the plug-in campus to better prepare SE students for industry. To support long-term collaboration, the four sustainability pillars were evaluated to ensure that the plug-in campus addresses current students' needs without compromising future generations' needs. The results show that the four dimensions of sustainability can support each other, creating a network of interconnected elements for a sustainable plug-in campus. The intertwining of the pillars is also acknowledged in a study by Suhonen and Sutinen (2014). Acknowledging potential trade-offs or conflicts among these sustainability pillars is crucial, and careful analysis is essential to navigate and resolve emerging issues at the FTLab. Although insights presented in PII are valuable for understanding the challenges and dynamics of sustaining an international campus, specific details may need to be explicitly covered. For instance, external factors such as social changes that could influence the long-term sustainability of an overseas campus need to be explored. Hence, PIII examined the gap between the plug-in campus initiative and the realities in Namibia, identifying various contributions the FTLab has made through its involvement in missions such as teaching, research, and community engagement.

PIII employed the DRG framework, facilitating the integration of evaluation into the design process (Bass and Heeks, 2011). According to the findings of the DRG model, the involvement of FTLab appeared beneficial—four of the seven ITPOSMO dimensions aligned with the FTLab's design and the realities of local users. A key objective of the FTLab was to implement a master's degree program, but it faced challenges as no students enrolled. Future research could investigate the reasons behind this failure. The FTLab was ultimately closed in March 2024. In Namibia, projects often fail without subsequent studies to determine the causes. By conducting a subsequent study, UTU and UNAM can foster a culture of continuous improvement and adaptability.

The original plan of this dissertation was to enhance collaboration between UNAM and UTU through the master's programs, but students did not enrol in the program. The study was later adjusted, shifting its focus to SE students enrolled at UNAM. Working with the SE students at UNAM provided valuable practical insights into the operations of the plug-in campus and highlighted opportunities to improve CE in Namibia further. These experiences deepen the understanding of students' needs in Namibia and challenges and reveal ways to enhance curriculum design, teaching methods, and industry collaboration to better equip graduates with the skills required for the evolving tech landscape.

One crucial lesson learnt is the significance of contextualising CE to reduce the surplus of computing graduates needing more employability skills. Despite computing theory being universally applicable and not constrained by context, users of computer-generated artefacts operate within specific local environments defined by their unique requirements and demands stemming from their everyday surroundings (Ntinda et al., 2023). Imported computing curricula seem effective if reassessed within the local context. The CATI model emphasises the significance of contextualising (Vesisenaho et al., 2006) and can be seen as applying the CDIO model, which emphasises applying knowledge in the real world (Ruwodo et al., 2022).

The results of this study emphasise the importance of reforming the curriculum from theory-based to project-based approaches, shifting away from learning outcomes that are predominantly evaluated through traditional written examinations that emphasise memorisation. Observations of the courses at the plug-in campus showed that students are engaged and enthusiastic when addressing real-life problems. This was similarly observed in the SE course at UNAM.

An additional takeaway from this dissertation suggests supplementing conventional CE degree programs with various micro-credentials to enable students to acquire competencies in the order they prefer. Initiatives permitting students to use micro-credential courses toward their formal degrees should be considered. Preparing students for potential off-shoring opportunities emerges as a strategic approach to addressing the unemployment challenge in countries with unemployment issues (Peck, 2017). Hence, off-shoring initiatives need to be researched.

Another finding from PIII advocates developing future technologies to advance the university by substituting physical facilities with digital counterparts. This includes introducing concepts such as metaverse and remote presence, which will pave the way for innovative solutions. To achieve relevant and meaningful CE and, consequently, CER in the GS, it is essential to foster close collaboration beyond the three existing academic fields of Computing, Cognitive Science, and Education.

PIV examined global university-industry initiatives from 2012 to 2023 and identified six UIC categories: UIC Joint, student self-sponsored projects, cross-border, Industry Involvement Only, industry visits, and gamification. In these UIC categories, the PjBL approach was found to be implemented most frequently in capstone courses. Since UNAM also offers a capstone course, further investigation into the capstone course at UNAM reveals that students who enrolled in capstone courses from 2020 to 2022 tackled challenges mainly in Education, Health, Crime, Technology, Arts, Transport, and Languages. Although Namibia has four key industries, only a few projects have addressed challenges within Namibia's key industries. Students concentrate on Tourism and Agriculture, with no collaborations evident in Mining and Fisheries. While some projects pointed to industry involvement, the extent of collaboration remained ambiguous. How deeply intertwined these projects are with industry partners is yet to be seen.

A further examination of these topics shows that students and their supervisors choose capstone projects without industry involvement. Additionally, capstone projects at UNAM are conducted individually, which does not promote collaboration, and creativity might be limited. Furthermore, the analysis of capstone projects highlights limited UIC, neglecting key Namibian industries. Recognising limited UIC is crucial for educators and institutions to align curricula with industry needs and foster exploration in specific sectors.

Results from PIV needed an in-depth understanding of why social disciplines attracted more attention in projects than challenges within Namibia's key industries. The results from PIV recommended implementing the PjBL approach into one of the courses at UNAM, supported by the CDIO model, to create a learning environment that helps students link formal knowledge with real-world experiences (Wan et al., 2018 Edström & Kolmos, 2014). Results from this dissertation show how students benefitted from the structured process of CDIO and the innovative and student-centred nature of the PjBL approach.

PV highlights that PjBL can identify and improve 4Cs. Although students possess these skills, further improvement is needed, evident from the development of the artefacts in their projects and the observation from the SE class.

PV emphasised the significance of fostering partnerships between UNAM and external entities to reform computing curricula, exemplified by the development of the CSPI model, as depicted in Figure 16. The CSPI model illustrates the five components UNAM could utilise to strengthen collaboration and enhance students' competencies. Although the CSPI model used an example of a SE course, this application could also be applied in other computing courses.

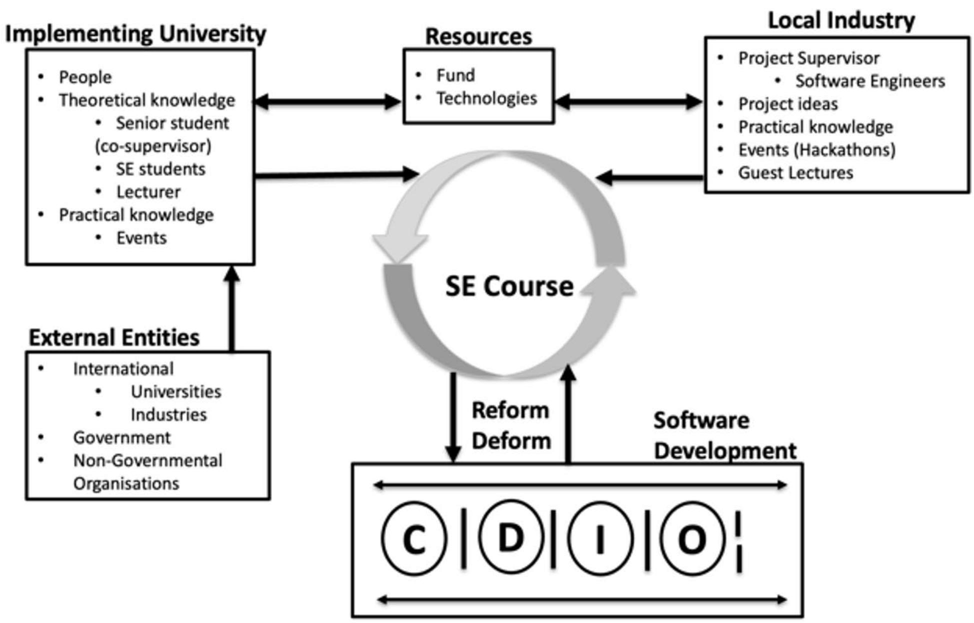

Figure 16. A CSPI Model.

In conclusion, introducing students to SE projects created a different learning experience which would not have sufficed in a traditional classroom. In DSR projects, learning can be approached from three perspectives: micro (designing learning for individual learners based on specific learning needs), meso (designing learning for local or distributed communities with diverse learning needs), and macro (designing learning on a national or global scale to address universal challenges)

(Apiola and Sutinen, 2021). Learning through the different projects in this study occurred at the micro level. This study demonstrates that the learning experience can be enhanced if the implementing university carefully considers students' needs, close collaboration with industry professionals, and the required resources.

Strategies should be developed to involve students in resource sharing and optimise and utilise the available resources. In addition, continuous feedback loops should be established to facilitate continuous curriculum refinement and ensure that computing courses remain aligned with industry demands instead of waiting for the curricula to be revised, which occurs only after four years at UNAM.

5.3 Recommendations to strengthen academic efforts at UNAM

This dissertation has put forward recommendations to solve these problems, hoping to assist institutions in sub-Saharan Africa and beyond in moving forward. These recommendations are derived from the lessons learnt from the study.

- Contextualise computing education to remedy the current situation of producing queues of unemployable graduates resulting from unfit pedagogies that do not fit the local context.
- Reform curriculum by moving away from theory and memorisation. Theory and practice should remain in constant dialogue to create a dynamic learning, refinement, and improvement cycle. Based on the observations in courses, students get excited when solving real-life problems.
- Make curriculum reform a continuous process, which includes updated teacher training.
- Introduce micro-credentials as informal and non-formal CE solutions. Enable students to learn competencies in the order they see fit; in some cases, the process can culminate in a highly individualised degree.
- Bypass ineffective approaches by introducing micro-credentials as informal and non-formal pedagogical solutions for computing education needs.
- Introduce students to industry as early as possible in the course by incorporating external clients into student projects. This will enhance project authenticity and relevance and foster cooperation, collaboration, teamwork, and the use of diverse skill sets.

- Adopt the CDIO model for the software engineering life cycle approach without operating the O phase every time. Due to time, not all projects will go into operation unless they span over a year.
- Use diverse project assessment methods instead of resorting to traditional assessment methods. Diverse methods promote a more inclusive, engaging, and effective learning environment that will accommodate diverse students' needs.
- Create initiatives that enable the offshoring of software engineering graduates. Implement strategies and programs to facilitate graduates' employment in offshore software development projects or companies.
- Devise future technologies to pave the way toward novel solutions by introducing metaverse and remote presence concepts. Many physical facilities can be replaced by their digital counterparts.
- Introduce a new stream of practically oriented computing education research to experiment with new pedagogical innovations and actively reshape education. This could be achieved by making more efficient use of educational technologies. Substantially increase practically oriented educational research on all of these mentioned issues. For example, one PhD dissertation per topic by a Namibian computing educator in the next five years or so.

5.4 Limitations

This research study exclusively focused on students at UNAM. The study also focused on lecturers and software engineers in Namibia, a country in sub-Saharan Africa. The sample size was small; more students, lecturers, and university administrators could have participated in the study. Although UNAM has other international partner universities, this study reports on collaboration solely conducted with UTU, leaving out other global partners. In addition, students collaborated exclusively with the SE industry in Namibia. However, the results of this study cannot be applied to the whole GS as GS exceeds Namibia's boundaries. Insights into the long-term effects of these collaborations on students' sustained career growth are absent and need a longitudinal view of the long-term effectiveness or sustained impact of these initiatives on students' careers or the industries involved.

6 Conclusions And Future Work

Previously defined models of computing curricula focused on knowledge, but recent work has transitioned towards a competency-based view (CC2020 Task Force, 2020). This dissertation emphasised the importance of meaningful collaboration between industries and universities to clearly define their roles and responsibilities in improving graduate employability. The collaborative execution of tasks with end-users in Namibia was highlighted in this dissertation, showcasing the synergy between academia and industry in study programs, a departure from the norm at UNAM in the computing discipline.

The FTLab's role in catalysing and accelerating Research, Development, and Innovation (RDI) to enhance CE and CER in Namibia was presented. The FTLab beneficiaries come from diverse socio-economic and cultural backgrounds, so designs may not always fit local realities where there was a mismatch in some initiatives. Hence, results from this dissertation demonstrated the significance of considering the contextualisation of imported concepts when implemented locally.

This study demonstrates the benefits of competency-based learning for students through a SE course. Students enhance their competencies through PjBL by applying the CDIO model. Using different initiatives, both components of CBL were identified to enhance students' competencies in this study. SE students collaborated with local SE industries, underscoring the importance of industry collaboration. This study shows that incorporating real applications in computing education enriches the learning experience by making it more engaging, inclusive, and applicable to real-world contexts, bridging the gap between theory and practice.

Addressing diverse learning styles while promoting the development of both hard and soft skills, which students have identified as lacking, can better prepare them for industry demands. In this study, collaboration with industry supervisors enhanced students' competencies and facilitated student employment, as some internships extended beyond the course. Furthermore, this study indicates that improving graduate employability should extend beyond merely equipping students with the competencies required by local industries. The CSPI model was developed to guide the implementation of SE courses in countries with limited resources and industry participation.

Future studies could evaluate the utility of the CSPI model by analysing the tension between a utility-based approach in SEE and a theory-based (traditional academic) approach using a SWOT diagram. The former follows teleological ethics, while the latter adheres to deontological ethics. Future studies could also focus on a new stream of practically oriented computing education research to experiment with innovative pedagogical strategies and actively reshape education. Additionally, entrepreneurship skills could be integrated into the curriculum to prepare students for launching their start-ups and exploring how to equip them for the international landscape (offshoring). Further research could investigate the computing curriculum at the University of Namibia to ensure its alignment with the Computing Curriculum 2020.

Acknowledgements

I want to extend my heartfelt thanks to the following people and organisations:

- My supervisors, Mikko Apiola and Erkki Sutinen, for their patience and support throughout the journey toward my Ph.D. degree;
- Hafeni Mthoko and Mikko Vesisenaho for guiding me throughout the journey of my PhD degree;
- Tulimevava Kauna Mufeti and Carolina Islas Sedano for co-authoring two articles that contributed to the success of the dissertation;
- Klaudia Ntinda (Mom), Paulus Ntinda (Brother) and Mennesia Vilho (sister) for their love and support;
- Jerkko Starck, Meme Marjaana and Kuku Tuula Valkonen, special friends who made my stay in Finland memorable;
- Hilma Aludhilu, Ville Myllynpää and Anton Limbo for endless support throughout the journey;
- God, the Almighty, for protecting me throughout the past years;
- All participants for data provided that led to valuable conclusions.
- the University of Turku for the financial support to conferences
- the University of Namibia for granting me a year's leave to complete my studies.

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TURUN YLIOPISTO
UNIVERSITY OF TURKU

Painosalama, Turku, Finland 2025

ISBN 978-952-02-0060-2 (PRINT)
ISBN 978-952-02-0061-9 (PDF)
ISSN 2736-9390 (Painettu/Print)
ISSN 2736-9684 (Sähköinen/Online)