Learning linkages between projects and work placements in engineering education

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ABSTRACT

This research study investigated the combined learning linkages of engineering projects (Problem-Based Learning [PBL]) and work placements (Work-Integrated Learning [WIL]) in engineering education in New Zealand. The learning process of both approaches was analysed based on the development of engineering knowledge, technical, and non-technical skills (collectively employability skills) in students. This research is aligned with theories of constructionism and sociocultural theory to understand learners' engagement in WIL and PBL as building knowledge through social interactions in classroom and work settings. Constructionism is a learning theory that puts importance on active knowledge construction by learners engaged in hands-on experiential learning activities. In this study, WIL and PBL are the hands-on experiential learning activities that aid in construction of engineering knowledge and skills of students through hands-on engineering practice. Sociocultural learning theory informs this study, as WIL and PBL can be considered approaches where learning happens as a social process, within a community of practise, where people are engaged in an activity, in a socially and culturally structured work environment.

In this thesis, the PBL was engineering applied projects and WIL was work placements. Data collection occurred from five cohorts across different stages of their study by conducting online surveys, individual interview transcripts, document analysis, and direct observations. Investigation into classroom learning also provided students insight into fundamental engineering concepts/theories via lectures and tutorials.

The engineering projects assisted students' ability to relate theory with practise and the ability to relate and understand previously developed engineering knowledge

embedded in the project's problem statement. Additionally, engineering projects were primarily interdisciplinary across engineering, which aided in developing additional engineering knowledge. Students also acquired technical skills such as problem-solving, critical thinking, design and manufacturing abilities, 3D drawing skills, 3D software skills, tools/machinery experiences, and non-technical skills like teamwork, communication, and interpersonal skills. The learning from engineering projects was then applied to students' classroom learning and work placements. Learning from the classroom became the knowledge background for students, who then applied it to their future engineering projects.

In work placements, students worked in an authentic work environment, allowing them to engage with authentic practise and develop professional skills. Students drew on their previous learnings from classroom and engineering projects through engineering practise. As work placements were interdisciplinary, they aided in developing additional engineering knowledge. In addition, work experience via industrial projects helped students gain and develop other non-technical skills such as time management, planning, and organising skills, project management, engineering work culture, work experience, work ethics, and professionalism. These findings suggested underlying learning linkages between engineering projects and work placements.

Additionally, in this study, professional skills are used in place of employability skills. In general, all technical and non-technical skills may be commonly considered as employability skills, which are essential skills that make graduates employable. Employability skills is the common term used in WIL literature (Batholmeus & Pop, 2017; Jackson, 2013; Kilpatrick et al., 2021). Whereas, professional skills can be considered as specific profession related technical and non-technical skills, which may be different depending upon different type of workplace, while employability skills are a broad term, which may include professional skills in it. As students do different mechanical engineering work placements, so they develop different professional skills which may be different depending upon type of work placement.

This study concludes that there are aspects of sequencing of scaffolding and complementary learning support between engineering projects and work placements. Engineering projects are placed before work placements to enable sequence of scaffolding of engineering knowledge and skills (technical and non-technical). Additionally, engineering projects provide new knowledge outside classroom learning, thereby, complementing classroom learning. Work placements builds on classroom and engineering projects learning as well as workplace acumen. Work placements are designed to complement projects and, through opportunities to practise in authentic work environments, may also develop employability skills. Therefore, the research findings present recommendations for engineering lecturers and WIL educators to emphasise individual learning outcomes and learning linkages between engineering projects and work placements, which may help enhance students' understanding of engineering knowledge and engineering practise.

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1 INTRODUCTION

1.1 Background

Before coming to New Zealand for my doctoral study, I worked as a Lecturer in the Electronics and Communication Engineering department at Lakshmi Narain College of Technology (LNCT), India. While working in LNCT, I taught subjects such as Fundamentals of Electronics, Analog and Digital Communication, Microwave Communication, Mobile Communication, and Optical Communication. Due to the technical nature of these subjects, I had to conduct practical laboratory sessions as part of the curriculum. Thus, I used both classroom learning and practical laboratory sessions together, where students developed theoretical understanding in classroom learning, and then they would apply it in laboratory experiments.

In doing so, I witnessed students who developed a deeper understanding of theory when they applied it in practise during their laboratory experiments. This experience helped me expand my interest in different ways of teaching and learning that could benefit students by giving them a better understanding of engineering concepts which will help in developing technical and non-technical skills. I could see students more active and engaged in laboratory sessions than in classroom learning, while applying classroom-learned engineering concepts in laboratory sessions. Such an experience encouraged students to relate classroom-learned engineering concepts to practical applications via laboratory experiments. I believed combining classroom learning with laboratory experiment sessions helped students develop knowledge retention and self-learning abilities, as students seemed to be motivated and active after doing laboratory experiments. These experiences motivated me to undertake further research into different teaching and learning approaches that could help the students to deepen their understanding of engineering theory. This became my research interest, and I actively researched advanced teaching and learning approaches used in engineering education across developed countries. Accordingly, I found that in developed countries, there are two primary prominent advanced teaching and learning approaches: Problem-Based Learning (PBL) and Work-Integrated Learning (WIL). I then researched these two approaches and learned of the significant changes they could bring in engineering education to boost students' overall learning process, engineering knowledge acquisition, and skill development. The growing interest in these advanced teaching approaches motivated me to pursue Ph.D research in this field, forming the motivation for my research study. There are several types of PBL and WIL approaches, which are specified later in this thesis. In this study, I would be focusing on engineering projects (university curriculum-based projects with no industrial partner) as potential PBL approach, and work placements as potential WIL approach.

Additionally, in this study, professional skills are used in place of employability skills. In general, all technical and non-technical skills can be commonly considered as employability skills, which are essential skills that make graduates employable. Employability skills is the common term used in WIL literature (Batholmeus & Pop, 2017; Jackson, 2013; Kilpatrick et al., 2021). Whereas, professional skills can be considered as specific profession related skills, which may be different depending upon different type of workplace, while employability skills is a broad term, which may include professional skills in it. As students do different mechanical engineering work placements, so they develop different professional skills which may be different depending upon type of work placement.

1.2 Engineering Education

Engineering is a field of study of the application of technical, scientific, and mathematical concepts about the understanding, design, manufacture, innovation, and use of tools and machineries to address real-world engineering problems (Bokova, 2010). Engineering education is a learning platform where students develop engineering knowledge and technical and non-technical skills, which leads to an-experience-based degree (Backa & Wihersaari, 2015). According to Craig (2017), engineering graduates should be able to integrate conceptual knowledge, techniques, processes, and tools, to solve interdisciplinary engineering problems.

Engineering education is a practice-based field of study, but it is primarily dependent on the traditional lecture-tutorial-laboratory teaching structure, especially in developing countries such as India (Gupta, 2002). Conceptual engineering knowledge can be imparted in students, but the practical aspects of engineering knowledge and skill development are not achievable to the full extent just with the traditional teaching process. According to Clogh et al. (2007), engineering graduates need to deal with complex interdisciplinary engineering problems, which may also have aspects of human and environmental factors in it embedded within them. Modern-day employers need engineering graduates who are skilled with the ability to innovate new ideas, ability to work in diverse work environments, ability to understand important aspects of engineering work culture, and the use of technical and non-technical skills.

Contemporary engineering employers require engineering graduates to be work-ready, who have hands-on experience and minds-on of what engineering is, of what it is to be a successful engineer, and of what contributions and efforts are required for success. According to Craig (2017) and Felder et al. (2000), engineering education should shift from traditional instruction-based learning to active or discovery-based learning that should promote curiosity, initiative, and interest in the subject, thereby favouring students' self-learning, enhancing problem-solving, critical thinking, and development of intellectual growth. Borikov et al. (2016) and Craig (2017) show that along with traditional teaching approaches, the use of additional teaching approaches, which favour active learning, will be beneficial for students. The new modern approaches, which could add more deeper understanding of engineering knowledge, and development of core technical and non-technical skills, are PBL and WIL.

Problem-Based Learning (PBL) in engineering education works by giving an engineering problem to a group of students. In order to solve this problem, students conduct research, extend their previously acquired engineering knowledge, and apply that learning in order to define a solution for the problem (Dahms, 2014; Hitt, 2010; Loyens et al., 2015). PBL provides engineering students an authentic learning opportunity to apply their classroom-developed engineering knowledge and concepts with practical application, which thereby enhances their understanding of previously acquired engineering knowledge, and also develops technical and non-technical skills (Guzelis, 2006; Mills, 2003).

Additionally, WIL is a learning approach in that students work under expert supervision in real work environments, and thereby blend theoretical understanding with practice-based learning (Dressler, 2011; Ferns et al., 2014; Fleming & Eames, 2005). According to Stirling et al. (2018), in WIL, students get an opportunity to combine theory and practice in an authentic work-learning environment, which helps them to deepen their theoretical understandings, and also helps to develop work-related competencies. In engineering education, WIL takes the form of work placements.

Craig (2017) outlines the benefits of implementing PBL and WIL in engineering education:

1. Students can integrate problem-solving, critical thinking, teamwork, and communication skills to address real-world engineering problems.
2. Students will be able to develop professional work ethics, leadership qualities, decision-making, professionalism, and creativity in engineering practise.
3. Students will understand the importance of science, mathematics, and business aspects in engineering.
4. Students will understand the significance of mathematical modelling, prototyping, analysis, and measurement, which leads to innovation and inventions.
5. Students get engineering work experience and a chance to develop employability skills before graduating.

Indeed, a number of studies around applying PBL and WIL in engineering education has shown that these approaches greatly benefit students in deepening their engineering knowledge and developing technical and non-technical skills (Christensen et al., 2006; Christiansen et al., 2013; Crump & Johnnson, 2011; Dahms, 2014; Delisle, 1997; Guzelis, 2006; Hills et al., 2011; Mills, 2003; Nuninger & Châtelet, 2011; Stirling et al., 2018; Tse & Chan, 2003). These studies outline the advantages of PBL and WIL in engineering education and their combined effect on developing engineering knowledge and skills in students. Indeed, there is a learning relationship between classroom learning, PBL, and WIL. The knowledge and understanding of the type of learning linkage can be beneficial, as it might show the specific learning outcomes from these approaches. This can help improve the framework of these three approaches in engineering education, which may help to enhance the overall learning experience of students and may help them to be work-ready graduates. There is no research study which investigates the learning linkages between engineering projects (PBL) and work placements (WIL) in relation to knowledge and skill application and development. The researcher identifies this as a potential research gap and considers this as the base study, which is addressed through this thesis.

1.3 Context of this Study

This research examines the advanced teaching and learning approaches (PBL and WIL) utilised in mechanical engineering education from 1st year to 4th year of study, focusing on developing engineering knowledge, technical and non-technical skills, and employability skills. Engineering has different fields of study, which are mechanical, civil, electrical, electronics, and software engineering. In university, mechanical engineering projects and work placements have aspects of the multi-engineering discipline, which means they will have aspects of civil, electrical, electronics, and software engineering in a mechanical context. In this study, the term interdisciplinary will be widely used to represent this concept.

This study adopted Constructionism as the epistemological stand, as the findings demonstrate that in WIL and PBL processes, students create knowledge through social interactions with lecturers, WIL supervisors, and peers in an environment created by classroom teaching, PBL, and WIL. This study considers Constructivism as the theoretical perspective, as the findings demonstrate that students construct new knowledge through experience of their previously acquired classroom knowledge via social interactions with teachers and peers in engineering projects and work placements. In addition, Sociocultural views of learning and experiential learning theories form the theoretical framework for this study. The research design finalised for this study was mixed methods research, based on explanatory sequential mixed method research.

The study occurred at the School of Engineering, University of Waikato, Hamilton, New Zealand. The major participants of this study were recent mechanical engineering graduates, current students, lecturers, and workplace supervisors. Data collection tools, such as surveys, were conducted online, while the individual interviews were conducted in person within the School of Engineering. Observing on-campus engineering project sessions and off-campus work placements were conducted, and documents, including lecturers' course outlines and students' assignment reports, were collected before the end of each semester. Analysis of the engineering project and work placement observations, online surveys, students' assignment reports, and students', lecturers', and workplace supervisors' interviews were used to identify how students progressed in their engineering education through the application of PBL and WIL.

1.4 Aim of the Research

The main aim of this research was to investigate the participants' views on the combined learning effects of engineering projects (PBL) and work placements (WIL) for preparing engineering students for professional practise in New Zealand. Through this exploratory research, an overview was obtained of how the work placements and engineering projects impact students' knowledge and skill development and their combined effect on engineering education. Thus, a relation was obtained about how engineering projects and work placements scaffolded and complemented each other.

This study used mixed methods research to gain information by conducting online surveys and individual face-to-face interviews and observations. The target participants of this research were lecturers, workplace supervisors, current engineering students, and recent graduates (related to mechanical engineering) who constitute the main stakeholders in engineering education. Thus, they are collectively termed 'participant stakeholders' in this study.

A recent study by Lu et al. (2018) points out the inefficiency of universities for under-preparing students in terms of work-readiness, keeping students disconnected from the real-world applications, and thus lagging them in terms of industrial trends and business etiquettes. According to the report of IPWEA (2018), there is high demand for skilled engineers, because there exists a "skill mismatch" between the potential jobseekers and the skills employers are seeking. According to Kozinski and Evans (2017), the engineering education has lost the inter-relation of theory and practise, whereas engineering education means theory and practise should go hand-in-hand, in order to make highly skilled engineering graduates. Thus, a shift is required in the engineering paradigm, that is, new teaching approaches need to be applied for the modern engineering requirements (Borikov et al., 2016).

Studies by Hitt (2010) and Jackson (2018) show that PBL and WIL approaches have proved to be successful in enhancing knowledge and understanding, and employability skills in the engineering students. Craig (2017) states that when WIL and PBL approaches along with engineering education are applied, students will enhance their problem-solving, team-working, communication skills, professionalism, leadership qualities, professional ethics, social responsibilities, creativity and critical thinking, business operations and management skills. Based on such findings, it is clear WIL and PBL can add more to the students in terms of knowledge and skill development compared to the traditional mode of teaching.

Better education and training could enhance students' knowledge and skill development and increase their chances of securing relevant employment. This study focused on identifying the relation between WIL and PBL and insight into how PBL and WIL scaffold and complement each other. This study also focused on how to improve current practices of WIL and PBL to enhance their future scope. Thus, the knowledge of the type of learning linkage between PBL and WIL could help to enhance the engineering knowledge acquisition and overall skill development of the engineering students. The findings demonstrate that knowledge of each approach's scope and learning outcomes may help to create an engineering education framework, which may be utilised to enhance students' overall development of engineering knowledge and technical and non-technical skills, thereby making them work-ready graduates.

1.5 Research Questions

The main research aim was:

What are stakeholders’ views on the combined learning effects of engineering projects and work placements for preparing engineering students for professional practise?

From this main aim, the following research questions were derived:

1. What are stakeholders’ perceptions of engineering student learning through engagement with PBL and WIL?
2. What, if any, scaffolding of learning occurs between PBL and WIL?

3. What aspects of PBL and WIL are complementary (or not) in advancing student learning of the practise of engineering?
4. How can understanding the synergies and differences between PBL and WIL inform and/or enhance the engineering curriculum?

1.6 Overview of Chapters

This thesis is organised into six chapters outlined as Chapter 1 (Introduction), which introduces a concise overview of the study and the various sections of the thesis document. Chapter 2 (Literature Review) introduces the literature around engineering, engineering education, knowledge, and skill development. The main sections of the Literature Review chapter are divided into four sections. The first section is on engineering knowledge and skills, including a detailed introduction and literature around engineering knowledge and different skills such as scientific-technological, interpersonal, leadership, and financial skills are presented. In the second section, literature around future-focused skills and dispositions in engineering education is presented, followed by the advanced teaching approaches and pedagogies in engineering education. In the third section, literature exploring the PBL and WIL partnership is presented, explicitly investigating scaffolding and complementary linkages between PBL and WIL. Lastly, in the fourth section, the research gap is presented, and the focus of this study is established. This chapter presents an expansion of the significance and motivation to undertake the study.

Chapter 3 (Methodology) discuss the research paradigm and justification adopted for this study. This chapter presents the research background, research design, methods, and processes used for data collection and analysis, and identification of themes. This chapter wraps up with the research design, which will be used in the following findings and discussion chapters.

Chapter 4 (Findings) presents the research design to investigate the learning linkages between PBL and WIL for mechanical engineering students and recent graduates from the School of Engineering, University of Waikato in Hamilton, New Zealand. The data in this study are presented as responses from an online survey (quantitative data) along with interview transcripts, observations, and document analysis, forming the qualitative data. The quantitative and qualitative data and their detailed analyses helped establish the learning linkages between engineering projects and work placements, and the relationship between how the learning transfer took place between classroom learning, engineering projects, and work placements.

Chapter 5 (Discussion) presents the findings, data, and literature triangulated along with interpretations from the researcher to understand the learning linkages between engineering projects and work placements. This chapter is structured around the study's research questions and key themes.

Chapter 6 (Conclusions) presents the conclusions of the study findings with implications for engineering students, lecturers, and workplace supervisors and the potential future scope of the study. The research questions are also addressed and answered explicitly in this chapter.

1.7 Conclusion

This chapter concludes with a brief overview regarding the context and the methodology with which to frame the study. It also briefly presents the background and significance of the study and gives a brief outline of the contents of each chapter. The next chapter, Chapter 2, Literature Review, presents a detailed review of the relevant literature in the field and identifies the research gap and outlines the research questions.

2 LITERATURE REVIEW

This chapter discusses the literature relevant to this research. There are four main aspects to this literature review. The first aspect is on tertiary education in general, introducing the different levels of education, commencing from early schooling to post-graduation. This is followed by the tertiary education system in New Zealand. The literature is then focused on engineering education in New Zealand, primarily on universities. The second aspect is on engineering knowledge and skills, whereas the skills can be categorised as scientific-technological skills, process skills, interpersonal, leadership, and financial skills. This second aspect also includes different knowledge domains in technology education, and how they correlate with engineering education. The third aspect is on future-focused teaching approaches, which favours future-focused skills and dispositions (engineering knowledge and skills). Here, the literature will be mainly focusing on Work-Integrated Learning (WIL) and Problem-Based Learning (PBL). The fourth aspect will be an exploration of the WIL and PBL partnership based on comparison to find the complementary and scaffolding linkages between them. The fourth section draws together all these aspects to outline the significance and rationale of the study, and the research questions based on the identified research gap.

2.1 Tertiary Education

Tertiary education is the level of education following the completion of secondary education. Continuation of study after compulsory education as undergraduate and postgraduate levels are collectively termed Tertiary Education. It culminates in the receipt of certificates, diplomas, or academic degrees (Bank, 2018).

2.1.1 Tertiary Education in New Zealand

The education system in New Zealand is governed by the New Zealand Qualifications Authority (NZQA). The NZQA has different levels of study as listed in their framework structure - New Zealand Qualifications Framework (NZQF). According to the NZQA (2021), the NZQF is divided into 10 education levels, covering a range of qualifications from certificates to doctoral degrees. Levels 1 to 6 are certificate qualifications, where students learn basic operational knowledge (level 1) of a field to broad operational and theoretical knowledge (level 6) in a field of work or study. Level 7 is a graduate certificate qualification, which can cover diploma courses, graduate diploma courses and bachelor's degrees. Level 8 is a postgraduate certificate qualification, which can cover postgraduate diploma courses and bachelor honours degrees. Level 9 is a master degree qualification and level 10 is a doctoral degree qualification (NZQA, 2021).

Tertiary education in New Zealand is offered by Universities, Institutes of Technology and Polytechnics (ITP), private training establishments (PTE), workplace training, and industrial training organisations (ITO) (Bank, 2018). According to Education Counts (2019), 0.06% of the New Zealand population undertook tertiary education during 2019. These all deliver a wide variety of educational career options, often in flexible ways to meet the needs of learners. Higher degree-level education is mostly offered at universities, where programmes are research-led and generally academic in nature (NZQA, 2017). The vocational degree level of education is usually offered at ITPs and PTEs (NZQA, 2017). The current education system of New Zealand, emphasises to both learning and training, to gain knowledge and skills via both classroom learning and training through work placements, internships, apprenticeships, etcetera (Murrihy, 2017). Innovative teaching and learning approaches are utilised in the tertiary education structure of many developed countries including New Zealand (New Zealand Education, 2017, 2018).

2.2 Science, Technology and Engineering: Defining and Differentiating

Science, Technology, and Engineering are repeatedly confused with each other. All three are closely related but mean different things (Dev, 2012; Poser, 1998; Quellmalz, 2015). Science is the study of how the natural world is put together, derived from observation of the world, and accordingly, creating meaning of natural phenomena (Dev, 2012; Dugger, 1993; Quellmalz, 2015). Science is an efficient venture that formulates and arranges information, quantifies, and clarifies expectations about the universe (Jin, 2020). Science aims to understand, while Technology is the set of designed and developed creations, derived from repeated application and approval of the tools, and accordingly creating a collection of purposeful and tested products and systems for mankind (Dev, 2012; Dugger, 1993; Quellmalz, 2015). Technology can also be referred as the accumulation of procedures, abilities, and routines utilised as a part of the creation of products or services or in the accomplishment of final goals. Engineering is a subset of Technology and is creation based on scientific knowledge combined and derived from acquiring and applying knowledge, and accordingly creating new products, devices, tools, and processes (Dev, 2012; Dugger, 1993; Quellmalz, 2015). Engineering is also referred as an application of the knowledge of the natural sciences (Poser, 1998). Engineering can also be defined as the use of arithmetic, logical, financial, social, and viable learning with a specific end goal to create, design, assemble, maintain, examine, and enhance structures, machines, devices, frameworks, parts, materials, and procedures (Jin, 2020). The following section discusses the related knowledges in engineering education.

2.3 Related Knowledges

In Engineering education, students learn about engineering concepts and theories throughout their four years of engineering study. Throughout this period, students develop different types of knowledge, from which tacit and expert knowledge are of interest in this study. Tacit knowledge can be defined as the ability to learn from experience (Drysdale & McBeath, 2012; H. Mohajan, 2017; Olomolaiye & Egbu, 2005). Tacit knowledge is the procedural information required to function in daily life that typically is not explicitly taught or even verbalised (Drysdale & McBeath, 2012; Miton & DeDeo, 2022). Tacit knowledge has also been acknowledged as both an outcome of experience-based learning and as a necessary basis for continuous learning (Drysdale & McBeath, 2012; Hugo-Burrows, 2022; McAdam et al., 2007). Tacit knowledge is technical or cognitive, as it is made up of mental models, values, beliefs, perceptions, insights, and assumptions (McAdam et al., 2007; H. K. Mohajan, 2017; Thomas & Gupta, 2022). This is a type of knowledge that workers possess, referred to as skilled, know-how, working knowledge and/or expertise, and can be used to describe tacit knowledge. For example, learning that happens through work placements, internships and apprenticeships brings mostly tacit knowledge in students/workers. According to Mitchell et al. (2022), tacit knowledge can be termed as practical, action-oriented knowledge or 'know-how' based on practise, acquired by personal experience, and seldom expressed openly.

On the other hand, explicit knowledge is termed as the academic knowledge or 'know-how' that is described in formal language, print or electronic media, often based on established work processes, and a people-to-documents approach (Asbari et al., 2019; Olomolaiye & Egbu, 2005; Smith, 2001). According to H. K. Mohajan (2017), explicit knowledge is theory-based knowledge, which can be transmitted in formal, systematic language. Explicit knowledge implies factual statements about matters as material properties, technical information and tool characteristics (Asbari et al., 2019; Olomolaiye & Egbu, 2005). Thus, the knowledge that is capable of being captured and widely distributed is explicit knowledge. These two knowledge types were evident in this study and so, these knowledges are of interest.

2.4 Engineering

Engineering is a branch of technology that draws heavily on science and dedicated to problem-solving through engineering design, analysis, testing structures, and processes to improve quality of life. Engineering involves the persistent application of mathematics and natural sciences with a collection of engineering knowledge, technology, and techniques (International Engineering Alliance, 2014). Engineering is the discipline and art that facilitates the development, attainment, and presentation of scientific, technical and mathematical knowledge about the understanding, planning, development, origination and use of resources, machines, arrangements, systems, and procedures for specific purposes (Bokova, 2010; Lopez-Cruz, 2022). There are different engineering disciplines such as computer science engineering, electrical engineering, electronics and communication engineering, civil engineering, mechanical engineering, aeronautical engineering, and chemical engineering.

2.4.1 Engineering Education

The ultimate purpose of Engineering education is to build a foundation of engineering knowledge and attributes to enable graduates to undertake successful engineering practise. Students learn and progress with constructive development to facilitate skills and competencies needed for this practise (International Engineering Alliance, 2014). Engineering education especially in higher education, should prepare students to be sound decision-makers, competent to have environmentally aware attitudes, competencies/skills and performance patterns, and also a sense of professional ethics (Broo et al., 2022; Paten et al., 2005).

The International Engineering Alliance (IEA) is a global organisation, which governs the recognition of engineering qualifications, and enforces internationally recognised standards for engineering education and anticipated competence for professional engineering practise (International Engineering Alliance, 2021). The IEA has established three accords for engineering education (International Engineering Alliance, 2021), which are:

1. Washington Accord: The Washington Accord is a global agreement signed between organisations responsible for accrediting tertiary-level engineering degree programmes. The main aim of the accord signatories is to assist developing globalisation of engineering qualifications. The Washington Accord is mainly focused on professional academic programmes which establish the practise of engineering (International Engineering Alliance, 2021).
2. Dublin Accord: The Dublin Accord is a global agreement instituting the required educational foundation or basis for engineering technicians. The Accord concedes that the educational foundation is a strategic basis for engineering practise as an engineering technician. It establishes the significance of the roles engineering technicians complete as part of a comprehensive engineering team (International Engineering Alliance, 2021).
3. Sydney Accord: The Sydney Accord is a global agreement signed between organisations responsible for accrediting engineering technology academic qualifications/programmes. The Accord mainly focuses on academic qualifications based on engineering technology. It establishes the significance

of the roles engineering technologists complete as part of a comprehensive engineering team (International Engineering Alliance, 2021).

These three Accords are directly related to engineering. For universities' engineering education, the Washington Accord is the most appropriate as it focuses on tertiary-level engineering degrees, which comprises bachelors, masters and doctoral levels of study. Universities in New Zealand follow the Washington Accord for their engineering education curriculum structure (Engineering NZ, 2018).

A major challenge in engineering education is the integration of classroom learned theoretical knowledge with practical experience, so that engineering practise is ethically constructed and skilled to tackle complex challenges faced throughout an engineering career. According to Chetty (2017), a university qualification alone does not guarantee employment. In a swiftly changing global economy institutions must create a learning environment which inspires students to enthusiastically participate in a process of engineering practise (Dempsey et al., 2001; Schleiss et al., 2022).

According to the Royal Academy of Engineering (2018), engineering education should be undertaken by "learning by doing" and then learning by failures. Indeed, of over-emphasis on theory and assessment within engineering education internationally, there should be more hands-on practical experience and activities that enhance engineering practise of students than just traditional classroom lectures. The engineering field, being practical in nature, requires hands-on experience and uncovering the real-world applications to be fully competent and successful. The best practise to train engineering students is by integrating work experiences with education, thus enabling students to be work-ready graduates on the completion of their course (Konyukhov et al., 2019; Yannul, 2009).

2.4.2 Engineering Education in New Zealand

New Zealand Education (2017) states that engineering education in New Zealand is of high quality, where learning occurs through a practical, hands-on teaching environment aiming to motivate students to think laterally, critically, and creatively. The New Zealand engineering curriculum is designed to incorporate several study-practise approaches for students, to enhance their knowledge and skill development, and enable them to be creative engineers by encouraging them to practise engineering training (New Zealand Education, 2017). NZQA along with Engineering New Zealand, monitors the engineering programmes in universities and ITPs in New Zealand (Engineering NZ, 2021; NZQA, 2021).

Engineering education in New Zealand can be undertaken in universities, institutes of technology and polytechnics (ITP), private training establishments (PTE), workplace training, and industrial training organisations (Bank, 2018). The universities provide four-year bachelor's degree and one-year master's degree and four-year doctoral degree programmes in Engineering, while ITPs provide a two-year diploma. Polytechnic courses focus on practise-based Engineering and offer three-year degrees and two-year diplomas courses in engineering.

2.4.2.1 Engineering Education in New Zealand Universities

New Zealand universities focus on duality, comprising academic learning and hands-on practical work through various versions of WIL, such as work-placements, internships, and apprenticeships, which are part of the curriculum (Khoo et al., 2020). These provide sources of knowledge and skill development in addition to classroom (New Zealand Education, 2018). Also, engineering education in New Zealand universities encourages students to perform high-end engineering projects, which helps students to better understand the classroom learning and design, and working of real-life applications of the learned theories (New Zealand Education, 2018). These sessions help students to take responsibility to discover the knowledge/information to solve the problem/project (Mikhridinova et al., 2022; Tse & Chan, 2003). Due to the application of various forms of WIL and PBL, students benefit from hands-on experience in engineering practise, which enhances their knowledge and skill development through authentic learning environments (New Zealand Education, 2018).

2.4.2.1.1 Authentic Learning

Authentic learning is a teaching and learning approach in which learning is improved when it is conducted in a surrounding designed to be as close as possible to the real world applications in which the course context will be used (Corrias et al., 2014). Authenticity contains several categories, which are:

1. Content authenticity which enables real-world context,
2. Task authenticity which enables students to access real-world applications, and
3. Impact authenticity which enables students to apply in-class learning to the outside world (Barad et al., 2000; Fox-Turnbull, 2002; Ornellas et al., 2019).

Higher educational institutions provide multiple occasions for students to master their skills on authentic tasks requiring cohesive application of various knowledge and skills (Bosman & Fernhaber, 2018). To bring authentic learning practices into classroom learning, WIL and PBL practices are predominantly used in New Zealand Higher Education Institutions, thus favouring knowledge and skill development. In the next section, a brief introduction is provided for engineering knowledge and related skills.

2.5 Engineering Skills and Engineering Knowledge

In this section, engineering skills and knowledge are introduced, along with their different types, which may be technical or non-technical in nature. In the next section, engineering knowledge is discussed, followed by engineering skills.

2.5.1 Engineering Knowledge

The NSPE (2013) states that engineering knowledge is comprised of understanding theories, concepts, and fundamentals, along with the ability to perform tasks and accordingly apply knowledge (NSPE, 2013). Antink-Meyer and Brown (2019) suggest that engineering knowledge can be related as a transference from the knowledge source to practical problem-solving. According to Deahl et al. (2013), engineering knowledge can be summed up as the following:

1. developing confidence on engineering ability,
2. using problem solving skills,
3. developing engineering identity,
4. applying classroom learning, and
5. accepting ambiguous information.

Deahl et al. (2013) state that professional growth can be categorised as technical knowledge, project management, community-based development, and communication. Personal growth can be attributed by intercultural awareness, communication, and community-based development. When students undertake work placement via WIL and engineering projects via PBL, students develop their project management, technical knowledge, communication, and interpersonal skills, along with the development of engineering knowledge.

Also, work placements and engineering projects enable students to mingle with students from other engineering disciplines and their lecturers and workplace coordinators, thereby enhancing their intercultural awareness, communication skills and community-based development. In the next section, the cross-discipline related terms and categorisations of engineering skills are presented as scientific-technological skills, process skills, interpersonal, leadership and financial skills.

2.5.2 Cross-Discipline Related Terms

2.5.2.1 Ability

Ability is defined as the skill or competence to accomplish an physical or mental assignment or task (Parker, 2016). According to Scott (2014), ability is referred to as the capacity to construct knowledge through proper training. Ability is the main measure to tell whether a person will be able to do an assigned task, and with how much precision.

2.5.2.2 Capability

Capability is defined as the ability that can be developed, in order to effectively apply individual competencies under the right conditions and exploit the results (Parker, 2016). Capabilities make individuals more productive, by focusing on the ability to develop and modify to meet future needs (Hans, 2014; Nagarajan & Prabhu, 2015; Parker, 2016). A person with capability has the potential to attain specific abilities or skills that will prove helpful for task completion.

2.5.2.3 Competence

Competence can be defined as the ability of an individual to correlate attitudes, skills and knowledge, applying them collectively for successful learning (Enginoglu & Arikan, 2016; Hans, 2014). The capability to successfully apply knowledge, skills, personal characteristics, and abilities to carry out critical tasks, functions in a defined work environment (Ennis, 2008; UTH Education, 2012; Vitello et al., 2021). Competencies are related to individual's job profile and capabilities.

2.5.2.4 Skills

The skills can be referred to as the ability to accomplish various tasks, which may combine mental and physical tasks to yield successful outcomes (Black et al., 2012; Boucher, 2020; Winterton et al., 2006). Skills can also be related to as the level of performance, that is, the measure of speed and accuracy to perform tasks. Skills can be learned through conventional instruction, or through training in the form of apprenticeship. According to Heckman and Corbin (2016), possession of skills is termed as having internal capabilities, and appropriate usage of skills through social interactions is termed as external capabilities.

2.5.2.5 Qualities

Quality is defined as the personality traits/characteristics or a framework through which skills can be applied efficiently (Frank, 2018). Qualities and skills are different because qualities are not something that an individual can learn, whereas skills can be learned over a period of time (Midkent, 2013). Quality is the part of an individual's personality, which is naturally within him/her, and improves over time (Sarfraz, 2014).

From the above stated cross-discipline related terms, the term "skills" will be widely used in this thesis, as it relates more to engineering education.

The engineering graduates need to have a strong grasp of creativity, critical thinking, problem-solving, communication, and teamwork skills, additional to other work-related skills such as attention to detail, self-discipline, organisational aims etcetera.

(International Engineering Alliance, 2014; Melchor, 2012; Shekhawat, 2020). Kay (2010) suggests that engineering skills can be sub-divided into three categories: technical skills, process skills and generic skills. A combination of these skills and processes becomes essential in an engineering professional. The different types of engineering skills and their groupings are shown in Table 2.1.

Table 2:1: Different engineering skills relevant to engineering education and graduate engineers.

GROUPS	SKILLS	CITATIONS
	Contextual understanding	(Allan & Chisholm, 2008; Christensen et al., 2006; Doleta, 2016; El-Baz & El-Sayegh, 2007; Engineers Australia, 2014; International Engineering Alliance, 2014; Male, 2010; NCSU, 2016; OECD, 2014; VBA, 2016)
	Interdisciplinary knowledge	
	Knowledge management	
	Analysis problem	
	Problem-solving	
Technical skills	Engineering design and analysis	
	Intercultural cooperation and communication	(Christensen et al., 2006; International Engineering Alliance, 2014)
	Utilisation of resources	
	Familiarity of methodologies, engineering knowledge and expertise	
	Strategic and operations planning	(El-Baz & El-Sayegh, 2007)
	Project management	(Allan & Chisholm, 2008; Christensen et al., 2006; El-Baz & El-Sayegh, 2007; International Engineering Alliance, 2014; NCSU, 2016)
	Human resource planning and selection	(El-Baz & El-Sayegh, 2007)
	Technical marketing	(El-Baz & El-Sayegh, 2007)
Process skills	Strategic networking	(OECD, 2014)
	Management of information	(Engineers Australia, 2014)
	Sensitivity / Empathy	(Doleta, 2016)
	Maintaining open relationship	(Doleta, 2016)
	Cultural Awareness	(Doleta, 2016; El-Baz & El-Sayegh, 2007)
Interpersonal skills	Team working	(Allan & Chisholm, 2008; Doleta, 2016; El-Baz & El-Sayegh, 2007; OECD, 2014; VBA, 2016)
	Vision	(El-Baz & El-Sayegh, 2007)
	Effective communication	(Allan & Chisholm, 2008; Doleta, 2016; El-Baz & El-Sayegh, 2007; Engineers Australia, 2014; Male, 2010; NCSU, 2016; Varnado, 2010)
	Multidisciplinary teamwork	(El-Baz & El-Sayegh, 2007)
	Ethics and social responsibilities	(El-Baz & El-Sayegh, 2007)
Leadership skills	Motivation	(El-Baz & El-Sayegh, 2007)
	Cultural awareness	(Doleta, 2016; El-Baz & El-Sayegh, 2007)
	Business etiquette	(Mannan, 2014)
	Stress management	
Financial skills	Financial analysis	(Allan & Chisholm, 2008; El-Baz & El-Sayegh, 2007; Male, 2010)
	Economic analysis and evaluation	(El-Baz & El-Sayegh, 2007)
	Cost estimation	(El-Baz & El-Sayegh, 2007; Male, 2010)

2.5.3 Scientific-Technological (Technical) Skills

These are the skills that help graduate engineers to enhance their capabilities of problem analysis and solving, contextual understanding and ability to apply interdisciplinary knowledge (Doyle, 2018). Engineers with scientific-technological or technical skills are creative thinkers and can work through abstract engineering concepts and ideas (Allan & Chisholm, 2008; Doleta, 2016; Saleh & Lamsali, 2020)

Mastery of the technical skills (Table 2.1) leads to effective analysis of the problem, raising ideas, courses of action, and suggestions. These skills help the engineering professionals to make sound decisions based on the resources available. For example, to analyse a problem and/or situation, engineers need abstract engineering knowledge and critical thinking (Christensen et al., 2006; Saleh & Lamsali, 2020).

For these skills to be operational, the engineering graduates must have:

- profundity of engineering knowledge that is obtained during the four-year engineering programme,
- ability of analysis - possessing theoretical thinking and investigation skills to formulate suitable solutions to the problems,
- awareness of issues and possess knowledge of different types of specific engineering discipline problems,
- interdependence - to possess interdisciplinary engineering knowledge, which indeed may help to resolve high-end problems; and
- sound judgement, or decision-making skills for resolving engineering problems (International Engineering Alliance, 2014).

With expert technical skills, the engineers learn to solve problems using interdisciplinary knowledge, within a team utilising their communication and interpersonal skills (Beagon et al., 2019; Saleh & Lamsali, 2020).

2.5.4 Process Skills

Process skills are skills that help engineering graduates take responsibility and prepares them to lead a team. These skills improve management of work operations within organisations (Christensen et al., 2006; Saleh & Lamsali, 2020).

The process skills stated in Table 2.1, show the efficient planning and organising abilities of the engineering professional. Skills such as planning, setting priorities, making decisions, and influencing people, shape the leadership qualities within the engineering professionals (TryEngineering, 2016). Cooperation within a team occurs due to better understanding between colleagues, with sound communication between them. Better understanding of the organisation needs and aims helps to pre-plan tasks related to the projects, based on effective decision-making and utilisation of resources, in order to execute works smoothly and flawlessly (Ornellas et al., 2019; Panuwatwanich, 2011).

2.5.5 Interpersonal, Leadership and Financial Skills

These are the skills related to moral and ethical values, communication skills, technical expertise, level of confidence, flexibility to adapt according to the workplace needs, teamwork, taking initiative, and financial management skills (Melchor, 2012; Ornellas et al., 2019; Saleh & Lamsali, 2020; Shekhawat, 2020). These skills can also be referred to as generic skills or lifelong learning skills, which are essential employment-related skills that can help engineering graduates throughout their professional, social and personal lives (Chikumba, 2011; Esa et al., 2013; Mannan, 2014). These skills encompass almost all aspects related to human nature and characteristics, especially interacting with people with whom the graduate engineers will work (Berglund & Heintz, 2014; Mannan, 2014). In the next section, different knowledge domains in technology education are presented.

2.6 Knowledge Domains in Technology Education

Dugger (1993) indicated that engineering is a branch of technology in which the knowledge of natural sciences and mathematics are developed by study, application, experience, and practise to solve engineering problems for the benefit of mankind. Technology practise is a valuable aspect and precursor to engineering, as technology outlines the learning of procedures, processes, and practise that are related to tools, machinery, gadgets, and manufacturing (Jin, 2020). Technology education involves learning of knowledge related to technology, involving complicated and correlated problems, and multi-dimensional learning of knowledge domains that are conceptual, procedural, societal, and technical knowledges (Jones, 1997). Technology education challenges students to learn, construct, solve problems, and create solutions using different artefacts such as tools, machinery, materials, computers, and processes, just as engineering does. This results in development of different knowledge domains (conceptual, procedural, societal, and technological) in students through technology education, all essential to the understanding and undertaking of authentic and holistic technology and engineering education. These knowledge domains are introduced in this section.

2.6.1 Conceptual Knowledge

Conceptual knowledge is the knowledge that focuses on relationships or inter-relations of concepts and procedures to explain technology (Compton, 2004; Jones, 1997). Conceptual knowledge defines learners' projections, clarifications, experiences, and perceptions of processes, procedures, and problems (Jones, 1997). The conceptual knowledge domain development happens in a social learning space, through listening, viewing, reading, reflections, experiences, and study activities. Accordingly, conceptual knowledge promotes understanding of the principles, concepts, process, procedures, and relationships that underlie a domain in a careful, supervised learning environment (Compton, 2004; Jones, 1997; Jones & Moreland, 2004).

2.6.2 Procedural Knowledge

Procedural knowledge is the knowledge that focuses on establishing 'know-how' to perform actions, 'what to do', and 'when to do it' that leads to desired outcomes (Compton, 2004; Jones & Moreland, 2004). This knowledge specifies the procedural use of actions, defining the conditions to use it, when to use it, how to use it, why use it, and what to expect as outcome when applied. The development of procedural knowledge happens by first developing conceptual knowledge behind the action, and then applying and practicing the action, which in turn develops the understanding of the applied action. In this way, knowledge related to methods, processes, procedures, and operation of tools, machinery, and equipment are developed in procedural knowledge (Compton, 2004; Jones, 1997; Jones & Moreland, 2004).

2.6.3 Societal Knowledge

Societal knowledge relates to knowledge associated with aspects of correlation between technology and groups of people in a social environment (Jones & Moreland, 2004). The knowledge that is constructed by a community or social circle, that is, classrooms, workshops, laboratories, seminars, conferences and so on, can be termed as social or societal knowledge (Jones, 1997; Jones & Moreland, 2004). Through sharing and contributing knowledge within a social environment, the social knowledge is constructed based on collective and collaborative efforts. Social knowledge is important as the knowledge is constructed socially, which involves the aspects of people and culture in the development of knowledge. The knowledge constructed in a social environment is not simply the sum total of the group's or community's knowledge, but it is also the product of relationships and associations within a particular group or community.

2.6.4 Technical Knowledge

Technical knowledge relates to knowledge associated with skills related to manual and practical techniques (Jones, 1997; Jones & Moreland, 2004). The knowledge of how to use a skill is referred to as technical knowledge. The experience-based know-how is a key factor which helps to develop the understanding and applications of skills in technological activities, such as in manufacturing and engineering designs. The next section focuses on integrating the technology education knowledge domains with engineering education.

2.7 Mapping Technology Education Knowledge Domains with Engineering Education

Technology is the learning of procedures, processes, and frameworks that are utilised as a part of the creation of products or services. Engineering is the application of procedures, processes, and frameworks to produce and evaluate solutions, designs, and technologies (Dev, 2012; Dugger, 1993; Jin, 2020). Thus, engineering is the branch of technology, therefore, the technology education's knowledge domains mentioned above may have correlations with engineering education. The knowledge domains in technology education are based on developing knowledge through aspects of conceptual, procedural, societal, and technical practices. In engineering education, the learning process includes development of learners' engineering knowledge and skills through aspects of conceptual, procedural, societal, and technical knowledges and practices. The application of future-focused teaching approaches (engineering projects and work placements) in engineering education aids in developing knowledge and skills, as indicated in Section 2.10.2 and 2.10.3. These approaches help students to develop knowledge and skills based on aspects of conceptual, procedural, societal, and technical practices. In technology education, conceptual knowledge is development of knowledge related to concepts, processes, and procedures (Compton, 2004; Jones, 1997; Jones & Moreland, 2004), and this relates to engineering education too. In engineering education, students develop conceptual knowledge of concepts, processes, and procedures through a range of approaches, such as classroom learning, engineering projects, and work placements. These approaches provide the necessary environment for development of conceptual knowledge, through aspects such as listening, viewing, reading, reflections, experiences, and student-centred activities.

In technology education, procedural knowledge relates to knowledge of knowing how to do an action, what to do, and when to do it (Compton, 2004; Jones, 1997; Jones & Moreland, 2004). This knowledge is developed based on prior developed conceptual knowledge and its applications to technological activities. In engineering education, students also develop procedural knowledge of how to do an action, by engineering training provided by engineering projects and work placements. There, students correlate prior developed conceptual knowledge with the actions to develop their understanding, applications, reflections, and experiences of those actions.

The societal knowledge of technology education relates to knowledge constructed through correlation between technology and group of people or community or culture (Compton, 2004; Jones, 1997; Jones & Moreland, 2004). In engineering education, students must develop collective social knowledge through relationships and connections within their student groups created in classroom activities, engineering projects, and work placements in order to work collaboratively and sensitively taking into account impacts and influences of people. The project’s problem-solving process and work placement’s work experiences encourage students to work under a team and they socially construct their knowledge by sharing and contributing knowledge within that specific group. These socially constructed outcomes in terms of knowledge and skills impact and influence people and their environment, as these outcomes helps in understanding how the social world is organised and regulated through the application of science, technology, and engineering.

Lastly, the technical knowledge of technology education relates to knowledge of skills related to manual and practical techniques (Compton, 2004; Jones, 1997; Jones & Moreland, 2004). In engineering education, students also develop technical knowledge of technical and non-technical skills by undertaking engineering projects and work placements. Through these approaches, students develop understanding and applications of different skills, which help them to develop their knowledge of know-how on applying these skills to technological and engineering activities. The technical knowledge in engineering education can be related to the development of scientific technological (technical) skills, as outlined in Section 2.5.3, as students develop knowledge of know-how to use these skills, when to use it, and where to use it for problem-solving purposes.

This mapping between technology education’s knowledge domains with engineering education shows that learners in both educational fields develop the common aspects of conceptual, procedural, societal, and technical knowledge domains through a range of learning approaches and activities, further evidence that technology education has the potential to be a strong prerequisite for engineering education. Other recommended prerequisite skills and dispositions for engineering education are the future-focused skills and dispositions, introduced and described in the next section.

2.8 Future-Focused Skills and Dispositions

This section highlights the skills and dispositions which are important for life-long purpose. These relate to the 21st Century skills also known as future-focused skills and dispositions. The 21st Century is moderately different from the 20th Century in terms of demand for highly skilled, knowledgeable, socially, and environmentally enlightened people for employment, citizenship, and self-learning. In the 21st Century, engineers should be sufficiently competent and equipped themselves with wide variety of technical and non-technical skills, such as core engineering knowledge, problem-solving, critical thinking, communication, teamwork and lifelong learning among others (Akinshipe et al., 2022; Kohlbeck et al., 2021; Melchor, 2012). The teaching and learning process in the 21st Century should be engaging, relevant and authentic, so that students develop deep critical cognitive abilities, so that they can understand, investigate, and use information for a variety of applications, including development of new ideas, products, and systems.

According to Kohlbeck et al. (2021) and Dede (2010), some essential desired future-focused skills and dispositions for today's graduates are:

- digital-age literacy - this is combination of scientific, economic, technological, visual, and information literacies, which help the graduates to better understand the modern way of working, co-operation and co-ordination;
- inventive thinking - comprising adaptability, managing complex issues and problems, self-learning, creativity, higher-order thinking, and sound reasoning;

- effective communication – teamwork, collaboration, interpersonal skills, and interactive communication between colleagues, within organisation and community, to better convey the proper work-related terms and issues to others in simple recognisable ways;
- high productivity - prioritising, planning, organising, effective use of resources such as people, money, and tools, ability to produce relevant high-quality ideas and products, creativity, and innovation.

Additionally, engineering graduates also need the ability to undertake the following:

- To apply current knowledge to generate new ideas and products (especially during their work placements and engineering project sessions), thus enhancing their level of creative thinking.
- To create resolutions for problems as a means of personal or group expression, thus enhancing their problem-solving skills, teamwork co-operation and coordination, and better knowledge retention.
- To use digital media, tools, and environments to communicate with each other, thus favoring effective collaboration. This enhances social interactions with each other formally and digitally, and thus enhancing their communication skills.
- use digital tools to gather information, plan strategies to guide inquiry, and accordingly, organise and analyse information, to address problem-solving and critical thinking and analysis. This encourages students to conduct research and effective planning and organising skills (Beagon et al., 2019; Dede, 2010).

This section presented necessary Future-Focused skills and dispositions deemed necessary for success in the 21st Century. In the next sub-section, links between future focused skills and engineering dispositions are presented.

2.8.1 Links between 21st Century skills and Engineering Dispositions

Commonalities of skills between engineering skills and 21st Century skills are extensive, but many are in short supply in engineering graduates at the present time (Craig, 2017). Employers indicate that most engineering graduates lack general engineering skills and 21st Century skills (Craig, 2017). The scientific-technological skills, process skills, and generic skills (interpersonal, leadership and financial skills) make direct links to the 21st Century skills such as digital-age literacy, inventive thinking, effective communication, and high productivity. Also, with the application of authentic learning, students should have direct contact with the context-based real-world environment, to enhance their knowledge and skills (Bosman & Fernhaber, 2018; Corrias et al., 2014; Mitchell et al., 2022; Shekhawat, 2020). With the cross-application of content, task and impact authenticities, learners can be brought closer to the realities of real-world applications, providing knowledge from external elements such as social and environmental constructs (Strobel et al., 2013). The linkages between engineering skills and 21st Century skills are presented in Figure 2.1.

Figure 2.1: Skill linkages.

With proper training and practise, engineering students who work through work placements and engineering projects, engage in authentic learning, balanced with classroom learning, develop as 21st Century graduates with the future-focused skills and dispositions within. In the next section, the future-focused skills and dispositions relevant to engineering education are discussed.

2.9 Future-Focused Skills and Dispositions in Engineering Education

All engineering students need to advance in complex intellectual abilities, identify the desires of people, to think critically, analyse and solve problems to advance human-focused ideas, to assimilate human values and corporate cultures into concepts, to manage complications, and to communicate outcomes accurately, clearly, and concisely (Beagon et al., 2019; Craig, 2017; Kohlbeck et al., 2021; Saleh & Lamsali, 2020).

The most important and essential skills that are required in modern engineering graduates are:

1). **Life and career skills**: This means engineering graduates must have sound understanding and life experience, which may help him/her in shaping their career future. Graduates should be flexible and adaptable with every phase of life and situation, for a smooth transition to the workplace. Graduates should take initiative at work and be self-directed, productive, and should have social and cross-cultural skills. Graduates should have good communication, collaboration, and interpersonal skills to maintain effective collaboration, teamwork, and understanding among colleagues (Chaiyama & Kaewpila, 2022; Kohlbeck et al., 2021; Melchor, 2012).

2). **Learning and innovation skills**: As technology advances, engineering graduates should be early adopters, and keeping themselves updated and adapted with the new emerging technologies. Also, graduates should be innovative to match with the new technologies and create ideas to work effectively. Graduates should have problem-solving skills to resolve any issues related to operations in their workplaces (Beagon et al., 2019; Kohlbeck et al., 2021; Muñoz-La Rivera et al., 2020; Pearlman, 2010; Saleh & Lamsali, 2020).

3). **Information, media, and technology skills**: Graduates live in a technological environment, where they have access to vast information, and modern technology tools. Graduates should exhibit a range of operational and critical thinking skills related to information, media, and technology (Binici, 2021; Burke & Maceli, 2020; Kay, 2010).

2.10 Future-Focused Advanced Teaching Approaches and Pedagogies in Engineering Education

The future-focused education supports application of new teaching approaches, comprising learning through verbal, aural, visual, physical, logical, and social aspects (Djenic & Mitic, 2017; Ferranti, 2013; Murugesan, 2019; Zainuddin & Halili, 2016). Knowledge changes from time-to-time, thus approaches to acquire this changing knowledge also changes. The future-focused advanced teaching approaches are primarily based on Experiential Learning theory.

2.10.1 Experiential Learning Theory

Experiential Learning Theory (ELT) provides a holistic model which emphasises the role of experience in the learning process, and accordingly construction of knowledge through the transformation of experience (Kolb, 1984a, p. 4). According to Kolb and Kolb (2012, p. 2), ELT is built on six propositions and are presented below:

1. Learning should be best conceived as a process, where students should engage in a practise that best enhances their learning, which also includes feedback on the effectiveness of their learning efforts.

2. Learning is best facilitated by the process that draws out the student's previous knowledge, beliefs, and ideas, so that they can be tested again with new refined ideas or problems.
3. The learning process should also include aspects of conflict, difference, and disagreement, so that learning takes place between opposing modes of reflection, action, feeling, and thinking.
4. Learning is not just the result of cognition, but also involves aspects of thinking, feeling, perceiving, and behaving.
5. Learning occurs by aligning new experiences into existing concepts and accommodating existing concepts to new experiences.
6. Learning should be based on the constructivist theory of learning, where social knowledge is created and recreated in the personal knowledge of the learner (Kolb, 1984a; Ord, 2012; Rizk, 2011; Sharlanova, 2004).

The teaching approaches necessary for 21st Century skills are advanced compared to the traditional means of classroom instruction-based learning, as 21st Century teaching approaches focus mainly on experiential learning, thereby on student-centred learning. Some of these innovative approaches are listed below:

- Work-Integrated Learning (WIL) is a teaching and learning approach in which the academic learning is integrated with work experiences via work placements or industrial projects with educational stakeholders, therefore, students can relate classroom-learned theories with practical applications in the workplace. Thus, students can develop the facility to integrate their learning process through an arrangement of academic and work placements. Additionally, students can also develop a range of employability and lifelong learning skills through their engagement in work placements (Dean & Campbell, 2020a; Khampirat et al., 2019).

- Problem-Based Learning (PBL) is a teaching and learning process in which the student-centred approach is essentially enabled. Students learn about a topic by working in groups to explain an open-ended problem. The problem or question is the driving factor that motivates the students, and they learn accordingly. Thus, by solving problems, students indirectly develop their knowledge by self-learning, and develop skills such as teamwork, communication, and interpersonal skills (Christiansen et al., 2013; Dahms, 2014; Ghani et al., 2021).
- Flipped classroom is an instructional teaching approach, where learning responsibility is transferred from the teacher to the student (Bergmann et al., 2014; Birgili et al., 2021). Flipped classroom aims to enhance the student engagement and learning process, by having students complete reading resources outside class at their preferred time and work on problem-solving questions during class time. In this mode of teaching, students study theoretical lessons via online videos, presentations, and learning management systems, so that they can keep their doubts and questions ready to be raised in their normal tutorials (Hinojo-Lucena et al., 2019; Ozdamli & Aşıksoy, 2016).
- Blended Learning is a teaching and learning approach that combines online educational resources and occasions for collaborative online learning with traditional instructional methods (Pandey, 2020). A blended learning approach enables students to apply technology to learn in a way that best suits their needs while encouraging critical thinking, problem-solving, and creativity (Seraji, 2022). Flipped learning is a form of blended learning, where both has advantages over traditional learning process. Both these approaches provide a

self-learning period through the application of electronic means before the class, so that students can keep their doubts and questions ready to be discussed in their classes (Kachalova et al., 2021). According to Bashir et al. (2021), COVID-19 has accelerated the uptake of the blended learning approach in several educational curricula, due to the limitation of studying from home isolation.

- Inquiry-Based Learning is a practise of active learning that is based on posing questions or problems (initiating an inquiry) (Kori, 2021). Students then work on identifying the issues and may proceed to research questions and related resources to find possible solutions, and accordingly, they build their knowledge. The focus is mainly on constructing questions and answers based on investigation of different materials and theories, so that students may develop inquiry skills and enhance their academic achievement, engagement, and motivation (Hughes et al., 2022; Reinmann, 2019).

A detailed introduction to two of the future-focused teaching approaches especially applicable to engineering are expanded in the next section. In this research study, the focus will be on WIL and PBL; both approaches are applied in the engineering education in New Zealand universities. Therefore, the literature review is now focused on PBL and WIL and presented in forthcoming sections.

2.10.2Problem-Based Learning

In this section, the Problem-Based Learning approach is explained and its relationship with engineering education is presented. The section explains the definition of PBL, followed by its history, working procedure, tripartite relationship, outcomes, and advantages of its application. The following section presented the definition of PBL.

2.10.2.1 Definition

Traditionally students obtained knowledge from the study of academic subjects via classroom lectures and academic reading. What if the emphasis shifted from teacher-driven instructive learning to student-centred self-directed learning, through solving a real-life authentic problem? If such an approach is initiated, then this could help the learner to be self-motivated to conduct research, integrate the learned topic, and apply that learning to develop authentic solutions to ill-defined problems (Ali, 2019; Dita et al., 2021). One approach that does this is PBL. Students frequently work in groups, draw on previous knowledge to solve new problems through self-directed learning, analysis, and practise in solving a problem (Liu & Pásztor, 2022; Simanjuntak et al., 2021). PBL is an organised teaching methodology that involves students in learning knowledge and skills/competencies through a prolonged analysis around the complex, carefully designed authentic questions, products, or tasks to resolve a problem (Nurkhin & Pramusinto, 2020; Pearlman, 2010). PBL aims to integrate knowledge and skills based on analysis and problem-solving.

PBL promotes students' active engagement with learning, as solving a problem requires student participation (Delisle, 1997; Saiful et al., 2020). Complex problems are designed to challenge students' critical thinking. In PBL, the main emphasis is given to students to encourage them for self-directed learning, research, and practise through solving a problem (Thorndahl & Stentoft, 2020). PBL facilitates learning through discovery or inquiry, as students examine the problem, and accordingly they study its background theory. Then students apply analysis to design a solution for the given problem, which then students present to others as their discovered solution (Ali, 2019; Delisle, 1997; Liu & Pásztor, 2022). Presenting a real-life problem to students before learning tends to motivate them. To be successful, students must think and understand why they are learning the new knowledge (Dita et al., 2021; Nurkhin &

Pramusinto, 2020). PBL promotes development of problem-solving, communication, and teamwork skills, and also aids in developing understanding of links between the discipline and real-world applications. Guzelis (2006) indicates that development of different skills and knowledge through PBL became the motivation for the incorporation of PBL within engineering curricular. PBL provides a technical problem to students, which they need to address by forming a group, and accordingly applying their previous classroom learnings onto the project. By undertaking PBL, students develop their engineering knowledge by engineering practise and application, and develop technical and non-technical skills by students' project learning experiences. In the next section, the history of PBL is presented.

2.10.2.2 History

Problem-Based learning originated at McMaster University, Canada, in its Medical Programme, in the mid-60s. A group of scientists and physicians were the originators of PBL at the McMaster School of Medicine, as the school had negative responses to their undergraduate programmes (McMaster, 2011).

The success of PBL in the McMaster School of Medicine attracted other educational institutions and fields of education to apply PBL into their curricula. During the 1970s in Europe, engineering education incorporated PBL into the curriculum based on real engineering problems, so that students may develop and practise problem-solving in their engineering education (Du et al., 2009; Guzelis, 2006). PBL can be used to solve real-world engineering problems by students applying their previously developed knowledge to problems through self-reflection, research and practise in solving a problem (Dahms, 2014; Hitt, 2010).

2.10.2.3 Procedure

According to Ali (2019), Christiansen et al. (2013), Dita et al. (2021), Gewurtz et al. (2016), Schmidt (1993), and Takahashi and Saito (2013), the PBL procedure can be elaborated in these 10 steps:

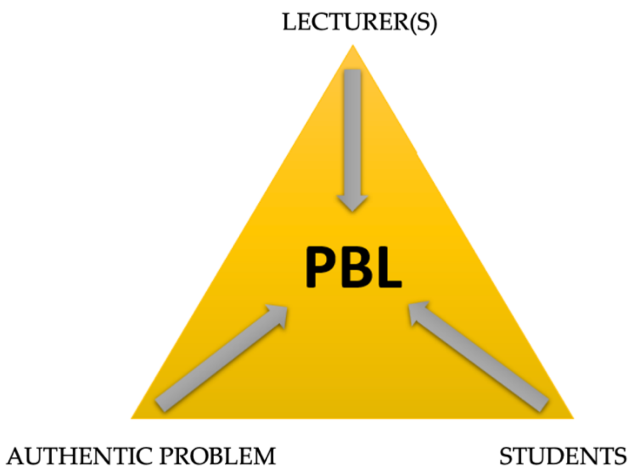
1. Present the issue,
2. Clarify terms and concepts,
3. Define the problem,
4. Analyse the problem,
5. Explore relevant aspects through research and experimentation,
6. Prepare explanations,
7. Formulate learning objectives,
8. Collect additional information,
9. Synthesise and testing newly acquired knowledge and technologies, and
10. Present solution.

The motivators in PBL are usually subject lecturers, Head(s) of the School and PBL organising supervisors because of the perceived benefits to students (Delisle, 1997; Dita et al., 2021; Nurkhin & Pramusinto, 2020). Benefits include deeper engagement with learning content, opportunities for feedback and revision, critical thinking, problem-solving, communication, and the use of interpersonal skills.

2.10.2.4 Tripartite Relationship in Problem-Based Learning

Tripartite relationship explains the basic elements found in any process or system, whose overall working and co-operation makes it work properly and effectively. The basic elements in PBL with respect to tripartite relationship are lecturers, students, and authentic problems. The lecturers create the real-world engineering problem-based projects for the students, which obviously favours authentic learning for students. Students then work on those authentic problems and develop content knowledge and different skills. In PBL, subject lecturers, authentic problems and students form the part of the tripartite relationship to favour student-centred learning (Ali, 2019; CanMeds, 2005; Dita et al., 2021). The tripartite relationship in engineering projects is presented in Figure 2.2.

Figure 2.2: Tripartite relationship in PBL, adapted from Hermann et al. (2021).



According to Dita et al. (2021), Liu and Pásztor (2022), Nurkhin and Pramusinto (2020), Saiful et al. (2020), and Barell (2010), some key elements of PBL are:

1). Real application problems that nurture inquisition, encourage the learners to investigate those problems;

2). Encourages choices about ways to learn and share knowledge, and understanding;

3). Problems reflecting the highest of cognitive challenges and comprising the essence to undertake research to solve the problem (think, decide and make conclusions);

4). Learning through small-group interactions, like listening, reasoning, and building knowledge and information based upon each other's ideas;

5). Valuable feedback from the teacher and peers helps students to acquire more knowledge and even helps them to have an overview of actual life experiences;

6). Opportunities to revise, alter, and expound on students' findings;

7). Effective planning, scrutiny and reflection on learning, and knowledge acquisition;

8). Opportunities to obtain advanced summative assessment information; and

9). Teachers and students together take control of decision making, teaching, and learning.

2.10.2.5 Outcomes and advantages of Problem-Based Learning

The literature suggests several outcomes of PBL. For example, PBL encourages learning strategies different to conventional classroom learning, students to identify and search for obligatory knowledge, delivers in-depth knowledge, and self-learning capability (Christiansen et al., 2013; Delisle, 1997; Pereira et al., 2017; Takahashi & Saito, 2013). Secondly, PBL endorses the ability to apply knowledge to new situations, improves problem-solving and interpersonal skills, and enhances creativity, research skills, and retention of learned materials (Dahms, 2014; Gewurtz et al., 2016; Loyens et al., 2015). Thirdly, PBL improves intellectual ability in education and professional problem-solving (Ali, 2019; Ghani et al., 2021; Wijnia et al., 2014).

According to the studies of Ferreira and Trudel (2012) and Ali (2019), students prefer PBL to more traditional modes of teaching. The students stated that they were able to develop analytical and reasoning skills, which helped them to make sound decisions

(Ferreira & Trudel, 2012; Liu & Pásztor, 2022). Students also stated that they found the PBL approach as finding a new way to solve a problem that may already have an answer, but not just the ideal one (Kirn & Benson, 2018). In their study, Yadav et al. (2018) stated that students reported the PBL approach took less time than conventional lectures in learning the course topics, and helped them develop constructive and contextual thinking, and encouraged self-directed learning. PBL familiarised the students with the relevant problem-solving methods to address problems, similar to the way an engineer approaches a problem (Kirn & Benson, 2018). PBL also encouraged students to master interpersonal skills (Ali, 2019; Ferreira & Trudel, 2012; Liu & Pásztor, 2022).

With development of new technology, PBL had been impacted positively in favouring digital and e-learning environments. The recent COVID-19 pandemic aided in further development of PBL approaches, as indicated by Randazzo et al. (2021) and Xie et al. (2022), who had online section of the teaching course using PBL which consisted of weekly projects that encouraged students to engage with the study materials and work both collaboratively and autonomously. The online-mode of PBL was able to provide self-efficacy, knowledge building, and development of skills such as team working, communication, problem-solving, and planning and organising skills, as indicated by Mona et al. (2022) and Elemam et al. (2022). The online or virtual mode of PBL provided students with the same benefits as of face-to-face experience, utilising the advancements of technology and simulation software.

2.10.2.5.1 Engineering Projects

There are different types or activities of PBL that can be embedded into curriculum, which poses potential problems and needs to be addressed via group works. Creel and Vitala (2015, p. 8), Barrett (2006), and Ungaretti et al. (2015) classifies different types of PBL, as listed below:

1. Case-Based Learning,
2. Challenge-Based Learning,
3. Community-Based Learning,
4. Design-Based Learning,
5. Game-Based Learning,
6. Inquiry-Based Learning,
7. Passion-Based Learning,
8. Place-Based Learning,
9. Proficiency-Based Learning,
10. Service-Based Learning, and
11. Project-Based Learning.

The above stated types differ from each other in function, but they all have sole motive, that is, students work through self-learning and reflection by attempting to solve a given problem by their teacher or lecturer. Amongst these types of PBL, in engineering education, projects are the most widely form of PBL. Projects facilitates formation of a real-world engineering problem, which then students must address via group works (Ali, 2019; Dahms, 2014; Liu & Pásztor, 2022). Thereby, students are benefitted with development of engineering knowledge, technical, and non-technical skills by undertaking projects. Students work through given engineering problems via projects, applying previously developed engineering knowledge and practise skills, to develop a solution. Students need to design the solution at software level, and then at hardware level by producing a working prototype, which indirectly addresses solution for the given engineering problem. Additionally, engineering projects are interdisciplinary across fields of engineering, therefore, they aid in developing interdisciplinary engineering knowledge. For this reason, this study focuses on engineering projects in this study, as projects are embedded already as an essential part in engineering education, and it is the most practical learning activity that occurs in engineering students' life.

2.10.2.6 Limitations of PBL

PBL faces a number of challenges and limitations associated with the application, structure, development, and operation of PBL programmes. Firstly, Aslanides et al. (2016) and Abdelkarim et al. (2018) indicated that PBL could be a time-taking process, which may force students to focus on them extensively, thereby, neglecting the rest of the courses in their study. As PBL may include demanding activities and projects, which may require students' collaboration and cooperation to work in groups, communicate, and problem-solve the issue to find the solution, and this can be a time-consuming process. Therefore, there can be a tendency for students to focus more on their PBL activities than on their other courses. Secondly, Vanishree and Tegginamani (2018) and Hidayah et al. (2021)indicated that PBL process could be bit expensive in cost factor, as students may need tools, machinery, simulation and design software helps, and components/parts relevant to their PBL activities/projects. Thirdly, Abdelkarim et al. (2018) and Vanishree and Tegginamani (2018) shared that lack of faculty training on PBL facilitation could be a potential limitation to the learning process. For example, overly correcting students on flawed statements may prevent them from critically thinking through tough questions and concepts. Proper training and practice are needed to successfully run a PBL session, so that the PBL facilitator can guide students to help fix improper reasoning, question students' ideas and logical thinking in a constructive manner, and motivating students to focus on specific aspect of the problem by asking targeted questions. These limitations can affect the overall quality of PBL, which may indirectly affect students' learning process from PBL activities/projects. A second pedagogical strategy particularly relevant to Engineering education is WIL, discussed in the following section.

2.10.3 Work-Integrated Learning

In this section, WIL approach is explained and its relationship with engineering education is presented. The section explains the definition of WIL, followed by its history, working procedure, tripartite relationship, types of WIL outcomes, advantages of its application, and limitations of WIL. The following section presents the definition of WIL.

2.10.3.1 Definition

WIL refers to an educational learning approach that practises work-based knowledge to allow students to incorporate theory with work experiences (Drysdale et al., 2016; IJWIL, 2021; Mackaway, Winchester-Seeto, Peach, et al., 2014). A key part of WIL is that there is support and guidance from two people; one who is an academic mentor from a university and another one who is an industry mentor from the workplace who works closely with students (Chetty, 2017). WIL provides learning with practise or learning by experience, in a real-world environment, that, in the concept of this thesis, is through undertaking work placements (Kay et al., 2019; Stirling et al., 2018). WIL integrates classroom learning with real-world practical application, which indeed helps to have a better understanding of acquired knowledge and skill development in an industry-based environment (Jackson, 2018).

Students need to be exposed to hands-on, minds-on experience within the industry setting, additional to classroom learning (Craig, 2017). As students engage within the workplace, the theoretical knowledge they have from the classroom learnings may be applied within the professional setting. Accordingly, students encounter problem solving within the workplace, which promotes socialised professional interaction and collaboration between team members (Jackson et al., 2022; Khampirat et al., 2019). WIL helps to detect the future inner skills of the students, which then could be enhanced, making the student more employable (Campbell et al., 2014; Mackaway, Winchester-Seeto, Peach, et al., 2014; Paull et al., 2019). WIL also assists graduates to tune into the work environment and build up self-confidence to undertake the work successfully (Ornellas et al., 2019).

2.10.3.2 History

Cooperative Education is a type of WIL important to engineering, which came into existence in the University of Cincinnati in 1906 by Herman Schneider (Sovilla & Varty, 2011). WIL became a popular term in 1990s in Australia to describe existing work-learning practices, in order to differentiate Australian work-learning initiatives, and other Western perceptions of 'work-based learning' (Dean, 2015). With timely progression, WIL has been named differently based on field of expertise or area of profession (Patrick et al., 2009), such as, for example, in occupational therapy, WIL is referred to as 'Fieldwork' (Crowe & Mackenzie, 2002; Haynes, 2011). Similarly, in sports management courses, WIL is known as 'Internship' (Stier, 2013; Young & Baker, 2004), and in nursing courses, WIL is referred to as 'Clinical Experience' (Cooper et al., 2005). In teacher education, it is called 'Professional Practise' or 'Practicum' (Ewing et al., 2022; Gillett-Swan, 2016; Merisi et al., 2022). Irrespective of the different terminology for WIL, the primary aspect related to WIL is that these all terminologies are designed to link students' classroom learning and their future working environment (Haynes, 2011).

2.10.3.3 Procedure

The general flow of the WIL process is:

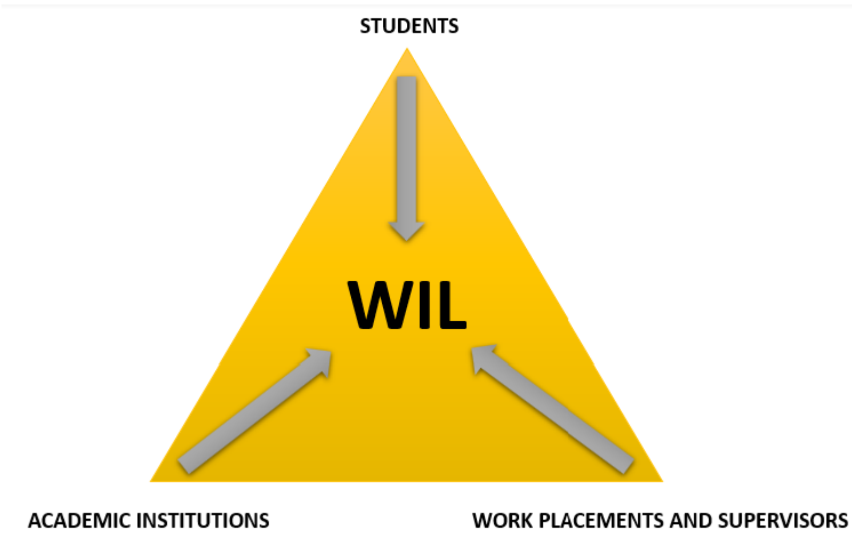
- For institutions to provide systems to identify and select a range of suitable providers, who meet necessary criteria from which WIL placements can be selected (Jackson et al., 2016; Sonnenschein et al., 2019);
- To design work plan and activities at the academic institution level by the academic supervisor in conjunction with workplace supervisor. Once the work plan and activities are formulated, they should be approved by the concerned teaching staff and Workplace supervisor, and then implementation of the work plan (Tran & Soejatminah, 2017);
- To have communication with students. Students will be provided with relevant information regarding the work plan and associated activities to bring up WIL experiences (Inceoglu et al., 2016);
- To match of students with suitable WIL experience (Jackson et al., 2016);
- To ensure students and WIL supervisors are clear about requirements and expectations (Winchester-Seeto, Rowe, et al., 2016);
- To commence WIL according to work plan and activities. Students work under professional workplace supervisor(s), relate their classroom learned theories with real-life applications available at the workplace, enhance their knowledge and develop skills (Jackson et al., 2016; Sonnenschein et al., 2019);

- For the students to work through their work placements based on their work timeline, work duties, and responsibilities, and accordingly they complete their work tasks such as placement technical report and other required assessments (Inceoglu et al., 2016; Kay et al., 2019; Winchester-Seeto, Rowe, et al., 2016); and
- For the university to then cross-check students' overall progress and development via work placement experience, as adapted from the works of Tran and Soejatminah (2017), Inceoglu et al. (2016), and Jackson et al. (2016).

2.10.3.4 Tripartite Relationship in WIL

The tripartite relationship is also relevant to different educational field, so it is related here with WIL. The basic elements in the WIL tripartite relationship may be considered as the students, academic institutions, and work placements and supervisors (Doolan et al., 2019a; Fleming, 2014). The tripartite relationship is presented in Figure 2.3.

Figure 2.3: Tripartite relationship of WIL, adapted from Fleming (2014) and Doolan et al. (2019)



In WIL, the academic institute or higher education institution, work placements and supervisors, and the students form the tripartite relationship, ensuring collaboration between the students, the higher education institution and an employer, to favour student-centred learning (Fleming, 2014; Nicholas, 2017). Academic institutions, students, work placements, and supervisors will constitute the overall stakeholders. Supervisors task is to effectively manage the WIL experiences for the students, where workplace will be the defining element in the whole tripartite relationship. Therefore, WIL's tripartite relationship would technically include the students, academic institutions, and workplaces and supervisors in the learning process. Between these three entities, the overall WIL process takes place. Thus, these three entities with their inter-relation or cooperative relations, make them known as Tripartite relations in WIL.

2.10.3.5 General Types of WIL

WIL is an umbrella term that represents a range of approaches and methods to integrate theories with the practise of work (Bowen, 2020; Khampirat et al., 2019; Sonnenschein et al., 2019). There are different ways to classify WIL, which mostly overlap by application. According to CEWIL (2018), Kay et al. (2019), McRae and Johnston (2016), Rowe et al. (2012), Winchester-Seeto, Hoskyn, et al. (2016), and Jackson et al. (2022), the different models of WIL are described below:

1. Industry-based learning/work experience/work placement/ WIL Placement: Work placement is a type of WIL, where learning happens through engaging in some constructive work at workplace, industry or community setting within a host organisation, that is, purely off-campus (IJWIL, 2021). Work placements include a variety of learning processes through observation, projects, and professional practise.
2. WIL non-placement (WIL Project): WIL non-placement is a type of WIL, where learning happens mostly on-campus, via work-related or research projects

designed by the workplace/WIL partner, within a workplace setting in the University/Institution (Kay et al., 2020; Rowe et al., 2012; Wood et al., 2020). WIL non-placements occur where WIL in an authentic workplace form is not available in practise. WIL non-placement can also be referred to as problem-based learning when industry projects are undertaken within university boundaries, as the students can be given a problem to solve in the form of a project (Dean & Campbell, 2020b; Rook & Mcmanus, 2020; Zegwaard et al., 2023).

3. Simulated Workplace Setting: Simulated workplace setting is a type of WIL, where learning happens on-campus, in artificially made workplace settings/environments. The Workplace is simulated within the University/Institution, to benefit the students with a better understanding of knowledge and skill development, within an artificial workplace setup (Kay et al., 2020; Rowe et al., 2012; Wood et al., 2020).
4. Apprenticeship: This is a mutual agreement between an apprentice and an employer where the apprentice wants to learn work skills, and employer needs a skilled worker. The apprentice is sponsored by the employer (unpaid employment); thus the apprentice develops skills in return for his work for the employer.
5. Internships: This approach provides a brief experience of real-world business practise during or after academic sessions. Usually, internships are one discipline specified, paid or unpaid employment, and counted as academic credit work placement (in the United States, internship is not for credit). Internships help the students to apply classroom learning in the workplace, enhances the skills and competencies required for successful employment, and improve their professional work trainings and networks.

6. Community-Based Volunteering: This approach provides hands-on learning by undertaking an unpaid placement in not-for-profit or community organisations such as hospitals and schools. This approach helps by giving manual support to organisations that can help people and give the students an opportunity to expand their general employability knowledge, skills, and graduate attributes that heighten their future employment opportunities.

2.10.3.6 Outcomes and advantages of WIL

WIL exposes the students with an opportunity to have real industry life experiences during their undergraduate studies, and exposes them with knowledge on teamwork, management processes and operations, and business culture. WIL is designed to support the students understand how to act in working communities and can also enhance their social skills and other relevant 21st Century skills, which indeed are necessary for their future career as engineers.

WIL helps the students to apply classroom theoretical learning to real-life problem solving, thus favouring interrelation of student's academic knowledge to practical problems. Also, they develop technical and technological skills as the students can encounter machines and other practical resources in operation which could not be found at many universities. WIL encourages a mutual bond formation between the industries and universities, by developing common activities and responsibilities in the educational and employment processes (Dominguez & Magdaleno, 2011; Paull et al., 2019).

There are three specific benefits that arise from WIL, these includes benefits for the students, academic institutions/universities, and employers. Advantages for the students are, firstly, career benefits, as WIL may provide graduates a direct entry into the workforce (Campbell et al., 2014; Chetty, 2017; Fleming & Eames, 2005). Placing the students in real industry placements enhances their knowledge on groupwork, management skills and workplace cultures (Chetty, 2017; Khampirat, 2021). WIL is likely to be successful for the students to secure employment and enable them to adapt easily to the work environment (Doolan et al., 2019a; Khampirat et al., 2019; Pan & Strobel, 2013). Secondly, academic benefit for the students through WIL, such as, the students may enhance academic performance, interdisciplinary thinking, and increased motivation to learn and discover through WIL (Chetty, 2017; Doolan et al., 2019a; Fleming & Eames, 2005; Khampirat et al., 2019). And thirdly, personal benefit for the students through WIL, as the students enhance communication skills, teamwork skills, and planning and organisational skills through WIL (Doolan et al., 2019a; Fleming & Eames, 2005; Khampirat et al., 2019).

Advantages for Employer are, firstly, that WIL exposes an easy way to recruit new graduates (Chetty, 2017; Fleming & Eames, 2005; Pažur Anicic & Divjak, 2022), through the knowledge of potential employees, which exposes a quick transition into the workplace. Secondly, employing WIL students is cost effective for the employers as there was less expense associated with recruitment (Braunstein et al., 2011; Chetty, 2017; Pažur Anicic & Divjak, 2022). Thirdly, WIL students who are hired and obtain permanent roles usually remain longer with the company and progress faster than non-placement hires (Braunstein et al., 2011; Roberts et al., 2021). Lastly, WIL exposes an easy way to bring new knowledge of the WIL students into the organisation (Braunstein et al., 2011; Roberts et al., 2021).

Crump and Johnnson (2011) and Doolan et al. (2019a) suggest advantages for institutions include the ability to provide advanced career development learning, and thus help the students secure placements. Secondly, the ability of the institutions to change and replenish curriculum according to the changing workplace requirements and feedback from employers/industries. And thirdly, the ability of the institutions to regulate and improve the learning approaches needed in professional practise during WIL sessions.

According to the studies conducted by Anderson and Novakovic (2017), the students who attended work placements deployed efficient time management skills that helped to successfully apply and complete placements in first place. The students felt that work placements had a positive impact on their self-efficacy, motivation to learn and practise and development of work-related attributes and skills (Anderson & Novakovic, 2017; Edwards, 2014; Gillett-Swan & Grant-Smith, 2018; Paisey & Paisey, 2010). According to Gillett-Swan and Grant-Smith (2018), the students favoured work placements more than any other learning approaches, as work placement gave them more opportunity to practise and learn, which they felt deprived off when studying solely in universities/institutions.

2.10.3.7 Limitations of WIL

WIL has a number of prevailing challenges or barriers associated with the structure, development, and application of WIL programmes. Firstly, according to Rook (2017), one major challenge identified is that there is a lack of available resources for providing WIL opportunities. There might be limited work placements for specific fields of engineering, and therefore, it is a major challenge to secure placements for engineering courses which may have large numbers of the students admitted. Secondly, the limited time of work placements due to timetable constraints was another challenge, as Doolan et al. (2019b) indicated that limited time of work placements could not provide much experience and confidence. If the length of time of work placements could be extended, then that would be more effective, as this could benefit the students with more experience and confidence (Doolan et al., 2019b;

Rook, 2017). Longer work placements may not be feasible for all the students or industries, but in general, they may be a valuable way for the students to gain practical experience and build their professional networks.

On the other hand, lengthy work placements may pose to deliver diminishing returns for the students on longer run (Oke et al., 2022), but Litchfield et al. (2010) and Gubrium et al. (2016) say that more work placements may embed more practice into students' development. Thirdly, the cost to employers was another challenge as the students may need initial training, induction, and orientation, which have to be done by the employers well before the students can be inducted in their workplace. This may indicate a lack of recognition of amount of work and skills required to run successful WIL programmes (Fleming & Hay, 2021; Rook, 2017).

Fourthly, students' workload was another challenge, as the students may have to maintain part-time work while finding time to undertake WIL programmes, which may impact students' performance and progression in WIL programmes. Fifthly, Doolan et al. (2019b) indicates that considerable time is required to develop the relationship between the University and the industry partner, for successful commencement of WIL programmes. The time requirement(s) to develop and maintain the university-employer relationship may add to limited time constraints of WIL programmes. Lastly, Rook (2017) indicated that lack of institutional support for WIL programmes can be challenging to deliver WIL for the students. These limitations can affect the quality and amount of work done by the students in work placements, which may indirectly affect their learning experience from WIL programmes. In the next section, WIL and PBL are compared with each other.

2.11 Distinctions between PBL and WIL

PBL and WIL benefit the students with development of knowledge and skills by offering them authentic learning experiences through their learning process. Still, both these approaches work differently, based on their way of operation, environment, tools, and artefacts. Therefore, they have some sort of dissimilarities based on their authenticity and proximity in their learning process and outcomes. Utilising the works of Kaider et al. (2017), Table 2.2 shows the differences between PBL and WIL (work placements considered in this study).

Table 2:2: Distinctions between PBL and WIL (work placements)

	PBL	WIL (work placements)
Definition	PBL is an educational approach that focuses on solving real-world problems. Students work in groups to identify problems, gather information, and develop solutions, with the goal of developing critical thinking and problem-solving skills.	WIL is an educational approach that integrates academic learning with practical work experience. It is designed to help the students develop workplace skills and knowledge, while also providing real-world context for their academic studies.
Methodology	In PBL, the students work in groups to identify and solve real-world problems. They use a structured approach to problem-solving, which typically included defining the problem, gathering information, brainstorming solutions, and evaluating outcomes.	In work placements, the students work in real-world environments, such as internships, work placements, or apprenticeships. They apply the theoretical knowledge they have learned in the classroom to real-world situations and receive feedback and mentorship from experienced professionals.
Learning outcomes	The goal of PBL is to help the students develop critical thinking and problem-solving skills, as well as to deepen their understanding of academic concepts by applying them to real-world situations.	The goal of work placement is to help the students develop the skills and knowledge they need to succeed in the workplace. This may include technical skills, such as problem-solving, critical thinking, software development, as well as non-technical skills, such as communication, teamwork, interpersonal, and project management.
Authenticity	Authenticity in PBL can be maintained by designing PBL activities that are authentic and relevant to students' current and future professional lives. Authentic problems help the students to see the value of what they are learning and to understand how the concepts they are studying apply to real-world situations.	Authenticity in work placement refers to the degree to which the workplace experience provides the students with real-world situations and challenges that are reflective of their future career. WIL activities should expose students to the actual tasks, duties, and responsibilities that they will encounter in their future profession. Authentic work placement experiences can help the students to see the value of what they are learning and to understand how the concepts they are studying apply to their future profession.
Proximity	Proximity in PBL refers to as degree to which the problems and scenarios are relevant and meaningful to students' current and future professional lives. Proximate problems help to engage the students in the learning process and make the content more meaningful and relevant to them.	Proximity in work placement refers to the degree to which the workplace experience is relevant and meaningful to students' educational goals and career aspirations. WIL activities should be designed to match the interests, skills, and career aspirations of the students. By providing work placement experiences that are proximate to students' goals, interests, and skills, placements can help the students to gain relevant skills and knowledge that will prepare them for their future profession.
Authenticity and Proximity	PBL has medium authenticity as the PBL activities may not be always 100% real-world based problems (authentic learning), as the activities may be confined to the study curriculum. PBL has low or negligible proximity as no industry partner is involved in PBL activities. If an industry partner is involved in PBL, then that would be called as Non-Placement WIL or WIL project.	Work placement has high authenticity as they provide real-world based authentic learning experience. Work placement has high proximity, as it includes industry partners providing the work placements to university students.

2.12 Exploration of PBL and WIL Similarities

2.12.1 Comparing PBL and WIL

WIL and PBL also have some sort of similarities based on their work processes and outcomes (Karim et al., 2019). Both are student-centred learning approaches that favour active learning rather than passive learning (Loyens et al., 2015; Stirling et al., 2018). In student-centred learning, the emphasis of instruction shifts from the teacher to the student, which helps to develop student autonomy and how to learn a specific subject, which indeed favours self-learning. Secondly, both WIL and PBL focuses on enhancing students' practical knowledge and skill development (Christiansen et al., 2013; Dahms, 2014; Hitt, 2010; Jackson, 2018; Jackson & Collings, 2017; Little & Harvey, 2006; Loyens et al., 2015; Martin & Hughes, 2009). Thirdly, both WIL and PBL helps to extend knowledge from classroom learning, and helps knowledge retention (Jackson, 2018; Takahashi & Saito, 2013). Despite these similarities, there are some dissimilarities, such as, PBL which occurs in universities or academic institutions, while WIL may take place outside academic institutions, in an authentic workplace setting (CEWIL, 2018; Pereira et al., 2017). This outlines the proximity to an industry partner and the degree to which a student is practicing authentic work, between PBL and WIL. Secondly, WIL focuses on training the students to be professional in a specific industry under expert supervision (Jones et al., 2019), while PBL motivates the students to self-learning practices by solving an authentic problem under the guidance of the teacher (Ali, 2019; Ruiz-Gallardo et al., 2011). Thirdly, PBL can take place in various forms, solving an authentic problem, for example, by doing engineering projects, seminars/presentations on a specific topic, group discussions based on specific problem/question, group tasks/activities which incorporate problem-solving and self-learning (Ali, 2019; Tse & Chan, 2003), while WIL focuses only on work experiences, which help the students to enhance their practical engineering knowledge and gain hands-on practical experiences (Bowen, 2020; Kay et al., 2020; Wood et al., 2020).

The comparison between WIL and PBL encourages this study to explore the two following phenomena:

1. Scaffolding; and
2. Complementing

2.12.2 Scaffolding

Scaffolding, in education, is a term that is related to bridge or connect learning gaps, that is, to connect the difference between what the students have learned and what they are expected to learn (Education Reform, 2015; Vygotsky, 1978a). Scaffolding is achieved by a variety of instructional and supportive techniques, which are applied at certain points in students' learning journeys to support learning (undertaking tasks or understanding key ideas) from that of a novice to that of an independent scholar. According to Vygotsky (1978a), learning occurs within a zone of proximal development (ZPD), which is the difference between a learner's present level of competence and their prospective degree of development with aid, is where the learning takes place. Scaffolding is based on the notion that students may do more with the assistance of a knowledgeable instructor or more competent peers, and this support can be gradually reduced as they develop competence and independence to do tasks. The scaffolding process can involve the following aspects:

- Breaking down of tasks: Simpler, more manageable steps are used to complete complicated jobs. This enables students to concentrate on one aspect at a time and gradually develop their knowledge and skills (Mahan, 2022).

- Clear instructions: To guarantee that students understand what is expected of them, teachers provide clear instructions and explanations. This included outlining procedures, presenting examples, and modelling various problem-solving techniques (MacLeod & van der Veen, 2020).
- Offering Support and prompts: To facilitate learners' thinking and problem-solving, scaffolding frequently entails giving them suggestions, clues, or hints. These clues may be physical, verbal, or visual clues that draw attention to pertinent facts or techniques (Puntambekar, 2022).
- Collaboration and social interactions: Collaborative exercises that require learners to accomplish tasks or solve problems as a group can be a part of scaffolding. Peer engagement enables the sharing of opinions, emotional support, and helpful criticism (Hill et al., 2020).
- Support Levels: Depending on the needs of the student, the teacher or peers will alter their level of support. More assistance is provided at first, but as the student gains competence, it is gradually lessened, fostering greater independence (Vygotsky, 1978a; Xi & Lantolf, 2021).

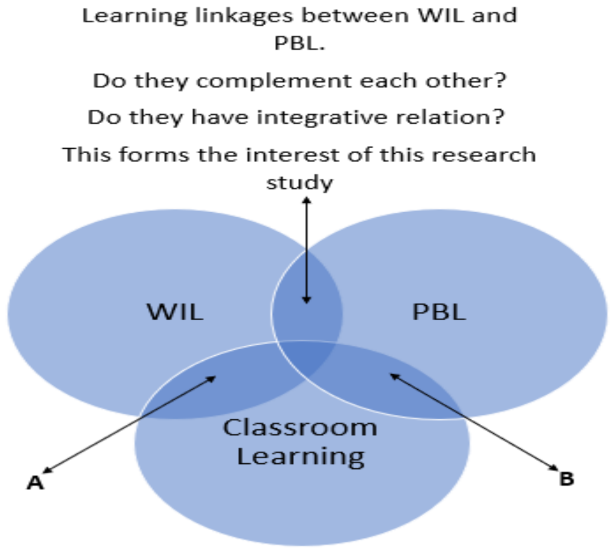
Reflection and metacognition: Leaners have the chance to reflect on their thought processes and keep track of their own progress through scaffolding. This encourages individual learning and the growth of metacognitive abilities (Doo et al., 2020)

According to Karim et al. (2019), a scaffolded relationship is one in which the development of professional practise, theoretical knowledge, hands-on practical knowledge and enhanced level of confidence are scaffolded between them. According to Gita and Apsari (2017) and Greening (1998), scaffolding also happens between PBL and classroom learning, through the teacher being the medium, or source of scaffolding. Gita and Apsari (2017) used PBL to cover linear algebra and found that the students enhanced their learning process more than with just classroom learning. Through PBL, students' confidence was increased, along with self-learning and development of intrinsic motivation. This process was administered with the help of teachers as facilitators and found that PBL scaffolded their learning process in classroom teachings. Additionally, Kaider and Bussey (2018) and Ruskin et al. (2018) suggest that there are scaffolding relations between WIL and classroom learning, showing that theoretical knowledge and skills are complemented from work placements to classroom learning, but no linkages with PBL stated.

Following an extensive search for the inter-relations between these teaching and learning approaches, there was not enough literature to fully support the learning linkages between WIL and PBL and those collectively with classroom learnings. The learning linkage between classroom learning and WIL is shown as letter A (Figure 2.4), and that between PBL and classroom learning is shown as letter B (Figure 2.4).

The letter A shows the learning linkage between WIL and classroom learning. That is, the theory learned in the classroom is practically related to the real-world applications available in the workplace (WIL); thus, it helps to build engineering knowledge from within the workplace. Also, the workplace provides complementary engineering knowledge, which is not covered in classroom learning and enhance students' employability and technical skills.

Figure 2.4: Inter-relations between WIL, PBL and classroom learning.



Similarly, the letter B shows the relationship between PBL and classroom learning; that is, the theory learned in the classroom can be applied to practical projects, which helps the students to relate theory with practical examples and thus enhance their engineering knowledge. Additionally, some technical and behavioural skills are also enhanced via PBL. Since the projects designed in PBL are based on their respective engineering trade/area, thus it helps the students to relate their classroom learned theories directly with their PBL projects. These A and B relations are evident from the literature; however, the learning linkages between WIL and PBL are not well supported in the literature, which interests this study to frame research questions for this study.

2.12.3 Complementing

In education, complement means something that completes a learning process (Merriam, 2020). Complementing learning is the practice of utilising several instructional strategies, tools, or techniques to strengthen and support the learning process. It entails incorporating various components to provide learners a thorough and well-rounded educational experience (Robbins, 2014). Learning that is complemented acknowledges that students have a variety of requirements, preferences, and learning styles.

Again, despite an extensive search, little literature was found about complementary nature of WIL and PBL, or between WIL, PBL and classroom learning. Jackson (2013) states that there is a complementary relationship between work placements and classroom learning, when theoretical knowledge and employability skills are not available through classroom learning. Thus, classroom learning is complemented by the work placement experiences. Jackson also suggests that there is a complementary relationship between WIL and PBL, in forming theoretical knowledge and skill development flow from WIL to PBL. But still there is a need for more literature specifically around the complementing nature between WIL, PBL and classroom learning (Karim et al., 2019). This literature gap becomes the focus for this research and is therefore discussed in brief in the next section.

2.13 Identified Gaps in the Literature

WIL and PBL approaches integrate several aspects of learning such as verbal, aural, visual, physical, social, and solitary in the learning environment (Ferranti, 2013), which indeed aids in enhancing 21st Century skills in the students. As both PBL and WIL aim to enhance the student's knowledge, skills, and employability outcomes, the learning outcomes acquired through WIL and PBL could be different. The impact of WIL on the students learning outcomes could be different compared to the impact of PBL. Also, the skills gained by the students through engaging with WIL could have similarities to that through engagement with PBL. There may also be a relationship between WIL and PBL in preparing the students for professional practise, for example, PBL helps the students prepare for WIL or vice-versa. There is research conducted to study how WIL scaffolds across the curriculum (Kaider & Bussey, 2018; Ruskin et al., 2018), and how PBL scaffolds across curriculum (Gita & Apsari, 2017; Greening, 1998; Stewart et al., 2007). Kaider and Bussey (2018) found that by sequentially structuring a series of inter-related and integrated WIL learning activities into the curriculum, helps in providing scaffolding of knowledge and skills across the curriculum.

Similarly, Gita and Apsari (2017) found through their study that PBL activities provide scaffolding of learning in classroom, which thereby enhanced students' learning achievement. However, there is no available research on how PBL and WIL scaffolds each other in the engineering context or whether these complement each other or not in engineering education, or what might not be scaffolded between PBL and WIL? The knowledge of learning linkages between PBL and WIL may show how PBL and WIL scaffold and complement each other in the overall learning process. The learning linkages between these approaches may also help in enhancing the curriculum structure, so that individual emphasis may be given to specific approaches which may yield specific outcomes, from which the students may benefit towards their engineering education. Therefore, understanding the important aspects of learning linkages may aid in enhancing the overall engineering education curriculum and students' overall learning experiences. Accordingly, the rationale of this study was to discover the specific linked learning outcomes between PBL and WIL in engineering education and to understand whether they scaffolded and complemented the overall students' learning experiences. Through conducting a comprehensive research study, clarity could be obtained on how this occurs and could provide answers to the stated research questions.

2.13.1 Justification for Research Questions

The literature gap that was identified by deeply analysing the available literature, aided in developing the research questions as stated in Section 1.5.

The main research aim:

What are stakeholders' views on the combined learning effects of engineering projects and work placements for preparing engineering students for professional practise?

Sub-research questions:

1. What are stakeholders' perceptions of engineering student learning through engagement with PBL and WIL?
2. What, if any, scaffolding of learning occurs between PBL and WIL?
3. What aspects of PBL and WIL are complementary (or not) in advancing student learning of the practise of engineering?
4. How can understanding the synergies and differences between PBL and WIL inform and/or enhance the engineering curriculum?

Based on the literature gap, the overarching aim of this study was then to identify combined learning effects of engineering projects and work placements, based on stakeholders' perceptions. To address this main research aim, four sub-research questions were framed, in which, the first sub-research question aims to establish the learning links between projects and work placements. The answer to first sub-research question would technically identify the type of learning linkages, which would then direct and answer the remaining sub-research questions. The second sub-research question aims to investigate whether there is scaffolding of learning between projects and work placements, as there is no findable research establishing this learning linkage. The third sub-research question aims to investigate whether there is complementary learning between projects and work placements, as again there is no findable research establishing this learning linkage. The last sub-research question aims to investigate enhancing the overall engineering curriculum based on identifying the learning linkages, similarities, and dissimilarities between projects and work placements. The answer to these sub-research questions would provide answer to the main research aim of this study and would, thereby, contribute towards filling the research gap identified in this study.

3 METHODOLOGY

3.1 Introduction

This study uses a mixed methods methodology within a constructivist paradigm to investigate the combined learning effects of WIL and PBL in engineering education. A constructivist paradigm assists the understanding of how students build linkages between classroom learning and real-world applications through WIL and PBL. Constructivism paradigms within sociocultural learning and experiential learning frameworks enable an in-depth description of students' views on the learning effects of WIL and PBL. This chapter introduces the overall research design of this study, reliability, validity, ethical considerations, and the data gathering methods used, as mixed methods methodology suggests the study a combination of qualitative and quantitative data collection methods, including online surveys, individual interviews, document analysis, and observations.

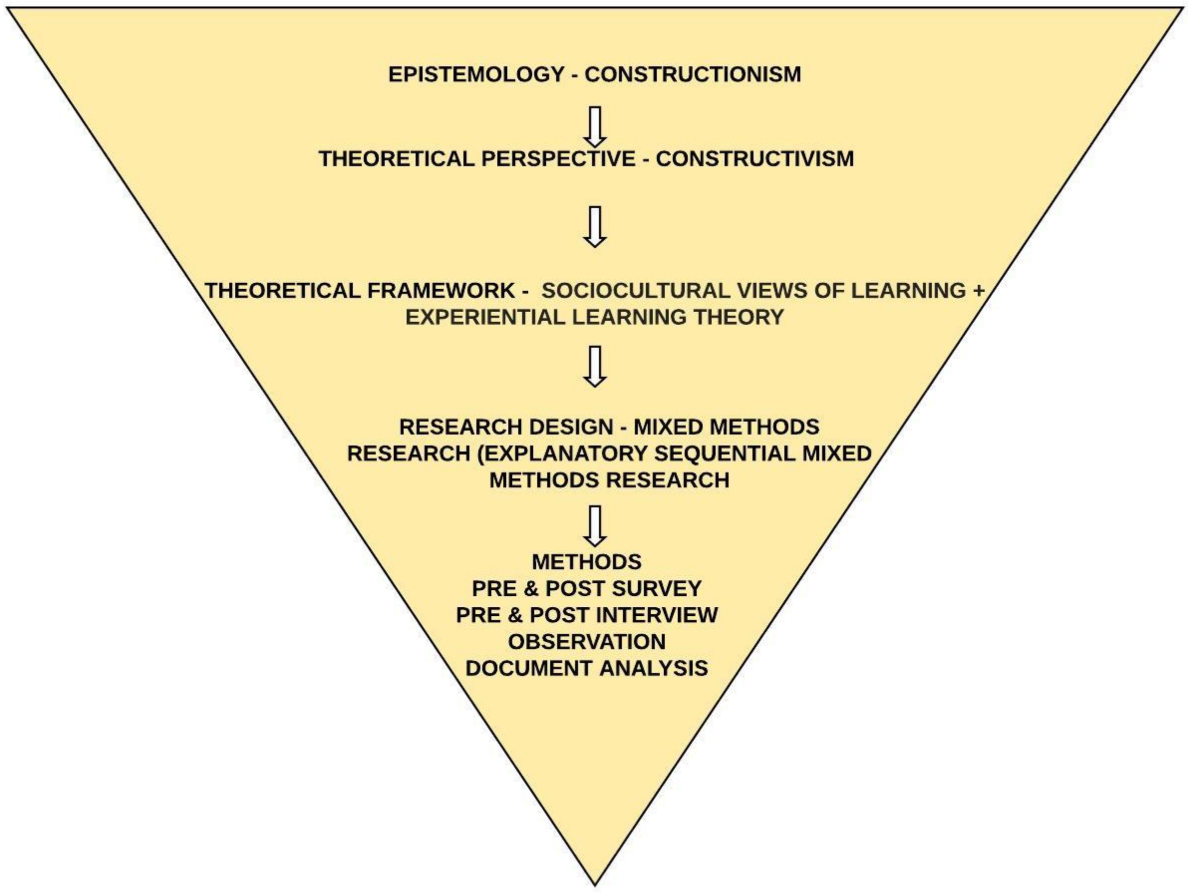
This chapter discusses the theoretical methodology and framework for this study. Further in this chapter, the methods, process used for the data analysis and generation of themes, ethics, reliability, and validity are indicated. The chapter concludes with a timeline of the study and an introduction of the following findings chapter.

3.2 An Outline of the Significance of the Topic

There is little research done on the combined learning effects of WIL and PBL within engineering education. This study advances research in the area of learning in engineering education via WIL and PBL by studying mechanical engineering students. This will give insight into students' perceptions regarding learning outcomes of WIL and PBL, and perceptions of recent mechanical graduates, lecturers, and workplace supervisors.

This section presents the overall research methodology intended for the study. The elements stated under this section are taken from the research design stated by Crotty (1998) namely epistemology, theoretical perspective, methodology, and methods. The hierarchy of decision making to inform choices and use of methods for the study are presented in Figure 3.1.

Figure 3.1: Overall research methodology design.



The research design aspects as stated in Figure 3.1 are described in the following sections.

3.3 Epistemology

According to Crotty (1998), the theoretical framework is a personalised perspective of looking at the world, and making self-meaning of it. Epistemology is the study of knowing what knowledge is. It is the way of perception and explaining how we know about a knowledge, what constitutes knowledge and how knowledge comes into existence (Ma, 2016; Tennis, 2008). Epistemology emphasises philosophical grounding for guiding the research methodology, or the approach to justify the knowledge one inherits.

Crotty (1998) states there are three main epistemological stances:

- Objectivism,
- Subjectivism, and
- Constructionism.

In WIL and PBL, students create knowledge through social interactions with lecturers, WIL supervisors, and peers interacting in the environment. Constructionists believe that knowledge or meaning is constructed through social interaction between human beings and their surroundings. Even Crotty (1998) indicated that knowledge or meaning is not discovered, rather constructed through social interactions. In WIL and PBL, students work in a social environment, collectively to achieve a goal, and thereby create their knowledge through the process, socially via interactions with different tools/artefacts available. Therefore, opposing both objectivism and subjectivism, the constructionism best suits as the epistemological philosophy of this study.

This research study adopts constructionism as an epistemology, because of the assumption that students are active learners, they can learn more through social interactions with their peers, lecturers, working professionals and workplace supervisors. These social interactions happen in a sociocultural environment and help students to develop their own understanding and knowledge (Vygotsky, 1978b). In this study, the engineering students undertake engineering projects and work placements; both are part of the engineering curricula in New Zealand Universities. These approaches help the engineering students familiarise with the real-world applications, which help them to better understand the classroom learned theories (Dominguez & Magdaleno, 2011). Also, these approaches assist students' skill development, which may not be possible just within the classroom learning boundaries (Clogh et al., 2007). Thus, within the engineering projects and work placements, it is the social interaction between the students, lecturers, working professionals and workplace supervisors, and their environments, which assist students to better understand the classroom taught theories, knowledge, and skill development. This favours the inter-relation between learning and practise, or in other words, learning with practise.

3.4 Theoretical Perspective

A theoretical perspective describes context for the research process, design, and methodology (Crotty, 1998). This study follows the constructivism worldview as its theoretical perspective. In this study, emphasis is given to a range of teaching practices in the engineering education, with a future aim to assist engineering education in developing countries such as India. In India, the engineering education authority lay focuses more on classroom teaching, and not on engineering practise (Banerjee & Muley, 2007); thus, the engineering graduate lacks the engineering technical skills, knowledge and work-readiness (Clogh et al., 2007). This may results in low-skilled engineers, who then are not able to secure employment. Engineering education in developed countries such as New Zealand, is highly advanced and focuses on both engineering knowledge and practise. Their engineering curriculum includes the advanced approaches of work placements and engineering projects (New Zealand

Education, 2017). A commonality with both approaches is that social interactions between the students, peers, lecturers, workplace supervisors, and working professionals and active physical interaction with their workplace applications are critical. These help the students better understand the working of real-world applications of the classroom learned theories and knowledge, thus relating the theory with its practical example. Through social and active interaction, the students receive guidance from peers and professionals to enhance their skill development. Thus, Vygotsky's Sociocultural Theory (Eames & Cates, 2011a; Gye & Grove-White, 2011; Vygotsky, 1978a) and Experiential learning theories of Kolb's and Dewey's (Dewey, 1897, 1938b; Eames & Cates, 2011a; Kolb, 1984a; Miettinen, 2000; Ord, 2012; Sharlanova, 2004) form the theoretical framework of this study.

To understand how WIL and PBL complement each other across the engineering curriculum, an intense methodology needs to be applied to analyse the problem/research question based on three-dimensional triangulation analysis. Mixed methods research best suits this study to gather in-depth descriptive and numerical data. Through this, qualitative and quantitative approaches can be applied to develop a more vital understanding of the research question and identify and analyse solutions to the problem. Thus, based on the epistemological framework in this context, this study follows a constructivist worldview to support mixed methods research approach, specifically explanatory sequential mixed methods research.

3.4.1 Constructivism

Constructivism as a theoretical perspective emphasises that truth and meaning or knowledge, do not exist in some external world, waiting to be discovered, whereas, knowledge or meaning is constructed by the subject's interaction with the world, within the social community (Gray, 2014; Kemp, 2007). Meaning is not discovered, as stated in positivism, rather, the individual constructs meaning in different ways. Knowledge is internalised by learners, through the process of accommodation and assimilation, and thus, they construct their new knowledge through experiences (Fatimah et al., 2022; Jia, 2010). In this study, students in WIL and PBL, construct knowledge at an individual level, through their experience with the social, cognitive, and physical interactions with the workplace or classroom, including lecturers, WIL supervisors, artefacts, and tools present in the workplace or classroom. In PBL, students work in groups, to solve staff developed authentic real-world problems, within the university environment, thus, they encounter the problem, and socialise with their peers and lecturers, they interact with and construct knowledge at an individual level, and then potentially distribute it to others. Thus, while working in groups, students construct theoretical knowledge and develop skills through discourse with other students and lecturer(s) (Kemp, 2007).

Similarly, in WIL, students work in a workplace under WIL supervisors and other professionals, where they construct knowledge at an individual level through the interaction with workplace surroundings (executing work and usage of tools) and supervisors. During PBL and WIL, knowledge is constructed at an individual level, by the interaction between the learner/student within the workplace. Accordingly, students interact with real-world environments based on social, physical and cognitive aspects, thus they completely match constructivism, which emphasises the creation of knowledge and understanding through learning different experiences (social, cognitive and physical aspects) and reflecting on them (Pennbrant & Nunstedt, 2017). Thus, constructivism best fits as the theoretical perspective for this study.

3.5 Theoretical Framework

A theoretical framework informs the theory that guides the principles to understand any natural phenomenon. The theories related to WIL and PBL, help to analyse how students learn successfully. From the list of theories relevant to WIL and PBL, stated in the works of (Eames & Cates, 2011a) and (Gewurtz et al., 2016),the two most relevant theories to this study are

- Sociocultural Theory of Learning (Vygotsky), and
- Experiential Learning Theory (Dewey and Kolb).

These theories inform the theoretical framework for this study and provide conceptual tools to seek answers to the research questions. The following section describes the theoretical framework for this study.

3.5.1 Sociocultural Views of Learning

Sociocultural views of learning comprise a set of different ideas, which collectively propose learning to comprise as a social process within a culturally defined boundary, or community of practise (Eames & Cates, 2011b). Four key ideas related to sociocultural views of learning are discussed below and outlined in Figure 3.2.

One idea depicted by Lave (1991) says that learning is an activity that happens in a community of practise, that is, learning, thinking and understanding occurs in a social setting. Learning occurs within people engaged in activity in a socially and culturally structured work environment (Lave, 1991). Thus, while students are in work placements, they become participants within the community of practise, that is, the workplace, and engage in authentic activities, and accordingly, through their participation, they develop meaning of their practise and adapt to the work culture (Billet, 1994; Rogoff, 1995).

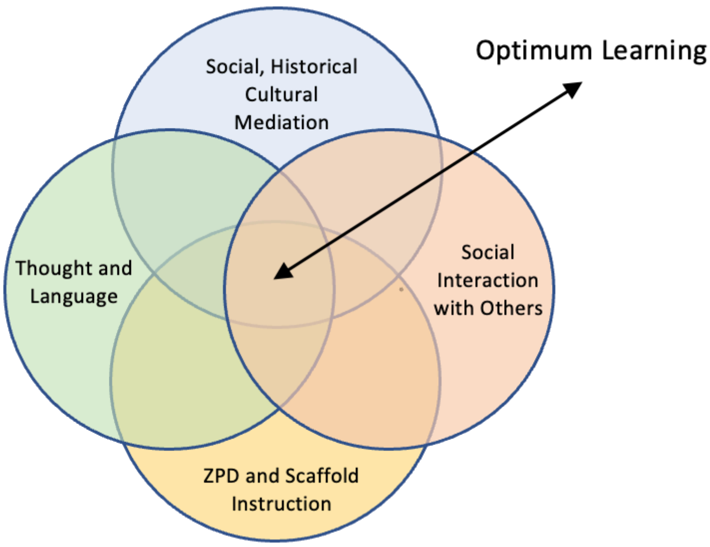
Perkins (1993) suggests the second idea that cognition is distributed across the community of practise, that is, learning not only happens at the individual or learner level, but also includes the surroundings, people, and artefacts. When a learner or student has access to a community of practise through a work placement, they develop distributed cognition through participation within the workplace with people and artefacts (Eames & Cates, 2011a).

The third idea depicted by Vygotsky (1978b) and Wertsch (1991) is that human action and learning are mediated with the application of tools and signs. The tools and signs are part of the community of practise, where learning occurs. The tools are categorised as technical tools (such as physical instruments and computers) and psychological tools (such as language) (Wertsch et al., 1995). These tools are part of the sociocultural context, or community of practise, and thus, they are used as a part of social interactions (Wertsch, 1991) to construct knowledge.

The fourth key idea related to sociocultural theory is related to Vygotsky's Zone of Proximal Development (ZPD), referred to as the distance between what a learner can do without help and what the learner can achieve under the guidance and support of a skilled partner (McLeod, 2018; Vygotsky, 1978b). The ZPD describes the actual level of the learner's development and the next attainable level (their potential) through the use of mediational tools and expert or peer guidance (Shabani et al., 2010). This synchronises well with WIL and PBL, because here, students learn better when working together with others under supervision, and it is through such collaboration with more skilled persons that students learn and inherit new concepts, psychological tools, and skills (Christensen et al., 2006; Christiansen et al., 2013; Crump & Johnnson, 2011; Dahms, 2014; Delisle, 1997; Shabani et al., 2010).

The intersection of the four spheres or ideas can be seen as the most effective learning point, which is here known as optimum learning. This intersection will provide the mixture of all the four ideas of the sociocultural views of learning, and thus, this study had concentrated on this area of optimum learning. The sociocultural views of learning would considers students on work placements like participants who learn as they participate in activities and social interactions using tools and signs within their workplace surroundings (Eames & Cates, 2011a). The intersection of the four ideas are presented in Figure 3.2.

Figure 3.2: Vygotsky's sociocultural theory of learning (adapted from Ferranti (2013)).



The WIL approach through sociocultural theory promotes students working more in the community, and thus making them more central participants in this research study.

3.5.2 Experiential Learning Theory

Experiential learning is a philosophical and methodological approach in which students are purposefully engaged in direct experience and focused reflection in order to enhance their knowledge and skill development (Kolb, 1984a; Ord, 2012;

Sharlanova, 2004). According to Kolb (1984a), learning is a constructive process, where knowledge is constructed through transformation of experience. The experiential learning theory involves learning through interconnection of doing, sensing, observing, reflecting, thinking, and planning, and thus forming social, physical, and cognitive relationships (Sharlanova, 2004). Such elements of experiential learning can be observed in practices of WIL and PBL. As in WIL, students are under expert supervision, and accordingly they work through practise and observation, build their reflections, make abstract concepts, and then apply it to new situations. Thus, with observation and feedback process, students build their knowledge and develop skills. In PBL, students are given an authentic problem to solve. They work on that problem, which can include observation, followed by reflection and discussion with their fellow group members (students), then form abstract concepts and apply it to new situations, and confirm whether they got a working solution or not. In PBL, students build their knowledge through observation and feedback through teacher(s) and students. Thus, WIL and PBL make a clear connection to experiential learning theory (Bethell & Morgan, 2011; Elijido-Ten & Kloot, 2013). Reflective learning is a central element of experiential learning, therefore, in the below section, reflective learning is discussed in brief.

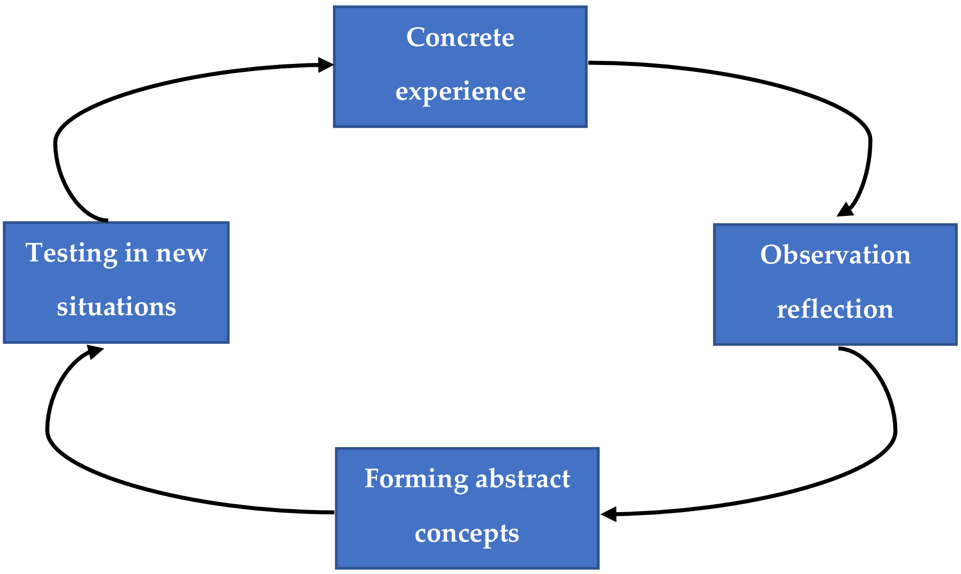
3.5.2.1 Reflective Learning/Practice

The main factor of transformative learning is the reflection process of learning (Colomer et al., 2013), where the reflection process can be defined as intellectual activities that encourage students to explore experience that leads to developing understanding and knowledge growth. Reflective practise is a way to reduce the gap between formal classroom learned theory and actual practise/application (Fook, 2006). According to Bubnys (2014), reflective learning favours student-centred learning at higher-education institutions. Learning is a step-by-step knowledge building process, where students analyse their experience based on prior and newly developed knowledge. That experience is again reconstructed by means of reflection process, based on prior knowledge and experiences (Bubnys, 2014). With reflective practise being an important part of the experiential learning theory, the works of Kolb and Dewey in the field of experiential learning theory are discussed below.

3.5.2.1.1 Kolb's Experiential Learning and Reflection

Kolb's experiential learning theory explains the learning process as a four level learning and reflection process, which happens on a continuous basis (Eames & Cates, 2011a). The four levels of Kolb's experiential learning are shown in Figure 3.3.

Figure 3.3: Kolb's cyclical model of experiential learning (Kolb, (1984b), p. 42).



The experiential learning cycle is a continuous process, where students will develop concrete experiences through their engagement in academic learning and their work assignments. Thus, they will observe their own experiences while in and after job assignments, which encourages self-reflection. The experience itself and the reflection through the experience will shape the formation of abstract concepts, which thus shape their concrete experience. This process keeps repeating through their classroom and workplace assignments. Both the experience and reflection will encourage students to form abstract concepts and understanding, which they then apply to new experiences. This leads to an aim-oriented learning process in WIL; for example, after completing a work placement, students apply the understanding and concepts in their forthcoming academic year/term, thus crystalising knowledge and skills learned.

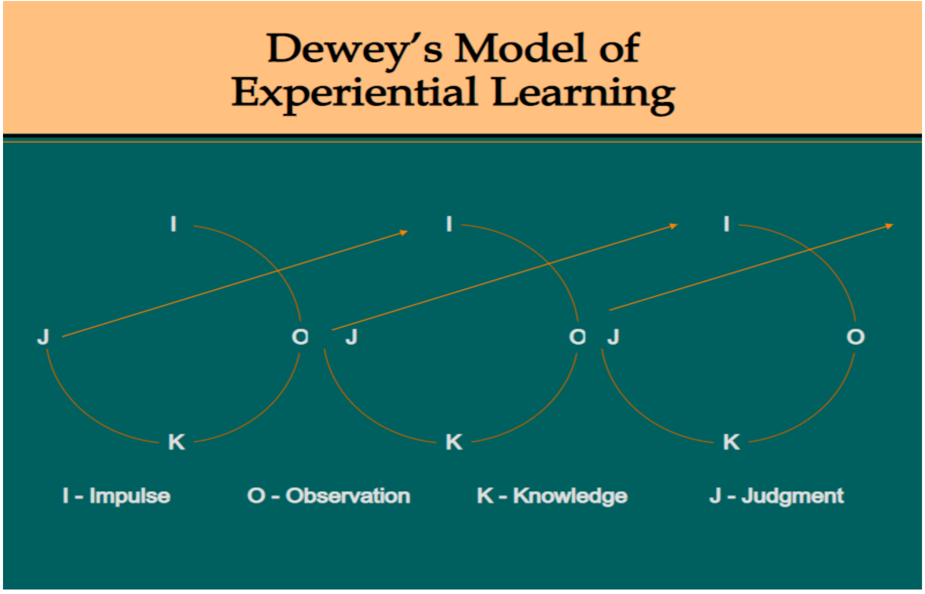
3.5.2.1.2 Dewey's Experiential Learning

In Dewey's experiential learning, emphasis is given on experience, which arises as a sum of interaction between a person and his/her environment, comprising physical, emotional, social, and cultural aspects (Dewey, 1897; Miettinen, 2000). That is, experience is based on the content of what is experienced (observed), and the process of how things are experienced, such as, when learners have a new experience, they act upon it based on their past knowledge. Following this, they may undergo the consequence dependent on outcome of the applied new experience. Based on this consequence of the experience, the learners build their new knowledge, and thus promote learning (Campbell, 1996; Dewey, 1897; Ord, 2012). According to Dewey (1938a), learning happens in a three step process:

- observation of one's present environment, comprising physical, social, emotional, and cultural aspects;
- past knowledge;
- judgement combining the observation and past knowledge, which leads to purposeful action (Hart, 2015).

The experiential learning process outlined in three steps are expressed in Figure 3.4.

Figure 3.4: Dewey's model of experiential learning by Hart (2015).



According to Dewey (1897) and Rizk (2011), interaction between what the student and learner brings to the given situation (past knowledge) and its consequence (after the application of action), together, build the meaning of the given experience. This theory is based on continuity of knowledge and interaction of past knowledge/experiences with the present situation. This helps the learner connect the new experience with his or her past knowledge and thus helps develop concrete understanding, knowledge, and experience. These educational theories indirectly favour authentic learning practices, where students apply their past knowledge to new experiences and develop a more substantial knowledge base and experience. Thus, there seems to be a linkage between these educational theories and authentic learning. Thus, it can also be understood that WIL and PBL approaches create a direct link between these theories and authentic learning. Therefore, the overall research study is based on these theories, and accordingly, the research methods are chosen to answer the overarching research questions. The research methods employed for this study are detailed in the next section.

3.6 Methodology

The methodology used for this study was mixed-method that employed a two-phase project and use both quantitative and qualitative data collection methods. In mixed methods, the research questions will be such that it cannot be explained with one data source, rather, multiple data sources are needed for exploring and then explaining the findings/results (Creswell & Clark, 2011). In this study, the research questions are based on stakeholders' views or perceptions, and highly critical research methods must be used under someone's views or thoughts. Using one method, approach, or angle would not be sufficient to build meaning. Combining qualitative and quantitative research methods is highly effective in building meanings based on people's views or perceptions. It is because, with the help of quantitative methods, factual or numerical data can be obtained, which can be described thoroughly with the help of descriptive data obtained from the qualitative methods. Thus, a mixed methods design was the best fit for this research study, as it combines both qualitative and quantitative research methods. Thus, mixed methods were chosen, which are detailed in the following sections.

3.6.1 Qualitative Research Methods

Qualitative research methods are a systematic collection, arrangement, and interpretation of textual information, which generates comprehensive descriptions of procedures, mechanisms, perspectives, and experiences (Creswell, 2014a; Young, 2017). Data collection methods are used in qualitative research, such as observations, interviews, documents, and audio-visual materials (Creswell, 2014a).

Advantages of qualitative research methods can be as follows. Firstly, it encourages data triangulation by examining evidence and then building themes based on it (Islam & Aldaihani, 2022). Multiple data sources can be used, and then outcomes from those sources can be triangulated onto a single aspect, and accordingly, themes can be built. Secondly, it provides rich, thick descriptive textual data to convey the findings (Hendren et al., 2022). Qualitative research methods can be undertaken in the form of individual or focus-group interviews, document analysis, ethnographic (observational) research, action research, and case study research (Valcheva, 2021). These approaches or methods can furnish in-depth descriptive data, conveying the results in a highly explanatory format. Thirdly, qualitative research occurs in natural human behaviours, events, and surroundings; for example, interviews can be treated as two or more people talking in a sociocultural context. Similarly, ethnographic observations, action research, and case study research all happen in natural surroundings (Creswell, 2014a; Lombardo, 2016).

The disadvantages of qualitative research are that the data gathered is highly subjective. Methods like interviews, ethnographic observation, action research, and case study research can provide highly in-depth descriptive data. Thus, it may be too subjective and requires intense data analysis structure to create meaning from the data. Secondly, it is complex to access and examine gathered data, as it will be highly descriptive, so interpretations and analysis of such data is challenging. Critical data analysis structures are again required to create themes from them. Thirdly, it is time-consuming to analyse qualitative data, which relates to the first, second, and third reasons. Fourthly, qualitative research data cannot be statistically represented because the data is in descriptive form and is best represented in themes or codes. Summarising into statistical or factual representation is not appropriate, as that will miss out on the exploratory information of the findings/themes (Lombardo, 2016).

3.6.2 Quantitative Research Methods

Quantitative research methods deal with numbers and anything that can be measured in a systematic manner, where the collected data is used to answer the research questions, by finding the relationships within measured variables with an intent to explain, predict and regulate a phenomenon (Creswell, 2014b; Tankonyvtar, 2013). There are different types of data collection methods under quantitative research, such as survey/questionnaire, direct observation, and experiments.

Advantages of quantitative research methods are, firstly, that collected data is highly objective, that is, it is easy to measure. Since data are factual or numeric representations, thus they are highly directive and easy to understand and derive meanings. Secondly, it is easier to make predictions based on collected quantitative data because of its numerical basis. Data are in number format or represented in figures, graphs, and charts, thus, predictions can be made quickly without using critical data analysis structures. Thirdly, the quantitative data findings can be easily generalised and replicated. This relates to the first and second reasons stated above, as data is in a numerical structure. Thus, they can be easily categorised, as data is too open or directive. Fourthly, quantitative methods allow this study to summarise vast sources of information and can also encourage comparison across other categories and over time (Academy, 2016; Creswell, 2014b; Learn Higher, 2017).

The disadvantages of quantitative research are that results are limited as they provide only numerical descriptions and no detailed descriptive data. Thus, the perceptions of the participants cannot be obtained. Secondly, the research mainly occurs in unnatural and artificial settings. For example, these data can be collected through surveys and questionnaires, which can occur online, via telephones, or in printed format. Thus, participants can have time to think and give their responses and lose the spontaneity of responses. Thirdly, quantitative data cannot be used to explain any social phenomena, as these data are limited due to their factual or numeric representation. Such data cannot explain any phenomenon or process, as they lack in-depth descriptive data (Academy, 2016; Learn Higher, 2017; Tankonyvtar, 2013).

Keeping these advantages and disadvantages in mind, it was clear that if quantitative research methods were used, they would furnish data from a single angle and would lack descriptive data, thus losing the exploratory functionality of the study. This limitation can be overcome by using qualitative and quantitative research methods. Here, quantitative methods will provide an overview of the data collected in the form of factual or numeric representation. It will then be explained with the help of qualitative methods in a highly descriptive form. Thus, with the help of these two research methods, the data can be collected from different angles and this study can examine the exploratory characteristics of the data. More in-depth information on structuring these two methods under mixed methods is provided in the next section.

3.6.3 Mixed Methods Research

Mixed methods research systematically integrates quantitative and qualitative data within a single investigation (Creswell & Clark, 2011). The data collected through qualitative and quantitative research are integrated through linking themes and thus, can give better perspectives, explanations, and understanding of the process under investigation (Creswell, 2018a).

In this study, mixed methods research will be applied because, firstly, this study is based on the views and perceptions of the participants; thus, qualitative research is needed. Also, this study focuses on the impacts of WIL and PBL on students before and after these sessions, for which descriptive statistics and inferential analysis are needed. For this purpose, quantitative research is needed. Thus, mixed methods research is the perfect match to incorporate these two approaches. Also, mixed methods research will allow a broad range of data triangulation in this study; it will incorporate a range of data such as surveys, interviews, observations, and document analysis. Mixed methods research is the best fit for this study to get an overview of the process via quantitative research and then to explain its findings through qualitative research.

3.6.4 Explanatory Sequential Mixed Methods Research (ESMM)

Explanatory Sequential Mixed Methods (ESMM) is a mixed methods approach in which the quantitative data are collected followed by qualitative data (Figure 3.5). With ESMM structure, the numeric or factual data from the quantitative method will help to frame the questionnaire for qualitative method (Creswell, 2012). The reason to use ESMM is that data from quantitative methods will be mainly numeric, which will act as the overview data. Thus, overview data will then be explained from the data obtained from qualitative methods, as these data will be highly descriptive. Through this structure, the explanatory and exploratory nature of the study can be obtained, thus the study requires mixed methods to answer the research questions. The ESMM model used in this research study is shown in Figure 3.5.

Figure 3.5: Explanatory sequential mixed methods research.

The ESMM approach supports the collection of quantitative data in the first stage, analysis of the obtained data, and then use of the data to plan the second stage, that is, data collection through the qualitative method. The so-obtained quantitative data typically helps to frame the types of participants to be shortlisted and the types of questions to be asked in the qualitative methods (Creswell, 2018a). The quantitative data and its outcome will help to provide a general overview of the research problem, and then more analysis through the qualitative data collection helps to refine and extend the outcomes of the quantitative data, that is, general overview of the research problem (Creswell, 2012). In this study, emphasis was given to the views of the participant, helping them to construct their beliefs in the sociocultural setting, and help them to understand the focus of inquiry (Check & Schutt, 2012). Construction of knowledge in a social setting is important in this research because it relates to the constructionism epistemological stance and theoretical perspective of this study. In constructionism and, subsequently, constructivism, knowledge or truth is constructed by individuals through social interaction with other individuals and their surroundings.

In this study, surveys captured the responses and experiences of the students. Then the interview rounds gathered explanations of those survey responses and experiences, which allowed the participants to construct their experiences and helped to explain the WIL and PBL learning processes. Additionally, observations and document analysis also helped validate the findings from surveys and interviews. Thus, through the ESMM procedure, the genuine construction of the meaning (views of participants) occurred, potentially contributing to understanding the WIL and PBL learning processes in engineering and answering the research questions.

In the first phase, survey data was collected, analysed, and then proceeded to the second phase of data collection through individual qualitative interviews to explain the outcomes of the surveys based on the participants' perspectives. The survey and interview questions of the first and second phases were the same, in order to study the students' progression due to effect of WIL and PBL before and after commencement. This would show comparative data of before and after WIL and PBL approaches, which would show any development of engineering knowledge and skills after WIL and PBL. Thus, this would promote a clear comparison of pre-and post-effects of WIL and PBL on students' perspectives and intended outcomes.

The advantage of mixed methods research is that it provides a more comprehensive understanding of the process than qualitative or quantitative methods alone. Secondly, it allows the use of both numbers with words and narratives, which can provide broad and more complete insight and knowledge of the process. Thirdly, it encourages the concept of complementarity, that is, however the strength of one method counters the weakness in another method (Hafsa, 2019; Malina et al., 2010). The disadvantages of mixed methods research can be, firstly, the overall design of mixed methods research which is very complex and immense. Secondly, mixed methods research is more expensive and time consuming than other methods. Thirdly, it may be difficult to implement one method based on the findings of another (Hafsa, 2019; Malina et al., 2010). However, mixed methods research was found to be the best match for this study, and accordingly, the methods were chosen and briefed in the following sections.

3.7 Methods

Research methods are the techniques that are used in educational research to collect and analyse data for explanation of the predefined research questions (Cohen et al., 2007). This study utilised an explanatory sequential mixed methods approach under the constructivist philosophical worldview. The methods used in this study were surveys, individual and focus-group interviews, observations, and document analysis. It is, therefore, vital to discuss the research settings, research design, sample size, and sampling procedures, and define the types of data collection tools. The data analysis techniques for the study and how they align with the theoretical framework will also be discussed in this section.

3.8 Mechanical Engineer Graduate Profile

The participants in this study were undertaking the Bachelor of Engineering with Honours (BE(Hons)) in Mechanical Engineering. It is a professional four-year degree, based on the study of systems or objects, engineering physics, and mathematics principles (Careers Govt NZ, 2021). Mechanical engineering at the University of Waikato, involves the design, manufacturing, and maintenance of mechanical systems (University of Waikato, 2020f). In this programme, the learning content includes design of systems for air conditioning and mechanical ventilation, electrical light and power, fire services, fire safety engineering, water and waste services, data and communications, security and access production equipment, production lines, and efficient production processes for industrial goods. Mechanical engineers work across a range of industries and are involved in the design and manufacture of a range of machines or mechanical systems, typically applying principles of hydraulics (fluid control), pneumatics (air pressure control) or thermodynamics (heat energy transfer) (Careers Govt NZ, 2021). Mechanical engineers may specialise in building services or industrial engineering.

The programme offered at the University of Waikato is designed to achieve the following outcomes involving mastery of content, acquisition of skills and development of attributes (University of Waikato, 2020f). Learning experiences incorporated into the programme bring about these desired outcomes; assessments are designed to ensure students have the opportunity to demonstrate their achievements. The BE(Hons) graduates have the opportunity to develop cross-disciplinary skills that respond to the needs of modern engineering and technology directly relevant to New Zealand's economic sustainability. The degree includes two work placements, each of 400 hours, arranged by the Cooperative Education Unit. The total 800-hour work experience requirement is part of the BE(Hons) degree accreditation requirements from Engineering New Zealand.

The BE(Hons) degree will allow students to graduate with advanced technical ability relevant to the skills expected of a professional mechanical engineer (Ismail et al., 2019). The graduate profile describes the mastery of content by the students (University of Waikato, 2020f, p. 2) as:

- Acquire basic knowledge of science and mathematics, which are required for being a professional engineer;
- Capable of communicating effectively and efficiently with their colleagues and clients in a professional, ethical and technical context;
- Capable of evaluating engineering problems, analysing methods, and be able to develop intellectual relevant solutions;
- Develop relevant practical engineering technical skills based on the field specialisation and be able to apply them,
- Capable of designing solutions to practical engineering problems, which define the needs and source relevant data to furnish those needs;
- Develop and practise life-long learning so that they can keep themselves updated with current and modern technologies, engineering practices, methods, legal and ethical issues;
- Capable of thinking outside the box, innovatively, intellectually, and thereby able to solve engineering problems;

- Capable of working unsupervised, and in groups/teams when needed;
- Act with a sense of responsibility and integrity in various aspects like social, ethical, economic, environmental, cultural, and legal issues;
- Capable of working in new environments with intellectual flexibility and ability to adapt to new changes, and
- Capable of integrating other professions and engineering trades/disciplines to address interdisciplinary engineering problems and provide innovative solutions.

Graduates from this programme will have acquired the following capabilities (University of Waikato, 2020f, p. 3):

- The capability of holding engineering training, knowledge, and conceptual ability on the basics of engineering and functionality to attain economic sustainability in New Zealand;
- The capability of undertaking engineering investigation(s), analysis, and documenting those investigation(s) as reports, incorporating report writing skills;
- Ability to apply engineering theoretical and practical knowledge and technical skills when needed, and
- Ability to apply technical and non-technical skills, engineering knowledge, and attributes to provide an engineering-based knowledge economy in New Zealand.

The engineering curriculum is accordingly designed and implemented to support this graduate profile. The graduate profile clearly shows that students will be educated and trained to develop their conceptual engineering knowledge, skills such as problem-solving, communication, interpersonal, critical thinking, teamwork, and qualities like initiative, flexibility, professional work ethics, and adaptability. To develop these learning outcomes, students are required to study several engineering courses, and then apply that knowledge to engineering projects and work placements. The application of classroom learning and engineering projects, along with work experience from work placements, will aid students to develop the graduate profile. This next section discusses facets of the engineering education programme at the University of Waikato.

3.9 Research Settings

The study occurred in the School of Engineering, University of Waikato, Hamilton, New Zealand. Most participants were recent graduates, current students, lecturers, and workplace supervisors connected to the School of Engineering. Some data collection methods, such as surveys, were conducted online, while the individual interviews were conducted face-to-face with the researcher within the school. Focus-group interviews were not possible because the number of participants was less than the predicted numbers, and due to the 2020 COVID-19 lockdown, individual interviews were conducted via telephone and online via the Zoom conference platform instead of face-to-face. Observation of on-campus engineering projects and off-campus work placements occurred before the COVID-19 lockdown, but the 2020 first-year Boat Race project was cancelled. Documents such as lecturers' course outlines and students' assignment reports were also collected before the end of each trimester.

3.9.1 Research Population

The participants in this study comprised current engineering students at the School of Engineering, University of Waikato, who were in 2nd, 3rd, and 4th year, and recent graduates (graduated within three years), lecturers, and workplace supervisors. Second year B Trimester engineering students were called the Second-Experience Cohort (as they had one experience of work placement and one experience of engineering project). Third year A Trimester engineering students were the Third-Experience Cohort (students had three experiences of engineering projects and work placements). Third year B Trimester engineering students were the Fourth-Experience Cohort (students had four experiences of work placements and engineering projects). Fourth year B Trimester students were the Fifth-Experience Cohort (students had five experiences of engineering projects and work placements), and recent graduates were in the Alumni Cohort. The structure of coding used to represent participant's name from different experience cohorts (Table 3.1).

Table 3:1: Participant name coding structure.

Cohorts	Coding Structure
2nd-Experience	I.2E.X – where 'I' stands for interview, '2E' stands for 2nd-Experience, and 'X' will be the individual numbered participant.
3rd-Experience	I.3E.X – where 'I' stands for interview, '3E' stands for 3rd-Experience, and 'X' will be the individual numbered participant.
4th-Experience	I.4E.X – where 'I' stands for interview, '4E' stands for 4th-Experience, and 'X' will be the individual numbered participant.
5th-Experience	I.5E.X – where 'I' stands for interview, '5E' stands for 5th-Experience, and 'X' will be the individual numbered participant.
Graduate Cohort	I.GC.X – where 'I' stands for interview, 'GC' stands for Graduate Cohort, and 'X' will be the individual numbered participant.
Lecturer	I.LC.X - where 'I' stands for interview, 'LC' stands for Lecturer, and 'X' will be the individual numbered participant.
Workplace supervisor	I.WS.X - where 'I' stands for interview, 'WS' stands for Workplace supervisor, and 'X' will be the individual numbered participant.

Su (2012) defines 'course' as an organised unit of instruction that focuses on a specific subject or topic in education. It is intended to offer a structured framework for teaching and learning that is systematic and orderly. In educational institutions, mostly the subjects are referred to as courses, but some universities like the University of Waikato use the term 'papers' in place of courses. In this study, the term 'course' will be used generally to represent the engineering papers of the University of Waikato. The name of different project and work placement courses which students complete in different years of study of engineering degree are shown in Table 3.2.

Table 3:2: Courses per year of study of engineering degree.

Year of Study	Experience	Courses
2nd year	2nd-Experience	Work Placement 1
3rd year (A Trimester)	3rd-Experience	Design and Manufacturing Project
3rd year (B Trimester)	4th-Experience	Work Placement 2
4th year	5th-Experience	Research and Development Project

In the qualitative research method, individual interviews were conducted for all cohorts. Graduate interviews were mainly face-to-face, with some via telephone or Zoom. Individual interviews were conducted for four lecturers (Appendix N) and two WIL supervisors (Appendix O). Because alumni Cohort could not assemble at one place for a focus-group interview, so they were individually interviewed. The quantitative survey (Appendix L) was in the form of questionnaires conducted with all the cohorts. Pre- and post-survey (Appendix L) and interview questions (Appendix M) were the same within each cohort. This was to study the effect of WIL and PBL on the engineering students before and after the sessions and thus to better understand perceptions of the students. Additionally, one survey question on important skills for being a successful engineer, was purposely kept the same for all cohorts' questionnaire, except in the 3rd-Experience cohort, where the list of skills was not fully included.

3.9.2 Academic Context

The academic context of this study was mechanical engineering. In the first year of mechanical engineering study, students covered several courses, including Foundations of Engineering ENGEN180. In this course, students learned theories related to basic manufacturing and design concepts. These were then applied to via problem-solving through a boat race project where students were required to build a boat to collect floating waste materials from the University lake. Thus, in this course, students learned and applied the basics of engineering knowledge via problem-solving projects. In the second year, students did their first Work Placement ENGEN271, where students applied classroom learned theories and practical knowledge from engineering projects to real-world applications available at the workplace. This work placement course was across a small number of engineering contexts and determined how students applied their engineering knowledge in workplace surroundings. In the third year, students did the Design and Manufacturing project ENGME382 where students enhanced their knowledge of modern manufacturing processes and how to use them when designing complex machines. All students worked on a common project topic. After the ENGME382 project, students completed their second Work Placement ENGEN371, which helped them relate their classroom and project learned theories to workplace applications. And then finally, in the fourth year, students did the Research and Development Project ENGEN582, where students worked on different project topics and contents, solving a problem, or building an actual product. All these courses covered the academic context necessary to develop future engineers. Specific learning outcomes of each course are introduced below.

3.9.2.1 Learning Outcomes of the Foundations of Engineering Course

In the engineering degree, several courses interconnect classroom learning with engineering projects and work placements. The specific courses will be discussed in this section. The first-year engineering students undertake the Boat Race project, as part of the Foundation of Engineering course, where students are to apply science to technology and engineering. It covers fundamental engineering design principles, open-ended problem solving, engineering analysis, and engineering accounting of mass and energy. These are the learning outcomes for the Foundations of Engineering course.

From this course, students should be able to:

1. explain the differences and links between science, engineering, and technology;
2. explain and apply a generalised engineering design technique,
3. recall the general 'accounting' equation and be able to solve appropriate problems where this is applied to account for mass and energy,
4. explain how expert problem-solvers operate and be able to use heuristic methods in problem-solving, and
5. realise the importance of engineering fundamentals (such as thermodynamics) in solving real-world problems and solving appropriate problems.

These were the learning objectives designed for the Foundations of Engineering course, and in the next section, the Design and Manufacturing project's learning outcomes are introduced.

3.9.2.2 Learning Outcomes of the Design and Manufacturing Project

In the third year of the engineering degree, students have the Design and Manufacturing project, which helps them learn about modern manufacturing processes and how to use them when designing complex machines. In this project, all students were given a common project topic and were required to apply modern manufacturing methods such as laser cutting, CNC machining, and 3D printing to design a complex machine. This will allow students to undertake a group project and build a working prototype machine that meets specifications.

On completion of this project, students should be able to:

1. use ‘dirty’ prototyping to evaluate design concepts effectively,
2. use traditional and modern manufacturing processes when designing parts and machines,
3. apply health and safety regulations when designing machines, and
4. design and build a complex machine to meet a given specification.

These are the learning outcomes from the Design and Manufacturing project. In the next section, the learning objectives of Research and Development are introduced.

3.9.2.3 Learning Outcomes of Research and Development Project

In the fourth year of the engineering degree, mechanical, software, and electronics-electrical engineering students were grouped together for the Capstone project. This course builds on student's knowledge and skills from the first three years of their degree and reinforces the multidisciplinary aspect of engineering. Students learn how to carry out a Research and Development project as part of a team, and gain an appreciation of the depth and breadth of knowledge and skills required for completing a project that addresses real-work problems. Students must either construct a significant product or undertake scientific investigation of an idea or hypothesis. Students worked on different project topics; either they selected the topic by themselves, or the topic was provided by their course convener.

On completion of this project, students should be able to:

1. comprehend and address an enormous task in a discipline, business, or multidisciplinary project context;
2. present outcomes and achievements to colleagues and management, and
3. document methods, results, and achievements comprehensively and concisely.

These were the learning outcomes of the ENGME582 Research and Development project. The following section introduces the learning outcomes of ENGEN271 Engineering and Business Professional Practise 1, ENGEN271 Engineering Work Placement 1, and ENGEN371 Engineering Work Placement 2.

3.9.2.4 Learning Outcomes of Engineering and Business Professional practise 1

The second year's Engineering and Business Professional Practise 1 is discussed here. This course focuses on empowering students to become "business savvy" and prepared for industrial placements. Building on systems thinking, problem-solving, and teamworking skills from the first tear Engineering in Society course, the course extends students by using lectures in conjunction with PBL workshops solving real-world industry problems. Topics covered include team formation, design thinking, project management, risk management, and project finance. The course runs a parallel stream covering professional ethics, CV preparation, interview techniques, job-seeking skills, online profiles, workplace and business culture in readiness for industrial placements. In this course, students attend three lectures, one workshop, and one tutorial class per week, where tutorials include external and industry speakers, networking events, and student group presentations. Workshops will include external and industry representatives and student group presentations.

The Engineering and Business Professional Practise 1 intended learning outcomes are:

1. the ability to use appropriate knowledge and skills to identify, formulate, analyse, and solve complex engineering problems to reach substantiated conclusions;
2. the ability to apply professional engineering ethics and accountability,
3. autonomy and teamwork: An ability to work effectively as a team member and leader,
4. research and development of a new business idea,
5. commercial and project management: The ability to incorporate business practices, including financial risk, project, and team management, into engineering practise;
6. identify and reflect on working style and develop the ability to work effectively as a team member and leader of teams with project-focused business goals,
7. successfully engage with or navigate workplace cultures,
8. be successful in presenting professionally to an employer to obtain a work placement, and
9. identify and undertake safe workplace practices.

Once students have completed ENGEN270 Engineering Professional Practise 1 course, in the next semester, students undertake ENGEN271 Engineering Work Placement 1, where they go on work placements during the summer break. The following section introduces the learning outcomes of ENGEN271 Engineering Work Placement 1.

3.9.2.5 Learning Outcomes of ENGEN271 Engineering Work Placement 1

The work placement is intended to develop professional skills through work in a relevant professional workplace, as students work alongside professional engineers. The work placement (400 hours) allow students to work with trained professionals, observe professional and technical practise, and workplace cultures, which may help students to consider potential careers. Students while undertaking work placement will have various opportunities to apply knowledge and skills learned at university and develop technical knowledge, interpersonal skills, and a professional work ethic.

Intended learning outcomes of ENGEN271 Engineering Work Placement 1 are:

1. to set learning objectives for their work placements and provide information on the progress of achieving learning objectives,
2. be able to complete a written technical report,
3. show the ability to reflect on learning progression by completing the reflection assignment, and
4. be familiar with workplace-specific health and safety requirements and responsibilities.

After students have completed their ENGEN271 course, their subsequent work placement is in the third year, in course ENGEN371 Engineering Work Placement 2. In the next section, the learning outcomes of the ENGEN371 course are introduced.

3.9.2.6 Learning Outcomes of ENGEN371 Engineering Work Placement 2

After students complete ENGEN271 Engineering Work placement 1, the subsequent work placement they do is in their third year of study, in course ENGEN371 Engineering Work Placement 2. The intent of ENGEN371 is similar to ENGEN271, therefore, only the learning outcomes are presented here.

The intended learning outcomes of ENGEN371 Engineering Work placement 2 are:

1. to set learning objectives for their work placements and provide information on the progress of achieving these learning objectives,

2. show the ability to reflect on learning progression by completing the reflection assignment,
3. be able to complete a written technical report,
4. be familiar with workplace-specific health and safety requirements and responsibilities, and
5. be able to provide evidence of professional competency using an ePortfolio.

The 4-year engineering degree can be summarised in the structure shown below in Figure 3.6.

Figure 3.6: Engineering education structure including classroom learning, engineering projects, and work placements.

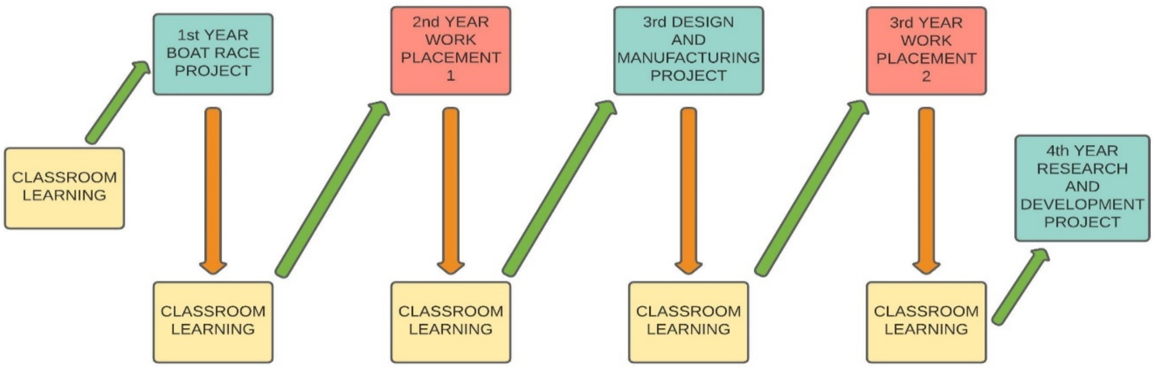


Figure 3.6 shows the learning process across the 4-year engineering degree as a flow diagram. In the 1st year of study, students learn basic engineering knowledge via classroom learning and have the opportunity to apply it in the 1st year's Boat Race Project (ENGEN180 Foundations of Engineering). On completion, students return to their classroom learning, undertaking different courses, and obtaining additional engineering knowledge; they move to their 2nd year of study. In the 2nd year, students go for their first work placement (ENGEN271 Engineering Work Placement) during their summer break. After their work placement, students return to classroom learning, undertaking upcoming different courses covering different engineering knowledge. Accordingly, students move to their third year of study, where they

complete the Design and Manufacturing project (ENGME382) in Trimester A. In Trimester B, students complete their second work placement (ENGEN371 Engineering Work Placement 2), covering 400 hours of work placement during their summer break. Accordingly, students move to their 4th year of study, where they complete their last project – the Research and Development Project (ENGME582). Through these courses, students cover a range of engineering projects and work placements in their four years of engineering education, scoping to develop comprehensive engineering knowledge and technical and non-technical skills. In this research study, engineering projects and work placements are considered as the main aspects, which help students to develop their employability throughout their studies. In the next section, the sampling process undertaken in this study is described.

3.10 Sampling

The sampling process is the technique of recruiting participants, subjects or other forms of data to a research study (Kei & Harland, 2018). Convenience sampling and Representative Random sampling techniques were adopted for this study, which are detailed in sections below.

3.10.1 Convenience Sampling

Convenience sampling is a type of non-random sampling, in which research is undertaken on subjects of the population that are easily accessible or available to the researcher (Etikan, 2016). Here, the elements which are directly accessible to the researcher are more likely to be included or selected (Suen et al., 2014). In this study, students' email addresses were obtained from the student database of the School of Engineering, when the approved ethics application (Appendix K) was produced to the Dean. Potential participants were contacted through their email IDs with the information letter, consent form, and a link for the online survey (Appendices C, D, E, F, G, H, I, and J). Respondents were selected based on their availability and location (close to Hamilton). It was hoped that there would be at least 200 students in total from the Second, Third, Fourth, and Fifth-experience Cohorts and Alumni Cohort. The number of respondents in surveys are indicated in Table 3.3.

Table 3:3 Number of respondents in surveys

Cohort	Invited	Initial Number	Final Number	Instrument
2nd-Experience	50	13 (Response rate 26%)	10 (Response rate 20%)	Appendix L
3rd-Experience	50	14 (Response rate 28%)	11 (Response rate 22%)	Appendix L
4th-Experience	50	16 (Response rate 32%)	12 (Response rate 24%)	Appendix L
5th-Experience	50	26 (Response rate 52%)	19 (Response rate 38%)	Appendix L
Alumni	100	63 (Response rate 63%)	57 (Response rate 57%)	Appendix L

The response rates from each cohorts as shown in Table 3.3 shows the number of participants who completed the survey, with some dropouts in between. In the 5th-Experience cohort, 26 participants started the survey and only 19 completed, similarly in Alumni cohort, 63 participants started the survey, and with some dropouts in between, the number reduced to 57 by the end of the survey. The participants who completed the survey where then invited for focus-group interviews, whose details are indicated in Table 3.4.

Table 3:4 Number of respondents in interviews

Cohort	Invited	Responded	Demographic Info	Instrument
2nd-Experience	13	2	0 Females, 2 Males	Appendix M
3rd-Experience	11	4	0 Females, 4 Males	Appendix M
4th-Experience	16	5	2 Females, 3 Males	Appendix M
5th-Experience	19	2	0 Females, 2 Males	Appendix M
Alumni	63	3	0 Females, 3 Males	Appendix M

Nevertheless, 13 students from the whole Second, Third, Fourth, and Fifth-Experience Cohorts agreed to participate in interview rounds, and only three graduates from the Alumni Cohort. Apart from interview rounds, observations of students' projects and work placements were also carried out, whose details are indicated in Table 3.5.

Table 3:5 Observational info of engineering projects and work placements

Approach	Course	Hours	Participants
Projects	ENGME382 Design and Manufacturing 1	6 hours	30 Approx.
	ENGME582 Research and Development	6 hours	4
Work placements	ENGEN271 Work Placement 1	2 hours	1
	ENGEN371 Work Placement 2	2 hours	1

In quantitative surveys (Appendix L), convenience sampling was used to select participants from the Second, Third, Fourth, and Fifth-Experience Cohorts. They undertook online surveys before the engineering project/work placement.

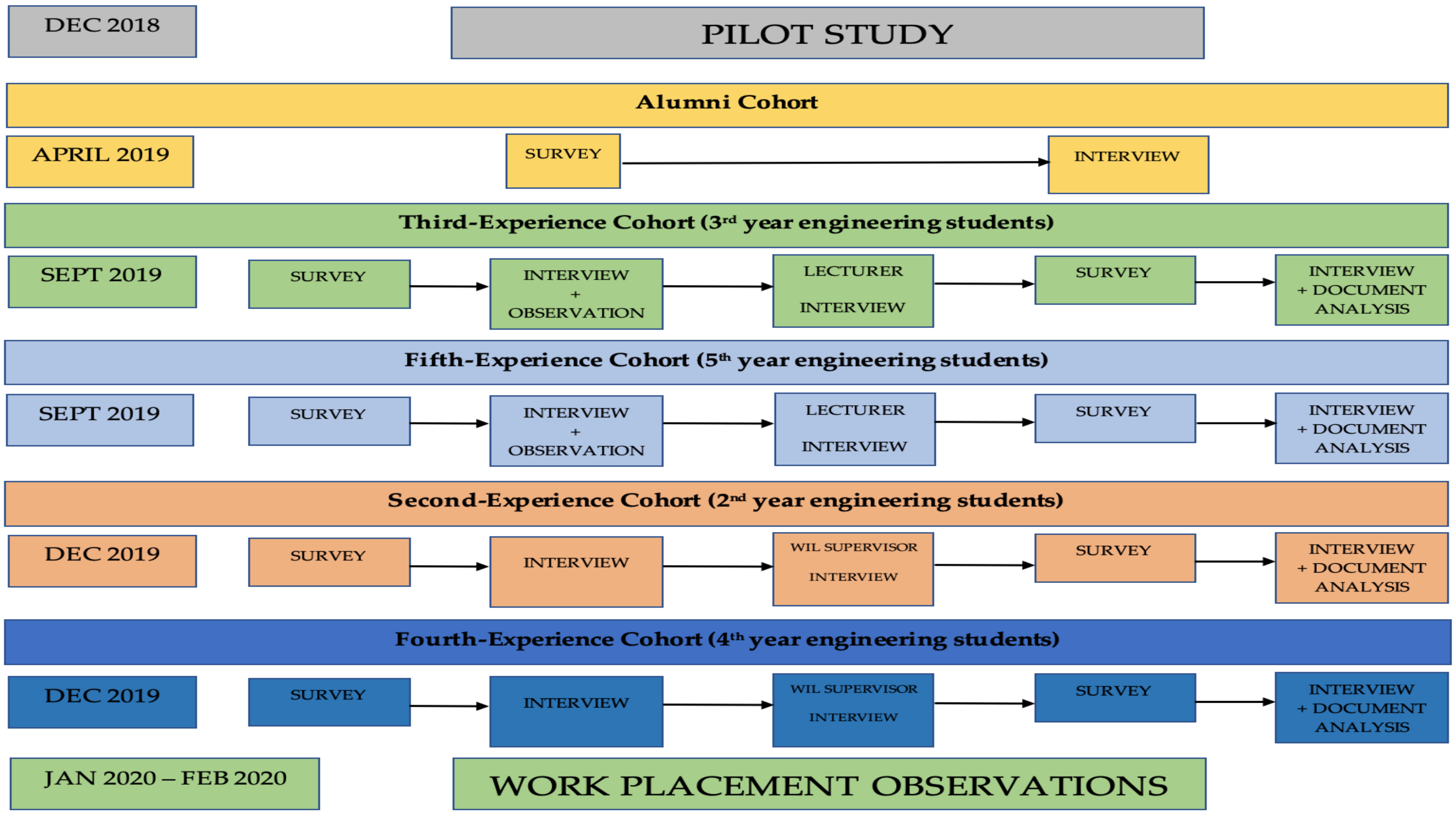
3.10.2Representative Random Sampling

Representative random sampling is a probability sample, in which each element in the population has an equal chance of being selected, and is assumed that those from the properly drawn sample represent the parent population in all ways (Rossi, 2022; Siegel & Wagner, 2022). Data from a representative sample allows this study to make conclusions that are representative for the population from which the sample is drawn. In this study, for qualitative interviews (Appendix M), representative random sampling was used to select participants from a total of 300 survey participants. The selection of lecturers and workplace supervisors as participants in the study were based on purposeful sampling. The four lecturers and two workplace supervisors were contacted with an invitation letter for individual interviews (Appendix I and Appendix J) to discuss student achievements, performance graphs, feedback, measures to improve student experiences, and their views on whether PBL and WIL complement each other.

3.11 Research Design

Current engineering students were grouped according to their number of WIL and PBL experiences, for example Second, Third, Fourth and Fifth-Experience Cohorts, along with Alumni Cohort, were subject to investigation throughout this study. The overall research design comprised these cohorts and are shown in Figure 3.7.

Figure 3.7: Research design



A pilot study included 4th-year chemical engineering students at the School of Engineering. The fifth-experience Cohort's survey and interview questions were used for the pilot study to check the validity of the interview and survey questions. Responses from the pilot study were used to alter or modify the questions.

In the Second, Third, Fourth, and Fifth-Experience Cohorts, pre-and post-surveys and interviews (Appendix I) were held for the same set of students who had shown interest at the initial stage of the study. Each cohort's survey questionnaires and interview questions were prepared to address how work placements and engineering projects facilitate students' progression in terms of development of engineering knowledge and skills. Also, the survey questionnaires and interview questions investigated whether there was scaffolding and/or complementary learning between engineering projects and work placements. Each cohort was compared based on the views of the students, lecturers, workplace supervisors, and recent graduates. In each 2nd-, 3rd-, 4th-, and 5th-Experience cohorts, students were observed in their respective engineering projects and work placements settings, after which they were interviewed. The data of the Alumni cohort highlighted specific areas/trends to be focused on in subsequent phases and thus assisted in altering survey and interview questions for the other cohorts.

3.11.1 Phases of Data Collection

The study comprised two phases; wherein the first phase, a pilot study was undertaken to study the validity of the instruments, and in the second phase, data collection from the Second, Third, Fourth, and Fifth-Experience Cohorts, once the ethics application was approved by the Ethics committee of the Division of Education, University of Waikato.

3.11.1.1 First Phase: Pilot Study

This phase aimed to conduct a pilot study with 4th year chemical engineering students. The overarching goal of this pilot study was to check the validity of the instruments. Thus, the generated data helped to evaluate overall feasibility, validity, question comprehension, and study design, and thus helped to improve survey-interview questions to collect accurate data. For this purpose, the fifth-experience Cohort's survey and interview questions were used in this pilot study, as the participants were in their 4th year of chemical engineering.

A formal request to the Dean of the School of Engineering (Appendix A) was sent to obtain permission to access the faculty's database of current 4th year chemical engineering students, and current mechanical engineering students of 2nd, 3rd, and 4th years, lecturers, WIL supervisors, and recent graduates. Once the permission was granted, the 4th year chemical engineering students were contacted by email with an information letter, consent form (Appendix C), and a link for the online survey. Students who took part in the online survey, and showed interest in participating further in the study, were contacted again with an information letter and consent form for their participation in the focus-group interview (Appendix D). Representative random sampling was used to select students for focus-group interviews, but individual interviews were conducted due to a smaller number of students who responded positively to participation. To get their views/ideas about PBL and WIL and to check how PBL complements WIL or vice-versa, open-ended questions were framed, and thus the data from this helped to check the validity of the instruments/survey-interview questions. In this way, subsequent changes from the pilot study informed all survey and individual/focus-group questions for each Cohort.

3.11.1.2 Second Phase

The second phase comprised data collection from the Second, Third, Fourth, and Fifth-Experience Cohorts and Alumni Cohort. The recruitment process for these cohorts was the same as stated in the first phase. The second phase was divided into three rounds, as stated below.

3.11.1.2.1 First Round: Alumni Cohort

A formal request to the Alumni Office was placed for granting access to its database to get the email address of recent graduates who graduated within the last three years (Appendix B). The recent graduates were sent an invitation mail for an online survey and an information letter and consent form (Appendix F). Those who participated in the online survey and showed interest in participating further in the study were again contacted with an information letter and consent form by email (Appendix H) for their participation in the focus-group interview. Representative random sampling was used to select graduates/participants for focus-group interviews, but since the number of students was fewer, individual interviews were conducted in place of the focus group.

3.11.1.2.2 Second Round: Third and Fifth-Experience Engineering Students Cohort

The Third and Fifth-Experience Cohorts consisted of 3^{rd} and 4^{th} year B Trimester students. The process of recruitment was the same as stated in the first phase. They were invited for an online survey and interviews (Appendix E and Appendix G). The data collection occurred separately for 3^{rd} and 4^{th} year students. For 3^{rd} year students, data collection occurred before and after their 3^{rd} year Design and Manufacturing project.

In the case of 4^{th} year students, data collection occurred before and after their 4^{th} year Research and Development (R&D) project. During the 3^{rd} and 4^{th} years' project, this study observed the students throughout the project session and paid attention to how students performed throughout the project, how easily they could solve the problem, and how much time they took to act/step/make decision. The lecturers were also interviewed during the project sessions (Appendix I), and documents such as lecturers' course outlines and students' assignments were collected during this round.

3.11.1.2.3 Third Round: Second and Fourth-Experience Engineering Students Cohort

The Second and Fourth-Experience Cohorts consisted of 2nd and 3rd year C Trimester students. The process of recruitment was the same as stated above. They were invited for an online survey and interviews (Appendix E and Appendix F). The data collection occurred separately for the 2nd and 3rd year students. In both situations, data collection occurred before and after their work placements. During the work placements of 2nd and 3rd year students, this study observed the workplace site for some time to get an idea of the workplace surroundings and processes/ways of working in the workplace environment. The WIL supervisors were also interviewed while students were undertaking work placements (Appendix J). Documents such as lecturers' course outlines and students' assignments were also collected during this round. In this study, data around unanticipated learning outcomes of different courses were not considered and therefore, were not included in any of the data collection instruments.

3.12 Data Collection Methods

The study employed qualitative and quantitative data methods (mixed methods research). This section below explains the different data collections methods adopted in this study.

3.12.1 Observation

The observational approach of data collection is generally applied in natural settings and has the objective of acquiring complete understanding of the incident being studied (Cohen et al., 2007; Creswell, 2014a; Kei & Harland, 2018; Neuman, 2014c). A naturalistic and participant direct observation without intervention was used, as this occurred in realistic settings where those being monitored were unaware that investigation was going on. The rationale for this observation technique was to closely monitor how events evolved over time in the work placement and engineering project sessions. The data produced through this observation technique were rich and informative (Cohen et al., 2007; Kei & Harland, 2018). This study observed the engineering projects in whole (except ENGEN180 Boat Race project, as it's observation was cancelled due to COVID-19 Pandemic), to get an idea about how students performed throughout the project, how easily they can solve the problem, and how much time they took to perform an action/step/make a decision. Students were observed in their laboratory settings, while they were attempting their engineering projects. Similarly, students were observed in their workplace setting, while they were working in their respective work placements. This study observed the workplace for comparatively less time, just to get an idea about the workplace ways of working of working in the workplace environment. The rationale to use observations was to get a visual experience of the process that happens in WIL and PBL, and to relate it to the student's performance and overall development.

3.12.2 Individual Interview

Individual interviews are one of the most conventional methods for data collection in higher education research, which provides an exceptionally rich source of data (Cohen et al., 2007; Creswell, 2014a; Kei & Harland, 2018). Individual interviews require an interrogative strategy, listening carefully to the participant and building opportunities for them to express their opinions and perceptions freely (Cohen et al., 2007; Kei & Harland, 2018; Neuman, 2014a). This study used semi-structured open questions for interviews (Appendix M, N, and O), as they provided both interviewer and interviewee to probe for evolving ideas. Individual interviews were conducted with students from all Cohorts, Lecturers, WIL Supervisors, and from the Alumni Cohort. The rationale to use individual interviews was to get in-depth descriptive data from the participants, related to their views and perceptions. The interview transcripts obtained were verbatim and the findings from it explained the overview created from the survey findings. This study had used interview samples from a previous study of Samadi (2013), for comparison of results.

3.12.3 Focus Group Interview

Focus groups are more of a type of group interview consisting of semi-structured open questions, where three to five participants were to be interviewed simultaneously. The goal for conducting focus-group interviews was to enable a group discussion on a topic which indeed initiated a range of responses (Cohen et al., 2007; Creswell, 2014b; Kei & Harland, 2018). New ideas are created through group member interaction, where participants learn new experiences of other participants, and indirectly gets more knowledge and understanding of others' views. Therefore, due to this advantage, focus group work different to interviews and is a powerful tool in research method (Cohen et al., 2007; Kei & Harland, 2018; Neuman, 2014a). In this study, the questioning format and Likert scales were adapted from the research study of Samadi (2013). Focus-group interviews were planned to be conducted for Second, Third, Fourth and Fifth-Experience Cohorts, and for the Alumni Cohort (Appendix M). The rationale to use focus-groups was to get participants' attitudes, feelings, beliefs, experiences, and reactions, through having open-ended interactive discussions. However due to the limited number of participants, focus-group interviews were not possible, and thus, individual interviews were used for this purpose. The findings from the individual interviews explained the overview created by the survey.

3.12.4 Survey

Surveys or questionnaires are tools for collecting quantitative data to measure social, behavioural and educational phenomena, in the form of numeric data (Cohen et al., 2007; Creswell, 2014b; Kei & Harland, 2018). The survey format usually consists of a set of closed questions with a choice of answers (that is, multiple choice questions), which may also include questions of a qualitative nature (Appendix L). The rationale to use a survey in this study was that it provides numerical data that is beneficial for straightforward statistical analysis (Cohen et al., 2007). While surveys typically produce quantitative data, many included questions that encourage more in-depth qualitative information (Cohen et al., 2007; Kei & Harland, 2018; Neuman, 2014b). In this study, an online survey was conducted for all Cohorts, where the questions were close-ended. The survey responses may provide an overview of the process of WIL and PBL, in terms of numerical data, which was then explained in detail by the findings of the qualitative research methods. A 5-point Likert scale survey was used, where 1 = strongly disagree and 5 = strongly agree. The neutral midpoint enabled participants, who may have been unsure of their answer to respond. This study had used survey samples from a previous study of Samadi (2013), for comparison of the results.

3.12.5 Document Analysis

Document analysis is defined as the study of the written text, or a systematic process for evaluating written documents, which may be printed or electronic or hand-written (Bowen, 2009; Given, 2008). Through document analysis, data were examined and interpreted so as to gain understanding, develop empirical knowledge and uncover elicit meanings of the written text (Bowen, 2009; Strauss & Corbin, 1998). In this study, document analysis was used as a means of data triangulation. It compared documents from lecturers (course outlines – a document that outlines learning outcomes of a specific course) and students (assignments). Document analysis of the lecturer's course outline helped to understand the planning undertaken to impart knowledge of the course (through classroom lectures and application of PBL and WIL). It provided outlines for engineering projects, work placements, and student assignments. Examining these outlines along with participants' perceptions through surveys and interviews helped to check if these outlines were fulfilled or not, and to what extent, through classroom learning and WIL and PBL. The project and workplace reports' instructions provided by the lecturers are shown in Appendices P, Q, and R.

Document analysis of students' assignments helped to determine what the students had achieved through the application of the classroom learning, PBL, and WIL. Due to COVID-19 and course restructuring within the School of Engineering at the University of Waikato, the 3rd year Design and Manufacturing project's report writing was dropped, and students were assessed based on online interviews conducted by their respective lecturers. Since there are no written assessments of students, nor copies of the online interviews, the lecturer was interviewed to get his views and perceptions regarding how students performed in this project.

The course outlines provided proposed learning outcomes of WIL and PBL; thus, analysis of these also provided evidence of synergies and differences between the proposed learning outcomes of WIL and PBL. Finally, document analysis helped frame the primary Cohort's final survey and interview questions.

3.13 Data Analysis Techniques

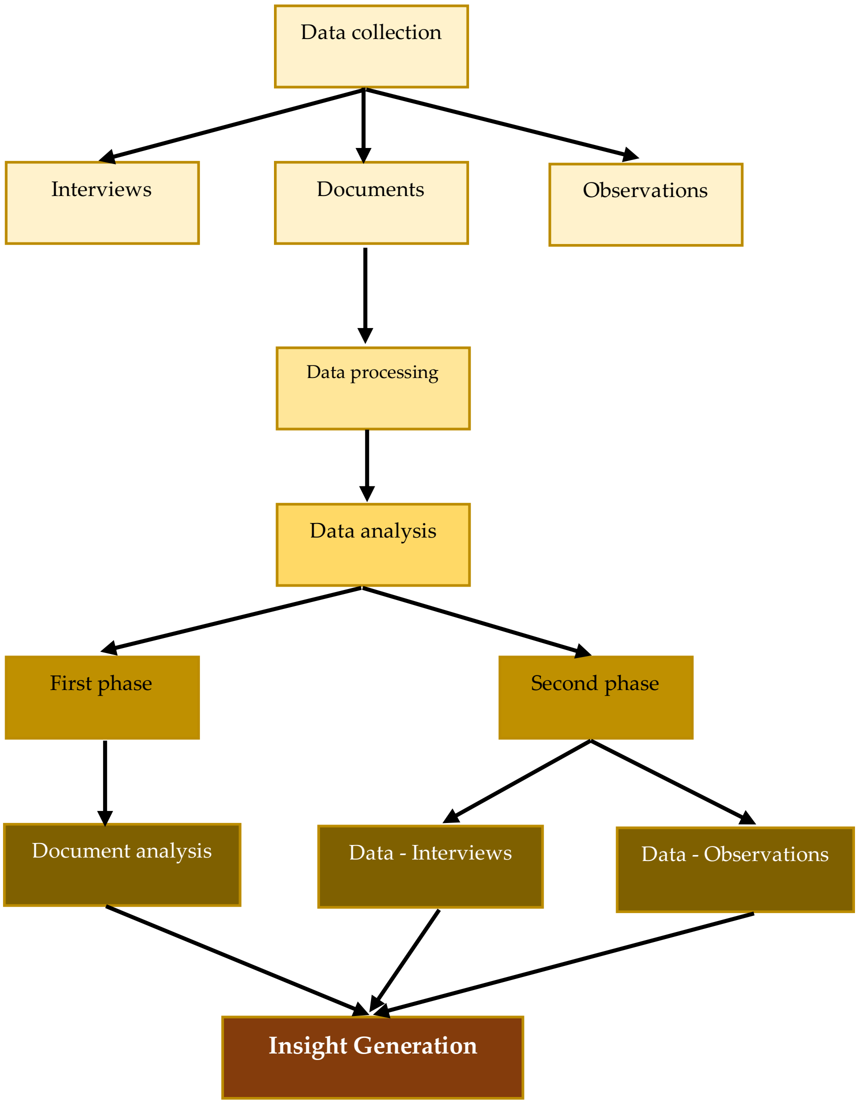
In mixed methods, data analysis comprises of separate analyses of quantitative data using quantitative methods and qualitative data using qualitative methods (Creswell

& Clark, 2018). In this section, a summary is presented of the data analysis techniques which were used in this study for analysing quantitative and qualitative data.

3.13.1 Analysis of Qualitative Data

Qualitative data gathered through individual interviews, observations, and document analysis were categorised based on recurring ideas or themes (Jason & Glenwick, 2016). Firstly, the data from the pilot study (interview transcripts) was analysed to check the validity of the instruments and accordingly reflected onto the primary Cohorts under investigation. The interview data were transcribed and then coded, and a combination of hand transcription and software transcription was used to achieve better accuracy. Otter voice note software was used for transcribing, and Microsoft Word was used for coding data and generating themes for thematic analysis. There were two phases of coding and thematising; the first phase of coding happened from the analysis of documents, lecturers' course outlines, and students' assignments. Two rounds of coding were done here to get the themes, where the second round was a refinement of the first. Also, data analysis of the documents helped to formulate more appropriate and focused questions for the primary Cohorts. The overall analysis process of qualitative data is shown in Figure 3.8.

Figure 3.8: Qualitative analysis process



Furthermore, codes from the pilot study and document analysis helped to create a framework of coding and theming, which were then emulated in the coding of the data from the primary Cohort. In the second phase, coding was undertaken through analysis of the individual interview, focus-group transcripts, and observational findings. These codes then formed relevant themes from the second phase. There were three rounds of coding completed in the second phase, in order to define the themes of this study.

3.13.2 Analysis of Quantitative data

Quantitative data gathered through online questionnaires were subject to descriptive analysis, followed by inferential analysis. As there were pre- and post-WIL and PBL online surveys, thus the analysis of variance (ANOVA) and covariance (ANCOVA) was performed using Microsoft Excel, where work placement and engineering projects were the two independent variables, and students were the dependent variable. Thus, ANOVA was applied in the case where different groups were subject to WIL and PBL separately, and ANCOVA was used in the case where the same group was subject to both WIL and PBL. Thus, ANOVA and ANCOVA suited this study under inferential statistics. Also, descriptive analysis was used in the data analysis of the Alumni Cohort (recent graduates), as this cohort was subject to only one online survey. Inferential statistics were used for the Second, Third, Fourth, and Fifth-Experience Cohorts (primary Cohorts) data analysis. The data from the pilot study were analysed first before the commencement of data collection from the primary Cohorts under investigation, as analysis of the pilot study's data helped to determine the validity of the instruments.

3.14 Validity

Validity is an important factor to effective and quality research, as it is a means to check the accuracy of the findings from the viewpoint of the researcher, the participant, or the audiences (Creswell, 2018b). Maintaining honesty, in-depth richness and extent of data achieved, and the way participants are approached, help in building the accuracy of the findings (Cohen et al., 2007). Validity refers to internal and external threats to the overall quality of the research, which may occur at the research design, data collection phase, data analysis and interpretation phases of the research process (Zohrabi, 2013). The factors stated in the following sub-sections were strictly complied to maintain the overall validity of this research study.

3.14.1 Content Validity

Content validity is referred to as the type of validity which provides adequate and effective measurement of different elements, skills and behaviours in the research process (Zohrabi, 2013). Thus, to get effective responses, valid and reliable instruments were used in this study. The engineering skill sets were used in the preparation of questions in the survey questionnaires and interviews, which were taken from the globally recognised Washington Accord Graduate Attributes and Professional Competencies (International Engineering Alliance, 2014). The interview questions were reviewed by experts in the field (supervisors). A pilot study was conducted to determine students' comprehension of the questions and based on received responses, unclear and unintelligible questions were revised, and complex items were reworded.

3.14.2 Internal Validity

According to Leavy (2017), internal validity focuses on the factors that affect the fundamental relationship between the independent and dependent variables. Such factors could pose a threat to the explanations of the variations in the dependent variable, and thus be a threat to the internal validity of the study. The methods stated in the following sections were adopted to maintain internal validity of the study.

3.14.3 Triangulation

Gathering data through one technique or source can be questionable, biased, and weak, but collecting information from a variety of techniques and sources can strengthen the internal validity of the findings (Zohrabi, 2013). Triangulation may be defined as the use of two or more means of data collection in the study of characteristics of human behaviour (Cohen et al., 2007). Triangulating different data sources, such as survey questionnaires, interviews, observations, and document analysis, helps to build themes. If themes were established by converging these data sources, then this process can be claimed as adding validity to the research study (Cohen et al., 2007).

In this study, the three elements for triangulation were:

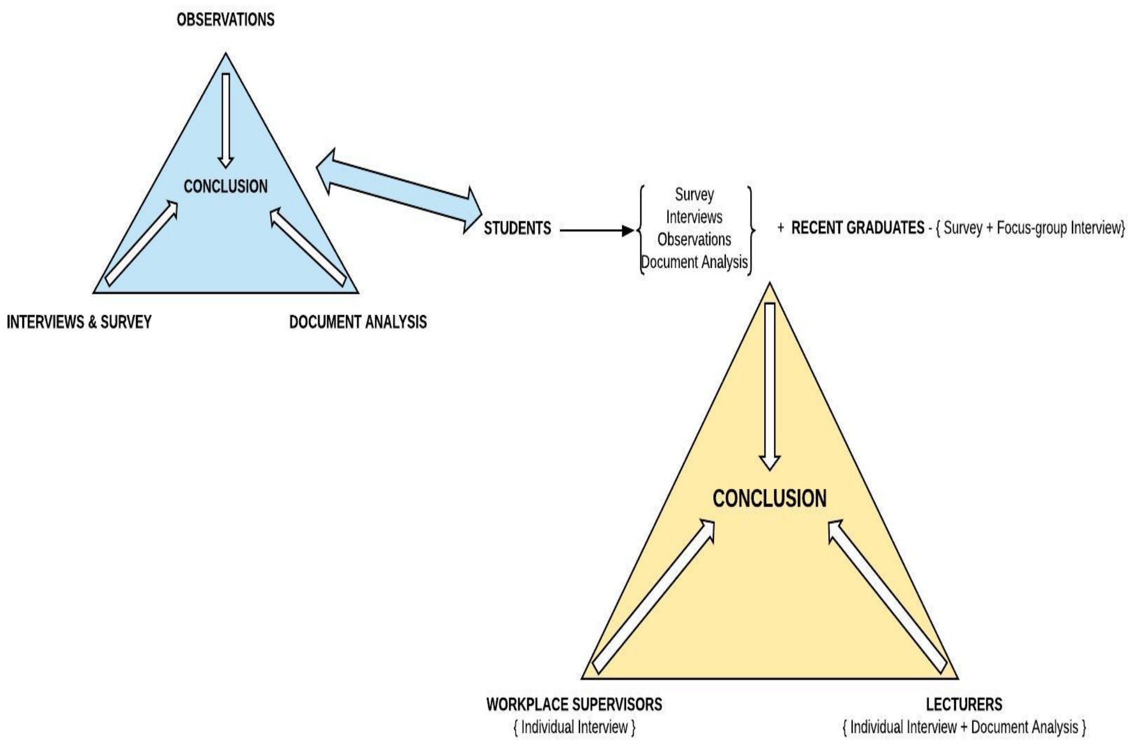
1). Observation,

2). Interview and Survey (participants' views), and

3). Document Analysis.

A model of Triangulation relevant to the study is shown below in Figure 3.9.

Figure 3.9: Triangulation of data collection methods.



The engineering students, who attended work placements and engineering projects according to their engineering curriculum needs, were subject to assessment based on observations, interviews and surveys, as shown in Figure 3.9.

As a sub-set to this triangulation, there was another three-dimensional methodological analysis based on students that is student-centred triangulation, which comprises observation, interview and survey. The three-dimensional analysis of students based on observation, interview, and survey, helped to understand the knowledge and skill development phenomenon during and after the work placement and engineering project sessions.

3.14.4 Member Checking

There was appropriate use of member checking, by taking back the final report or descriptions to participants and determining whether the results/interpretations were valid to confirm the content they shared during the interview process; and thus maintain the accuracy of the collected information (Creswell, 2018b; Zohrabi, 2013). Therefore, the individual interview transcripts were shared within three weeks after the interviews with the study participants for confirmation and validation.

3.14.5 Selection Bias

Having more than one group or a huge population involved in a research study, increases the chances for the occurrence of selection bias in recruitment of the participants (Alexander et al., 2015). To minimise the occurrence and threat of selection bias, intensively random sampling was used from the body of consenting potential participants for interviews in this study.

3.14.6 External Validity

External validity focuses on applicability of the research findings to the population beyond other settings or subjects (Leavy, 2017; Zohrabi, 2013). It emphasises the proper assumption of suitable research design, sampling techniques and sample size selected for the research study. This was applicable in the quantitative data analysis, since it covered a large population of participants. But in the case of qualitative data analysis, external validity faces an applicability problem, as it holds the view of fewer participants. Thus, to minimise threats to external validity, random assignment from a suitable sample size was subject to analysis for this study.

3.15 Reliability

The main requirement of any research process is the reliability of the data, that is, consistency, trustworthiness, and reproduction of the findings obtained from the research study (Zohrabi, 2013). Reliability indicates the researcher's approach and findings are consistent and applicable across different researchers and among different research studies (Creswell, 2018b). Threats to reliability may occur from several factors, such as, variation in observation, lack of clear and 'to the point' instructions, measurement instruments describing items as ambivalent so that they are misinterpreted and questions not presented in proper order. Therefore, to minimise such threats, recommended methods were used for data collection and focus was given to the suitability and convenience of time and place to obtain reliable responses from the participants. Also, fairness was maintained in recording the responses visually and audibly to avoid the researcher's bias.

3.16 Ethics

An ethics application (FEDU065/18) was submitted within the first four months of the doctoral study. A few comments were raised on the application, which were addressed, and the researcher obtained the approved application on 13th of August 2018 from the Human Research Ethics Committee (Appendix K), and later it was amended on 24th April 2019 with minor changes.

3.16.1 Access to Participants

An information letter and consent form were sent to the Dean of the School of Engineering (Appendix A) to obtain access to the database (having email addresses of current students, lecturers, and workplace supervisors - in short, stakeholders) for this research study. Permission letters and consent forms were sent to the Alumni office (Appendix B) to grant access to the database (having the email address of the recent graduates who graduated within the past three years). The pilot study students were contacted formally through email, inviting them to participate in an online survey and focus-group interview with an information letter and consent form (Appendix C and Appendix D). Current students (Second, Third, Fourth, and Fifth-Experience Cohorts) were contacted formally through email, inviting them to participate in online survey and focus-group interviews, with an information letter and consent form (Appendices E, F, G, and H). The lecturers and WIL supervisors were contacted formally through email, inviting them for individual interviews with information letters and consent forms (Appendix I and Appendix J).

3.16.2 Informed Consent

Participation in this research was voluntary and, therefore, informed consent of participants was essential. They were provided with the information letter that stated the research aim and purpose of the study, the procedures, the potential risks and benefits of their participation. The researcher provided his contact details if participants have any questions about the study or raise concerns they may have.

3.16.3 Anonymity and Confidentiality

All participants were assigned codes for data coding and reporting on the study findings, including graduates, current students, lecturers, and workplace supervisors. Data were used only for this doctoral study and the resulting publication. All measures were taken to protect participants' identities and the information they provided; confidentiality was explained to all participants. They were informed that the researcher would do everything possible to maintain complete confidentiality and anonymity, but this cannot be guaranteed. The details of the lecturer and his/her subject course were kept anonymous, as sharing such details may uncover their identity. Also, the industrial workplace details were kept anonymous because of the sensitive nature of the workplace operations. The workplace details were not identified or openly directed, which may have led to their identification. The workplace details were encoded for their identification, which will be known only to the researcher and supervisor.

3.16.4 Potential Harm to Participants

No potential risks for participants during and after the study were anticipated. Codes were used in raw data as well as in the thesis. In all circumstances, the names of all participants and the information they provided remained confidential. Also, the details of the workplace industries were kept anonymous, and the researcher did not assign any direct details about them, which may indirectly lead to their identification. The details of the industries in any documents will not be recognised, and they were coded for their representation.

3.16.5 Participants' Right to Decline to Participate and to Withdraw Data

All qualitative participants could verify the accuracy of what has been transcribed from individual interviews and document analysis. Consent forms include a detailed explanation of this process. The researcher also notified participants when transcripts were available to be checked. Each participant had two weeks to make comments on the transcript. Given the sensitive nature of the material, participants were not offered a summary of the survey results, as they contained responses of other participants too. Additionally, those survey summary results may give mis-conceptions to participants regarding the WIL and PBL process, as during data collection, this study was at its initial stage. Member checking was not available to members of focus-group interviews.

4 FINDINGS

4.1 Introduction

This chapter presents the perceptions of students, lecturers, and workplace supervisors of work placements (Work-Integrated Learning; WIL) and engineering projects (Problem-Based Learning; PBL) practices in the School of Engineering, University of Waikato. For coherency, the data in this study are presented in several sections: student perceptions, graduate perceptions, lecturer perceptions, workplace supervisor perceptions and analysis of relevant documents (course outlines and student assessments), and learning linkages between classroom learning, engineering projects, and work placements. In the initial sections of this chapter, the mechanical engineer graduate profile is explained, which outlines the list of learning outcomes and attributes a student will develop on completion of the engineering degree. The data are presented here based on the main facets of the engineering degree, that is, engineering projects and work placements, which are then further categorised based on the perceptions of students, graduates, lecturers, and workplace supervisors. The actual learning outcomes from the data are then compared with the intended learning outcomes of each engineering project and work placement courses, and accordingly the learning linkages are established between engineering projects and work placements.

4.2 Facets of Engineering Education

In Chapter 2, Literature Review, three facets of engineering education were identified and described as desirable: classroom learning, engineering projects, and work placements. The learning process flow between classroom learning, engineering projects, and work placements during different years of engineering education at the

University of Waikato is shown in Figure 3.6 in Chapter 3 Methodology. The individual links between classroom learning-engineering projects, classroom learning-work placements, and engineering projects-work placements will be presented later in this chapter and will be discussed in detail in the next chapter- Chapter 5 Discussion.

This study was designed to accumulate information and learning across these facets. The data relating to these three facets directly answer this study's research questions. Each section of the results explores aspects from all three facets. Mechanical engineering students (second, third, and fourth year), along with recent graduates, lecturers, and workplace supervisors are the main participants of this study. In line with Explanatory Sequential Mixed Method Research, students' responses were collected via online surveys and individual interviews. The students' responses are categorised into two sub-sections:

1. Engineering Projects (Problem-Based Learning)
    a. Students' perceptions of learning
    b. Graduates' perceptions of learning
2. Work Placements (Work-Integrated Learning)
    a. Students' perceptions of learning
    b. Graduates' perceptions of learning

This section includes an analysis of the student's perceptions concerning their respective course outlines or learning outcomes, which identifies what they thought they had learned from their classroom learning. In this chapter, the order of findings is reported firstly through engineering projects (covering perceptions of students and graduates), followed by work placements (covering perceptions of students and graduates). The next section presents the intended learning outcomes of different engineering projects, and perceptions of students and graduates of their learning experiences.

4.3 Engineering Projects

This section introduces analysis of the intended learning outcomes of ENGEN180 Foundation of Engineering course, ENGME382 Design and Manufacturing project, and ENGME582 Research and Development project. Additionally, the responses of students and graduates on their perceptions of learning experiences when undertaking these engineering projects in university are also stated and analysed. This section is divided into two parts, where the first part describes students' perceptions of learning, and the second part describes graduates' perceptions of learning from engineering projects. Here the engineering projects are comprised of the application of classroom learned engineering theories and the development of practical engineering knowledge. Students and graduates share what they believed (their perceptions) they achieved from engineering project experiences. The perceptions of students and graduates to reflect on the actual learning outcomes are presented by analysing the data obtained from online surveys, interviews, observations, and document analysis. The following section discusses students' perceptions of each engineering project.

4.3.1 Perceptions of Students

This section introduces the students’ perceptions of their learning experiences of engineering projects. The actual outcomes from these projects are stated here, which may match or mismatch with the intended learning outcomes. This section also discusses what limitations students experienced in their engineering projects. The following sub-section discusses students' experiences with engineering projects and their perceived outcomes.

4.3.1.1 ENGEN180 Foundations of Engineering: Intended Learning Outcomes

ENGEN180 Foundations of Engineering introduces students to the engineering profession and the role of engineers and technologists in shaping technology in the industrial and post-industrial ages (University of Waikato, 2020a, p. 2). It covers fundamental principles of engineering design, open-ended problem solving, engineering analysis, and engineering accounting of mass and energy. Learning outcomes, as seen in Section 3.8.2.1 of Chapter 3 Methodology, defines this course as a major design project, which mainly focuses on the design and construction of a remote-controlled model boat to collect floating plastic waste from the University lake. The main ideas emerged by analysing the intended learning outcomes are listed below (University of Waikato, 2020a, p. 2) as sub-sections.

- Links between Science, Engineering and Technology

Students get introduced to the concepts of science, engineering, and technology through the Boat Race Project. At first, these concepts may sound similar, but when completing this course, students can filter the differences between them. Science can be termed as the knowledge of the cause of natural processes (Jin, 2020). Using reason and logic, it examines apparent phenomena, rationalises a physically consistent explanation, and refers to the collective body of this knowledge and the processes used to establish it. On the other hand, engineering is the process of developing outcomes that accomplish some practical task for humankind (Dev, 2012; Poser, 1998). In this context, Technology can be the tool that accomplishes a valuable task for humankind (Dugger, 1993; Jin, 2020). In this course, students build a working remote-controlled boat model. So, the general theory behind the working of a remote-controlled boat is obtained from science, and then the steps and processes defined to build a working boat model (designing process) are accomplished under Engineering. Lastly, by practical use of tools to build models based on engineering and science concepts, Technology accomplishes the final make of the model. By going through these stages, students understand the differences and links between science, engineering, and technology.

- Engineering design technique application

Engineering design is developed with the combination of science concepts and engineering processes, and accordingly, a suitable design concept is described for the boat model. Students apply an engineering design concept developed by an underlying science concept based on the working of a boat/engineering problem. Students then apply that concept and technology to build the working boat model.

- Solving mass and energy problems by applying general accounting knowledge

The students must develop a working boat model; thus, they must consider minute details like mathematical calculations, thermodynamics, propulsion and mechanical strength concepts, and safety requirements. To develop these aspects, students must apply several equations based on the boat's mass, thermodynamics, and kinetic and potential energy. Accordingly, students define these constraints for developing the model of the boat.

- Problem-solving

Students need to understand concepts such as propulsion and mechanical strength in order to build their boat's design structure. Students must work through several problem-solving techniques to find the appropriate engineering design technique to build the boat model.

- Solving engineering problems by applying fundamental engineering knowledge

While developing a working boat model, students will need to address concepts based on the mass of the boat, thermodynamic concepts, propulsion, and mechanical strength issues. To understand these concepts, students must study and understand relevant theories and then apply mathematical calculations to find the respective design concepts that suit the requirements. As students work through this process, they, directly and indirectly, apply problem-solving techniques to shortlist the relevant engineering design concept from available options.

These intended learning outcomes emerged from the ENGEN180 Foundations of Engineering. In the next section, the actual learning outcomes are shown, based on the data collected from students, showing their perceptions of learnings from this project.

4.3.1.1.1 Student Perceptions of Achievements

4.3.1.1.1.1 Quantitative Data: Online Survey

An online survey was conducted, in which 13 students (response rate 26%) responded. Students were asked about what they achieved by doing the Boat Race Project (Question 11, 2nd-Experience cohort, Appendix L) and the received responses are presented in Table 4.1.

Table 4:1: Students' response on their personal work in ENGEN180, foundations of engineering, boat race project (n = 13; Likert 1-3), where 1 indicates seldomly and 3 indicates very regularly.

		Seldomly	Reasonably regularly	Very regularly	Mean	Standard Deviation
1.	I contributed ideas and facts for completion of the project	0	8	5	**1.61**	0.487
2.	I was able to understand the project based on the prior classroom knowledge	3	5	5	**1.84**	0.769
3.	I used a variety of resources when doing the project	3	7	3	**2.00**	0.679
4.	I was able to learn more from the project than from classroom learning	4	5	4	**1.69**	0.784
5.	I enhanced my problem-solving skills	1	8	4	**1.76**	0.576
6.	I helped my group efficiently in working as a team	0	7	6	**1.53**	0.499
7.	I was able to understand the theory that underpinned the project	3	8	2	**2.07**	0.615

All participants stated that they very regularly or reasonably regularly contributed ideas and facts for the completion of their project. While 10 (76%) participants felt that they very regularly or reasonably regularly understood the project based on their prior classroom knowledge, 24% felt that they seldomly understood the project. When participants were asked whether they enhanced their problem-solving skills via this project, 12 participants (93%) indicated they very regularly or reasonably regularly did, with only one (7%) indicating that they seldomly enhanced their problem-solving skills. Another finding showed that all participants very regularly or reasonably regularly worked efficiently in group work for the project. Ten participants (77%) indicated that they very regularly or reasonably regularly understood the knowledge behind the project as these projects were designed based on classroom-taught engineering concepts and theories. Therefore, students felt they enhanced their understanding of the engineering knowledge underpinned within the project through undertaking engineering projects.

In order to get an insight into the learning effects of the Boat Race project, questions were framed to check if the following were the learning outcomes (Question 12, 2nd-Experience cohort, Appendix L), as shown in Table 4.2.

Table 4:2: Students' Perceptions on whether the following were the actual learning outcomes from ENGEN180 boat race project (n = 13).

		Yes	No
1.	Obtain better understanding of classroom learned theories	9	4
2.	Obtain practical hands-on experience of engineering design	10	3
3.	Develop skills such as communication, teamwork, problem-solving, critical thinking, and project management	10	3
4.	Get Academic credit points to pass the course	11	2

The participants' responses in Table 4.2 show that 84% agreed that by completing the Boat Race project, they got academic credit points to pass the course, while 16% disagreed. On the other hand, approximately 31% disagreed that they understood the classroom learned theories by completing the Boat Race project. Similarly, 23% disagreed that they obtained practical knowledge and experience in engineering design and developing technical and non-technical skills from Boat Race project. In the next section, descriptive data from individual interviews are presented.

4.3.1.1.1.2 Qualitative Data: Interview

This section presents the descriptive data obtained via interview of students on their learning experiences of the Boat Race Project, in which students indicated that they developed engineering knowledge, some technical skills, and non-technical skills. Additionally, students found this project as a place of opportunity to apply their classroom learning to solve the project's problem. As students manufacture their boat models, they must use them on the University Lake to see whether their boat models fulfil the requirements or not. The project comprised theory classes, tutorials, and laboratory sessions to gain relevant theoretical knowledge and develop technical skills to address the engineering problem posed by project. Based on the research's data collection timeline, the observation of the Boat Race project was scheduled for March 2020 to June 2020. During this time, due to the global pandemic COVID-19 Lockdown in New Zealand, the teaching went online and there was no Boat Race Day. Thus, significant observations could not be undertaken, therefore, instead students' project reports were analysed and presented in this section to triangulate the findings based on the Boat Race project.

Students worked from home online, coordinated with their group members, and created simulated boat models in CAD software. Additionally, students subsequently created their project reports. These reports were analysed, resulting in the identification of the following essential aspects. Students appeared to work efficiently as a team in a virtual space, with adequate planning and organisation skills and collaborative discussions (via Zoom platform) enabling them to finalise their boat model. The statement by participant I.1E.2 supports this observation:

> For concept selection, each team member separately brainstormed ideas and came back with a minimum of one overall concept to discuss with the group (via zoom). After a week of deliberation, we returned to the group with a few designs. Then we spent time going through each design with the group via zoom, and we discussed the pros and cons of each design, and at last, collectively, we shortlisted one design for the boat model. We collectively applied teamwork skills virtually via zoom and critical thinking to finalise the boat model. (I.1E.2)

Students worked as a team during lockdown conditions (via Zoom) as they brainstormed ideas and concepts for the boat designs. All team members put forward different boat design structures based on discussions of different engineering concepts via zoom. They discussed the pros and cons of each boat design, demonstrating elements of critical thinking, as each boat design is based on 3D structures, encapsulating concepts of mathematics, basics of design, and structures. Studying boat models based on these concepts will require elements of critical thinking and reliance on prior knowledge of classroom learned knowledge. The students discussed and shortlisted their project's most successful boat design structure. Teamwork and critical thinking were evident in the above statement. A similar response also came from participant I.1E.1:

> For our project, we split our team into three; Team 1 worked on the collection method – to design the system which collects wastes from the university lake. Team 2 worked on the steering and propulsion system, and Team 3 worked on the electrical system. Each team came up with their design concepts, and we discussed that in the group via zoom. Once the work from all members was done, we gathered (online) to finalise the overall boat design. (I.1E.1)

Participant I.1E.1 stated that the overall project work was divided among the group members, which indicated that they practised efficient planning and organising, communication, and leadership skills. Additionally, they had to practise critical thinking as they had to discuss their findings with each other to finalise their overall boat design.

From another student's report, the following statement suggests that critical thinking and problem solving continued during the COVID-19 Lockdown.

> Due to the COVID-19 Lockdown, we could not build a physical working boat model and instead had to move on to online collaboration to design a 'virtual' boat. Since we had to design the boat on software, thus we had to make sure that the implement electronic design process in depth so that the boat met all criteria. Coordinating with the group online was tough at first, but then we got used to it via zoom. We had to involve lots of critical thinking and mathematical calculations during this time. (I.1E.3)

Students faced challenges while doing project works via Zoom (Online) as they had to apply concepts of engineering design virtually to find values of design constraints and, thereby, build boat designs in software. They had to apply critical thinking and mathematical calculations to find values of all design constraints and then have group discussions to shortlist appropriate boat design models. This exemplifies that teamwork, critical thinking, project management, and problem-solving skills were applied during this project.

These findings suggest that the project’s intended learning outcomes and students' perceived learning outcomes are aligned. After this course, students completed ENGME380 Design and Manufacturing in their third year of study, which is presented in the next section.

4.3.1.2 ENGME382 Design and Manufacturing (undertaken by 3rd-Experience students): Intended Learning Outcomes

The ENGME382 Design and Manufacturing course, aimed to furnish students with a knowledge of modern manufacturing processes and how to use them when designing complex machines (University of Waikato, 2020d, p. 2). Students (3rd-Experience) are required to use laser cutting, CNC machining and 3D printing for designing the project's complex machine. The analysed intended learning outcomes for this course are presented in next sub-section (University of Waikato, 2020d, p. 2).

- Prototyping to test design concepts

Students are given an engineering problem and are asked to solve that by building a working model. This regulates the students need to research the given problem, define its constraints, work through the mathematical calculations, and apply design logic. Then, they have to define the design criteria and find the suitable engineering design technique that suits the requirement. Lastly, with the defined design concept, they need to build a prototype that tends to be 'quick and dirty' – low fidelity, which showcases whether their design concept makes sense or not.

- Application of manufacturing processes for design purpose

Students use traditional manufacturing techniques like machining, foundry, welding, and hand-operated tools, and modern techniques like lathes, mills, drill presses, 3D printing, and laser cutting during the project works. With these manufacturing techniques, students build their designed parts and machines and thereby manufacture working models to address the project's posed engineering problem.

- Health and safety practices

As students must use heavy tools and machinery, they learn about health and safety procedures before they enter into their laboratories and workshops. They were given health and safety inductions at the commencement of the projects and were required to demonstrate those practices while working on their project.

- Design machine based on specifications

Students had to identify their project aim, research it, and study its theory. Based on theory identification, students then work on mathematical concepts, identifying the constraints related to their project. They then apply problem-solving to finalise their design and manufacturing to build their working models to meet working conditions. Through this process, students finally build the required machine, which solves the given engineering problem. The following section presents students' perceptions of learning via quantitative and qualitative data.

4.3.1.2.1 Students' Perceptions of their Learning

4.3.1.2.1.1 Quantitative Data: Online Survey

Students (3rd-Experience) were given a list of skills and were asked how strongly they agreed or disagreed with whether those skills were enhanced in their third year ENGME382 (Question 10, 3rd-Experience online survey, Appendix L), from which the following responses were obtained (Table 4.3).

Table 4:3: Students' responses to online survey questionnaire on enhancement of following skills in ENGME382 design and manufacturing skill set (n = 14), with 1-5 likert scale, where 1 indicates strongly disagree and 5 indicates strongly agree.

	Skills	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Standard Deviation
1.	Problem-solving	1	0	3	5	5	3.93	1.100
2.	Teamwork	0	0	0	7	7	4.50	0.500
3.	Critical thinking	0	0	2	7	5	4.21	0.674
4.	Communication	0	0	2	7	5	4.21	0.674
5.	Physical presentation	0	2	4	4	4	3.71	1.030
6.	Planning and organisation skills	0	0	5	3	6	4.07	0.884
7.	Leadership qualities	0	1	2	5	6	4.14	0.915
8.	Self-learning	0	1	2	6	5	4.07	0.884
9.	Professional ethics	0	0	5	4	5	4.00	0.845
10.	Retention of information	1	0	4	6	3	3.71	1.030
11.	Engineering knowledge	0	0	1	7	6	4.36	0.610

Participants also shared their responses when considering the project's learning experiences (Table 4.4). Ten (72%) participants agreed or strongly agreed that they enhanced their problem-solving skills via design projects, whereas three (7%) disagreed. All participants agreed or strongly agreed that they enhanced their teamworking skills. On the other hand, five (36%) were neutral to enhancing planning and organisation skills via the project. For engineering knowledge, 13 (92.8%) participants agreed or strongly agreed that they enhanced their engineering knowledge via the project, while one participant (8%) was neutral. Additionally, students' responses to the overall learning experience of ENGME382 Design and

Manufacturing project (Question 13, 3rd-Experience cohort, Appendix L) is shown in Table 4.4.

Table 4:4: Students' responses to online survey questionnaire on their learning experience of ENGME382 design and manufacturing 1 (n = 11), with Likert scale 1-3, where 1 indicates seldomly and 3 indicates very regularly.

	In Design and Manufacturing 2 course:	Seldomly	Reasonably regularly	Very regularly	Mean	Standard Deviation
1.	I contributed ideas and facts for completion of the project	0	2	9	1.18	0.386
2.	I was able to understand the project based on the prior classroom knowledge	1	5	5	1.63	0.643
3.	I used a variety of resources when doing the project	1	3	7	1.45	0.656
4.	I was able to learn more from the project than from classroom learning	1	4	6	1.54	0.656
5.	I enhanced my problem-solving skills	2	2	7	1.54	0.782
6.	I helped my group efficiently in working as a team	0	2	9	1.18	0.386
7.	I was able to understand the theory that underpinned the project	0	5	6	1.45	0.498

All participants reasonably regularly or very regularly contributed ideas and facts to complete the project. One out of 11 participants seldomly understood the project background based on prior classroom knowledge. Two participants (16%) seldomly enhanced problem-solving skill via the project. All participants indicated that they reasonably or very regularly worked as a team and understood the theory underpinning the project. Project appeared to help students strengthen their engineering knowledge and develop technical and non-technical skills based on these responses.

4.3.1.2.1.2 Qualitative Data: Interview

Semi-structured questions were prepared around learning outcomes and experiences of the Design and Manufacturing project. A total of 11 students (3^{rd}-Experience) were invited for an interview, and four responded positively. Participants were asked about their learning experiences from the project. All felt that working in the project enhanced their engineering knowledge, critical thinking, problem-solving, collaborative skills, and communication skills based on their perceptions. Participants I.3E.1 and I.3E.2 shared the following:

> In my third-year design course, we had to develop an inventive way to multi-design our project, which involved a high level of problem-solving and critical thinking in designing a prototype and assembling the prototype. (I.3E.1)

> Design projects allowed me to apply what I have learned, which helped me think about the project topic/problem differently, additional to the textbook perspective. We can get different solutions for a specific project topic/problem by researching. However, it requires the practise of considerable knowledge and skills to find the most appropriate design concept solution for the specific problem. (I.3E.2)

The project appeared to strengthen students' design concepts, enabling them to undertake appropriate research to identify possible solutions, problem-solving, and critical thinking to determine the best solution for the problem. The successful solution covered theoretical concepts behind the problem and practical knowledge needed for the design process. This was exemplified by I.3E.3's response as shown below:

> The design project was very interdisciplinary; that is, it involved many mechanical aspects, electronics, and software aspects, and we had to

> integrate them all to make the machine work. This project helped us gain interdisciplinary knowledge and related practical experience. (I.3E.3)

Project also enabled students to experience the implementation of interdisciplinary engineering knowledge as their project included mechanical, electronics, and software programming aspects to build their project prototype. This encouraged them to refer to previously acquired engineering knowledge (from classroom learning) and self-research to study different engineering aspects outside mechanical engineering. Additional to knowledge, students also benefitted from developing some non-technical skills, as identified by I.3E.4:

> One main outcome I got from the Design project was teamwork skills. We need to work together and ensure that everyone is on the same page when working with different aspects of the project. (I.3E.4)

Students developed teamwork, communication, and project management skills through their participation in project. The following section presents findings from students' project report assessment.

4.3.1.2.1.3 Qualitative Data: Students' Achievement

In the Design and Manufacturing project, the Course Convenor (Staff member in-charge of this course) replaced project reports with online group interview questionnaires, as he wanted to practise an alternative assessment structure. During the interview, students had to evidence their work through software simulation using AUTOCAD and were not asked to write a project report. These group interviews carried 20% weighting in this course.

Through these group interviews, students had to explain and answer questions on their project's design, manufacturing concepts, health and safety considerations, and the finished machine/model (software level simulation). The group interview took 20 minutes, including presentations and questions. The group interview was designed to replicate what happens in the industry when they show their final prototype design work to a client. The narrative talk explained the design and how it meets the requirements. The students' task was to convince their lecturer that their design performs the task effectively, which complies with the rules and meets the project's objectives. There were two sets of group interviews: one was on selecting engineering concepts for addressing the project, and the second was on the final design and prototyping of the project. In the first group interview, four aspects of students' learning were assessed based on the following (University of Waikato, 2020d, p. 3):

1. Understanding,
2. Concepts,
3. Selection, and
4. Proof – Dirty prototypes.

In the second group interview, students were subject to the following four assessments (University of Waikato, 2020d, p. 3):

1. Design,
2. Manufacturing,
3. Health and Safety, and
4. Finished Machine (software level simulation).

The lecturer conducted these interviews face-to-face and there were no permanent records (transcripts, audio-video recordings) of these interviews.

4.3.1.2.1.4 Qualitative Data: Researcher's Observation

Students were required to apply modern manufacturing processes to design complex machines. Students had a mix of theory classes and laboratory sessions (software simulation) to assist with completing this project. A total of 30 students were observed by the researcher directly in laboratory settings. A few aspects were noted during the observations, such as teamwork, problem-solving, critical thinking, and technical skill development. These aspects are summarised below.

- Teamwork

The students worked in groups of four, where everyone was allotted specific tasks. For example, the first student worked on mathematical calculations to find design constraints; the second worked on designing the prototype in computer software (3D drawing – AutoCAD/Solid Works software). The third student worked on short-listing materials and components required for making the working model and ordering it, and the fourth student worked on general coordination and model assembly. “I noticed that the students had divided the whole project works within themselves and worked accordingly” (Observation Journal, 9th September 2019). “Students coordinated internally to their group and externally with other groups” (Observation Journal, 9th September 2019). This indicated that the students were able to practise efficient teamwork during their project.

- Problem-solving

Most of the time, group members worked together to help solve the problems. There were instances where the students got stuck in a challenging situation. For example, in one of the groups, a student had incorrect mathematical values due to faulty calculations. His group members helped him to correct the error by re-doing the calculation with him. In another example, “a student was designing a model in CAD software, there are some drawing concepts that he was unsure about” (Observation Journal, 9th September 2019). The student shared this issue with his group, and “he received help from his group members, which helped to address the issue and favoured learning through collaboration in a social environment" (Observation Journal, 9th September 2019).

- Critical thinking

Critical thinking is mostly required to solve engineering problems, as deep thinking to analyse the problem is the next step towards problem solving (Negley, 2022; Russell Iii et al., 2021; Tuzlukova & Usha-Prabhukanth, 2018). In the project, the students had technical problems that required intense thinking around formulating relevant engineering concepts to address them. It was interesting that the students actively participated in their group to work together to fulfil their project goal(s). For example, in a group, a student was confused about a design concept. His group helped him, and "they used a variety of resources like the use of computer and internet to find related information, communication/doubt clearing with their lecturer and classmates, library books and referring to classroom notes, to understand more about that specific design concept" (Observational Journal, 9th September 2019). "Using these resources and group discussions, the students collectively decided about their design concept as a team" (Observation Journal, 9th September 2019). This evidence suggests that the students practised critical thinking, teamwork, and communication skills via group discussion, which appeared to help them address their project problems.

- Technical skill development

During the project work, the students had to practise and apply technical skills to do their project works. For example, when doing mathematical calculations for finding the values of the constraints, the students used statistical concepts, general mathematical formulas, and trigonometric identities to find related design values. This way, "students mastered engineering mathematical calculation abilities" (Observation Journal, 9th September 2019). In another instance, "students were working on designing 3D drawing in AutoCAD and Solid Works, they developed skills related to advanced 3D drawing skills, and establishing parameters related to designing such as stress, strain, materials, and standards." (Observation Journal, 9th September 2019). "When the students worked on building their working models, they used a variety of tools/machines such as laser cutting, CNC machines, lathe machine, 3D printer, and drilling machine." (Observation Journal, 9th September 2019). With such experience, "students enhanced their machinery and tools skill set, 3D drawing and designing skills" (Observation Journal, 9th September 2019). The following section presents ENGME582 Research and Development project learning outcomes.

4.3.1.3 ENGME582 Research and Development project (R & D project undertaken by 5th-Experience students): Intended Learning Outcomes

In the fourth year of the engineering degree, the students from mechanical, software, civil, and electronics engineering were grouped together for a Capstone Project. This course provides an opportunity for the students to apply previously developed engineering knowledge and skills (from their first three years of study) onto an interdisciplinary project posing an engineering problem (University of Waikato, 2020e, p. 1). The students learn how to carry out research as a team and gain an appreciation of the depth and breadth of engineering knowledge and skills required for completing this interdisciplinary project. The intended learning outcomes, as shown in Section 3.8.2.3 of Chapter 3 Methodology, are presented below (University of Waikato, 2020e, p. 1).

- Address a real-world interdisciplinary engineering problem

The students are given a project topic, which is based on an industrial application, and involves research content. It is likely to be interdisciplinary in nature, which encourages students to work on different engineering disciplines, and that helps them to gain engineering knowledge outside their field of expertise, that is, mechanical engineering.

- Showcase Research outcome(s)

The students research their project topic to develop the concept (design and manufacturing) and build their working model. They then present these findings to their colleagues, lecturers, and other staff, where students also experience question and answer sessions with their colleagues and lecturers based on their work. This facilitates testing of their knowledge, potentially assisting their confidence and enabling the identification of possible errors which can be corrected before submission.

- Documenting the whole research and development project

Once the working model is finalised, students document their project work as a poster, report, and presentation. The poster involves demonstrating the final working product and explaining its outcome. A report is a lengthy document and typically incorporates all the material produced during the project. It should provide all the context, methods, designs, and results, required to understand and duplicate the work. Lastly, students present their whole report in a short version via presentation slides showcasing their project work.

4.3.1.3.1 Students' Perception of Learning in ENGME582

4.3.1.3.1.1 Quantitative Data: Online Survey

The students were asked how strongly they agreed or disagreed that aspects of engineering learning were enhanced by the ENGME582 project (Question 12, 5th-Experience cohort, Appendix L). Table 4.5 shows that 23 participants (88%) agreed or strongly agreed that logical/analytical thinking and discovery and analysis of engineering problems were enhanced via project works. Additionally, 21 participants

(80%) agreed or strongly agreed that conceptual understanding and engineering design were enhanced. On the other hand, one participant (3%) strongly disagreed that classroom theoretical and interdisciplinary knowledge and engineering design were enhanced via the project (Table 4.5).

Table 4:5: Students' responses to online survey questionnaire on whether the following aspects were enhanced or not in ENGME582 R & D project (n = 26), on likert scale (1-5), where 1 indicates strongly disagree and 5 indicates strongly agree.

	Aspects	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Standard Deviation
1.	Classroom theoretical knowledge	1	2	6	14	3	3.62	0.923
2.	Interdisciplinary knowledge	1	1	5	15	4	3.77	0.890
3.	Logical/analytical thinking	0	1	2	13	10	4.23	0.750
4.	Conceptual understanding	0	1	4	16	5	3.96	0.706
5.	Discovery and analysis of an engineering problem	0	1	2	15	8	4.15	0.717
6.	Engineering design	1	0	4	12	9	4.08	0.917

The participants were also given a list of skills and qualities and were asked whether they strongly agreed or disagreed that those skills/qualities were enhanced in ENGME582 (Question 11, 5th-Experience cohort, Appendix L). Table 4.6 shows that 15 participants (79%) agreed or agreed that they developed problem-solving skills via project. On the other hand, one participant (5%) disagreed that they developed teamwork skills. Most participants agreed they developed critical thinking, communication, planning, and organisational skills. On the other hand, three participants (16%) disagreed that they developed leadership qualities via the project. Lastly, one (5%) participant disagreed with the enhancement of engineering knowledge (Table 4.6).

Table 4:6: Students' responses to online survey questionnaire on whether the following skills were enhanced in ENGME582 R & D project (n = 19), with likert scale (1-5), where 1 indicates definitely disagree and 5 indicates definitely agree.

	Skills	Definitely Disagree	Disagree	Neutral	Agree	Definitely Agree	Mean	Standard Deviation
1.	Problem solving skills	0	0	4	8	7	4.16	0.744
2.	Teamwork	0	1	2	7	7	4.18	0.856
3.	Critical thinking	0	0	4	6	9	4.26	0.784
4.	Communication skills	0	0	2	13	4	4.11	0.552
5.	Planning and organising skills	0	0	1	11	7	4.32	0.567
6.	Leadership qualities	0	3	5	6	5	3.68	1.029
7.	Self-learning	0	0	1	8	10	4.47	0.595
8.	Engineering knowledge	0	1	3	10	5	4.00	0.795

It can be seen that the students benefitted primarily with skills such as problem-solving, critical thinking, teamwork, communication, planning and organisational, leadership qualities, self-learning, and engineering knowledge while participating in the project. The following section presents students' descriptive perceptions via qualitative data.

4.3.1.3.1.2 Qualitative Data: Interview

Semi-structured interview questions were prepared to gain access to descriptive students' perceptions of learning from the project. Two 5th-Experience students were interviewed based on their learning experiences from the project. The students indicated that they found the project useful, as they could apply previously acquired engineering knowledge, design and manufacturing concepts, and skills like researching, problem-solving, critical thinking, and 3D drawing to the project's engineering problem(s). This is exemplified by I.5E.1's quote below:

> In the R & D project, I studied how to do research, look, and find solutions that already exist. It even helped me in my work placement, as we also needed to solve a problem, and for that, we had to do intense research to find an appropriate solution. Additionally, I also gained engineering knowledge, manufacturing, and design concepts by doing intense research via this project and other 3D AutoCAD drawing, problem-solving, critical thinking, teamwork, and communication skills. (I.5E.1)

The students thought the project helped them to enhance their research skills, because they developed engineering knowledge outside classroom learning and could also relate classroom learned theories with practical applications. Since the students worked in groups to create working models for their projects, this enhanced their problem-solving, communication, planning, and organising skills. As the project included aspects of mechanical engineering and design concepts, it helped the students to master their skills around 3D AutoCAD drawing. As the students needed innovative ideas to address the project-based problem, this suggests they enhanced their critical thinking and problem-solving. Lastly, as the students worked in groups, the project experience might have assisted in enhancing their teamwork and communication skills. Another student shared his experiences as shown below:

> In the R & D project, I felt we were making something that would impact industries. We were doing a project based on real-world applications or concepts, which posed an entirely new challenge for us compared to the third year's Design project. The project was designed based on the idea that everyone in the class was doing – the same project topic for the whole class. In the R & D project, each group had a different project topic, and thus it made us feel more complex and challenged to solve this project. (I.5E.2)

The student felt intensely challenged while working on the project because he and his group were addressing a complex real-world engineering problem, which demanded the use of a high level of problem-solving and critical thinking skills. His group had to research several theories that could match the project's engineering problem to find a suitable solution. They had to develop problem-solving to find the appropriate concept that best fits the problem. Based on these students' experiences, it appears that project posed challenging and innovative real-world problems to help the students master engineering knowledge and develop technical and non-technical skills.

4.3.1.3.1.3 Qualitative Data: Students' Achievement (Project Report)

Students documented their full project details in the form of a project report. This included an abstract, introduction, literature review, research findings, and final design related to their project. Analysis of the reports found that students researched the problem statement and theoretical background and applied several ideas to the trial-error method to see if they could modify the project parameters to develop a required solution. This can be exemplified by the I.5E.1's quote below:

> In this project, a supercapacitor bike was built and tested, for which the supercapacitor section was fitted into an old bike frame. The bike had less

> storage capacity, so few supercapacitors were fitted in. The bike was designed for hilly terrains, and it worked well as this bike had greater regeneration capacity than batteries. With the initial idea completed, there was scope for more modifications and improvements like increasing the motor's regeneration limiter, increasing the number and size of capacitors, and making bike frames from lighter materials, etcetera. (I.5E.1)

The response of I.5E.1 shows that he practised some real-life problem-solving experiences via this project. He worked in a group to research supercapacitors and related mathematical calculations. This suggests that group members found the operating values on which the supercapacitor could work based on the given specifications as per their project topic. Students researched and found the ways by which they could develop their bike model by performing some alterations, such as increasing the number and size of capacitors, using different manufacturing materials for bike frames, and increasing motor regeneration values. Another student's report suggested that they experienced real-life problem-solving via this project, where he had to research possible options for implementing renewable energy usage. This is evidenced through the quote below:

> A scoping study was conducted to design a possible model of a renewable energy system for Bora Bora. The proposed system uses a combination of generation and storage technologies to supply the island's energy demands and proposes to use solar energy to cut down electricity demands. A renewable transport system is also proposed to reduce the island's carbon emissions. The use of hydroelectric power stations can meet additional power requirements. By 2030, Bora Bora will be at least 90% reliant on renewable energy with all these techniques. (I.5E.2)

Participant I.5E.2 researched possible renewable energy options that would match the geographical terrain of Bora Bora, where the project was contextualised. With the analysis and research based on Bora Bora's geographical terrain and possible renewable resources available, his group shortlisted the following options – use of solar energy, hydro energy, and renewable transport energy. With his research findings, he and his team designed a framework for a renewable energy system for Bora Bora as the outcome of their research project.

The students developed research skills and engineering knowledge, on which they based proposed solutions/models to fulfil project aims. These perceived learning outcomes mostly matched the intended learning outcomes from this course. The students addressed an interdisciplinary project comprising mechanical, software, and electronics-electrical engineering skills and knowledge. They researched interdisciplinary engineering knowledge to finalise design concepts and develop the solution. In summary, the students worked on and seemed to achieve most of the intended learning outcomes based on this course ENGME582 project.

4.3.1.3.1.4 Qualitative Data: Researcher's Observation

Students were required to apply knowledge and skills gained from the first three years of engineering education and reinforce the interdisciplinary aspect of engineering within this project. Students learned how to carry out a Research and Development project as a team and appreciated the depth and breadth of knowledge and skills required for completing the project that addresses real-world problems. When doing this project, the students mostly spent their time in laboratories, where the researcher observed them via direct observation without an intervention method, in a laboratory setting. A total of 4 students were observed for a total of 6 hours, spanned during three-days schedule. The following aspects were observed during the laboratory sessions.

- Teamwork: Allocation of tasks

Students worked in assigned groups, where every member was allotted some project work. For example, in one group, project works were divided among members, like mathematical calculations were given to one student, another took the designing role in software, another took up components' procurement part, and the last student took the overall coordination and manufacturing role. "Each member did their part of work and coordinated with each other to show their findings or discuss their doubts/queries" (Observation Journal, 9th September 2019). "Members helped each other throughout, especially when they got stuck at doubts/queries" (Observation Journal, 9th September 2019).

- Problem-solving

During the project, there were instances when "members faced challenges or problems, usually based on mathematical calculations, or 3D designing of the model in AutoCAD/Solid Works software, and issues in components procurement, or manufacturing process." (Observation Journal, 9th September 2019). When issues happened, "members within the group worked together to solve them with available resources (computer-internet, reference books, lecturers, and classmates)" (Observation Journal, 10th September 2019). This was evident in almost all groups in the laboratory; as they were in the process of solving a real-world problem, they worked in a team and tried to find a resolution for the given project problem.

- Critical thinking

When students had problems during their project work, they worked together as a team to research the issue, gather necessary information, and then discuss that within their group to have a collective decision. For example, "in a group, when a student had difficulty understanding an engineering concept relevant to their project, he tried to draw a diagram of that concept" (Observation Journal, 10th September 2019). Later, he wrote vital factors or parameters associated with that concept. "He created a spider web diagram based on the key parameters related to those engineering concepts" (Observation Journal, 10th September 2019). Then, "he formulated the factors or parameters from the diagram which related to his project, shared with his group members and had discussion on it" (Observation Journal, 10th September 2019). This showcased an element of critical thinking and problem-solving. Likewise, each member within the group had a chance to think critically about the problem and share their thoughts in the group discussion. Group discussion appeared to assist the students, who then shared their thoughts and findings, reaching a joint resolution.

- Skill development

This project included aspects of research and product development based on the inter-disciplinary nature of the project. Almost all groups worked on 3D drawing structures on AutoCAD software; thus, they might have enhanced their 3D drawing skills. "Students in their respective groups built working models based on their 3D drawings, using various hand tools and machinery like CNC machine, laser cutting, 3D printer, soldering, and printed circuit board assembly." (Observation Journal, 10th September 2019). Also, as the students developed a designed model, they may have enhanced their design and manufacturing skills, problem-solving, critical thinking, hands-on tools experiences, project management, and teamwork skills. These are the overall skills that the students showcased while working on their project, as per the researcher's observation.

4.3.1.4 Students' Perceptions of Possible Drawbacks in Engineering Projects

Based on students' overall experience of learning from engineering projects, they also indicated possible aspects that could have enhanced their overall learning experience. They liked the level of engineering knowledge and skills developed via the projects.

However, they stated they did not encounter challenging situations with challenging/innovative projects/topics, more application of critical thinking and problem-solving. The response of participant I.5E.1 shared below exemplifies this:

> I am thrilled with the skills and learning I get from the engineering projects. But, for the third year's Design and Manufacturing project, I cannot comment on it as very positive. There was no innovation or critical thinking in it. The third-year project should be more challenging, bringing more critical thinking, as seen in the fourth year's Research and Development project. (I.5E.1)

Participant I.5E.1 liked to be given challenging project topics, which he had in his fourth year's Research and Development project. He expected such a level of innovation and critical thinking from the third year's Design and Manufacturing project too, but instead, it was direct and less challenging for him. He felt that being a graduate engineer, he should possess problem-solving and critical thinking skills, which may be developed via solving intensive, challenging engineering problems. Related to this same context, another participant shared their thoughts:

> If the university could include a project that would impact the industry, like designing something that could help the industry, that would be very beneficial for the students. Boat Race, and Design and Manufacturing projects are more straightforward than any industrial-level project. The fourth year's Engineering design show was incredible and motivating, where students presented something new in front of others. Whereas in the Boat Race, and Design and Manufacturing projects, we are doing the same as everyone else is doing in class, same project and so no challenges. (I.5E.2)

The above response indicates that the Boat Race, and Design and Manufacturing projects may have helped this student to master his engineering knowledge and skill development, and he expected more challenging and innovative project topics in upcoming projects. Participants I.5E.1 and I.5E.2 expressed an interest in more challenging and industrial-based projects, as they would boost their problem-solving and critical thinking skills. This is because they perceive industrial projects pose real-world complex engineering problems, which may require a high level of critical thinking and problem-solving skills. With a similar context, another participant responded:

> Engineering projects in university are critical, as they help the students build initial relations between classroom-learned engineering knowledge and real-world working applications. I feel that universities should focus more on doing projects that relate to theory. I feel there is a lack of alignment between the project and the theories taught in class. I believe that projects did help a lot to bridge theory with practise, so there were not enough projects to cover most of the diverse engineering knowledge. (I.5E.3)

The above statements suggest that engineering projects did help the students to relate classroom learned theories with real-world applications, thereby bridging theory with practise. Participant I.5E.3 suggested bringing more projects into engineering education, which may cover almost all mechanical engineering concepts and would help the students develop their overall engineering knowledge and understanding. This summarises students' perceptions. In the next section, the perceptions of graduates are presented.

4.3.2 Perceptions of Graduates

This section introduces the perceptions of graduates on their learning experiences of engineering projects. This section also discusses graduates' perceived limitations of engineering projects. In the following sub-section, graduates' experiences of engineering projects and their perceived outcomes are presented.

4.3.2.1 What Graduates Achieved from Engineering Projects

Data from the online survey, individual interviews, document analysis, and observations are used to draw the perceived learning outcomes identified by graduates. In the next sub-section, data from the online survey are presented.

4.3.2.1.1 Quantitative Data: Online Survey

In the online survey, graduates were asked how strongly they agree or disagree with a series of statements related to the knowledge and skills enhanced via engineering projects (Question 9, Alumni cohort, Appendix L) including the Boat Race, Design and Manufacturing, and Research and Development projects (Table 4.7).

Table 4:7: Graduates' responses to online survey questionnaire on enhancement of learning aspects from engineering projects (n = 57), on likert scale (1 to 5) where 1 indicates strongly disagree and 5 indicates strongly agree.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Standard Deviation
1.	Classroom theoretical knowledge	0	4	12	30	11	3.84	0.812
2.	Interdisciplinary knowledge	0	2	10	33	12	3.96	0.725
3.	Logical/analytical thinking	0	5	3	20	29	4.28	0.913
4.	Conceptual understanding	0	3	7	28	19	4.10	0.810
5.	Discovery and analysis of an engineering problem	0	1	4	20	32	4.45	0.703
6.	Engineering design	1	1	2	17	36	4.50	0.797

Table 4.7 shows that 52 (91%) participants agreed that discovery and analysis of engineering problems were enhanced via projects. Similarly, 53 (93%) participants agreed that engineering design was enhanced. On the other hand, five (8%) participants disagreed that engineering projects helped enhance their logical/analytical thinking. Similarly, three (5%) participants disagreed that enhancement of conceptual understanding was achieved via the project. In the next section, qualitative data obtained via interviews are presented.

4.3.2.1.2 *Qualitative Data: Interview*

In order to obtain descriptive data around learning experiences from projects, three graduates were interviewed. The graduates appeared aware of their learning benefits while participating in all engineering projects. These included application and enhancement of critical thinking, problem-solving, practical knowledge, design process, research, engineering, and time/project management skills. This is exemplified by the responses of participant graduate I.GC.1 as shown below:

> I enjoyed doing engineering projects, as they challenged me to think critically and evaluate how to solve a problem in a more inventive way, to think outside the box when problem-solving. I also gained practical knowledge of machine operations, designing processes, and researching skills. (I.GC.1)

Participant I.GC.1 felt that there were several challenging projects that helped him enhance his problem-solving, critical thinking, and research skills. Another participant, graduate I.GC.2, shared his experience as stated below:

> I think the engineering projects were more descriptive and had more information. They are directly related to the engineering curriculum of the university and thus helped me to understand the classroom learned theories very well. We had a timeline designed for the projects and worked accordingly to accomplish that. I found projects more challenging than work placements. (I.GC.2)

Participant I.GC.2 found engineering projects closely related to their classroom studies, as they were designed based on the University's engineering curriculum. Thus, this relation helped him understand the theory with its practical applications. His respective lecturers/project coordinator provided him with a project timeline, based on which everyone worked to finish their project on time. Because of the project's timeline and complexity, he found projects to be more challenging than their work placements.

To explore the practical learning experience of engineering projects, participants were asked – how the engineering projects provided an actual practical learning experience. The responses indicated that projects did help to obtain practical engineering knowledge outside the classroom. However, as engineering is a practical field, some engineering theories were unrelated to their work placements. This is exemplified in the response of I.GC.3, as stated below:

> I am in an industry where I am essentially using techniques that were not taught at university. The university gave me the skills to do that, but the physical skills out of those projects are not immediately applicable. They do not work particularly well, not for my role particularly. (I.GC.3)

The engineering projects did help I.GC.3 to achieve some engineering knowledge and skill development (technical and non-technical), but that was not directly applicable to his work placement/present job. For example, knowledge and skills obtained via thermodynamics projects can only be applied to the workplace based on thermodynamic concepts/fields. This knowledge and skills cannot be applied to a workplace or job based on some other engineering context/field, like materials, dynamics and control, product design and manufacturing, and mechanics. Based on this information and from the perspectives of the graduate students, engineering projects seems to help students enhance their engineering knowledge and develop skills, but they also have some shortcomings, which are discussed in the next section.

4.3.2.2 Graduates' Perceptions of Possible Drawbacks in Engineering Projects

The engineering graduates undertook several projects during their four-year degree. They also perceived some limitations of project work based on their learning experience. Few engineering graduates felt that the third-year project was not as challenging and innovative as they were intended to be. Projects were mostly trial and error and lacked high-level critical thinking and problem-solving elements. This is exemplified by the responses of I.GC.1 as stated below:

> I found that projects in university follow the trial-and-error method, which is good when we are in the initial stages of our engineering study, like the

> first-second year. But, when we are transiting to the third-fourth year, there should be fewer trial and error methods and more challenging projects, which encourages problem-solving skills and critical/analytical thinking capability. (I.GC.1)

Participant I.GC.1 specifies that projects' complexity should increase from the first year to the fourth year of study because that would help students to enhance problem-solving and critical thinking capabilities. The first year's Boat Race project was an initial approach where students learn about engineering practise; therefore, the trial-and-error approach was acceptable. However, for second, third- and fourth-year students, I.GC.1 felt that this was not enough. As second, third- and fourth-year students have more experience and knowledge than first-year students, their projects should be encouraging students to undergo high-level problem-solving and involve critical thinking. Another graduate I.GC.2, suggested that more projects would have been more beneficial, as they helped him to understand engineering knowledge more profoundly and enhanced related practical knowledge. This is exemplified as shown below.

> Projects were more technical and helped me to enhance my engineering knowledge and practical knowledge and promoted skill development. Thus, I feel that the university can add more projects so that students get more benefits. Also, if there is more support from lecturers regarding projects, it will help students get more explicit guidance and support to accomplish their project goals. (I.GC.2)

Participant I.GC.2 specified that the projects aided in developing engineering knowledge, practical knowledge, and technical and non-technical skills. By undertaking projects, he had opportunities to apply the classroom learned theories to practical applications, which aided in developing his engineering knowledge. Additionally, solving engineering problems helped him to enhance his problem-solving and critical thinking skills. I.GC.2 suggested that including more small-scale projects would benefit students as this may provide more opportunities for students to enhance the application of their engineering knowledge, practical knowledge, and technical and non-technical skills. Also, a more significant number of engineering projects based on different engineering concepts could help students to understand diverse engineering knowledge and relate those theories to their real-world applications.

Lastly, graduates were asked "What they thought should be changed in engineering projects to enhance the overall learning experience?" (Question 14, Alumni cohort, Appendix L). The responses are summarised below in Table 4.8.

Table 4:8: Students' responses to online survey questionnaire on what changes in engineering projects would benefit them more (n = 55), on likert scale (1 to 3), where 1 indicates less and 3 indicates more.

		Less	Same	More
1.	Genuine and challenging problem/project	0	35	20
2.	Support and guidance from Lecturer	1	35	19
3.	Preparation in laboratories before the project begins	3	28	24
4.	Theory/coursework in classrooms	10	34	11
5.	Industry links	0	20	35
6.	Support from project manager	4	33	18

From Table 4.8, 20 (36.3%) participants indicated that a more genuine and challenging problem or project would enhance their project learning experiences. Similarly, 35 (63.6%) participants indicated that more industrial links to their projects would have enhanced their learning experiences. On the other hand, 10 (18%) participants indicated that less theoretical work in the classroom would enhance their engineering project learning experiences. Similarly, four (7%) participants shared that less support from the project manager would also be good enough. Also, three (5%) participants indicated that less preparation in laboratories prior to the project would be beneficial.

In summary, based on graduates' perceptions, it may be deduced that engineering projects helped students in acquiring engineering knowledge, technical skills, and non-technical skills during the learning process. In the next section, perceptions of students and graduates on their work placement experience are presented.

4.4 Work Placements

This section explores the perceptions of students and graduates on their learning experiences from work placements. This section is divided into three parts. The first part describes intended learning outcomes of each work placement course, and the second part shows the actual learning outcomes for students. In the third part, shortcomings from the work placements are presented. Overall, in this section, students and graduates share what they believed (their perceptions) they achieved from work placement experiences. As an orientation and introductory course, students first learned the ENGEN270 Engineering and Business course, which is a course that familiarises students to industrial work placements. After this, the work placements undertaken by students and graduates occurred in the following courses: ENGEN271 Engineering Work Placement 1, and ENGEN371 Engineering Work Placement 2. The following section discusses students' perceptions of each work placement course.

4.4.1 Perceptions of Students

The actual learning outcomes (based on students' perceptions) from the work placements are stated here. This section also discusses the limitations students felt (based on their perceptions) about work placements. In the next sub-section, students' experiences of work placements and their perceived learning outcomes are presented.

4.4.1.1 ENGEN270 Engineering and Business

In the engineering degree, students undertake two 400 hours work placements, one at the end of the second year and another at the end of the third year of their study. The second year's course, ENGEN270 Engineering and Business, is presented here. This course focuses on empowering students to become "business savvy" and preparing them for industry placements. Students develop problem-solving and teamwork skills via first-year engineering projects, which they then apply further in conjunction with Project-Based Learning workshops. These workshops introduce real industrial projects and cover topics like team formation, design thinking, project management, risk management, and project finances. The course runs a parallel stream covering professional ethics, CV preparation, interview techniques, job-seeking skills, online profiles, workplace, and business culture in readiness for industry placements. In this course, students attend three lectures, one workshop, and one tutorial class, where tutorials include outside-the-business and industry speakers, networking events, and student group presentations. Workshops will include outside-the-business and industry representatives and student group presentations.

Once students have completed the ENGEN270 course, the following semester, students complete ENGEN271 Engineering Work Placement 1, which is presented in the next section.

4.4.1.2 ENGEN271 Engineering Work Placement 1: Intended Learning Outcomes

This work placement is intended to develop professional skills through work in a relevant professional workplace, as students work alongside professional engineers (University of Waikato, 2020b, p. 1). The intended learning outcomes of ENGEN271, as stated in Section 3.8.2.5 in Chapter 3 Methodology, are presented below (University of Waikato, 2020b, p. 2):

- Understand learning objectives and to achieve them

Work placements allow students to observe professional practise and workplace cultures and consider potential careers. Through work placement, students can apply engineering knowledge, and skills learned at university to work placement operations. They develop more advanced technical knowledge, interpersonal skills, and a professional work ethic through this approach. Additionally, by working in placements, students get insight regarding their future employment opportunities, what field they should focus on, and related skills and attributes to develop. Based on these learning objectives, students can check their progress and self-evaluate based on their reference learning objectives. Students must document this in the form of a reflection assignment, which is a part of the work placement assessment.

- Document a written technical report

Students need to document a technical report outlining the progress, process, and results of the workplace learning experience. Students document the whole process of learning experience through work placement through the technical report. Students outline details of their work roles in their technical report, with details such as what they were meant to do in their work placement, what they actually did, and what they learnt from work placement.

- Show evidence of achieving learning outcomes by completing a reflection assignment

In the reflection assignment, students highlight what they learned while in the work placement. They give an overview of the learning experience perceived while progressing through their work placement. This can include the engineering knowledge and skills mastered while working, indirectly showing the self-evaluation of their progress.

- Familiarity with workplace health and safety protocols and procedures

Before starting to work in their work placement, students must undergo a health and safety induction programme in the University and workplace. Students gain knowledge regarding do's and do not's while working in a placement or industry. As students consistently apply the health and safety procedures, it allows them to be more responsible and aware of hazards, thus minimising workplace accidents. The next section shows what the students achieved in practice from work placement experiences.

4.4.1.2.1 What students achieved

The actual learning outcome as perceived by students are reported below. These were identified through an online survey, interviews, and document analysis of their assignments.

4.4.1.2.1.1 Qualitative and Quantitative Data: Online Survey

In this survey, 50 students were invited, and 13 students participated (26% response rate). The survey explored the engineering knowledge students perceived as an outcome of the second year's work placement (ENGEN271). The students developed engineering knowledge and skills such as problem-solving, critical thinking, time management, teamwork, hands-on experience with tools and machinery, and health and safety practices. The students were asked about outcomes of work placements in the form of an open-ended question, for which the responses are shown below:

> Second-year work placement helped me to gain typical engineering knowledge like quality control measures, universal standards, gear ratios and helped to enhance skills like problem-solving and critical thinking. (I.3E.1)

> Work placement enhanced my time management, teamwork, basic and advanced tools skills, and developed my knowledge around health and safety observations. (I.4E.2)

> I learned about project management skills and how project managers and controllers in a consultancy must plan extensively in large-scale projects to set up dates and budgets, which constantly must be updated. I learned how important it is to stick to client budgets and schedules and to help colleagues in this organisation's aim. (I.5E.1)

Work placement strengthened the participants' knowledge of essential health and safety protocols they had to follow while at work. Additionally, they could develop and enhance skills such as time management, teamwork, and essential tools operation and experience. Working under project managers, they developed deep knowledge about how big projects are managed meticulously, applying time management – deadlines and how to manage financial activities. They also developed expertise in project management and financial budgeting skills.

Additionally, a question was asked about whether the skills were developed in their first work placement (Question 11, 3rd-Experience cohort, Appendix L), to which the following responses were obtained (Table 4.9).

Table 4:9: Students' responses to online survey questionnaire on whether they agree or disagree with development of skills via ENGEN271 engineering work placement 1 (n = 10), on likert scale (1 to 5), where 1 indicates strongly disagree and 5 indicates strongly agree.

S. No	Skills	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Standard Deviation
1.	Problem-solving	0	0	2	3	5	4.41	0.493
2.	Teamwork	0	0	1	4	5	4.33	0.624
3.	Critical thinking	0	0	0	6	4	4.25	0.595
4.	Communication skills	0	0	0	5	5	4.50	0.50
5.	Physical presentation	0	0	2	5	3	3.50	0.764
6.	Planning and organising skills	0	0	1	6	3	4.08	0.493

All participants indicated that the listed skills as per Table 4.9 were developed through work placement experiences. Some additional skills were listed, when asked whether they were developed from work placement (Question 15, 2nd-Experience cohort, Appendix L), are reported in Table 4.10.

Table 4:10: Students' responses to online survey questionnaire on whether the following skills were enhanced in ENGEN271 engineering work placement (n = 10).

S. No	Skills/Qualities	Disagree	Agree
1.	Communication skills	0	10
2.	Professional ethics	0	10
3.	Management skills	2	8
5.	Problem-solving skills	0	10
6.	Self-learning	0	10
7.	Analytical thinking	1	9

All participants indicated that they developed communication skills, professional ethics, problem-solving skills, and self-learning attributes from work placement. Two (20%) participants thought that work placement did not enhance management skills. Additionally, one (10%) participant thought that analytical thinking was not enhanced via work placement. Before work placement, students were also asked what they would expect to learn from their upcoming second work placement (Question 14, 2nd-Experience cohort, Appendix L), shown in Table 4.11.

Table 4:11: Online survey response on aspects of learning in ENGEN271 engineering work placement (n = 10).

S. No	Aspects of Learning	Disagree	Agree
1.	Obtain a future employment opportunity	0	10
2.	Obtain practical hands-on experience	0	10
3.	Develop employability skills such as communication, teamwork, problem-solving, critical thinking, project management, professional ethics, leadership qualities and work-readiness	0	10
4.	Get academic credit points to pass the course	2	8

All participants indicated that they expected to obtain a future employment opportunity, practical hands-on experience, and skills such as communication, teamwork, problem-solving, critical thinking, project management, professional ethics, leadership qualities, and work readiness through their upcoming second work placement. While 80% indicated they expected to get academic credit points to pass the course, 20% disagreed. In the next section, qualitative data obtained through interviews are presented and described.

4.4.1.2.1.2 Qualitative Data: Interview

Two students were interviewed and asked about their overall experience of their first work placement. The responses showed that participants developed skills in 3D Drawing via Solid Works and AutoCAD software and enhanced design and manufacturing knowledge, critical thinking, and problem-solving skills. This is exemplified by I.4E.1 below.

> My work placement allowed me to work on designing materials via Solid Works and AutoCAD software. I enhanced my manufacturing process knowledge. I worked on several projects during my placement there, which helped me enhance project management, critical thinking, and problem-solving skills. (I.4E.1)

Participant I.4E.1 got hands-on experience with mechanical work during work placement. Being in the role of Designer, he designed 3D models via software such as Solid Works and AutoCAD, which helped him to master 3D drawing skills and related designing and manufacturing knowledge. Additionally, as he worked on several projects, he mastered project management skills–managing all project deadlines, critical thinking – designing appropriate models based on given specifications and problems, and problem-solving – designing models to provide solutions to real-world engineering problems/requirements. Another participant I.3E.2 shared his work placement experience in developing 3D Drawing capabilities and related parameters calculations. This is exemplified below:

> In my first work placement, I was required to do some Solid Works designing, and documentation work (office work). Through that, I learned about new knowledge, like how practical works are carried out based on

> theoretical understandings, how designs are made, and how to read critical design diagrams and calculate material stress/strain values. I could not do much more technical work there, and mostly I did office work. (I.3E.2)

Work placement helped participant I.3E.2 to practise 3D drawings by doing drawings and designing works in Solid Works software. This practise also helped participant I.3E.2 to develop knowledge of reading crucial design diagrams and material stress/strain calculations. These benefits were highly technical however he felt the overall experience of the work placement seemed unsatisfactory, as he felt he was made to do mostly office work rather than core technical work. He expected to do core technical engineering work and not much non-technical work. May be I.3E.2 did not realize that the aim of work placement is to enhance students' employability skills, for which they need to work in both technical and non-technical work tasks.

4.4.1.2.1.3 Qualitative Data: Student's Project Report

During work placement, students had to summarise their overall learning experience by writing a technical report. The researcher analysed two students' workplace reports, and found that they developed engineering concepts, software expertise of Solid Works and AutoCAD, time management, and planning and organising skills. One indicated that he developed knowledge of 3D Drawing via Solid Works and AutoCAD software and related parameters calculations and mastered skills like time management, organisational management, communication, leadership, teamwork, and engineering knowledge. This is exemplified in the statement of Participant I.5E.1 shown below:

> In my work placement, I was part of the structural engineering team. Every week, the team would congregate to discuss the progress of each other and inform the team of deadlines or tasks that needed to be done. Regular

> meetings ensured the team was on the same page for goals. I carried out several tasks during this work placement: software knowledge of Solid Works and AutoCAD software, prestressed concrete beams, seismic load calculations, reinforcement calculations for concrete structures, and timber footbridge designs. (I.5E.1)

Participant I.5E.1 had weekly meetings with his supervisor and colleagues to discuss his progress based on his job responsibilities. This habit might have helped the student to enhance his planning and organising, time management, and project management skills, to match the work timeline/deadlines. Also, the student developed substantial engineering knowledge, such as software expertise of Solid Works and AutoCAD for structural analysis, pre-stressing concrete beams, seismic load calculations, reinforcement calculations for concrete structures, and timber footbridge designs. These skills and knowledge were initially developed through classroom learning and engineering projects and were further enhanced by doing the work placements. Another participant I.4E.1's workplace report shared the following:

> In my work placement, I worked on a big project related to Waikato Expressway. I have enjoyed my time on the project and have learned so much. I learned time management, organisational skills, communication, leadership, teamwork, engineering knowledge around mechanical construction, and confidence from my work placement. This opportunity has given me a real 'hands-on' experience that I cannot get in a classroom environment. Now I know what it feels like to be out in the real world. (I.4E.1)

Participant I.4E.1 had worked on an industrial project, which helped him develop skills like time management, planning and organising, communication, leadership, and teamwork. This project was based on the Waikato Expressway (a large-scale local road project), so it was very hands-on and authentic. He also enhanced his engineering knowledge of mechanical construction. This was exclusive knowledge obtained outside classroom learning. With these statements, it may be deduced that work placements seemed to help students develop some core engineering knowledge and technical and non-technical skills, which sat outside classroom and project learning.

4.4.1.2.1.4 Qualitative Data: Researcher's Observation

Students in work placements are provided opportunities to apply knowledge and skills developed at university to work placement applications to develop technical knowledge and technical and non-technical skills in an authentic work environment. The researcher observed the students working in their work placements, and findings include development of engineering knowledge, practical knowledge, problem-solving, critical thinking, project management, and health and safety responsibilities. Each is presented below:

- Engineering knowledge development

Students worked alongside professional engineers, where the work environment was interdisciplinary across engineering, which included mechanical-electrical-electronics and software engineering. It helped students to develop mechanical engineering knowledge and also interdisciplinary engineering knowledge. The researcher observed one student who worked on designing complex 3D structures of metallic platforms, stairs, and support structures in Solid Works software. It was seen that the "student developed some technical questions regarding 3D structuring via software, and he cleared it with his workplace supervisor" (Observation Journal, 6th January 2020). Here, the student received professional help from an experienced engineer, which helped the student develop some 3D drawing skills outside the classroom/university boundaries.

- Practical knowledge development

During work placement, students had the opportunity to develop their practical knowledge. For example, the researcher observed that "a student was involved in design and manufacturing works, and so he got several tools to access such as CNC machining, lathe, 3D printing, and complex manufacturing machinery" (Observation Journal, 6th January 2020). When students use such sophisticated tools and machinery, they develop knowledge of their operational working and related operational skills. This practical knowledge also helped to relate classroom learned theories, such as, for example, "one of the students in the workplace was able to relate thermodynamics concepts with one of the workplace manufacturing techniques" (Observation Journal, 6th January 2020).

- Problem-solving

Students had to research several concepts and theories to solve the given real-life problem. Thus, students indulged actively in research and discussions with their supervisors and colleagues to find a resolution for the given problem. For example, there was an error in a student's designed model in AutoCAD software. To clear that issue, students researched that issue, mainly from online books and resources. "After accumulating relevant information, the student tried to solve the issue again" (Observation Journal, 6th January 2020). When it did not work, he consulted his supervisor about this issue and ask for his help to understand the issue and seek resolution. "Thus, with self-researching and communication with supervisor and colleagues, the student, at last, was able to resolve the issue" (Observation Journal, 6th January 2020). This experience supports the finding that problem-solving developed during the work placement.

- Critical thinking

Students faced several problems in work placements, which they addressed with the help of critical thinking. Critical thinking is essential to problem-solving, as it helps to objectively analyse and evaluate an issue to form a judgment. The researcher observed critical thinking when students had an issue with their software designed models, and they had to discuss this issue with their supervisor and/or colleagues to resolve the issue. "Along with students researching the issue, they undergo deep thinking to link all the findings together to find the solution" (Observation Journal, 6th January 2020). Likewise, critical thinking was applied by students during problem-solving.

- Project management

Students were given a timeline for the completion of their respective projects. Since "students worked with professional engineers, they got trained to follow the deadlines, and they accordingly managed their day-to-day routines and work duties" (Observation Journal, 6th January 2020). With this practise, students were required to autonomously to frame their timelines and finish the work on time. "Students' divided their work schedule to cover almost all aspects of the industry project, and that trained them to effectively apply project management to their works" (Observation Journal, 6th January 2020).

- Health and safety responsibilities

Before students worked in an authentic work environment, they had to complete a health and safety induction and practise all procedures. This practise helped them familiarise themselves with the industry's health and safety procedures and reflect that practise in their daily work routines. The researcher noted "students using appropriate PPE gear within their respective workstations in workshops and followed stated Health and Safety protocols displayed at their workplace" (Observation Journal, 6th January 2020).

In the next section, ENGEN371 Engineering Work Placement 2 is described.

4.4.1.3 ENGEN371 Engineering Work Placement 2: Intended Learning Outcomes

After students complete ENGEN271, the next work placement they complete is in third year, which is ENGEN371. This course requires students to be in a relevant workplace for at least 400 hours. The intended learning outcomes of ENGEN371 are very much similar to that of ENGEN271 (as shown in Section 3.8.2.5 in Chapter 3 Methodology) with one additional Learning Outcome (University of Waikato, 2020c, p. 1), which is stated below:

- able to provide evidence of level of professional skill using an e-Portfolio (University of Waikato, 2020c, p. 1):

  As students do their second work placement, they must show evidence of their learning experience by documenting an e-Portfolio. Writing an e-Portfolio enables the students to highlight their best work and provide details that cannot be conveyed in a resume. Thus, with the help of e-Portfolios, students can prepare documents to shape their CV, engage with potential employers, and invite inquiries for future employment. The next section discusses what students achieved in practice from this work placement.

4.4.1.3.1 What students achieved

In this section, the actual learning outcomes as perceived by students are reported below. These were identified through an online survey, interviews, and document analysis of their assignments.

4.4.1.3.1.1 Quantitative data: Online Survey

For the online survey, 50 students were contacted, with responses from 16 students. Through the online survey, students were asked what they expected to learn from work placement (Question 14, 4th-Experience cohort, Appendix L). Their responses showed their perceptions of the learning outcome they achieved, as shown in Table 4.12.

Table 4:12: Students' response to online survey questionnaire on whether the following aspects they expected to use in ENGEN371 engineering work placement 2 (n = 16), on likert scale (1 to 3), where 1 indicates seldomly and 3 indicates very regularly.

		Seldomly	Reasonably regularly	Very regularly	Mean	Standard Deviation
1.	Contribute ideas and facts during work placement	2	11	3	1.94	0.556
2.	Understand the classroom taught theories during work placement	0	12	4	1.75	0.433
3.	Use a variety of resources to understand working of different processes in the workplace	0	5	11	1.31	0.464
4.	Learn more during work placement than doing classroom learning	0	4	12	1.25	0.433
5.	Learn entirely different to that learning from engineering projects	2	7	7	1.68	0.682
6.	Help efficiently by doing the teamwork	0	3	13	1.18	0.390
7.	Learn entirely different to that learning from classroom learning	1	7	8	1.56	0.609
8.	Communicate professionally during work placement	0	4	12	1.25	0.433

Two participants (12.5%) were expected to contribute ideas and facts seldomly during the work placement. On the other hand, two participants (12.5%) seldomly expected to learn entirely different outcomes from work placement than from projects. Lastly, one participant (6.25%) seldomly expected to learn different things from work placement than from classroom learning.

After they completed their work placement, students were asked about what they perceived as actual outcomes from work placement (Table 4.13).

Table 4:13: Students' response to online survey questionnaire on whether the following aspects they actually used in ENGEN371 work placement 2, on likert scale (1 to 3), where 1 indicates seldomly and 3 indicates very regularly.

		Seldomly	Reasonably regularly	Very regularly	Mean	Standard Deviation	Sample (n)
1.	Contributed ideas and facts during work placement	0	9	3	1.75	0.433	12
2.	Understood the classroom taught theories during work placement	1	6	4	1.727	0.617	11
3.	Used a variety of resources to understand working of different processes in the workplace	0	4	7	1.36	0.481	11
4.	Learned more during work placement than doing classroom learning	1	5	6	1.58	0.640	12
5.	Learned entirely different to that learning from engineering projects	2	8	2	2.00	0.577	12
6.	Helped efficiently by doing the teamwork	1	5	6	1.58	0.640	12
7.	Learned entirely different to that learning from classroom learning	0	7	5	1.58	0.493	12
8.	Communicated professionally during work placement	0	4	8	1.33	0.471	12

All participants felt that they reasonably regularly or very regularly contributed ideas and facts and used various resources to understand the working of different processes in the workplace. This included engineering knowledge from classrooms, engineering knowledge from engineering projects, tutorials, and workshops via ENGEN270 and ENGEN271 courses, professional communication with work colleagues, and online resources. On the other hand, one (17%) participant felt that they seldomly understood previously learned theory during the work placement. All participants felt that they reasonably regularly or very regularly learned different things from work placements than from classroom learning. On the other hand, one (8%) participant felt that they seldomly applied teamwork skills in work placement.

In the survey, participants were given a list of skills and qualities and asked whether they developed these in their work placements (Question 12, 4th-Experience cohort, Appendix L), as shown in Table 4.14.

Table 4:14: Students' responses to online survey questionnaire on whether the following skills were enhanced in ENGEN371 work placement 2 (n = 12), on Likert scale (1 to 5), where 1 indicates strongly disagree and 5 indicates strongly agree.

	Skills and qualities	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Standard Deviation
1.	Problem-solving	0	0	0	7	5	4.42	0.493
2.	Teamwork	0	0	1	6	5	4.33	0.624
3.	Critical thinking	0	0	1	7	4	4.25	0.595
4.	Communication	0	0	0	6	6	4.50	0.500
5.	Physical presentation	0	1	5	5	1	3.50	0.764
6.	Planning and organising	0	0	1	9	2	4.08	0.493
7.	Leadership qualities	0	1	2	5	4	4.00	0.913
8.	Self-learning	0	0	0	4	8	4.67	0.471
9.	Professional Ethics	0	0	1	7	4	4.25	0.595
10.	Retention of information	0	0	3	6	3	4.00	0.707
11.	Engineering knowledge	0	0	0	6	6	4.31	0.606
12.	Application of information technology	0	0	0	7	5	3.54	1.082
13.	Industrial and technical exposure	0	0	0	6	6	4.38	0.487

All participants agreed or strongly agreed that they developed problem-solving, self-learning, retention of information, engineering knowledge, application of information technology, and industrial and technical exposure from the work placement. On the other hand, one (8.3%) participant disagreed that physical presentation and leadership qualities were developed via the work placement. The following section explains students' work placement learning experiences via interview data.

4.4.1.3.1.2 Qualitative Data: Interview

Forty students were invited, from which were five responses. In this interview, students were asked about skills and knowledge they developed during the work placement. They developed fabrication knowledge, air-conditioning knowledge (HVAC – heating, ventilation, and air-conditioning), motion dynamics and vibrations, design and manufacturing concepts, and 3D drawing expertise in AutoCAD and Solid Works software. This is exemplified in the response of Participants I.4E.1 and I.4E.2, as shown below:

> During my work placement, I learned about fabrication knowledge, which helped me a lot while I did my projects at university. Additionally, I worked on design concepts, which helped me master Solid Works software for design purposes. (I.4E.1)

> In my first work placement, as I worked in the air conditioning industry, I developed knowledge around air-conditioning, thermodynamic concepts, and HVAC (heating, ventilation, and air conditioning). (I.4E.2)

As these students were from the mechanical engineering field, their work placements were mainly based on design and fabrication/manufacturing, motion-dynamics/vibration, and HVAC related. Therefore, these participants developed related discipline-specific engineering knowledge. In addition to knowledge development, students also developed essential skills such as problem-solving, critical thinking, teamwork, time-management, and communication skills. This is exemplified in the responses as shown below:

> In terms of skills, I developed time management, communication, critical thinking, and problem-solving skills, as we were subject to fabrication and design tasks, so that covered all these aspects. (I.4E.3)

> The skills that I enhanced while doing my work placements were managerial skills, problem-solving and communication skills. (I.4E.2)

> My first work placement was based on machining workshop works, and so from there, additional to hands-on tools experience, I developed skills like teamwork, communication and problem-solving. (I.4E.4)

Students developed time-management skills as they were given a timeline for their work and, thereby, had to plan and organise their work routine. As students had to deal with design-fabrication works via Solid Works software, they had to apply problem-solving and critical thinking skills to address the design concept issues. They had to think of ideas outside-the-box to design software-modelled prototypes, subject to simulations for analysis. If any errors occurred, they had to investigate those errors thoroughly to understand them theoretically. Additionally, they had to draw on previously acquired engineering knowledge and skills through classroom learning and online resources, and information from colleagues to get ideas to solve the issue, and then apply problem-solving to find the solution. As I.4E.4 was in a machining workshop, he worked in a team, which helped him enhance his teamwork and communication skills, along with problem-solving (machining issues). The following section presents data from students' work placement assignments.

4.4.1.3.1.3 Qualitative Data: Student's Reflection Report

Students had to write a skill reflection assignment once they completed their work placement. In this assignment, questions were asked on what important technical skills they had developed from the work placement, how they developed, where they applied that skill, and how they plan to use them in the future. Students answered those questions, and recorded responses, which indicated development of design and manufacturing knowledge, project management, communication, problem-solving, and critical thinking skills.

These outcomes are exemplified in sections as shown below.

- Design and manufacturing knowledge

The work placements were of mechanical engineering background; thus, it helped the students to enhance design and manufacturing knowledge, as exemplified by the statement of Participant I.4E.1 as shown below:

> By my work placement, I had learned in-depth about design and manufacturing process, especially plastic injection moulding. I learned how the machine works. (I.4E.1)

This response indicates that the student got in-depth knowledge about the design and manufacturing process related to plastic injection moulding, which was not taught in university. In the work placement, this participant could practically see how the whole process of plastic injection moulding worked, and that experience helped him to build their knowledge around this concept. Another Participant I.4E.2 stated that:

> From my work placement, I think I made significant progress in understanding the fabrication process, details about parts and dimensions relevant to fabrication, and expertise in using Solid Works software. I

> learned about dimensions and details from the work placement, which was not available in-depth from classroom learnings at university. I learned new features within Solid Works, which have helped me show required detail, such as how to add unique screw features, add empty views for custom detail sections, and hide unnecessary/unwanted lines from a generated view. (I.4E.2)

The above response shows that the student gained significant knowledge about the fabrication process, as he was primarily involved in design and fabrication using 3D structures via Solid Works software. Thus, attention to detail was crucial, and knowledge of details, dimensions of the fabrication process, and software command were enhanced. Another student's experience is stated below:

> I have gained tremendous confidence in my ability to operate a wide range of tools and equipment, such as Dremel, torque wrench, and heat gun. I have cut, stripped, crimped, ferrule, solder, and connected a large variety of wirings. By doing this work placement, I feel I have gotten my feet firmly planted on the ground from both a mechanical and an electronics perspective. (I.4E.3)

Participant I.4E.3's response evidence that he got hands-on experience using a wide variety of tools and machinery while at work placement. This type of work environment and experience was unavailable in the university's engineering projects. Thus, they could not get exposure to colossal machinery and tools available at their workplaces.

- Project management

The work placement provided students with an opportunity to work within teams in real-world industrial projects, which helped them to enhance their project management skills, as exemplified by the statement of Participant I.4E.1 as shown below:

> “The team I was placed on was solid about setting dates for the project timeline, which helped me enhance my time management skills (I.4E.1)

As students worked in a team to finish a specific project, it enhanced their time management skills because, technically, they had to prioritise their timings to match the project timeline. Also, students had opportunities to effectively communicate with their colleagues and supervisors about their work progress and any queries related to their work. That made them organise and plan for their work responsibilities.

- Communication, problem-solving, and critical thinking skills, and work experience

The work placement provided students with an opportunity to apply and practise some essential technical and non-technical skills, as exemplified by statements of Participants I.4E.1 and I.4E.3 as shown below:

> The main thing I have learned is that we need to be able to effectively communicate our progress on a project, as well as explain any issues that have cropped up, especially explain how and when. (I.4E.1)

> I have enhanced problem-solving, critical thinking, communication skills, and knowledge of robotics from my work placement. I am still applying the practices I learned from my work placement to my university studies and personal life. (I.4E.3)

The work placement gave the opportunity for students to enhance their communication skills. Additionally, students become familiar with different career options for a mechanical engineering graduate. Participant I.4E.3 worked in the robotic industry; thus, she gained mechanical and electronics engineering knowledge and developed skills as stated above. Also, the student gained insight into their job demands in terms of knowledge, skill sets, duties, and responsibilities, enhancing their professionalism. The student(s) learned a wide variety of knowledge of engineering design and manufacturing processes, tools-machinery workings, and technical and non-technical skills.

4.4.1.3.1.4 Qualitative Data: Researcher's Observation

The work placement allows students to observe professional engineering practices and workplace cultures, which enhances their employability. Thus, the work placement is a platform where various engineering knowledge, concepts, and technical and non-technical skills are developed. The researcher observed two students working in their work placement to get an idea of students' work process, and the following aspects were observed, as shown below as sub-sections.

- Engineering knowledge development

Work placements were interdisciplinary across engineering, with aspects of mechanical, electrical, electronics, and software engineering. This helped students to develop knowledge outside mechanical engineering. In one such observation, a student worked on designing complex 3D structures of metallic platforms, stairs, and support structures in Solid Works software. It was seen that the "student developed some technical doubts, and he cleared it with his workplace supervisor" (Observation Journal, 20th February 2020). "His supervisor helped him to clear his technical doubt" (Observation Journal, 20th February 2020). Students in university might not get such an expert support system and development of interdisciplinary engineering knowledge via industrial exposure.

- Practical knowledge development

The work placement gave students various opportunities to develop their practical engineering knowledge. For example, the researcher observed that “a student was involved in design and manufacturing works, and so he got access to several tools such as laser cutting, CNC machining, lathe, 3D printing, and complex manufacturing machinery” (Observation Journal, 20th February 2020). When students work in intense technical surroundings, using tools and machinery as stated above, they develop knowledge of their operational working, skills, and health and safety practices. This practical knowledge also helped to relate classroom learned theories.

- Problem-solving

As students worked in their work placement, they indulged in research and discussions with their supervisors and colleagues to find a resolution for rising problems. For example, “there was some error in student’s designed model in AutoCAD software” (Observation Journal, 20th February 2020). To clear that issue, students firstly researched that issue, mainly from books and the internet. “After accumulating data/information, the student tried again to solve that issue” (Observation Journal, 20th February 2020). If that did not work, he would consult his supervisor and would ask for his help for resolution. Thus, self-researching and communication with supervisor and colleagues, along with problem-solving, caters to finding the solution for the given problem.

- Critical thinking

Critical thinking was identified when “the student got an issue with their software designed models, and he had to discuss this issue with his supervisor/colleagues to plan the resolution” (Observation Journal, 20th February 2020). Along with students researching the issue, they undergo critical thinking to link all the findings to find the solution.

- Project management

The students were given a timeline for completing their respective workplace industrial projects, as noted in the researcher's observation journal "in this particular work placement, a student worked with professional engineers, he got trained to follow the deadlines, and accordingly, they managed their day-to-day work duties" (Observation Journal, 20th February 2020). With this practise, the student divided their work schedule to reflect the assigned project timeline, which trained them to apply project management to their work effectively.

- Health and safety responsibilities

Both students underwent a health and safety induction before starting their work placement and had to practise all the set rules to keep their workplace safe for everyone. The researcher saw "the student using appropriate PPE gears within his respective workstation in workshop and followed stated Health and Safety protocols displayed at his workplace" (Observation Journal, 20th February 2020).

The following section presents the limitations (as per students' perceptions) in work placements.

4.4.1.4 Students' Perceptions of Limitations in Work Placements

The students shared their overall learning experiences from the two work placements, including the perceived limitations they faced during their work placement experience. They suggested that the following were the limitations they faced in the work placement process:

- The challenge of getting appropriate work placements (work placement process),

- Lack of specificity and mismatch of work placements related to their specific field of engineering study (Mismatch), and
- Overloading of university assessments (Study-Work imbalance).

These aspects form the critical themes for analysis and are exemplified in the sections below.

4.4.1.4.1 University of Waikato Work Placement Process

In this study, students indirectly identified these benefits from work placements, and thus thought that if the university could provide more than two work placements, it would enhance their overall engineering knowledge and skill development. The students identified that securing a relevant mechanical engineering work placement was difficult. This can be exemplified by the statement of Participant I.5E.1 as shown below:

> Work placements provide more engineering knowledge and professional skills development, which are very important for engineering graduates. I want to say that students should have more opportunities to get various work placements. The thing is the university provided an excellent decent number of opportunities for us to do a work placement. Nevertheless, it is not enough for all students. Some students end up finding their own, and some students even end up doing nothing in the second year and may later do two placements. Why can't the university provide all students with work placements in one go? (I.5E.1)

Work placements did help students to develop in-depth engineering knowledge, mostly interdisciplinary engineering knowledge, and encouraged the use of classroom-learned concepts during the work placements. Such practise helped them to apply theoretical knowledge to real-world applications. Students also developed various professional, technical, and non-technical skills from the work placements. Thus, students felt that the University should have provided more than two work placements so that all students could benefit from this approach. As there were only two work placements, placements were limited in variety. It was, therefore, difficult for some students to get relevant placements. Students felt this as a possible disadvantage because they were aware of the wide variety of benefits of work placements. Thus, the students felt that if the University provides more than two work placements based on interdisciplinary engineering fields, it would be more beneficial for students to gain a wider variety of engineering knowledge and skills related to different fields of cross-related engineering aspects.

4.4.1.4.2 Mismatch

Some students perceived a mismatch between what was taught in classroom learning at university and their applications at work placements. They indicated that not all classroom learned engineering theories relevant to practical applications were seen during work placements. That is, not all classroom learned engineering knowledge was reflected at specific workplaces, as exemplified by the following statement of Participant I.5E.1:

> Also, not all classrooms learned theories related to work placement examples. Suppose the university could include different variety of work placements to cover many of the engineering concepts. In that case, it will be conducive for students to relate much of engineering theories with their practical applications via work placements. (I.5E.1)

Participant I.5E.1 said that if the University could find different work placements that match all of the mechanical engineering curriculum (engineering theories/concepts), then that would be beneficial for students to link more theoretical knowledge with real-world applications.

4.4.1.4.3 Overloading due to University Assessments

One student perceived that he was overloaded with assessments. In general, students were required to complete a brief placement assignment, health, and safety report, skill reflection report, learning outcomes reflection report, and technical report based on their work placement experience. This is exemplified by the statement of Participant I.4E.2 as shown below:

> Work placements are very beneficial for gaining work experiences and related skills. We are required to do 400 hours of work placement. However, we are also required to do several assessments of this course, which is quite a nuisance because after working so intensely, it is quite hard to do those assessments. If the university can work on assessment structures in such a way that it is balanced between work and study, it will be very much relaxing for the students. (I.4E.2)

The above response shows the additional workloads of students in the form of assessments that they need to complete along their work placements. In ENGEN271 and ENGEN371, students are required to complete four assignments or reports. Completing these assignments and working full-time in a workplace was challenging for the students; thus, they felt overloaded. Overall, students were satisfied with the current practices of work placements and wanted the University to add more work placement opportunities based on various engineering aspects. However, they could also work on minimising the overall assessment workload. The following section presents the perceptions of Graduates about their work placements.

4.4.2 Perception of Graduates

The recent graduates, those who graduated within the last three years, were invited to participate in this study. The actual outcomes from these work placements were compared to the Engineering Graduate profile (University of Waikato, 2020f, p. 1), and a clear matching between these were identified. This section also discusses perceptions of graduates on limitations of work placements. In the next sub-section, graduates' experiences of engineering work placements and their perceived outcomes are presented.

4.4.2.1 What Graduates Achieved from Work Placements

This section presents the graduates' perceptions of actual learning outcomes from work placements, through the data obtained from interviews. The quantitative data obtained from the graduates were similarly to that from 4th- and 5th-Experience cohorts, therefore, the quantitative data are not included in this section. The following section presents the qualitative data obtained through interviews.

4.4.2.1.1 Qualitative data from questionnaire

Graduates were asked about their work placement learning experiences and perceived outcomes through an open-ended question (Question 12, Alumni cohort, Appendix L), and they responded that work placements enhanced their engineering knowledge and design, drawing, and manufacturing (Table 4.15).

Table 4:15: Graduates' response on the perceived learning outcomes from work placements.

	Please specify what you took from work placements and applied successfully in your classroom learning/engineering projects?
1.	Work placements did help to build more engineering knowledge which was indeed applied on my engineering projects in university.
2.	Engineering drawing process knowledge was very important from work placements, and I applied that in my Design and Manufacture project in third year.
3.	Skills like project management and working in a team.
4.	My first work placement was on experimentation and statistical analysis.
5.	My first work placement involved concept generation, selection, prototyping and manufacture of a final product. This was valuable for the third-year project.

Graduates believed they attained more engineering knowledge from their work placements as these were diverse and interdisciplinary in an engineering context, thereby enhancing students' interdisciplinary engineering knowledge. As most work placements were Applied Engineering, graduates developed knowledge of engineering drawing based on 3D AutoCAD and SolidWorks software and design and manufacturing field. Students were then able to apply this knowledge to their future university studies and engineering projects. The following section presents graduates' descriptive data around learning experiences from work placements via interview data.

4.4.2.1.2 Qualitative Data: Interview

Two graduates were interviewed and were asked about their learning experiences from classroom studies via university and work placements. They shared that the

University did not provide them with all the technical skills around engineering drawing (CAD or Solid Works software). They developed them fully from their respective work placements. This is exemplified in the response of Participant I.GC.1 below:

> The university studies lacked some core technical skills, like technical drawing using CAD or SolidWorks software. When I went for my work placement, I discovered that this piece of fundamental knowledge was lacking in me and knowledge of ISO standards for technical drawing (ISO 128). My employer required me to do many technical drawings for any design work related to the Research and Development department. However, with the help and support from my employer, I learned these skills via my work placements and brought that knowledge back to my university studies/engineering projects. (I.GC.1)

These statements from I.GC. 1's indicated that the University provided him with basic engineering technical drawing concepts but could not provide complex practical experiences of using it. At university, students cover basic engineering knowledge related to design and manufacturing processes. One such application of the design and manufacturing process is 3D drawing. The University provides essential CAD/SolidWorks software experience, but the industry-level applications will only be available in work placements. These are the benefits students acquire while they do their work placements. They acquired core technical knowledge and skills that they did not obtain from their university studies, such as 3D drawing software, ISO standards, complex geometry, complex trigonometric calculations, how an engineering team works together to solve a problem, project management, problem-solving and critical thinking. The other graduate, I.GC.2, also supported the exact cause by sharing his experience of work placements, as stated below:

> Work placements helped me develop some professional skills, like customer management, problem-solving, communication, time management, 3D drawing via CAD, and hands-on tools experiences – like drilling machines, CNC machines, laser cutting, etcetera. This kind of exposure I got only via work placements, as these applications were not available in detail in the university's engineering projects. (I.GC.2)

The above statement again highlighted the outcomes that I.GC.2 perceived in terms of developing technical and non-technical skills. Work placements gave more engineering knowledge outside the university classroom learning range. In short, work placements helped to complement classroom learning with practical learning experiences, engineering knowledge, and skill development. In this sense, the engineering curriculum is so designed where basic foundational engineering knowledge is developed via classroom learning. Additionally, after classroom learning, students completed projects from which they develop more advanced engineering knowledge and technical and non-technical skills. Finally, students undertake work placements from which they further develop advanced engineering knowledge and skills, which then complete the overall engineering knowledge and skill development for students. There are multiple learning links between classroom learning, engineering projects, and work placements, which will be explained later in this chapter. The graduates' perceived limitations in work placements are presented in the next section.

4.4.2.2 Limitations in Work Placements: Graduates' Perceptions

The graduates' perceptions of overall work placement learning experience were recorded, and they indicated that they preferred fewer assignments, more communication from industry to university, and more relevant work placement which would have enhanced their learning experience from work placements. This is stated as shown in Table 4.16.

Table 4:16: Graduates' response to online survey questionnaire on what could have enhanced their learning experience from work placements.

		Less	Same	More
1.	Appropriate work placement	0	34	21
2.	Support from university	2	33	20
3.	Support from the Industry/Workplace Supervisor	1	38	16
4.	Guidance from University	4	35	16
5.	Preparation such as Induction course	9	37	9
6.	Communication from the Industry to University	2	28	25
7.	Liaison between the University and Industry	2	31	22
8.	Assignments	25	26	3

Table 4.16 shows that 25 (46%) graduates perceived fewer assignments from the University may have enhanced their learning experience from work placements, as these overloaded them and caused participants to have less concentration on the work placements. Additionally, around 28 (45%) graduates indicated that if the university provided more communication feedback from industry to the university, that would have enhanced their learning experience from work placements. Around 34 (38%) graduates indicated that having more appropriate or relevant work placements would benefit them with a good learning experience. The following section presents the key themes of this study based on analysis of collected data.

4.5 Key Themes of the Study

This section focuses on establishing the key themes of this study, based on the perceptions of participants regarding the learning experiences of engineering projects and work placements. Qualitative data (interviews) from all cohorts were analysed to form the key themes of this study. Three key themes were identified based on analysis of the collected data, which are: Development of Engineering knowledge, Development of Advanced Engineering Technical Skills, and Development of Advanced Engineering Professional Skills. The employability skills and professional skills are bit similar in definition, and so this study uses professional skills in this section. This section is divided into two parts, where the first part presents key themes from engineering projects, and second part presents key themes from work placements. In the next section, key themes from engineering projects are presented.

4.5.1 Engineering Projects

This section presents findings from participants' perceptions of learning experiences of ENGEN180, ENGME382, and ENGME582 Engineering Projects, along with their intended learning outcomes. In ENGEN180 and ENGM382, four emergent subthemes were identified, which are:

- Application of critical thinking,
- application of problem-solving,
- practical knowledge using tools, and
- design and manufacturing concepts.

In ENGM582, six emergent subthemes were identified, which are:

- Application of critical thinking,
- application of Problem-solving,

- practical knowledge using tools,
- researching skills,
- real-world application, and
- design and manufacturing concepts.

Subsequently, the emergent subthemes were collapsed into two key themes: conceptual engineering knowledge and advanced engineering technical skills. The intended learning outcomes, critical quotes as evidence of students' learning, emergent subthemes, and key themes are presented in Table 4.17. The same type of subthemes and key themes are highlighted with yellow and green colours (Table 4.17).

Table 4:17: Analysis of assessment learning outcomes from engineering projects and work placements based on students' quotes (perceptions).

Serial No.	Document	Course Learning Outcome	Evidence – Students' quotes	Emerging Subthemes	Key Themes

1.	ENGEN180 Foundation of Engineering – Boat Race project	• Explain the differences and links between science, engineering, and technology
		• Explain and apply a generalised engineering design technique
		• Recall the general 'accounting' equation and be able to solve appropriate problems where this is applied to account for mass and energy
		• Explain how expert problem solvers operate and be able to use heuristic methods in problem-solving
		• Realise the importance of engineering fundamentals (such as thermodynamics) in solving real-world problems and solving appropriate problems
			• "In boat race project, we collectively applied teamwork skills virtually via zoom and critical thinking to finalise the boat model" (I.1E.2)
			• "Each team came up with their design concepts, and we discussed that in the group via zoom to finalise overall boat design" (I.1E.1)
			• "We had to involve lots of critical thinking and mathematical calculations to build boat model in software" (I.1E.3)
				• Design and manufacturing concepts (Conceptual and Societal Knowledge)
				• Application of Critical thinking (Procedural and Technical Knowledge)
				• Application of Problem-solving (Procedural and Technical Knowledge)
				• Practical knowledge using tools (Procedural and Technical Knowledge)
					• Conceptual Engineering knowledge
					  • Design and Manufacturing concepts (Conceptual and Societal Knowledge)
					• Advanced Engineering Technical skills
					  • Application of Critical thinking (Procedural and Technical Knowledge)
					  • Application of Problem-solving (Procedural and Technical Knowledge)
					  • Practical knowledge using tools (Procedural and Technical Knowledge)

2.	ENGME382 Design and Manufacturing project	• Use 'dirty' prototyping to effectively evaluate design concepts • Use traditional and modern manufacturing processes when designing parts and machines • Apply health and safety regulations when designing machines • Design and build a complex machine to meet a given specification	• "In design project, we had to come with an inventive way to design our project model" (1.3E.2) • "We had to think a lot for finding the appropriate theories and related solution for the project problem" (I.3E.3) • "Design project helped to bring in classroom learned theories and concepts to real-world practical applications, thereby we engaged more into engineering practise" (I.3E.1) • "Design project was like developing an idea to solve a particular problem" (I.3E.1)	• Application of Critical thinking (Procedural and Technical Knowledge) • Application of problem solving (Procedural and Technical Knowledge) • Practical knowledge using tools (Procedural and Technical Knowledge) • Design and manufacturing concepts (Conceptual and Societal Knowledge)	
3.	ENGME582 Research and Development project	• Comprehend and address a large task, situated in the context of a discipline, business, or interdisciplinary project • Present outcomes and achievements to colleagues and management	• "R & D project made me learn how to do research, look and find solutions" (I.5E.1)	• Researching skills (Procedural and Technical Knowledge) • Application of Critical thinking (Procedural	

		• Document methods, result, and achievements comprehensively and concisely.	• "This project was a big one, gave us so much space for improvising" (I.5E.2) • "We had to come up with multi-design concepts for solving this project" (I.5E.3) • "We were actually making something that could impact the real-world/industries" (I.5E.2)	and Technical Knowledge) • Application of Problem solving (Procedural and Technical Knowledge) • Real-world application (Procedural and Technical Knowledge) • Practical knowledge using tools (Procedural and Technical Knowledge) • Design and manufacturing concepts (Conceptual and Societal Knowledge)	

The findings from each are presented below through each project course ENGEN180, ENGME382, and ENGME582. Each theme below is described by explaining the emerging themes within them and the work practise in engineering projects. The key themes are presented below.

4.5.1.1 Conceptual Engineering Knowledge

The key theme, conceptual engineering knowledge, is comprised of emerging theme – Design and Manufacturing concepts, which is an important engineering concept in mechanical engineering. In engineering projects, students have the opportunity to experience the application of design and manufacturing concepts, and thereby students further master their understanding of engineering 3D drawings. This is explained in detail along with students' quotes based on their learning experiences of each engineering project.

4.5.1.1.1 ENGEN180 Foundation of Engineering (Boat Race Project)

Analysing students' quotes on learning experiences of the Boat Race project indicated the development of the four emergent subthemes presented here. The first subtheme, design and manufacturing concepts, relates to the aspect of application of Design and Manufacturing concepts in the Boat Race project (Conceptual and Societal Knowledge). Participant I.1E.1 shared that "Each team came up with their design concepts, and we discussed that in the group to finalise the overall boat design". Students had to work in groups, on making design concepts of their boat, and then they had to discuss it with their group, in order to finalise their final boat design. This shows that students got an opportunity to apply their Design and Manufacturing concepts, which may have been developed from their previous learnings, for example, from classroom or prior experiences. This subtheme constitutes the formation of the key theme – conceptual engineering knowledge. In the next section, ENGME382 project learning is presented.

4.5.1.1.2 ENGME382 Design and Manufacturing Project

Analysing participants' quotes showed that by undertaking ENGME382 project, participants developed the first subtheme, Design and Manufacturing concepts (Conceptual and Societal Knowledge). Participant I.3E.1 indicated that "Design project helped to bring in classroom learnt theories and concepts to real-world practical applications, thereby we engaged more into engineering practise". Students got an opportunity to apply their prior knowledge developed from classroom learnings onto their project's problem-solving, which further helped them to strengthen their knowledge understanding of design and manufacturing concepts. Participant I.3E.1 also stated that "Design project was like developing an idea to solve a particular problem", which indicates that students developed ideas based on their previously acquired engineering knowledge via classroom, to solve their project's problem statement. These statements of Participant I.3E.1 supports the development of design and manufacturing concepts via ENGME382. In this way, this subtheme (design and manufacturing concepts) constitutes formation of the key theme – conceptual engineering knowledge. In the next section, ENGME582 project learning is presented.

4.5.1.1.3 ENGME582 Research and Development Project

Analysis of participants' quotes showed that by undertaking ENGME582 project, participant developed the first subtheme, Design and Manufacturing concepts (Conceptual and Societal Knowledge). Participant I.5E.3 indicated that "We were making something that could impact the real-world/industries". This is a broad statement, and this study anticipates that participant I.5E.3 applied and practised classroom-developed Design and Manufacturing concepts onto his project works, which provided him an opportunity to apply theory into real-world engineering practise. This indicates that Design and Manufacturing concepts were further enhanced by this project, which relates to the development of the key theme – conceptual engineering knowledge. In the next section, the second key theme is presented.

4.5.1.2 Advanced Engineering Technical skills

Application of critical thinking, problem-solving, researching skills, practical engineering knowledge, and real-world applications (Procedural and Technical Knowledge) together constitutes the development of advanced engineering technical skills. Here, the technical knowledge of how these skills are to be applied is first developed. Then, as students apply this technical knowledge to the project's problem-solving, they develop the technical skills through practise and experience. Along with the development of conceptual and technical engineering knowledge, students also developed technical engineering skills through their participation in engineering projects ENGEN180, ENGME382, and ENGME582.

Engineering is a creative process of identifying engineering problems and then devising a solution to fill those engineering problems by successfully applying engineering concepts/theory alongside problem-solving and critical thinking skills. The development of these skills and qualities assists in administering the development of advanced engineering technical skills. The next section presents learning experiences of ENGEN180 project.

4.5.1.2.1 ENGEN180 Foundation of Engineering (Boat Race Project)

Analysis of participants' quotes revealed that by undertaking the Boat Race project, participants developed critical thinking, problem-solving (including teamwork), and practical knowledge using tools (Procedural and Technical Knowledge), which constitutes the three emerging subthemes. The first subtheme, critical thinking, was developed by undertaking this project, as students had to study several design and manufacturing concepts and then critically think to relate which concept would better suit their boat's design model. This can be exemplified by Participant I.1E.2 who stated that "We collectively applied critical thinking to finalise the boat model". Another Participant I.1E.1 shared that "Each team came up with their design concepts, and we discussed that in the group via zoom to finalise overall boat design". These statements of participants I.1E.2 and I.1E.1 indicate that students had practised critical thinking, teamwork and problem-solving skills while selecting the appropriate design concepts for building their boat models in software. So, along with the first subtheme – application of critical thinking, it also relates to the second subtheme – application of problem-solving. As students applied problem-solving for shortlisting the relevant design concepts within their respective groups, they further applied critical thinking to relate best suited design concepts with respect to their project needs. Additionally, students applied team working skills for brainstorming the best design concepts in their group, therefore, teamwork is also included in the application of problem-solving. The third subtheme, practical knowledge using tools, relates to the development of practical knowledge by undertaking this project. Participant I.1E.3 shared that "We had to involve lots of critical thinking and mathematical calculations to build boat models in software". Students had to use software to design their boat models in this project, and this opportunity helped them to develop their software technical abilities, and how to use them in real-world applications. These subthemes together constitute development of the key theme – advanced engineering technical skills. In the next section, the learning experience of ENGME382 project is presented.

4.5.1.2.2 ENGME382 Design and Manufacturing Project

The participants’ quotes on analysis presented the development of critical thinking, problem-solving, and practical knowledge (Procedural and Technical Knowledge) using tools by undertaking ENGME382 project. These constitute the subthemes, which are presented here. Firstly, the subtheme – application of critical thinking Participant I.3E.1 stated, “We were given a project topic, which posed a challenging engineering problem, and we felt like we were developing an idea to solve that particular engineering problem”. Students had to apply critical thinking and problem-solving skills, in order to understand the background of the given engineering problem, and then accordingly shortlist the design concepts.

The second subtheme, application of problem-solving, relates to the aspect of problem-solving applications in this project. Participant I.3E.2 stated that "By researching, we can get different solutions for a specific problem, but again it requires the practise of considerable knowledge and skills to find the most appropriate design solution for the specific problem." Participant I.3E.2 had to apply problem-solving to relate specific engineering theory and design concepts with the project's posed engineering problem. The third subtheme, practical knowledge using tools, relates to development of practical engineering knowledge by undertaking the ENGME382 project. Participant I.3E.2 stated that “In design project, we had to come with an inventive way to design our project model”. This study anticipates that students had to apply traditional and modern manufacturing technologies to create their project models. Thereby, students used software to create 3D designed project models and then may have used different tools and machinery to build their project prototypes. These suggest that students developed practical engineering knowledge outside their classroom learning by undertaking this project. These subthemes together constitute the development of key theme – advanced engineering technical skills. In the next section, the learning experience of ENGME582 project is presented.

4.5.1.2.3 ENGME582 Research and Development Project

The ENGME582 Research and Development project allowed students to apply their engineering knowledge to more complex real-world applications and engineering problems, thereby developing their technical engineering skills. The subthemes, application of critical thinking and problem-solving (Procedural and Technical Knowledge), relates to development of these skills by undertaking this project. As students work on problem-solving, they further develop these skills by applying them to a given engineering problem. Participant I.5E.2's stated that "This project was a big one, gave us so much space for improvising. We had to come up with multi-design concepts for solving this project". Through this process, students had to apply critical thinking and problem-solving to solve this interdisciplinary engineering project, which involved multiple complex design and manufacturing concepts. To develop multi-design concepts, students must apply research, critical thinking, and problem-solving skills to find appropriate, innovative, and creative design structures and solutions for the project. Thereby, this process also aids in developing students' creativity and innovative abilities. This further supports the third subtheme, researching skills (Procedural and Technical Knowledge), as students had to research different design and manufacturing concepts, to define solution of this project. This can be supported by the statement of Participant I.5E.1 who said, "Research and Development project made me learn how to do research, look, and find solutions".

The fourth and fifth subthemes, that is, real-world applications and practical knowledge using tools (Procedural and Technical Knowledges), relates to the practical learning environment provided by this project. Participant I.5E.2 stated that "We were actually making something that could impact the real-world or industries". Students were using modern manufacturing techniques for creating their project models, based on real-world engineering problems, by using industry-level tools and machinery. Therefore, students were given exposure to real-world applications and development of practical engineering knowledge using tools, by undertaking this project. These subthemes together constitute the development of the key theme – advanced engineering technical skills. The following section presents findings related to learning experience of work placement based on participants' perceptions.

4.5.2 Engineering Work Placement

Work placements allowed students to apply their design and manufacturing concepts to workplace projects and processes. This section presents findings from participants' perceptions and how they link to the learning outcomes of ENGEN271 and ENGE371. Table 4.18 also shows key quotes as evidence of students' learning, emergent subthemes, and the key themes. In these courses, the emergent subthemes which were identified are:

- Attention to detail,
- Design and manufacturing concepts,
- Proficiency in Solid Works design software,
- Health and safety familiarisation,
- Proficient in Arduino programming,
- Application of critical thinking,
- Application of problem-solving,
- Communication/interpersonal skills,
- Planning and organising skills,
- Teamwork, and
- Project management skills (Table 4.18).

Table 4:18: Analysis of assessment learning outcomes based on students' quotes (perceptions).

Serial No.	Document	Learning Outcome	Evidence	Emerging Themes	Key Themes

1.	ENGEN271 Engineering work placement 1	• To be able to set learning objectives for their work placements and provide information on progress of achieving these learning objectives
		• To be able to complete a written technical report
		• Show ability to reflect on learning progression by completing the reflection assignment
		• Be familiar with workplace specific health and safety requirements and responsibilities.
			• "From this work placement, I have learned the importance of attention during manufacturing process" (I.2E.1)
			• "Building and drawing accurate and reliable 3D models on Solid Works. This design skill I possessed from university but developed further in work placements" (I.2E.3)
			• "On the very first day of my work placement, I was briefed with the health and safety procedures, which helped me to work effectively and safely in the workplace" (I.2E.4)
			• "Work placement helped to enhance skills like problem-solving and critical thinking" (I.3E.1)
			• "From my work placement, I have a better understanding of the Arduinos and the Arduino IDE and could more confidently use libraries and install programs in the future" (I.2E.2)
				• Attention to details (Procedural and Technical Knowledges)
				• Design and manufacturing concepts (Conceptual and Societal Knowledges)
				• Proficient in Solid Works design software (Procedural and Technical Knowledges)
				• Health and safety familiarisation (Procedural and Technical Knowledge)
				• Proficient in Arduinos programming (Procedural and Technical Knowledge)
				• Application of Critical thinking (Procedural and Technical Knowledge)
				• Application of Problem solving (Procedural and Technical Knowledge)
					• Conceptual Engineering Knowledge
					  • Design and manufacturing concepts (Conceptual and Societal Knowledge)
					• Advanced Engineering Technical Skills
					  • Application of Critical thinking (Procedural and Technical Knowledge)
					  • Application of Problem-solving (Procedural and Technical Knowledge)
					  • Proficient in Solid Works design software (Procedural and Technical Knowledge)
					  • Proficient in Arduinos programming (Procedural and Technical Knowledge)
					• Advanced Engineering Professional Skills
					  • Attention to details (Procedural and Technical Knowledge)
					  • Health and safety familiarisation (Procedural and Technical Knowledge)
					  • Communication and interpersonal skills

2.	ENGEN371 Science work placement 2	• Show ability to reflect on learning progression by completing the reflection assignment • Be familiar with workplace specific health and safety requirements and responsibilities	• "I have become more efficient in the utilisation of the CAD software – Solid Edge (Solid Works) (I.4E.2) • "I learned that when in a high-risk environment with a team of people, it is important to have clear communication and precise instructions so to keep everyone safe and aware" (I.4E.3) • "By doing work placement, I understood all protocols and procedures that help to	• Proficient in Solid Works design software (Procedural and Technical Knowledge) • Design and manufacturing concepts (Conceptual and Societal Knowledges) • Health and safety familiarisation (Procedural and Technical Knowledge)	

		• Be able to provide evidence of level of professional competency using an e-portfolio.	ensure workplace is safe and poses no hazards to the workers" (I.4E.1) • "While working on site to fix problem or malfunction, I learned how to alternate tasks, organise number of team members, motivate co-workers and coordinate different complex processes" (I.4E.3)	• Application of Problem solving (Procedural and Technical Knowledge) • Application of Critical thinking (Procedural and Technical Knowledge) • Communication and interpersonal skills (Procedural and Technical Knowledge) • Planning and organising skills (Procedural and Technical Knowledge) • Project management (Procedural and Technical Knowledge) • Teamworking (Procedural and Technical Knowledge)	(Procedural and Technical Knowledge) • Project management (Procedural and Technical Knowledge) • Planning and organising skills (Procedural and Technical Knowledge) • Teamworking ((Procedural and Technical Knowledge)

These emergent themes were further categorised into three key themes, which are: Conceptual Engineering Knowledge, Advanced Engineering Technical Skills, and Advanced Engineering Professional Skills. In the next section, the first key theme – conceptual engineering knowledge is presented.

4.5.2.1 Conceptual Engineering Knowledge

During work placements, students' engineering conceptual knowledge were enhanced by working in technical environments under supervision. Development of design and manufacturing concepts as subtheme favoured the development of key theme – conceptual engineering knowledge. In the sub-sections, each work placement course is presented with students' learning experiences.

4.5.2.1.1 ENGEN271 Engineering Work Placement 1

Analysis of the participants' data identified that their knowledge was developed, and further enhanced by undertaking the ENGEN271 work placement, which aided in the development of subtheme:

- Design and Manufacturing concepts (Conceptual and Societal Knowledge)

Participant I.2E.3 stated that "Building and drawing accurate and reliable 3D models on Solid Works. This design skill I possessed from University but developed further in work placements". This study anticipates that students had developed design skills underpinning design and manufacturing concepts from university studies, which they further developed by undertaking the work placement. The work placement further aided in strengthening their design and manufacturing concepts, by providing them opportunity to apply this knowledge and skills from university to workplace applications. This subtheme constitutes the development of the key theme of this study – conceptual engineering knowledge. In the next section, the learning experience of ENGEN371 is presented.

4.5.2.1.2 ENGEN371 Engineering Work Placement 2

Analysis of the participants' data identified that they developed design and manufacturing concepts (Conceptual and Societal Knowledge) by undertaking this work placement. Participant I.4E.2 shared that "I have become more efficient in the utilisation of the CAD software – Solid Edge (equivalent to Solid Works software)". This study anticipates that by undertaking the work placement, participant I.4E.2 enhanced his design and manufacturing concepts, which when applying CAD software utilisation in the work placement, further enhanced his software abilities. This experience aided in the further development of design and manufacturing concepts, and thereby, this subtheme constitutes the development of key theme – conceptual engineering knowledge. The following section presents the development of advanced engineering technical skills via work placements.

4.5.2.2 Advanced Engineering Technical skills

The subthemes associated in development of key theme – advanced engineering technical skills, are application of critical thinking, application of problem-solving, proficiency in Solid Works software design, and proficiency in Arduino programming (Procedural and Technical Knowledge). These subthemes will be presented in the upcoming sections. In the next section, ENGEN271 work placement and participants' learning experiences are presented.

4.5.2.2.1 ENGEN271 Engineering Work Placement 1

Analysis of the participants' data identified that they developed knowledge of the technical skills (Procedural and Technical Knowledge) as listed below:

- Critical thinking,
- Problem-solving,
- Solid Works design software, and
- Arduino programming.

The first and second subthemes, application of critical thinking and problem-solving relates to the development of critical thinking and problem-solving skills by undertaking work placements. Participant I.3E.1 shared that “Work placement helped to enhance skills like problem-solving and critical thinking”. As participant I.3E.1 worked in a design and manufacturing related work placement, he had to apply critical thinking and problem-solving to find the errors in the design models. The third subtheme, proficiency in Solid Works software design, relates to development of 3D drawing and designing capabilities via software. Participant I.2E.3 shared that by “Building and drawing accurate and reliable 3D models on Solid Works. This design skill I possessed from University, but developed further in work placements, as I worked under several projects in my work placement”. Participant I.2E.3 applied and practised 3D drawing and designing in his work placement, which helped him to enhance this skill.

Similarly, the fourth subtheme, proficiency in Arduino programming, relates to development of programming abilities via Arduino. Participant I.2E.4 shared “From my work placement, I have a better understanding of the Arduinos and the Arduino IDE and could more confidently use libraries and install programs in the future”. Participant I.2E.4 learned about Arduino programming from her work placement, which helped her to enhance her command of programming abilities, and accordingly made her confident in this skill set. These subthemes together constitute the development of key theme – advanced engineering technical skills. In the next section, ENGEN371 work placement and participants' learning experiences are presented.

4.5.2.2.2 ENGEN371 Engineering Work Placement 2

Analysis of the participants' data identified that they developed knowledge of the technical skills (Procedural and Technical Knowledge) as listed below:

- Critical thinking,
- Problem-solving, and
- Solid Works design software.

The first and second subthemes, application of critical thinking and problem-solving, relate to the development of critical thinking and problem-solving skills by undertaking work placement. Participant I.4E.3 shared that "While working in work placement, I had to do several problem-solving to fix malfunctions". Participant I.4E.3 got an opportunity to apply and practise his problem-solving, thereby, further enhancing this skill by undertaking work placement. Along with problem-solving, the findings demonstrate that critical thinking skills will also be applied in this problem, so with the development of problem-solving skills, critical thinking skills will also be developed.

The third subtheme, proficiency in Solid Works design software, relates to the development of 3D drawing and designing abilities by undertaking work placement. Participant I.4E.2 shared that "I have become more efficient in the utilisation of the CAD software – Solid Edge (equivalent to Solid Works software)." Through this work placement experience, I.4E.2 was able to apply his technical knowledge and skill around 3D drawing from university learnings to his work placement. This work placement helped him to further apply his knowledge in real-world engineering applications and develop his 3D drawing capabilities. Design skills are essential for engineers because mechanical engineers require these to design complex 3D structures. These subthemes collectively constitutes the development of key theme – advanced engineering technical skills. The next section presents the third key theme – advanced engineering professional skills by work placements.

4.5.2.3 Development of Advanced Engineering Professional skills

Professional skills are common to most fields of work and are sometimes identified as lifelong learning and generic skills. Engineers need to communicate professionally and technically to supervisors and colleagues as they work in teams on complex problems; thus, professional skills are critical to successful engineering practise. Students worked in real-world work environments and live projects in the work placements. Findings indicate that students developed several professional skills such as communication and interpersonal skills, planning and organising, teamworking and project management skills (Procedural and Technical Knowledge) through work placement practise. The next section presents participants' learning experiences of the ENGEN271 work placement.

4.5.2.3.1 ENGEN271 Engineering Work Placement 1

Analysis of the participants' data identified that they developed health and safety familiarisation. This first subtheme, relates to the development of awareness of health and safety protocols and practices (Procedural and Technical Knowledge) in workplaces. Participant I.2E.2 shared that "On the very first day of my work placement, I was briefed with the health and safety procedures, which helped me to work effectively and safely in the workplace". This statement indicates that Participant I.2E.2 was briefed about the company's health and safety practices and procedures, and that helped him to understand the possible hazards, potential accidents, and their implications in the workplace. By following health and safety protocols of different workplaces, students may develop the habit of attention to detail, following instructions, making sound decisions, and thereby keeping their workplace safe and hazard-free for themselves and others. This subtheme constitutes the development of the key theme – advanced engineering professional skills. In the next section, ENGEN371 work placement and participants' learning experiences are presented.

4.5.2.3.2 ENGEN371 Engineering Work Placement 2

Analysis of the participants' data identified that they developed the following professional skills (Procedural and Technical Knowledge):

- Health and safety familiarisation,
- Communication and interpersonal skills,
- Planning and organising skills,
- Project management, and
- Teamwork.

The first subtheme – health and safety familiarisation, relates to the development of health and safety practices of workplaces. Participant, I.4E.1, shared that "By doing a work placement, I understood all protocols and procedures that help to ensure the workplace is safe and poses no hazards to the workers". Participant I.4E.1 became familiar with the workplace's health and safety practices, which helped him understand the workplace's risks and hazards. Having a good understanding of these protocols and procedures helped him to work safely with his co-workers and equipment in his workplace.

The second subtheme – communication and interpersonal skills, relates to the development of these skills by undertaking work placement. Participant I.4E.3 shared that "While working on-site to fix problem or malfunction, I learned how to alternate tasks, organise some team members, motivate co-workers and coordinate different complex processes”. Participant I.4E.3 had to coordinate effectively with his team members and co-workers for better coordination and co-operation, therefore, he had to apply and practise communication and interpersonal skills to maintain a good professional relationship with them.

The third, fourth, and fifth subthemes – planning and organising, project management, and teamwork, relates to the development of these skills by undertaking work placement. As stated by Participant I.4E.3, in instances of problem occurrences, his team had to look for alternative options so that the work was not affected. This encouraged his planning and organising skills and project management skills for the participant, as alternative work options has to be planned, so that overall work was not affected even in the presence of faulty or malfunctioning equipment. Along with this work planning, he had to coordinate with his colleagues as a team to work through deadlines, and, therefore, to apply and practise his teamwork in his work placement for smooth operations. These subthemes collectively constitute the development of the key theme – advanced engineering professional skills. In the next section, the differences in the themes of engineering projects and work placements are presented.

4.6 Themes Across Engineering Projects and Work Placements

This section outlines the key themes identified in this study, through the analysis of collected data. Intended and actual learning outcome analysis from engineering project and work placements through students' and graduates' perceptions and document analysis helped to formulate the themes of this research study. The individual themes of engineering projects and work placements, and their commonalities and differences are shown in Table 4.19.

Table 4:19: Theme matching from engineering projects to work placements.

Engineering Projects Themes	Work Placements Themes	Common Overall Key Themes	Key Difference(s) (in work placements only)
Development of Engineering knowledge Development of Advanced Engineering Technical skills	Development of Engineering knowledge Development of Advanced Engineering Technical skills Development of Advanced Engineering Professional skills	• Engineering knowledge development • Engineering skill development	Development of Advanced Engineering Professional skills

In engineering projects, the development of engineering knowledge and advanced engineering technical skills emerged as the key themes. In contrast, for work placements, the key themes indicated the above plus the development of advanced engineering professional skills.

Engineering projects and work placements differ based on their operation, learning approaches, number of participants, level of complexity, and proposed learning outcomes. However, it is not surprising to find that they both contribute to students' understanding of engineering concepts and technical skills. One significant difference between them was that work placements developed advanced engineering professional skills. The reason is self-explanatory, as work placements happen in authentic work environments, where students work under experienced engineers, on real industrial projects, in a natural work environment. This exposure helped students adapt to their workplace culture and practices, including health and safety protocols. Also, by working in an authentic work environment, students may develop professional skills like communication, interpersonal skills, time management, project management, planning and organising skills, and teamwork. Such a detailed learning outcome around professional skills was not wholly available in engineering projects, as projects happened within a confined laboratory space, with limitations such as the lack of availability of complex and critical industrial projects, lack of authentic workplace environment, and lack of sophisticated tools and machinery. Thus, engineering projects could not provide opportunities for advanced engineering professional skills. Similarly, due to the technical differences between the operation of work placements and engineering projects, students got better opportunities to work on real-world applications more in work placements than in engineering projects. The similarities and differences within and across projects and work placements will be discussed against respective research questions in the following chapter, Chapter 5 Discussion.

4.7 Students' and Graduates' Perceptions of Attributes of a Successful Engineer

At the University of Waikato, engineering students do a total of three engineering projects and two work placements as part of their engineering curriculum. The learning development that happens in both approaches covers engineering knowledge, and technical and non-technical skills. From each cohort, students were asked to rate the importance of skills that are required of an engineering graduate (Table 4.20).

Table 4:20: Perceived importance (using a 5-point likert scale) of engineering skills as perceived by different cohorts of students.

	2nd-Experience (n = 13)	3rd -Experience (n = 14)	4th-Experience (n = 16)	5th-Experience (n = 26)	Graduate (n = 63)	Combined Cohorts (n = 132)
Problem-solving	4.66 (0.834)	5.00 (0)	4.69 (0.480)	4.48 (0.714)	4.70 (0.497)	4.67 (0.541)
Communication skills	4.50 (0.522)	4.75 (0.462)	4.61 (0.506)	4.68 (0.556)	4.52 (0.689)	4.58 (0.608)
Logical thinking	4.33 (0.651)	4.50 (0.755)	4.15 (0.554)	4.40 (0.577)	4.41 (0.629)	4.38 (0.617)
Fast learner	4.58 (0.514)	4.00 (0.925)	4.23 (0.599)	4.04 (0.734)	4.20 (0.755)	4.19 (0.730)
Engineering knowledge	4.16 (0.834)	4.00 (0.925)	4.30 (0.480)	3.84 (0.850)	4.05 (0.755)	4.04 (0.772)
Intelligence	4.08 (0.792)	4.00 (0.755)	4.15 (0.554)	3.84 (0.800)	3.87 (0.746)	3.92 (0.740)
Self-starter	3.58 (0.668)	4.00 (0.925)	3.61 (0.767)	3.88 (0.832)	4.05 (0.730)	3.91 (0.774)
Engineering work experience	3.66 (0.778)	3.50 (0.925)	4.00 (0.707)	3.88 (0.881)	4.00 (0.860)	3.90 (0.844)

Note: mean Likert data is presented with standard deviations within brackets

The perceived importance of skills for the 2nd-Experience cohort shows that students felt problem-solving was the most important (mean value 4.66), followed by fast learner (4.58) and communication skills (4.5). In the 3rd-Experience cohort, the most important skill was problem-solving. On the other hand, in the 4th and 5th-Experience cohorts, the most important skills were problem-solving and communication skills. The skills questionnaire prepared for the 3rd-Experience was different compared to other cohorts, which are presented in Table 4.21.

Table 4:21: Important engineering skills as perceived by students except the 3^{rd-}Experience cohort, in likert scale 1 to 5, where 1 = totally disagree and 5 = totally agree, where each number shows mean value and bracket number shows standard deviation.

	2^{nd-} Experience (n = 13)	4^{th-} Experience (n = 16)	5^{th-} Experience (n = 26)	Graduate (n = 63)	Combined Cohorts (n = 118)
Team skills	4.41 (0.514)	4.69 (0.630)	4.64 (0.489)	4.67 (0.610)	4.63 (0.573)
Adaptability	4.41 (0.792)	4.38 (0.767)	4.52 (0.653)	4.45 (0.661)	4.45 (0.679)
Self-management	4.08 (0.900)	4.61 (0.650)	4.36 (0.568)	4.41 (0.629)	4.39 (0.657)
Critical thinking	4.33 (0.492)	4.23 (0.832)	4.40 (0.707)	4.38 (0.680)	4.36 (0.681)
Hard worker	4.33 (0.651)	4.46 (0.660)	4.20 (0.577)	4.43 (0.631)	4.36 (0.641)
Initiative	4.25 (0.753)	4.38 (0.650)	4.36 (0.7)	4.29 (0.685)	4.31 (0.683)
Planning and organising	3.83 (0.937)	4.23 (0.832)	4.48 (0.509)	4.34 (0.615)	4.30 (0.681)
Employability skills	3.91 (0.792)	4.61 (0.650)	4.00 (0.816)	4.07 (0.813)	4.10 (0.807)
Flexible	4.00 (0.738)	4.38 (0.506)	3.96 (0.789)	4.03 (0.768)	4.05 (0.744)
Analytical reasoning	3.41 (0.514)	4.07 (0.862)	4.00 (0.645)	4.16 (0.687)	4.02 (0.713)
Technically minded	3.58 (0.668)	3.84 (0.800)	4.08 (0.702)	3.96 (0.719)	3.93 (0.724)
Creative	4.00 (0.738)	3.92 (0.954)	3.88 (0.665)	3.81 (0.840)	3.86 (0.797)
Humble	3.83 (0.514)	3.69 (0.751)	3.88 (1.129)	3.89 (0.895)	3.82 (0.956)
Studious	3.25 (0.753)	3.61 (0.650)	3.76 (0.723)	3.65 (0.907)	3.62 (0.823)
Artistic	2.83 (0.717)	2.69 (1.031)	2.92 (0.909)	2.72 (0.951)	2.78 (0.919)

In Table 4.21, the 2^{nd}-Experience cohort students indicated more important skills like teamwork, adaptability, hard work, critical thinking, and initiative. Nevertheless, with increasing experience, students from the 3^{rd}, 4^{th}, and 5^{th}-Experience cohorts indicated that hard work, team skills, adaptability, self-management, critical thinking, planning and organising skills, analytical reasoning, and employability skills were important skills for being a successful engineering graduate. These may be related to the facts that students, having completed several engineering projects and work placements, develop a deeper understanding and importance of engineering work practices and culture, thereby developing some technical and non-technical skills. Students develop these skills gradually from the 2nd-Experience to the 5th-Experience, with their yearly engineering project and work placement experiences. In the next section, each skill is compared across cohorts, as shown in Table 4.22.

Table 4:22: Statistical comparison of significance of difference of the means of perceived importance of skills between cohorts, where the differences were significant for p<0.05, as shown with a shaded cell.

SKILLS	CO 2-4	CO 2-5	CO 2-G	CO 4-5	CO 4-G	CO 5-G
Adaptability	0.459	0.349	0.439	0.296	0.382	0.340
Analytical reasoning	0.014	0.003	0.002	0.390	0.369	0.154
Artistic	0.346	0.377	0.334	0.254	0.456	0.195
Creative	0.411	0.319	0.230	0.443	0.360	0.362
Critical thinking	0.354	0.370	0.388	0.269	0.275	0.457
Employability skills	0.012	0.384	0.273	0.008	0.008	0.356
Flexibility	0.074	0.440	0.440	0.026	0.028	0.344
Initiative	0.319	0.337	0.432	0.457	0.324	0.341
Planning & organising skills	0.137	0.020	0.046	0.168	0.323	0.155
Self management	0.054	0.172	0.120	0.122	0.167	0.341
Studious	0.104	0.032	0.060	0.268	0.429	0.290
Team skills	0.121	0.118	0.002	0.398	0.460	0.399
Technically minded	0.190	0.024	0.048	0.191	0.317	0.249

Note: where CO 2-4 = Cohorts 2nd- and 4th-Experience, CO 2-5 = Cohorts 2nd- and 5th-Experience, CO 2-G –=Cohorts 2nd- and Graduate Experience, CO 4-5 = Cohorts 4th- and 5th-Experience, CO 4-G = Cohorts 4th- and Graduate Experience, and CO 5-G = Cohorts 5th- and Graduate Experience.

Table 4.22, in combination with Table 4.21, shows different skills and their importance level across different cohorts, based on students' perceptions. Each column shows if there is a significant difference between two skills across different cohorts. The yellow-coloured cells in Table 4.22 show a significant difference between respective cohorts (as stated column-wise) for a particular skill. When comparing responses from the 2nd- and 4th-Experience cohorts, skills such as analytical reasoning and employability skills differed significantly in perceived importance. In comparison to Table 4.20, it shows that the 4th-Experience cohort perceives analytical reasoning and employability skills to be significantly more important than the 2nd-Experience cohort's perceptions.

Similarly, analytical reasoning skills were perceived to be more important by the 4th- and 5th-Experience cohorts than the graduate cohorts. Similarly, the 5th-Experience cohort thought that skills like planning and organising skills, studious, and technically minded were significantly more important than what the 2nd-Experience cohort's perceived. On the other hand, team skills and technically minded were significantly more important than the 2nd-Experience cohort's perceptions. On the other hand, flexibility is significantly more important for the 4th-Experience cohort when compared with the 5th-Experience and graduate cohorts. The 4th-experience cohort thought that employability skills were more important compared to the graduate cohort. In Table 4.22, the 3rd-Experience cohort's responses were not included because their questionnaire did not include those listed skills. However, some other skills listed in the 3rd-Experience matched with other cohorts, shown in Table 4.23 below.

Table 4:23: Comparing skills across cohorts, where the differences were significant for p<0.05, as shown with a shaded cell.

SKILLS	CO 2-3	CO 2-4	CO 2-5	CO 2-G	CO 3-4	CO 3-5	CO 3-G	CO 4-5	CO 4-G	CO 5-G
Communication skills	0.138	0.290	0.173	0.439	0.270	0.364	0.129	0.360	0.302	0.148
Engineering knowledge	0.344	0.307	0.140	0.337	0.202	0.336	0.438	0.018	0.071	0.142
Engineering work experience	0.340	0.137	0.231	0.102	0.107	0.164	0.092	0.326	0.500	0.286
Fast learner	0.068	0.063	0.007	0.022	0.271	0.456	0.287	0.198	0.438	0.187
Hard worker	0.411	0.314	0.276	0.312	0.285	0.442	0.290	0.1200	0.451	0.052
Humble	0.198	0.331	0.444	0.416	0.272	0.173	0.155	0.272	0.209	0.483
Logical thinking	0.309	0.234	0.382	0.343	0.142	0.369	0.388	0.106	0.074	0.449
Problem-solving	0.019	0.448	0.180	0.395	0.019	0.0006	0.000	0.142	0.455	0.077
Self starter	0.147	0.456	0.127	0.089	0.171	0.375	0.405	0.168	0.126	0.440

Note:

CO 2-3 – Cohorts 2nd- and 3rd -Experience, CO 2-4 – Cohorts 2nd- and 4th-Experience, CO 2-5 – Cohorts 2nd- and 5th-Experience, CO 2-G – Cohorts 2nd- and Graduate Experience, CO 3-4 – Cohorts 3rd- and 4th-Experience, CO 3-5 – Cohorts 3rd- and 5th-Experience, CO 3-G – Cohorts 3rd- and Graduate Experience, CO 4-5 – Cohorts 4th- and 5th-Experience, CO 4-G – Cohorts 4th- and Graduate Experience, CO 5-G – Cohorts 5th- and Graduate Experience

Table 4.23, along with Table 4.20, shows the different skills with significant differences and importance levels across different cohorts. Table 4.20 is referred here because it shows the mean values of each skill from each cohort. The yellow-coloured cells in Table 4.23 show a significant difference between the respective cohorts (as stated column-wise) for a particular skill. When comparing responses from the 2nd- and 3rd-Experience cohorts, problem-solving has a significant difference (p<0.05) between these cohorts (Table 4.20), it may be deduced that for the 3rd-Experience cohort problem-solving was significantly more important than what the 2nd-Experience cohort thought. Similarly, being a fast learner is a significantly more important quality for the 2nd-Experience cohort when compared with the 5th-Experience and graduate cohorts. Additionally, the 3rd-Experience cohort believed problem-solving was significantly more important than the 4th- and 5th-Experience and graduate cohorts. Lastly, engineering knowledge was significantly more important for the 4th-Experience cohort when compared with the 5th-Experience cohort.

A more detailed analysis comparing these skills within the 2nd-Experience cohort is presented below in Table 4.24. It shows the significance of difference (if any) of the perceived level of importance of the 2nd-Experience cohorts for each skill. Where $p<0.05$ shows a perceived significant difference between two specific skills, and then by referring to Tables 4.20 and 4.21, the level of importance of respective skills may be deduced. First, problem-solving was compared with every other skill, and the following outcomes were identified when comparing communication skills with problem-solving, the p-value recorded was 0.214, which is greater than the significant difference value of 0.05, and that would indicate that communication skills and problem-solving have a significant difference between them. In Table 4.20, the mean values of communication skills (4.50) and problem-solving (4.66) indicate that problem-solving is significantly more important. Additionally, when comparing engineering work experience with problem-solving, the p-value of 0.0007 showed that engineering work experience has a significant difference when compared with problem-solving but based on the mean values (Table 4.20 and Table 4.21) of engineering work experience (3.66) and problem-solving (4.66), it indicates that problem-solving is perceived to be significantly more important, which is indicated in orange (Table 4.24). Table 4.24, 4.25, 4.26, 4.27, and 4.28 shows the significant difference based on colouring, where orange colour specifies that the skill in the header row is more important than the skill in the left column, whereas blue colour specifies that the skill in the header row is less important than the skill in the left column.

Table 4:24: Comparison of significance of difference (p<0.05) of perceived importance of skills within the 2nd-Experience cohort (n = 14).

SKILLS	(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
PROBLEM-SOLVING (1)																							
COMMUNICATION SKILLS (2)	0.214																						
CRITICAL THINKING (3)	0.055		0.214																				
HARD WORKER (4)	0.086		0.248	0.500																			
ENGINEERING WORK EXPERIENCE (5)	**0.0007**		**0.003**	**0.010**	**0.016**																		
EMPLOYABILITY SKILLS (6)	**0.006**		**0.023**	0.069	0.087	0.222																	
ENGINEERING KNOWLEDGE (7)	**0.045**		0.127	0.279	0.295	0.071	0.230																
FAST LEARNER (8)	0.344		0.348	0.118	0.154	**0.001**	**0.012**	0.079															
PLANNING & ORGANISING SKILLS (9)	**0.007**		**0.022**	0.060	0.072	0.320	0.408	0.183	**0.013**														
SELF MANAGEMENT (10)	**0.032**		0.091	0.205	0.222	0.119	0.317	0.408	0.056	0.256													
LOGICAL THINKING (11)	0.086		0.248	0.500	0.500	**0.016**	0.087	0.295	0.154	0.072	0.222												
TEAM SKILLS (12)	0.118		0.348	0.344	0.365	**0.005**	**0.041**	0.194	0.218	**0.038**	0.140	0.365											
TECHNICALLY MINDED (13)	**0.0001**		**0.0006**	**0.002**	**0.005**	0.390	0.139	**0.036**	**0.0003**	0.230	0.069	**0.005**	**0.001**										
ANALYTICAL REASONING (14)	**0.000**		**0.000**	**0.0001**	**0.0005**	0.182	**0.041**	**0.008**	**0.000**	0.097	**0.019**	**0.0005**	**0.000**	0.250									
FLEXIBILITY (15)	**0.008**		**0.035**	0.104	0.126	0.146	0.396	0.304	**0.018**	0.316	0.403	0.126	0.062	0.080	**0.018**								
ARTISTIC (16)	**0.000**		**0.000**	**0.000**	**0.000**	**0.006**	**0.001**	**0.0002**	**0.000**	**0.004**	**0.0006**	**0.000**	**0.000**	**0.007**	**0.016**	**0.0004**							
INITIATIVE (17)	0.062		0.178	0.376	0.387	**0.037**	0.151	0.399	0.110	0.121	0.314	0.387	0.267	**0.016**	**0.002**	0.210	**0.0001**						
CREATIVE (18)	**0.008**		**0.035**	0.104	0.126	0.146	0.396	0.304	**0.018**	0.316	0.403	0.126	0.062	0.080	**0.018**	0.500	**0.0004**	0.210					
HUMBLE (19)	**0.004**		**0.015**	**0.045**	0.058	0.309	0.402	0.169	**0.008**	0.500	0.244	0.058	**0.026**	0.213	0.079	0.304	**0.002**	0.106	0.304				
STUDIOUS (20)	**0.000**		**0.0001**	**0.0003**	**0.0005**	0.098	**0.023**	**0.005**	**0.000**	0.053	**0.011**	**0.0005**	**0.0001**	0.132	0.267	**0.011**	0.089	**0.001**	**0.011**	**0.043**			
ADAPTABILITY (21)	0.182		0.382	0.380	0.390	**0.014**	0.068	0.230	0.274	0.057	0.173	0.390	0.500	**0.005**	**0.0008**	0.098	**0.000**	0.301	0.098	**0.046**	**0.0006**		
SELF STARTER (22)	**0.0001**		**0.0006**	**0.002**	**0.005**	0.390	0.139	**0.036**	**0.0003**	0.230	0.069	**0.005**	**0.001**	0.500	0.250	0.080	**0.007**	**0.016**	0.080	0.213	0.132	**0.005**	

KEY

Orange colour indicates that the skill in the header row is MORE important than the skill in the left column.

Blue colour indicates that the skill in the header row is LESS important than the skill in the left column.

One of the findings identified from this table is that fast learning (0.001), initiative (0.037), and adaptability (0.014) are significantly more important than engineering work experience for the 2nd-Experience cohort, which may be due to these students being just in their first year of engineering education, and thus may lack the overall idea and importance of engineering work experience. Similarly, these students indicated that flexibility (0.018), initiative (0.002), creativity (0.018), and adaptability (0.0008) are significantly more important than analytical reasoning, which might show that students hold these responses/thoughts due to their lack of experience and technical thinking related to engineering practices. Additionally, the un-coloured cells in Table 4.24 indicate that those skill comparisons did not have any significant differences. The following section shows the comparison of skills within the 3rd-Experience cohort, presented in Table 4.25.

Table 4:25: Comparison of skills within the 3rd-experience cohort, where p-value is 0.05 (n = 17).

SKILLS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PROBLEM-SOLVING (1)										
COMMUNICATION SKILLS (2)	0.085				KEY		Orange colour indicates that the skill in the HEADER row is MORE important than the skill in the left column.			
HARD WORKER (3)	**0.024**	**0.0166**					Blue colour indicates that the skill in the HEADER row is LESS important than the skill in the left column.			
ENGINEERING WORK EXPERIENCE (4)	0.0013	**0.0026**	0.0557							
ENGINEERING KNOWLEDGE (5)	**0.0092**	**0.0100**	0.175	0.175						
FAST LEARNER (6)	**0.0092**	**0.0240**	0.281	0.085	0.500					
LOGICAL THINKING (7)	0.051	0.225	0.258	**0.016**	0.175	0.113				
HUMBLE (8)	**0.0048**	**0.0019**	**0.0105**	0.413	0.258	0.324	0.110			
SELF STARTER (9)	**0.0092**	**0.0100**	0.085	0.157	0.500	0.500	0.085	0.258		
INTELLIGENCE (10)	**0.0036**	**0.039**	0.324	0.137	0.500	0.500	0.085	0.500	0.500	

Fewer skills are shown here compared to other cohorts because the questionnaire which was prepared for this cohort was different compared to other cohorts. Each skill was compared with other skills within the cohort, and their respective p-values are in Table 4.25. By referring to Table 4.20, the level of significance of the importance of skills can be analysed. First, problem-solving was compared with every other skill, and the following were the outcomes. On comparing, it was found that problem-solving and communication skills were significantly more important than hard worker, engineering knowledge, fast learner, humble, self-starter, and intelligence.

This change is interesting when compared to the responses of the 2nd-Experience cohort, which may be because the 3rd-Experience cohort have already had a work placement experience, whereas the 2nd-Experience students had not.

On the other hand, students indicated logical thinking was significantly more important than engineering work experience. This would indicate that students still have not fully developed the understanding and importance of engineering work experience to their comprehensive engineering education and future career options. Additionally, the un-coloured cells of Table 4.25 show that skill comparisons did not have any significant difference in importance. In the next section, a comparison of skills within the 4th-experience cohort is presented in Table 4.26.

Table 4:26: Comparison of skills within the 4th-experience cohort, where p-value is 0.05 (n = 15).

SKILLS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
PROBLEM-SOLVING (1)																							
COMMUNICATION SKILLS (2)	0.360											KEY		Orange colour indicates that the skill in the header row is MORE important than the skill in the left column									
CRITICAL THINKING (3)	**0.026**	0.104												Blue colour indicates that the skill in the header row is LESS important than the skill in the left column.									
HARD WORKER (4)	0.136	0.218	0.193																				
ENGINEERING WORK EXPERIENCE (5)	**0.003**	**0.012**	0.213	0.055																			
EMPLOYABILITY SKILLS (6)	0.376	0.500	0.068	0.250	**0.012**																		
ENGINEERING KNOWLEDGE (7)	**0.009**	0.082	0.376	0.250	0.109	0.082																	
FAST LEARNER (8)	**0.026**	**0.048**	0.500	0.168	0.244	**0.048**	0.336																
PLANNING & ORGANISING SKILLS (9)	**0.041**	0.087	0.500	0.168	0.244	0.068	0.376	0.500															
SELF MANAGEMENT (10)	0.360	0.500	**0.009**	0.274	**0.012**	0.500	0.109	0.104	**0.027**														
LOGICAL THINKING (11)	**0.001**	0.055	0.376	0.082	0.250	0.055	0.218	0.360	0.388	**0.026**													
TEAM SKILLS (12)	0.500	0.360	**0.026**	0.193	**0.006**	0.336	**0.048**	**0.026**	**0.026**	0.360	**0.013**												
TECHNICALLY MINDED (13)	**0.002**	**0.017**	0.087	**0.027**	0.306	**0.022**	**0.026**	0.104	0.087	**0.003**	0.082	**0.004**											
ANALYTICAL REASONING (14)	**0.012**	**0.044**	0.168	0.104	0.396	**0.033**	0.193	0.318	0.168	**0.013**	0.388	**0.012**	0.193										
FLEXIBILITY (15)	0.051	0.136	0.274	0.360	0.087	0.136	0.292	0.218	0.250	0.193	0.136	0.082	**0.033**	0.109									
ARTISTIC (16)	**0.00**	**0.000**	**0.000**	**0.0001**	**0.0009**	**0.000**	**0.000**	**0.0001**	**0.0001**	**0.000**	**0.0003**	**0.000**	**0.0006**	**0.0001**	**0.0002**								
INITIATIVE (17)	0.109	0.168	0.250	0.388	0.087	0.213	0.376	0.306	0.218	0.095	0.193	0.109	**0.013**	0.051	0.500	**0.0001**							
CREATIVE (18)	**0.013**	**0.022**	0.109	0.065	0.409	**0.028**	0.119	0.183	0.082	**0.003**	0.230	**0.0056**	0.388	0.218	0.082	**0.0004**	**0.003**						
HUMBLE (19)	**0.001**	**0.003**	**0.033**	**0.003**	0.196	**0.005**	**0.027**	**0.023**	**0.033**	**0.0004**	**0.026**	**0.003**	0.292	0.119	**0.016**	**0.006**	**0.010**	0.230					
STUDIOUS (20)	**0.0001**	**0.001**	**0.035**	**0.002**	0.104	**0.006**	**0.003**	**0.012**	**0.027**	**0.001**	**0.006**	**0.001**	0.095	0.069	**0.003**	**0.008**	**0.001**	0.132	0.376				
ADAPTABILITY (21)	0.109	0.168	0.250	0.292	0.087	0.095	0.376	0.274	0.250	0.193	0.168	0.109	0.055	0.132	0.500	**0.0001**	0.500	0.106	**0.010**	**0.017**			
SELF STARTER (22)	**0.0004**	**0.001**	**0.006**	**0.002**	0.104	**0.0004**	**0.010**	**0.019**	**0.006**	**0.001**	**0.023**	**0.0004**	0.213	**0.003**	**0.003**	**0.002**	**0.003**	0.132	0.388	0.500	**0.001**		
INTELLIGENCE (23)	**0.001**	**0.026**	0.376	0.109	0.292	**0.026**	0.082	0.336	0.376	**0.041**	0.500	**0.013**	0.132	0.388	0.041	**0.0003**	0.193	0.244	0.069	**0.023**	0.193	**0.033**	

First, problem-solving was compared with every other skill, and it was found that problem-solving was significantly more important than most other skills. In contrast, problem-solving did not significantly differ between team skills, adaptability, self-management, and employability skills. Students' responses indicated that self-management and team skills were significantly more important than critical thinking. This cohort's second work placement experience may have been why students felt that self-management and team skills are more important in a workplace. Another finding showed that students indicated employability skills, self-management, and team skills were significantly more important than engineering work experience.

In most responses, team skills were significantly more important than most other skills, and this might be because students' work experiences in engineering projects and work placements necessitated work in teams in order to achieve their objectives or work responsibilities or duties. Also, students indicated that flexibility and initiative were significantly more important than being technically minded, which might relate to students' engineering projects and work placement experiences. In addition, as these students had more experience with these approaches than less experienced cohorts, students therefore indicated that artistic skills were not significantly more important than any other skills listed.

On the other hand, adaptability was perceived to be significantly more important than being humble and studious, and this likely shows the students' far better understanding of engineering workplaces and work culture; that is, students should be adaptable to all workplaces/surroundings, to modern knowledge and changing technology, should continually be updated. Similarly, intelligence was significantly more important than being studious and a self-starter, which might show students' mature understanding of modern engineering education and the work environment. The comparison of skills within the 5th-Experience cohort is presented in Table 4.27.

Each skill was compared with other skills within the cohort, and their respective p-values were recorded. Then, in order to determine the level of significance of importance of the skills, the mean values of skills were considered from Table 4.20 along with Table 4.27. For example, problem-solving was perceived to be significantly more important than 13 other skills, whereas adaptability was perceived to be significantly more important than problem-solving. This can be due to these students having had the experiences of three engineering projects and two work placements, having high exposure to real-world work experiences, and this might be the rationale that students think skills such as planning and organising, self-management, logical thinking, team skills, initiative, and adaptability are more important skills than others. After Table 4.27, Table 4.28 shows comparison of skills within the graduate cohort.

Table 4:27: Comparison of skills within the 5th-experience cohort, where p-value is 0.05 (n = 30).

SKILLS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
PROBLEM-SOLVING (1)																							
COMMUNICATION SKILLS (2)	0.129											KEY		Orange colour indicates that the skill in the header row is MORE important than the skill in the left column									
CRITICAL THINKING (3)	0.245	0.054												Blue colour indicates that the skill in the header row is LESS important than the skill in the left column.									
HARD WORKER (4)	0.083	**0.0006**	0.142																				
ENGINEERING WORK EXPERIENCE (5)	**0.003**	**0.0001**	**0.006**	0.066																			
EMPLOYABILITY SKILLS (6)	**0.018**	**0.0007**	**0.028**	0.129	0.271																		
ENGINEERING KNOWLEDGE (7)	**0.0003**	**0.0001**	**0.001**	0.053	0.401	0.258																	
FAST LEARNER (8)	**0.002**	**0.0001**	**0.018**	0.178	0.178	0.428	0.116																
PLANNING & ORGANISING SKILLS (9)	0.500	**0.028**	0.323	**0.025**	**0.001**	**0.007**	**0.0009**	**0.004**															
SELF MANAGEMENT (10)	0.188	**0.014**	0.384	0.147	**0.007**	**0.047**	**0.0006**	**0.021**	0.163														
LOGICAL THINKING (11)	0.269	**0.034**	0.500	0.085	**0.006**	**0.014**	0.0006	**0.012**	0.287	0.356													
TEAM SKILLS (12)	0.106	**0.0373**	0.055	**0.004**	**0.0001**	**0.001**	**0.0001**	**0.0001**	0.080	**0.015**	0.068												
TECHNICALLY MINDED (13)	**0.023**	**0.0006**	0.051	0.188	0.142	0.345	0.113	0.419	**0.007**	**0.034**	**0.028**	**0.0006**											
ANALYTICAL REASONING (14)	**0.002**	**0.0005**	**0.007**	0.142	0.261	0.500	0.106	0.416	**0.003**	**0.004**	**0.001**	**0.0003**	0.301										
FLEXIBILITY (15)	**0.006**	**0.0001**	**0.015**	0.103	0.323	0.407	0.261	0.323	**0.002**	**0.023**	**0.009**	**0.0001**	0.251	0.401									
ARTISTIC (16)	**0.000**	**0.000**	**0.000**	**0.000**	**0.0003**	**0.000**	**0.0001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**								
INITIATIVE (17)	0.188	**0.021**	0.401	0.178	**0.018**	**0.047**	**0.006**	**0.021**	0.208	0.500	0.373	**0.044**	0.091	**0.018**	**0.019**	**0.000**							
CREATIVE (18)	**0.0003**	**0.000**	**0.0003**	0.288	0.500	0.294	0.393	0.147	**0.0001**	**0.0002**	**0.0006**	**0.000**	0.101	0.239	0.323	**0.000**	**0.0055**						
HUMBLE (19)	**0.0127**	**0.002**	**0.033**	0.059	0.500	0.332	0.444	0.252	**0.011**	**0.031**	**0.022**	**0.002**	0.173	0.324	0.365	**0.0006**	**0.024**	0.500					
STUDIOUS (20)	**0.0002**	**0.000**	**0.0005**	**0.002**	0.224	0.103	0.323	0.054	**0.000**	**0.0001**	**0.0001**	**0.000**	**0.008**	0.068	0.085	**0.0001**	**0.001**	0.188	0.294				
ADAPTABILITY (21)	**0.037**	0.128	0.208	**0.036**	**0.001**	**0.004**	**0.0005**	**0.001**	0.373	0.106	0.224	0.132	**0.012**	**0.0013**	**0.0018**	**0.000**	0.147	**0.0001**	**0.010**	**0.0001**			
SELF STARTER (22)	**0.0003**	**0.0003**	**0.004**	0.087	0.500	0.328	0.423	0.202	**0.001**	**0.003**	**0.003**	**0.0002**	0.173	0.261	0.361	**0.000**	**0.003**	0.500	0.500	0.279	**0.001**		
INTELLIGENCE (23)	**0.0003**	**0.000**	**0.001**	**0.029**	0.407	0.230	0.500	0.085	**0.0003**	**0.0001**	**0.0001**	**0.000**	0.132	0.178	0.294	**0.0006**	**0.002**	0.401	0.422	0.301	**0.001**	0.423	

Table 4:28: Comparison of skills within the graduate's cohort, where p-value is 0.05 (n = 63).

SKILLS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
PROBLEM-SOLVING (1)																							
COMMUNICATION SKILLS (2)	0.033											KEY		Orange colour indicates that the skill in the header row is MORE important than the skill in the left column									
CRITICAL THINKING (3)	0.001	0.125												Blue colour indicates that the skill in the header row is LESS important than the skill in the left column.									
HARD WORKER (4)	0.001	0.230	0.303																				
ENGINEERING WORK EXPERIENCE (5)	0.000	0.0001	0.004	0.002																			
EMPLOYABILITY SKILLS (6)	0.000	0.0004	0.014	0.004	0.280																		
ENGINEERING KNOWLEDGE (7)	0.000	0.0008	0.009	0.001	0.342	0.441																	
FAST LEARNER (8)	0.0001	0.010	0.043	0.028	0.094	0.175	0.130																
PLANNING & ORGANISING SKILLS (9)	0.0005	0.057	0.374	0.225	0.006	0.035	0.018	0.104															
SELF MANAGEMENT (10)	0.006	0.195	0.371	0.431	0.003	0.003	0.0009	0.048	0.271														
LOGICAL THINKING (11)	0.002	0.146	0.336	0.431	0.0007	0.001	0.001	0.031	0.260	0.500													
TEAM SKILLS (12)	0.354	0.051	0.012	0.013	0.000	0.000	0.000	0.0004	0.001	0.014	0.018												
TECHNICALLY MINDED (13)	0.000	0.0001	0.0001	0.0001	0.396	0.221	0.214	0.036	0.003	0.000	0.000	0.000											
ANALYTICAL REASONING (14)	0.000	0.001	0.013	0.010	0.114	0.240	0.190	0.396	0.083	0.012	0.003	0.0002	0.046										
FLEXIBILITY (15)	0.000	0.002	0.004	0.0003	0.404	0.380	0.440	0.114	0.010	0.0006	0.001	0.000	0.284	0.155									
ARTISTIC (16)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000								
INITIATIVE (17)	0.0001	0.007	0.201	0.104	0.017	0.035	0.056	0.263	0.325	0.133	0.105	0.001	0.0056	0.133	0.016	0.000							
CREATIVE (18)	0.000	0.000	0.000	0.000	0.145	0.056	0.053	0.004	0.0002	0.000	0.000	0.000	0.115	0.003	0.079	0.000	0.0003						
HUMBLE (19)	0.000	0.000	0.0009	0.0001	0.245	0.133	0.148	0.025	0.0006	0.0002	0.0001	0.000	0.333	0.015	0.153	0.000	0.003	0.331					
STUDIOUS (20)	0.000	0.000	0.000	0.000	0.020	0.004	0.002	0.0005	0.000	0.000	0.000	0.000	0.0050	0.000	0.007	0.000	0.0001	0.130	0.075				
ADAPTABILITY (21)	0.010	0.235	0.235	0.431	0.001	0.004	0.002	0.023	0.160	0.359	0.367	0.011	0.0001	0.009	0.0003	0.000	0.047	0.000	0.0002	0.000			
SELF STARTER (22)	0.000	0.0001	0.0056	0.0006	0.356	0.448	0.500	0.153	0.018	0.0009	0.0007	0.000	0.235	0.200	0.447	0.000	0.028	0.048	0.126	0.004	0.001		
INTELLIGENCE (23)	0.000	0.000	0.000	0.000	0.195	0.083	0.070	0.002	0.0002	0.000	0.000	0.000	0.187	0.007	0.070	0.000	0.0007	0.332	0.456	0.061	0.000	0.110	

These entries of Table 4.28, along with mean values of each skill set from Table 4.20, aided in performing analysis of the level of significance of importance of each skill. First, compared to every other skill, problem-solving was perceived to be significantly more important. Similarly, team skills, adaptability, and planning and organising were perceived to be significantly more important than other skills. These results were mostly the same as the responses from the 5th-Experience cohort likely because these students have the same number of experiences of engineering projects and work placements. The following section presents lecturers' perceptions of the teaching and learning process.

4.8 Lecturers' Perceptions

Five lecturers were interviewed during the research data collection process. They were asked about their perspectives on engineering projects and work placements. They indicated that students benefitted from their participation in engineering projects. This is best exemplified by I.LC.1, who responded:

> Students are subject to real-world problems when working on their university engineering projects. They must research general ideas, apply problem-solving techniques and critical thinking, and then generate solutions for their project/real-world problem. Thus, accordingly, they generate new knowledge which is subject to challenging projects/problems. By doing projects, they develop several skills, such as knowledge of using instruments and tools significant skills developed, develop printed circuit board (PCB) designing skills, MATLAB software experience, etcetera. (I.LC.1)

This lecturer stated the benefits of students participating in engineering projects because they are given real-world problems and are required to find innovative solutions. To do this, students must relate their previously acquired engineering knowledge from classroom learning and have to short-list the appropriate theory to address the given problem. This indirectly strengthens students' engineering knowledge and understanding and favours applying critical thinking and problem-solving in the project.

The data also suggests that lecturers expected students to research new concepts and theorems that match the project-posed problem and apply critical thinking and problem-solving techniques to address and find a solution. Through intense critical thinking and problem-solving, lecturers believed that students find a solution for the given problem and develop prototypes for their project. Thus, by this experience, lecturers believe students further develop engineering knowledge and skills from their projects.

I.L.C.2 suggested that students develop other technical skills, such as hands-on tools/machine experience, PCB board design concepts, and MATLAB software expertise and use machines/tools such as laser cutting, CNC machines, soldering, oscilloscope, electronic circuit development, and fault-checking devices to assist in their projects. Thus, lecturers suggested that this experience aided in the development of knowledge of these tools too. Similarly, students created PCB designs via computer, had them printed, and assembled components as part of their project, they also conducted testing processes over the PCB board. Students also did some programming as part of their project, and thus they learned to programme on Matlab and Arduino software. Acquisition of these skills and processes was best evidenced by lecturer I.LC.2 when he shared his perspective on engineering projects, as stated below:

> Engineering projects primarily cover all engineering concepts/theories taught in classroom learning. In the third year's Design and Manufacturing project, students are subject to apply their previously learned knowledge such as Applied Mechanics, Physics, Mathematics, and Computing systems to solve a real engineering problem. In short, projects allow students to apply prior learning to solve a real engineering problem. Students develop skills in 3D drawing capability via Computer-Aided Design (CAD) software, laser cutting, new manufacturing techniques, design skills, 2D drawing, planning, organising skills, kinematic calculations, microprocessor and Arduino software experiences, critical thinking, and problem-solving skills. (I.LC.2)

I.LC.2 specifies the beneficial outcomes students gain through participation in engineering projects, especially in the third year's Design and Manufacturing project and fourth year's Research and Development project. These projects become a platform where students can apply their previously acquired engineering knowledge and concepts to generate ideas to solve a real engineering problem. The problem-solving process may require students to undertake aspects such as using 3D and 2D drawing, laser cutting, design and manufacturing concepts, programming modules/integrated circuits by the microprocessor and Arduino software, critical thinking, and problem-solving skills. Lecturers believed these process further enhanced students' previously developed knowledge and skills from classroom learning and previous engineering projects. Another lecturer (I.LC.3) identified the importance of engineering projects in relation to future employment as stated below:

> Students can get a degree with theoretical engineering knowledge but cannot do anything with it when they enter industries. Because that is not what industries want, they want graduates to be practically minded and

> problem solvers. I want my students to be capable of problem-solving so that when they go to industries, they will know how to tackle problems, and accordingly, they will be able to solve them. While in a design project, I give students such projects which involve design concepts. Because it will be beneficial for students to have a theory with practise, and thus it is good to include design concepts in the projects. (I.LC.3)

The lecturers know the importance of practical knowledge, theory with practise, and problem-solving skills; thus, they impart these characteristics in their projects. Lecturers believe that by doing projects, students get the opportunity to enable theory with practise, which helps them enhance their engineering knowledge and skill development. As projects pose real engineering problems, it allows students to practise critical thinking and problem-solving skills via these projects.

Lecturers were also asked about the impacts of work placements on students' engineering education. They identified quite a variety of skills, knowledge, and dispositions as identified by lecturers I.LC.4 below:

> Work placements do have a significant impact on the development of students' overall engineering knowledge and skill development. Students get to learn different knowledge based on the company's discipline, and accordingly, they mature in it. They should have worked in teams and with others in a more professional situation in work placements. I consider that students in their fourth year will be able to do projects much better after their work placements since they will develop teamwork, project management, and organising skills from their work placements. (I.LC.4)

Lecturers believed that students develop more engineering knowledge and skills via work placements since it is primarily interdisciplinary across engineering; thus, students develop engineering knowledge outside mechanical engineering and related skill development. Also, as students work in teams in work placements, they understand the significance of project management, teamwork, communication, planning, and organising skills. When students return to university after their work placements, they apply these learnings in their classroom learning and engineering projects. The lecturer witnessed this in their fourth year students, as they could better manage their projects within their group. The lecturer considers that students can marvel at their projects because of the knowledge and skills they developed from their work placements. Another lecturer (I.LC.5) who supervised the ENGME582 Research and Development project highlighted work placements, as stated below:

> Work placements help students develop skills like teamwork, communication, project management, hands-on tools experience, design and manufacturing knowledge, and problem-solving skills. However, they do not have components of researching skills; thus, that component is missed when students transition from their work placement to fourth year's ENGME582 Research and Development project. So personally, this is a lacking component, and additionally, students bring different engineering knowledge and skills back to their classroom learning and engineering projects via these work placements. (I.LC.5)

In the case of the fourth year Research and Development project, students were involved in a higher level of research practise. Students developed skills such as teamwork, communication, project management, hands-on tools experience, and problem-solving. If students obtain a work placement based on research and development, this may help them develop their research skills and may help in their project. Nevertheless, there is a wide variety of work placements, which may vary in terms of their field of engineering operation and application. Therefore, not many

Research and Development work placements may be available for students. These are the perspectives of the lecturers on work placements and engineering projects. The following section discusses Workplace Supervisors' perspectives on work placements and engineering projects.

4.9 Workplace Supervisors’ Perceptions

Two workplace supervisors were interviewed during the process to uncover their perspectives on engineering projects and work placements. Firstly, they were asked if their placement students could relate classroom learned theories with real-life applications at the workplace. Participant I.WS.1 responded as shown below:

> The students could bring their classroom-learned engineering knowledge and concepts to workplace examples, like the use of complex mathematical concepts and calculations, core Mechanics concepts, design and manufacturing knowledge, 3D drawing knowledge, etcetera. They apply these learnings in our workplace, learn more from here, and take it back to their classroom learning (university). I see that students have demonstrated good enough knowledge, skills, and work ethics during the work placements. (I.WS.1)

Supervisors indicated that work placements did provide students with an opportunity to apply their classroom learning theories in workplace surroundings. Knowledge such as complex mathematical concepts and calculations, mechanics concepts, design and manufacturing concepts, and 3D drawing, were developed in the University’s classroom learning. While in work placements, students apply some of the learnings to workplace real-world applications and develop a relationship between theory and practice, which helps them develop more in-depth engineering knowledge. In the design and manufacturing industries, 3D drawing skills are essential, and thus, students bring basic knowledge of 3D drawing from university, apply that in the workplace, and further develop their 3D drawing skills. Supervisors also monitor on students' performance progression, and they would check students' performance and progression during their work placement training. Another workplace supervisor I.WS.2 shared his thoughts as shown below:

> Students referred to their past engineering knowledge/concepts learned from their classroom learning and engineering projects while working in their work placements. They found their classroom learned theories matched the real-world applications available in the workplace, and they could bridge theory with practise or theory with practical examples. Accordingly, they enhanced their knowledge retention via work placements. Also, they showed skills like teamwork, communication, critical thinking, problem-solving, and hands-on tools experiences. Students indicated that they had learned these from their university projects. I think the engineering projects help students deepen their engineering knowledge and sharpen their technical and non-technical skills. (I.WS.2)

Effective bridging between engineering projects and work placements may be observed by the statement above. Students learned about core engineering concepts, design and manufacturing process, and 3D drawing concepts via doing their engineering projects. Students could bring these learnings from university to their work placements and apply them to real-world applications. They could relate design and manufacturing concepts with the relevant examples available at the workplace, which helped them bridge the connection between classroom learned theory and its practical application.

The data suggest that workplace supervisors thought students could blend with the engineering team and work with total commitment and co-operation. Supervisors also indicated that students applied critical thinking and problem-solving when required during instances of problem-solving in work placements. Supervisors also suggested that learning from engineering projects was transferable to work placements. Students collectively applied learning outcomes from classroom learning and engineering projects to work placements, showing the flow of engineering knowledge and skills from projects to the work placements. This evidence suggests that engineering projects scaffold learning into work placements. The following section outlines the linkages between classroom learning, engineering projects, and work placements.

4.10 Learning Linkages

In this section, the learning linkages between engineering projects and work placements are introduced, based on the perceptions of the participants, and intended learning outcomes of these courses. The learning linkages are established based on the development of engineering knowledge, technical, and non-technical skills. The established learning linkages are important as they indicate the students' education progression through each of these approaches in their engineering degree study. Additionally, having knowledge of these learning linkages may help the teaching staff to focus on particular learnings from individual approaches, and may benefit students with enhanced learning experiences. In this section, the intended linkages are introduced based on the learning outcomes of each course, followed by perceived learning outcomes based on students' and graduates' perceptions. These perceptions of students and graduates help to define the learning linkages between engineering projects and work placements, which are presented at the end of this section.

4.10.1 Intended Linkages

In the engineering degree, the main facets are classroom learning, engineering projects, and work placements. There are several engineering projects and work placement courses, with a wide variety of learning outcomes that promote the development of the graduate profile of mechanical engineering students. This section presents the intended learning outcome linkages across engineering projects and work placements. The University identifies what successful students are expected to learn during the engineering degree. These are termed as intended learning outcomes. The following section presented the intended learning linkages within engineering projects.

4.10.1.1 Engineering Projects

The engineering projects were covered through the following courses: ENGEN180 Foundation of Engineering, ENGME382 Design and Manufacturing Project, and ENGME582 Research and Development Project. The intended learning outcomes of these courses are listed below in Table 4.29.

Table 4:29: Intended learning linkages within engineering projects.

Engineering Project courses	LEARNING OUTCOMES	COMMONALITIES
ENGEN180 FOUNDATION OF ENGINEERING – BOAT RACE PROJECT (1st YEAR OF ENGINEERING STUDY)	Explain the differences and links between Science, Engineering, and Technology. Explain and apply a generalised engineering design technique. Recall the general 'accounting' equation and be able to solve appropriate problems where this is applied to accounting for mass, and energy. Explain how expert problem solvers operate and be able to use heuristic methods in problem solving. Realise the importance that engineering fundamentals (such as thermodynamics) have in solving real-world problems and be able to solve appropriate problems.	Engineering design concepts/techniques. Manufacturing process Building a model via problem-solving, critical thinking to solve an engineering problem.
ENGME382 DESIGN AND MANUFACTURING PROJECT (3rd YEAR OF ENGINEERING STUDY	Use 'dirty' prototyping to effectively evaluate design concepts. Use traditional and modern manufacturing processes when designing parts and machines. Apply health and safety regulations when designing machines. Design and build a complex machine to meet a given specification.	
ENGME582 RESEARCH AND DEVELOPMENT PROJECT (4th YEAR OF ENGINEERING STUDY)	Comprehend and address a large task, situated in the context of a discipline, business, or interdisciplinary project. Present outcomes and achievements to colleagues and management. Document methods, results, and achievements comprehensively and concisely.	

The project courses' intended learning outcomes indicated that students progressively acquire some engineering knowledge and skills by doing their project work. In the ENGEN180 course, students learn and apply engineering design techniques and problem-solving skills to their projects. Students then take these developed attributes from ENGEN180 to their 3rd year ENGME382 course. Here, students apply traditional and modern design manufacturing techniques, with a problem-solving aspect, to build prototypes for their projects. After this, students do the ENGME582 course, where students research engineering concepts, design concepts, manufacturing, and classroom-learned theories, and then apply them to real-world problem-solving to design solutions. On analysing the learning outcomes across these courses, the commonalities that emerge are:

- Engineering design concepts/techniques,
- The Manufacturing process, and
- Building a working model via problem-solving to solve an engineering problem.

These were the intended learning linkages and the common achievements between engineering projects. The intended learning linkages between work placements are presented in the next section.

4.10.1.2 Work Placements

There are two work placements in the four years of engineering study. In Table 4.30., ENGEN271 and ENGEN371 have common areas of focus and progression for students' professional development. For example, in ENGEN271, students must self-evaluate their progress by recording their actual learning outcomes via a reflection report. Based on their experience, knowledge, and skills, they need to document a report showing proof of their learning and progression. Additionally, students must familiarise themselves with workplace health and safety practices to keep themselves and their workplace safe. These learning outcomes from ENGEN271 have similarly been reflected again in ENGEN371, which indicates little thought had been given to progression across work placements. However, undoubtedly students do have the opportunity to enhance their previous work placement the ENGEN271 learnings with

ENGEN371 work placement. The intended learning linkages of these two work placements are shown in Table 4.30.

Table 4:30: Intended learning linkages between work placements.

Work Placement courses	LEARNING OUTCOMES	COMMONALITIES
ENGEN271 Engineering Work Placement 1 (2nd YEAR OF ENGINEERING STUDY)	To be able to set learning objectives for their work placements and provide information on progress of achieving these learning objectives. Be able to complete a written technical report. Show ability to reflect on learning progression by completing the reflection assignment. Be familiar with workplace specific health and safety requirements and responsibilities.	• Self-reflection • Self-learning • Document writing (technical, reflection report) • Health and safety practices • Professional skill development
ENGEN371 Engineering Work Placement 2 (3rd YEAR OF ENGINEERING STUDY	To be able to set learning objectives for their work placements and provide information on progress of achieving these learning objectives. Be able to complete a written technical report. Show ability to reflect on learning progression by completing the reflection assignment. Be familiar with workplace specific health and safety requirements and responsibilities. Be able to provide evidence of level of professional skill using an e-portfolio (Additional Learning Outcome)	

The commonalities between these two work placement courses are stated below:

- Self-learning,
- Self-reflection,
- Document writing (technical and reflection reports and e-portfolio),
- Health and Safety practices, and
- Professional skill development.

These common developments emerge from the mapping between ENGEN271 and ENGEN371. The following section presents the students' and graduates' perceived learning linkages in engineering projects and work placements.

4.10.2 Perceived Linkages

This section will establish the perceived learning linkages between classroom learning, engineering projects, and work placements based on data from participants' ideas, understandings, and perceptions. This section shows three parts; the first explains the linkages between classroom learning and engineering projects. The second explains the linkages between classroom learning and work placements, and the third explains the linkages between engineering projects and work placements. The following sub-sections present the learning linkages between engineering projects and classroom learning.

4.10.2.1 Between Engineering Projects and Classroom Learning

In classroom learning, students learned theoretical knowledge of different engineering concepts, which they then applied in their engineering projects by relating theory to practical applications, enhancing their practical engineering knowledge. Learning linkages between classroom learning and engineering projects is shown in Figure 4.1.

Figure 4.1: Learning linkages between classroom learning and engineering projects.

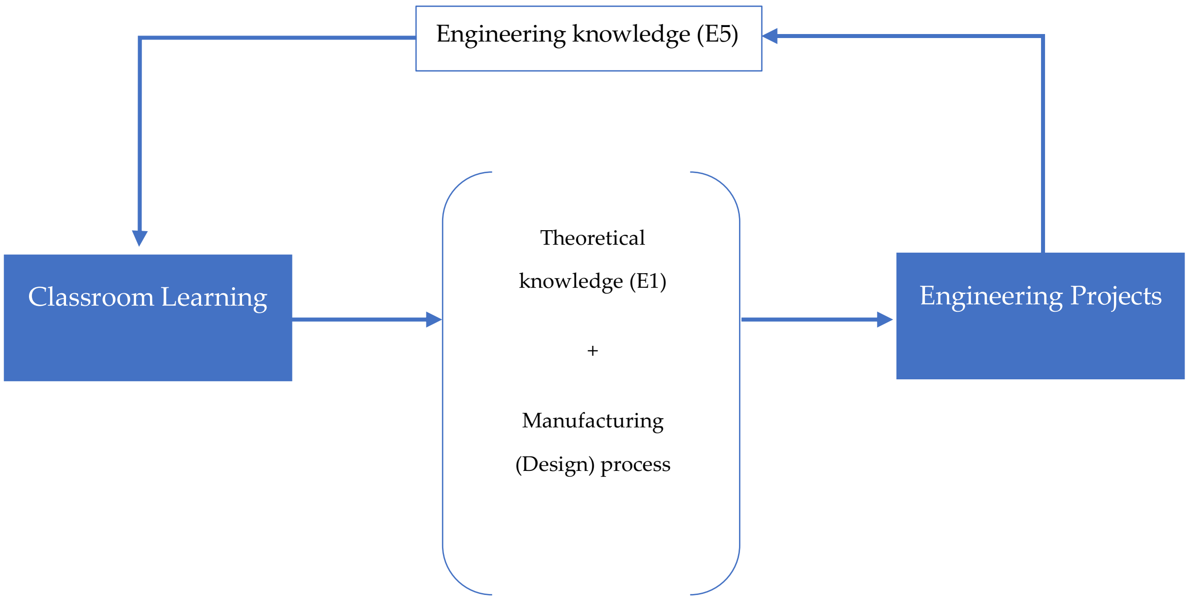


Figure 4.1 shows that students learned theoretical knowledge related to mechanical engineering, such as design and manufacturing concepts, 3D Drawing, dimensions, and structures from classroom learning. This knowledge was implemented in the first year's Boat Race project, then again in the third year's Design and Manufacturing project, and finally in the fourth year's Research and Development project. The theoretical learning from the classroom became the students' knowledge 'backbone', which they applied in their three engineering projects. This helped them to relate their classroom learned theories with practical, real-world applications. Therefore, it helped students to link theory with practise, and the findings demonstrate this could have enhanced their knowledge retention.

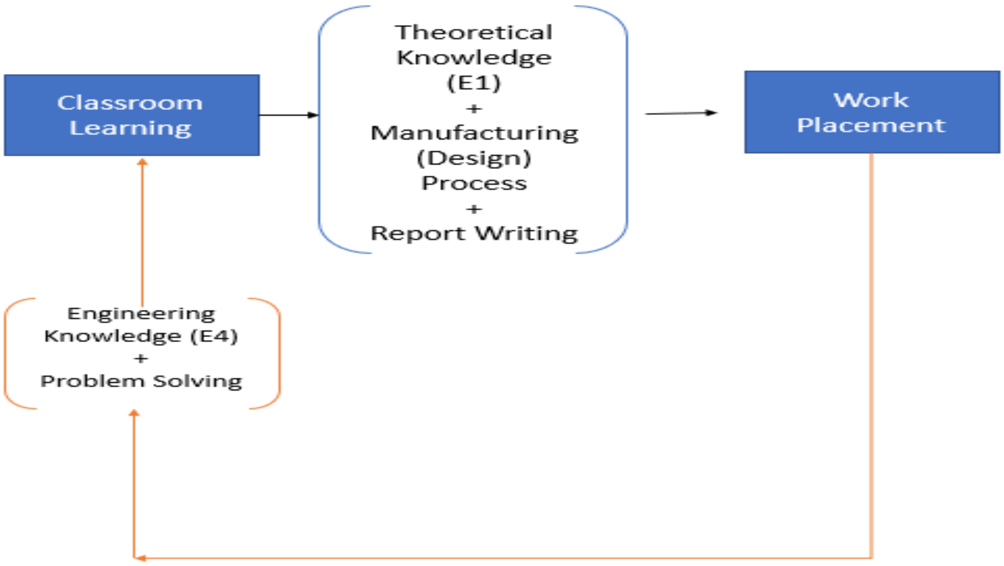
As students work on projects, they gain experience in machinery operations, hands-on tools (like laser cutting, welding, and 3D printing), 3D Drawing via AutoCAD software, and developed design and manufacturing concepts. Additional to knowledge development, students also developed skills like problem-solving, critical thinking, teamwork, communication, and project management skills. One interesting point to note is that while students worked on their engineering projects, most students learned additional engineering knowledge outside the classroom.

Some students indicated that they did not learn 3D Drawing in class but learned about it from the projects. This was knowledge they could take back to the classroom. Also, there were some engineering concepts (E5) they did not learn from the classroom; they learned from the projects, such as gear ratios, trigonometric calculations, design, and manufacturing processes. Students were able to take this learning back to the classroom and were able to apply it further in their studies. These learning linkages between engineering projects and classroom learning (based on participants' perceptions) showed that engineering projects complemented classroom learning in engineering knowledge and skill development. The following sub-section presents the learning linkages between work placements and classroom learning.

4.10.2.2 Between Work Placements and Classroom Learning

Students first gained a basic understanding of engineering and business operations via the ENGEN270 Engineering and Business course, and then they went on to do two work placements. Detailed analysis of the collected data shows a progressive learning linkage between them, as shown in Figure 4.2.

Figure 4.2: Learning linkages between classroom learning and work placement.



Students undertook several engineering courses related to Design and Manufacturing and also ENGEN270 Engineering and Business. Students developed engineering knowledge (E1), design and manufacturing process, and report-writing skills from classroom learning. Students took these outcomes to their work placements, which enabled them to apply newly acquired skills and knowledge to real-world applications. During work placements, students gained additional engineering knowledge outside classroom learning and developed technical skills, which students brought back to university to their classroom learnings. Students brought engineering knowledge (E4) and problem-solving skills from work placements. They could apply these outcomes to their classroom learning and engineering projects. Therefore, based on participants' perceptions, work placement provided complementary support to classroom learning, which will be discussed in detail in the next chapter – Chapter 5 Discussion.

4.10.2.3 Between Engineering Projects and Work Placements

In engineering education at university, students did three projects and two work placements. The hierarchy of their occurrence is shown below:

1. The first year of engineering education – Boat Race project,

2. The second year of engineering education – 1st Work placement,

3. The third-year engineering education – Design and Manufacturing project + 2nd Work placement, and

4. Fourth year of engineering education – Research and Development project.

While students complete their ENGEN271 work placement, they could draw on knowledge and skills developed from the ENGEN180 project. Similarly, students gained additional knowledge and skills from the ENGEN271 work placement, which they implemented in their ENGME382 project. The learning outcomes from the ENGME382 project in terms of knowledge and skills, then flowed to the ENGEN371 work placement and finally to the ENGME582 project. This flow suggests that students apply their previously developed engineering knowledge and skills to upcoming projects and work placements.

Students identify the following as their learning outcomes from undertaking engineering projects:

1. Development of engineering knowledge such as 3D Drawing, design and manufacturing, dimensions, structures, and technical knowledge of 3D software and Arduino programming;

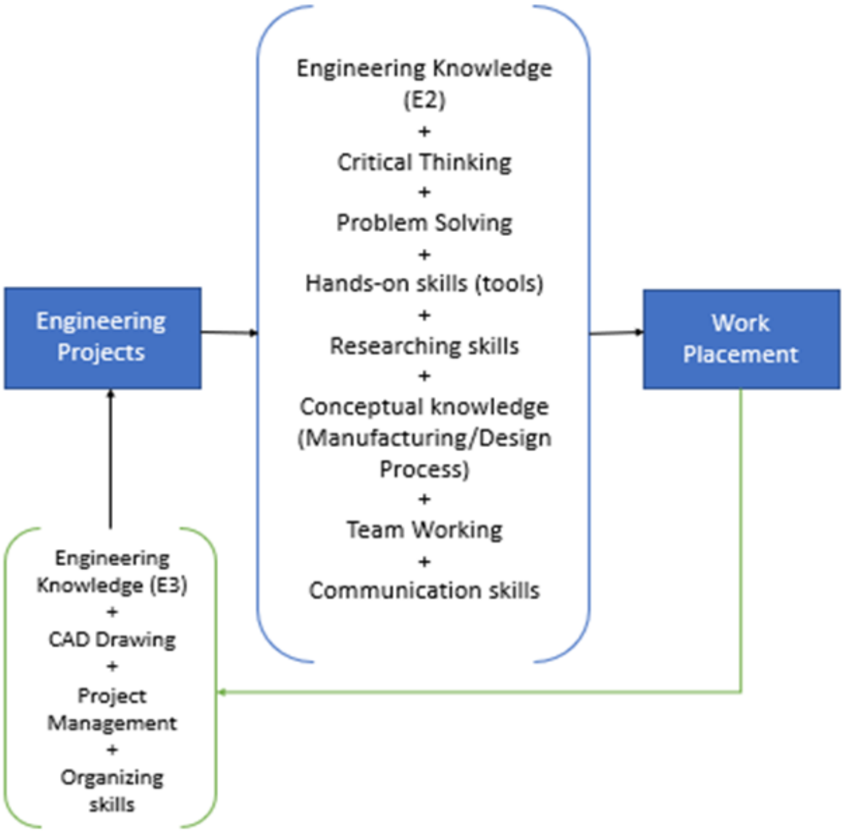
2. Development of critical thinking and problem-solving,

3. Development of professional skills like teamwork and communication skills,

4. Hands-on tools experience, and

5. Development of research skills (Table 4.3).

Figure 4.3: Learning linkages between engineering projects and work placements.



By working on problem-posed projects, students were given opportunities to relate classroom-learned engineering theories to the project and to research relevant engineering concepts related to the project-posed problem. They developed their engineering knowledge (E2), conceptual knowledge, and skills such as research, critical thinking, problem-solving, and teamwork from projects. These project learning outcomes were then taken to their work placements. Students worked under expert supervision in work placements and related classroom and learned theories and engineering knowledge from projects and classroom learning onto workplace applications. This process helped the students relate their previously learned engineering concepts to their practical applications, bridging theory with practise. Also, as the work placements were diverse in engineering, students developed interdisciplinary engineering knowledge (E3). Additionally, some students worked on industrial projects in their workplaces, where they could apply research, critical thinking, teamwork, communication, and problem-solving skills. Thus, students could transfer engineering knowledge and skills from engineering projects to work placements. Now, once students work in their work placements, because of the workplace's interdisciplinary engineering nature, students develop the following:

1. Engineering knowledge (E3) – additional to classroom learned engineering knowledge,
2. 3D Drawing via AutoCAD/Solid Works software,
3. Project management skills, and
4. Organising skills.

According to students' and workplace supervisors' perceptions, these actual learning outcomes from work placements favoured the transition of engineering knowledge and skills to the University's classroom learning and engineering projects. Students could apply engineering knowledge (E3), CAD drawing experience, project management, and organising skills from their work placements to engineering projects in university. Therefore, based on participants' perceptions, the learning linkage between engineering projects and work placements could be established, which indicates that engineering projects gave sequencing of scaffolding (of engineering knowledge and skills) support to work placements. On the other hand, work placements provided complementary learning support to engineering projects. In the next section, the conclusion of this chapter is presented.

4.11 Summary

This chapter presented the findings from five student cohorts, lecturers, and workplace supervisors. The methods used were mixed methods research, combining quantitative data (via online surveys) and qualitative data (via individual interviews, document analysis, and observations). The results demonstrated that the students and graduates benefitted from engineering projects and work placements, enhancing their engineering knowledge, and supporting skill development. The results also indicate several learning linkages between engineering projects and work placements. The findings revealed that there were aspects of sequencing of scaffolding (of engineering knowledge and skills) between engineering projects to classroom learning and engineering projects to work placements. Specifically, there was the sequencing of scaffolding of engineering knowledge and skills between engineering projects to classroom learning, and the sequencing of scaffolding of engineering knowledge and skills between engineering projects and work placements. The findings also revealed that there were aspects of complementary learning links between classroom learning, engineering projects, and work placements. These findings were subject to triangulation analysis between collected qualitative and quantitative data and will be discussed in detail in the next chapter – Chapter 5 Discussion.

5 DISCUSSION

5.1 Introduction

This chapter discusses the main research questions related to stakeholders' views on the combined learning effects of engineering projects (PBL) and work placements (WIL) for preparing engineering students for professional practise. This chapter is organised around key themes identified through data analysis and answers the research sub-questions to identify learning links between engineering projects and work placements.

5.2 Themes Identified in this Research Study

The overarching aim of this research was to identify learning linkages between engineering projects and work placements in preparing engineering students for engineering practise in New Zealand. The research questions are:

Main Research Question:

> What are stakeholders' views on the combined learning effects of engineering projects (PBL) and work placements (WIL) for preparing engineering students for professional practise?

Research sub-questions:

1. What are stakeholders' perceptions of engineering students' learning through engagement with PBL and WIL?
2. What, if any, scaffolding of learning occurs between PBL and WIL?

3. What aspects of PBL and WIL are complementary (or not) in advancing student learning of the practise of engineering?

4. How can understanding the synergies and differences between PBL and WIL inform and/or enhance the engineering curriculum?

The following themes were identified through data analysis:

1. Engineering knowledge development,
   - Real-world application: Practical engineering knowledge,
   - Unexpected holistic nature of applied engineering (lack of awareness),
   - Impact of assessments,
2. Engineering skill development,
3. More challenging projects and work placements wanted, and
4. More content feedback.

The first theme, 'Engineering knowledge development', relates to engineering knowledge development through the learning process via engineering projects and work placements. In both projects and work placements, activities and tasks were designed so that students could further develop their engineering knowledge through these approaches. The sub-theme 'real-world applications – practical engineering knowledge' arises from both projects and work placements provided students with a functional working space. The sub-theme 'Unexpected holistic nature of applied engineering (lack of awareness)' is based on students' over-expectation from engineering projects and work placements. The sub-theme 'Impact of assessments' is based on lack of awareness of assessment procedures and requirements. This facilitates the linking of learned classroom theory with real-world examples. The second theme, 'Engineering skill development', relates to technical and non-technical skills being developed through the learning process via engineering projects and work placements. As both approaches provided students with engineering training practices, they developed a range of technical and non-technical skills as part of their learning experiences.

The third theme 'more challenging projects and work placements' is based on the findings that students enjoyed these learning approaches that differed from the traditional teaching-learning process. They believed that this approach would be more beneficial for them. Lastly, the fourth theme 'more content feedback' indicated that students wanted more constructive feedback from their work supervisors. Feedback on their performance, progression, and experiences may help the university and students identify their weak areas and focus on improvements (Table 5.1).

Table 5:1: Sub-research questions with their themes.

	Sub-Research Questions	Key and Sub-Themes
1.	What are stakeholders' perceptions of engineering students learning through engagement with PBL and WIL?	• Engineering knowledge enhancement • Real-World applications – Practical engineering knowledge • Engineering skill development

2.	What, if any, scaffolding of learning occurs between PBL and WIL?	• Engineering knowledge enhancement
		  • Real-World application – Practical engineering knowledge
		  • Unexpected holistic nature of applied engineering – (Lack of engineering context in work placements)
		• Engineering skill development

3.	What aspects of PBL and WIL are complementary (or not) in advancing student learning of the practise of engineering?	• Engineering knowledge enhancement • Engineering skill development
4.	How can understanding the synergies and differences between PBL and WIL inform and/or enhance the engineering curriculum?	• More challenging work placements and engineering projects • More content feedback between work placements and university

This chapter synthesises and discusses the research findings with relevant literature and aims to answer the research questions mentioned above. The chapter is divided into sections based on themes relating to each sub-question. These themes will be discussed based on the analysis of collected data, literature, the researcher's interpretations, and triangulation of these aspects to answer each research question.

5.3 Engineering Knowledge Enhancement

The literature states that work placements and engineering projects support the enhancement of engineering students' knowledge outside classroom learning, and thereby strengthens links between theory and practise (Barron & Wells, 2013; Govender & Wait, 2017; Khampirat, 2021; Simanjuntak et al., 2021; Xie et al., 2022). The findings from this thesis support this literature. Student enhancement of engineering knowledge via engineering projects and work placements are discussed in this section. Firstly, engineering knowledge enhancement via engineering projects will be discussed, followed by work placements.

5.3.1 Engineering Knowledge Enhancement via Engineering Projects

Through engineering projects, students in this study developed engineering knowledge, which was not otherwise obtained through classroom learning. This supports the work of Simanjuntak et al. (2021), Thorndahl and Stentoft (2020), and Zhou (2012) who indicated that in order to complete interdisciplinary projects, students needed to do research, self-study and understand concepts that were not taught in classroom learning. This indicates that engineering projects may aid in the development of engineering knowledge that is outside the learning scope of classroom learning. Students were provided opportunities to develop practical knowledge through engineering projects, where classroom learned theories were combined with engineering practise. Participants I.5E.1 and I.5E.2 identified that via projects, they dealt directly with real-world engineering problems that helped them to develop associated engineering knowledge via problem-solving projects, as Dita et al. (2021) also stated in their study, that projects aid in developing knowledge through problem-solving the project.

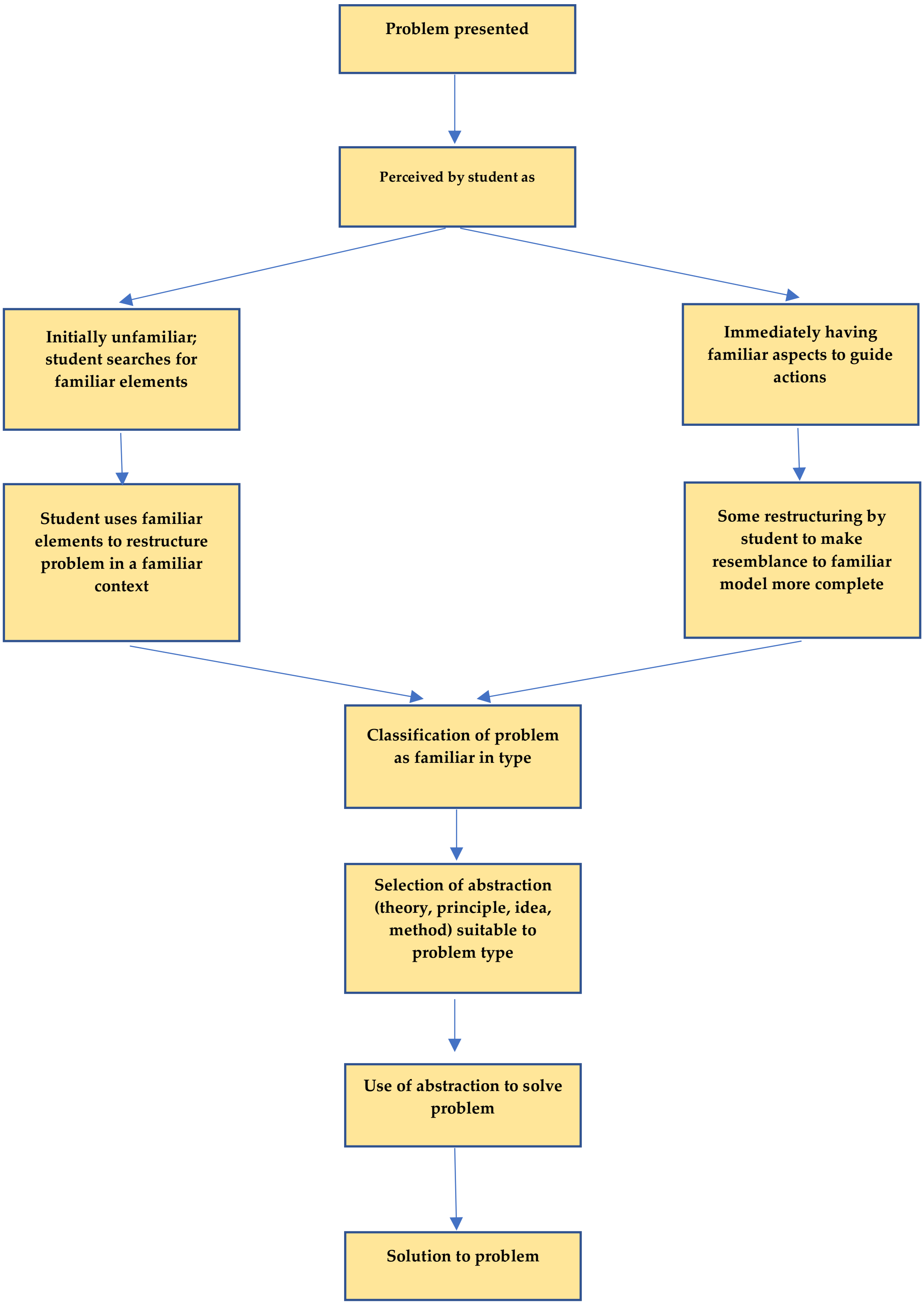
The study of Loyens et al. (2015) indicates that projects help students activate prior acquired engineering knowledge by the problem-solving process, and also help them to identify any knowledge gaps. Engineering projects act as a platform where students may apply their classroom learned engineering concepts for problem-solving the projects. Thus, in addition to further developing students' prior engineering knowledge, interdisciplinary engineering projects also encourage students to learn and develop new engineering knowledge that they may not have learned from their previous classroom learning. The development of engineering knowledge from engineering projects relates to the development of the conceptual knowledge domain (Section 2.6.1), as students practise and apply prior engineering knowledge onto projects to learn new engineering concepts. For example, Participant I.5E.1 exemplified, "I got knowledge of gear ratios and concepts of 3D Drawing and related software experience by working on my projects, and also enhanced classroom developed knowledge by doing problem-solving in projects." This also indicates that students developed procedural knowledge (know-how) of these concepts, that is, how to apply, when to apply, and where to apply these concepts so as to get desired outcomes. The combination of conceptual and procedural knowledge yields in developing the in-depth understanding of engineering concepts in engineering projects. Thus, students utilised learning from their classroom in projects, which helped them to develop engineering knowledge along with conceptual and procedural knowledge, through understanding, analysing, applying, and learning new engineering concepts.

Learning through social interaction in engineering projects is also evident from the works of Barron and Wells (2013), Bevinakoppa et al. (2016), and Zhou (2012) who state that students construct their knowledge via the application of concepts, processes, and procedures with social interaction. The data also indicate engineering projects aided construction of knowledge through the problem-solving process, which shows that engineering projects support the epistemology of constructionism. As students develop engineering knowledge and related practical knowledge through social interactions within the classroom and collaborative engineering projects, constructionism is evident in this learning process. As shown in the works of Galbin (2014), social constructionism focuses on linkages within a social environment, and an individual's role in social construction of knowledge.

In engineering projects, students jointly construct their understanding of the engineering problem posed by projects, and based on social interactions with their peers, lecturers, tools, and machinery, creating their engineering knowledge via reflection and experience. This relates to the aspects of Social Constructionism Theory (Galbin, 2014; Kynigos, 2015) because the students worked together in the construction of artefacts and engineering knowledge (Eames & Cates, 2011a; Galbin, 2014; Kynigos, 2015; Lave & Wenger, 1991). This also indicates that societal knowledge (Section 2.6.3) is developed through engineering projects, as students construct knowledge by sharing and contributing knowledge within the project groups. The engineering knowledge and skills that are socially constructed through the project's learning process may be related as the result of development of societal knowledge. Kynigos (2015) also indicated that students share concepts and collaborate construction of engineering knowledge through social interactions with colleagues, lecturers, tools, and machinery through engineering projects. The overall learning process of engineering projects links with the works of Bloom et al. (1956), where students through projects, practise to remember and understand prior classroom knowledge. Then, students apply it onto project’s problem statement, analyses it, evaluates it, and then create the solution via the overall problem-solving process.

Figure 5.1 shows the overall problem-solving or cognitive domain steps, which reflect the learning process students undertake while solving engineering problems in engineering projects.

Figure 5.1: Overall process of cognitive domain illustrated by Bloom (1956, p. 121).



The next section uses these three approaches to support further discussion around engineering knowledge development through participation in projects. These steps of problem-solving can be further sub-categorised into three aspects, as stated by Chandrasekaran et al. (2012) where learning through projects comprises of learning (pedagogy), content, and social approaches.

5.3.1.1 Pedagogical Approach

Cuenca (2010) and Hinchliffe (2000) stated in their study that pedagogy is the science of the learning process, that outlines the method and procedure of the teaching process. In engineering projects, students are given a problem statement, which defines the content and issues, and by applying self-directed learning via problem-solving favours to be an effective way of learning. Chandrasekaran et al. (2012), categorised one aspect of the problem-solving process, as learning approach, and this also specifies the way of learning process.

The findings demonstrate that learning approach can be better termed as pedagogy, because learning approach defines how the learning has to take place, which is similar to pedagogy, which emphasises how knowledge and skills can be developed in an educational context via designing appropriate teaching styles. Cuenca (2010) states that pedagogy is the act of teaching specifying how knowledge and skills are developed by social, political, psychological aspects of learners. The engineering projects are a learning approach or pedagogical tool, as they dictate how learning is facilitated, and how the learning process is structured for the delivery of teaching and student engagement. Therefore, this section is renamed as pedagogical approach in place of learning approach.

In engineering projects, the learning content is presented as a problem statement to students for investigation, where students apply a higher level of thinking to solve the given problem, as indicated in works of Bloom et al. (1956). According to de Graaff and Kolmos (2007), by presenting the content to be learned via the project's problem statement, students are encouraged to apply inquiry-based learning (section 2.8.1, Chapter 2 Literature Review), motivating them to self-direct their learning through experiences and reflections. In this study, this approach was initiated by the application of engineering projects from the engineering curriculum, where projects posed as engineering problems that students had to collectively solve via groups, through the application of prior engineering knowledge and skills, research and reflection. The pedagogical approach in engineering education facilitates the overall development of conceptual, procedural, societal, and technical knowledge domains.

5.3.1.2 Content Approach

The focus of content learning is based on teaching around the content, where specifically the content is defined (Bula, 2014). In engineering projects, the problem statements were based on the content that was taught in class, and on the content yet to be learned to solve identified problems in the projects, as shown by Bloom et al. (1956). Engineering projects occur within and across different engineering disciplines, such as mechanical-, civil-, electronics-, electrical-, and software engineering. If more engineering content is added when setting and defining the problem statement of the project, that is, by making the project interdisciplinary in engineering, then more contextual learning can be promoted via their problem-solving in projects (de Graaff & Kolmos, 2007; Zhou, 2012). Therefore, if engineering projects are designed based on content to be enhanced and developed, then accordingly students' overall engineering knowledge development can be promoted. Thus, by content approach, the focus can be laid on developing the specific learning content, by carefully prototyping the problem statement of the project, in order to reflect the required content to be studied and learned. Through content approach, the development of conceptual and procedural knowledge is achieved in engineering projects.

5.3.1.3 Social Approach

Social learning comprises of the learning process happening with social interactions with peer students, lecturers, project managers, and via machines/equipment (Kuppuswamy & Mhakure, 2020), along with incorporating learning (pedagogy) and content approaches. These elements socially work together in constructing the engineering knowledge within the social environment, while incorporating learning, content, and social approaches together. The social approach is an important aspect, as this approach impacts the people and environment with the development of new knowledge. The social approach plays a critical role in the construction of understanding of how the social world is organised and regulated. Here in engineering education, engineering projects and work placements are two approaches where students work in a social environment, and develop engineering knowledge and skills, which they then further apply back in social environment. As the social approach promotes development of engineering knowledge in engineering projects, it therefore indicates that the societal knowledge domain is developed in this learning process. The developed engineering knowledge and skills through engineering projects can be considered as the result of development of societal knowledge, as engineering projects happen in a social environment. The developed knowledge and skills are then further shared and collaborated with others through social interactions, which further aids in social construction of knowledge. Therefore, social knowledge is impacting the people and environment with development of knowledge.

5.3.1.4 Combining Pedagogical, Content, and Social Approaches

The combination of pedagogical, content, and social approaches together define the holistic learning process that takes place through engineering projects (Bloom et al., 1956; Chandrasekaran et al., 2012), as shown in Figure 5.2.

Figure 5.2: Engineering project in terms of pedagogical, content, and social approaches.

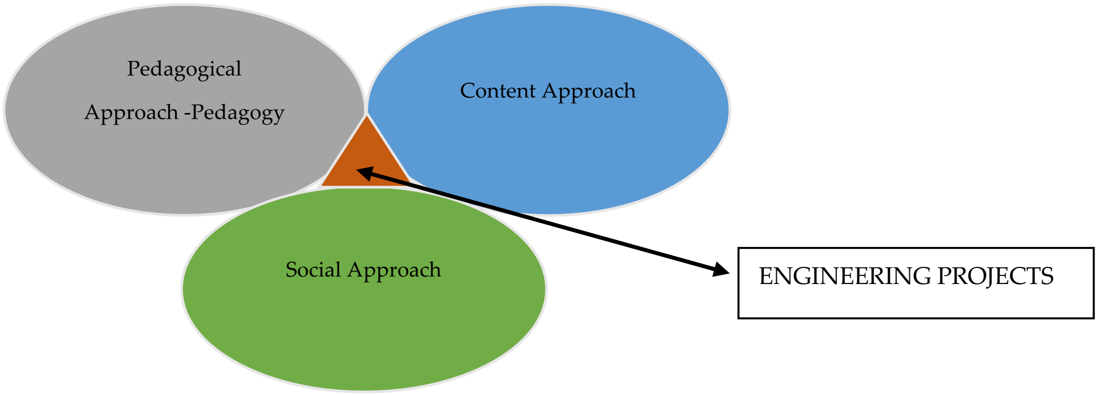


Figure 5.2 illustrates the interconnected nature of the three aspects of learning in relation to engineering projects. Students are given a problem statement to be solved as a collaborative project, the nature of which specifies the pedagogical approach, as this shows that students have to learn about engineering concepts by problem-solving the given engineering project. Here, this approach is inquiry-based learning via projects. Students also need to work in groups, collaborate their research findings about the problem statement and related engineering concepts, undertake group discussions to select relevant engineering concepts, and then, by critical thinking and application, undertake problem-solving for finding the required solution (Chandrasekaran et al., 2012; Kuppuswamy & Mhakure, 2020; Wood, 2008; Zhou, 2012). This approach promotes linking of prior acquired engineering knowledge with the given project's problem statement, and that promotes linking of theory with practise (Uziak, 2016).

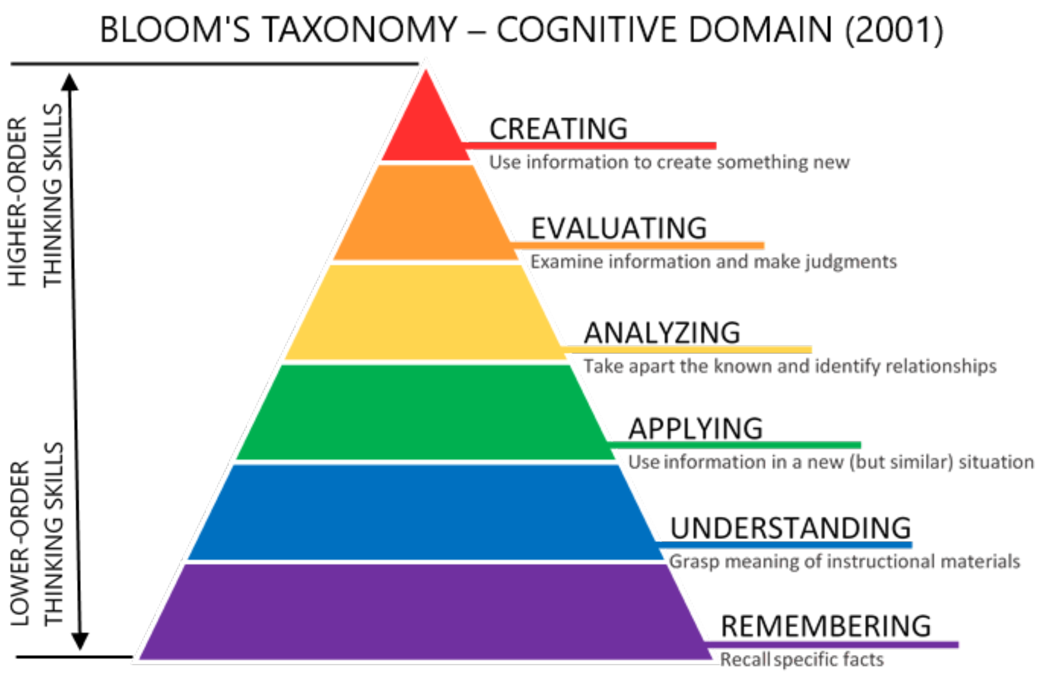
Additionally, the project's problem statement is designed and defined in such a manner that it reflects the previously learned theoretical contents through classroom learning. The problem statement is so designed to reflect the interdisciplinary engineering aspect. The works of Barron and Wells (2013), Bevinakoppa et al. (2016), and Chen (2008) indicate that the problem statements should reflect the content that students need to self-learn through reflection, application, and experience, while problem-solving the project. This relates to the development of conceptual and procedural knowledge domains through engineering projects.

Lastly, students work in groups collectively and collaboratively, with the common goal to address the given engineering problem and find its working solution. Students communicate within their groups, other students, experts, and lecturers, as they engage with tools and machinery to socially construct their solutions and knowledge. Chandrasekaran et al. (2012) also indicated that students socially construct their knowledge while working in a social environment of projects, through collaborating with tools and artefacts available in the learning environment. This relates to development of the societal knowledge domain through engineering projects, as the learning and the knowledge construct is happening in a social environment through social interactions with the environment, tools, and artefacts.

In sum, students bring classroom learned concepts to projects, where they further develop their engineering and practical knowledge, with the help of pedagogical approaches, their peers, lecturers, tools, and machineries in a social environment, in order to collectively construct students' reality or engineering knowledge. This is supported by participant I.3E.2 who indicated that through projects, he further enhanced his engineering knowledge collectively with the help of his lecturer, group members, and peers. This also indicates the epistemology of constructionism underpinning this study.

Additionally, on deeply analysing the problem-solving steps in engineering projects, this study interprets that the engineering projects correlate with Bloom's taxonomy structure. Engineering projects activate higher levels of Bloom's taxonomy during its problem-solving process. Hyder and Bhamani (2017) stated that the engineering project's problem-solving process encapsulates Bloom's taxonomy, showing levels of higher-order thinking skills in projects. The learning process in engineering projects may be explained starting from the lower levels to higher levels of Bloom's taxonomy (Figure 5.3).

Figure 5.3: Bloom's taxonomy diagram adapted from Information Technology, University of Florida (Krathwohl, 2002, p. 1).



The lowest level or first level 'Remembering', second level 'Understanding', and third level 'Applying' relates collectively to a form of recalling previous engineering concepts learned during prior classroom learnings, engineering projects, and work placements. Students remember their previously learned engineering concepts and skills, understand their background and application, and then analyse them to apply to the given engineering problem, as also evidenced by Participant I.5E.2 in Section 4.4.1.3.1.2. Participant I.5E.1 also indicated the authenticity and working of the design concept is evaluated via application to the given engineering problem – whether it completely solves the problem or not. The first, second, and third levels focus on remembering the engineering concepts learned prior and stored in students' conceptual, procedural, and technical knowledge domains.

The fourth level, 'Analysing' involves extracting more information about the engineering concepts, that is, researching the concepts to determine the critical relationship to the problem statement, and how appropriately it would solve the problem? Participant 1.3E.1 (Section 4.4.1.2.1.2) also identified that he and his team had to critically think around the problem statement and related engineering concepts, to decide their solution framework (design parameters) for the project. The fourth level utilises students' conceptual and procedural knowledge domains for analysing the engineering concepts relevant to the engineering problem. For the second level, 'Evaluation', students carefully study the matching engineering concepts to see what is relevant to the given project's problem statement. This indirectly aids application of classroom learned engineering concepts onto projects. In this study, it was evidenced that I.3E.2 and other students (Section 4.4.1.2.1.2) related their previously acquired classroom engineering knowledge with their engineering projects by the application of critical thinking and problem-solving skills. The fifth level applies students' conceptual and procedural knowledge domains to create linkages between the previously learned engineering concepts and problem statement.

The top level or sixth level, 'Creating', can be referred to as creating a solution from the available understanding and application of the engineering concepts – this can relate to the presentation of the solution for the problem statement of the engineering project by the students. The top level applies all the knowledge domains (conceptual, procedural, societal, and technical) in creating the solution of the problem statement by utilising the problem-solving process along with the application of engineering concepts. Therefore, by applying all the lower levels of Bloom's taxonomy, students create the solution framework to address the given engineering problem, and accordingly, students progress in their learning process through projects. These levels of Bloom's taxonomy demonstrate a relation with the learning process of engineering projects while students attempt to solve the project's problem statement via critical thinking, analysis, application, reflection, and experience building (Kuppuswamy & Mhakure, 2020). The engineering projects cater to the higher level of thinking because the students must design and create a successful outcome for an authentic engineering problem.

Engineering projects also appear to provide additional sequencing of scaffolding with classroom learning by providing a practical learning opportunity, which is not available in classroom boundaries. This can be exemplified by one participant I.3E.2, who stated in Section 4.4.1.2.1.2 that by doing projects, he was able to learn about 3D drawing and designing concepts, which were not taught in class until project learning. This finding supports the idea that engineering projects deploying the PBL paradigm scaffolds classroom learning to provide students with practical learning and engineering knowledge outside classroom learning (Education Reform, 2015; Gita & Apsari, 2017; Greening, 1998). The way engineering projects provide sequencing of scaffolding of practical learning aspects to classroom learning, indirectly indicates that engineering projects are a pedagogical approach to learning through practical application.

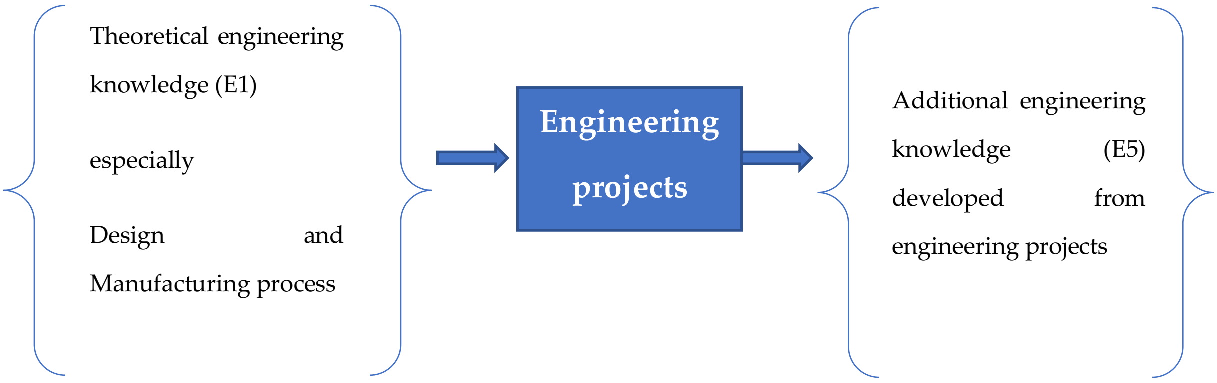
Based on the findings, this study suggests that classroom learning has a major limitation by not providing a practical learning environment within its closed boundaries, whereas projects mostly occur outside the classroom environment. Additionally, projects may be interdisciplinary in engineering, which may benefit students by developing engineering knowledge outside classroom learning and their field. Engineering projects may be interdisciplinary across engineering (Feisel & Rosa, 2005), and thus, incorporate various fields of engineering, possibly providing students with the opportunity to work on practical aspects outside area field of specialisation. By doing so, students develop engineering knowledge that is not covered in their classroom learning, thereby encouraging them to develop conceptual, procedural, and technical knowledge domains through projects.

In addition, the data suggest that students also applied their project-acquired engineering knowledge to further classroom learning, and subsequent engineering projects. For example, participant I.5E.1 (Section 4.4.1.3.1.3) stated that while he was doing his project, he learned about gear ratios, which was not taught earlier in the classroom. Once that participant completed his project, he was able to bring this knowledge to his classroom learning in a future course, thereby enhancing his understanding. Additionally, lecturers indicated that students were more confident in some engineering concepts/theories after undertaking their engineering projects. Students recounted that certain engineering projects helped them to understand the theory by practise. This supports the studies of Bevinakoppa et al. (2016), Dahms (2014), Guzelis (2006), and Zhou (2012), where this study indicate that engineering projects enhance previous classroom developed knowledge by performing problem-solving of the given authentic problem in the project. The triangulation of the findings, analysis, and researcher’s interpretations shows that engineering projects provided scaffolded support to the classroom learning.

The findings indicate that there are learning linkages between the classroom learning and engineering projects, in terms of engineering knowledge and skill development.

Classroom learning gives the basic engineering knowledge, which students then take to their engineering projects for further application and development via the problem-solving process. As presented in Chapter 4 Findings, from classroom learning students develop their foundational engineering knowledge and concepts, along with design and manufacturing concepts, which they then take to their engineering projects (Figure 5.4).

Figure 5.4: Learning linkages between classroom learning and engineering projects.



Note: E1 = Classroom developed engineering/theoretical knowledge

E5 = Engineering project developed engineering knowledge

In engineering projects, students identified the linkage between classroom learned theory and the project's problem statement. Participant GC.2 (Section 4.4.2.1.2) shared that the engineering projects mostly reflected their classroom learned theories and engineering curriculum, which helped them to enhance understanding of their classroom developed knowledge. Engineering concepts like design and manufacturing, 3D or technical drawing, mathematics, and statistics, which were learned through classroom learning, were applied in engineering projects by students. By recalling the previously learned engineering concepts and applying it onto projects, this aided students to further develop their engineering knowledge. This indicates that students developed their conceptual knowledge domain of the above-stated engineering concepts, and also procedural knowledge domain (know-how) of these concepts.

Additionally, if the projects are interdisciplinary in engineering, then students develop new engineering knowledge through self-study, application, reflection, and experience building. Participant I.3E.3 (Section 4.1.1.1) undertook an interdisciplinary project including mechanical, electronics, and software engineering, which helped her to develop new engineering knowledge outside her area of study. The project likely developed engineering knowledge (E5) that can then be taken back to classroom learning and was not knowledge developed through classroom learning. The learning outcomes from projects indicate that conceptual and procedural knowledge domains were developed by students while undertaking engineering projects and were taken back to their classroom learning. Seeing this relationship, this study anticipates that engineering projects complement classroom learning by offering development of engineering knowledge (conceptual knowledge domain) otherwise not possible in classroom learning.

5.3.2 Engineering Knowledge Enhancement via Work Placements

Students' perceptions also indicated that WIL aided in the development of engineering knowledge that was not taught in either classroom learning or engineering projects. This might be because work placements covered a wide variety of engineering aspects and disciplines such as electrical, mechanical, civil, computer software, and electronics engineering. Such interdisciplinary exposure through work placements assisted the students to develop a vast variety of engineering knowledge, including engineering knowledge around and outside their area of specialisation. Even Mackaway, Winchester-Seeto, Peach, et al. (2014) indicate in their study that work placements offer a wide variety of knowledge, which may be outside the learning scope of classroom studies, as work placements are mostly interdisciplinary in engineering.

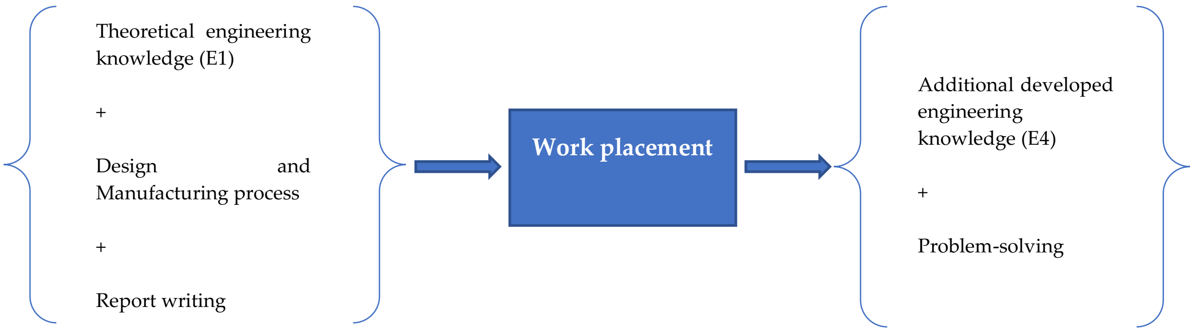
In the classroom learning, students learn about basic engineering theories such as design and manufacturing, 3D or technical drawing, mathematics, and statistics, which students then take chronologically to their engineering projects. Participant I.4E.1 (Section 4.5.1.2.1.2) indicated that he was able to apply previously learned engineering concepts from classroom learning and engineering projects onto work placements. Students learn about different engineering concepts in their classroom learning, which specifies that students develop conceptual and procedural knowledge domains from classroom learning activities such as tutorials, brainstorming sessions, icebreaker sessions, problem-solving sessions, and peer review sessions. These approaches aid in developing students' understanding of engineering concepts, where they are applied, how they are applied, and why they are applied, which indeed aids in developing their conceptual and procedural knowledge domains. Additionally, students apply these knowledge domains further into their engineering projects, specifically into the problem-solving process.

The previously learned engineering concepts from classroom learning and engineering projects were then further enhanced and developed through work experiences. Participant I.4E.1 exemplified that he was able to apply previously learned design concepts onto his work placements and was able to enhance his command of Solid Works software. Through the work placement approach, students were given the opportunity to apply their previous learnings onto authentic engineering applications available in the workplace. Another Participant I.3E.1 shared that he gained typical engineering knowledge such as quality control measures, universal standards, and gear ratios from work placements, which he then took to his classroom learning and engineering projects.

Dressler (2011), Ferns et al. (2014), and Hills et al. (2011) argue that work placements provide students greater understanding of their classroom learned theories, and aid in developing new engineering knowledge outside classroom learning. In this study, mechanical engineering students had different mechanical engineering work placements, such as industries based on design and manufacturing, HVAC, and construction, which aided in developing their engineering knowledge related to these aspects. Also, these work placements were interdisciplinary in engineering, therefore these learning experiences helped students to develop engineering knowledge outside their classroom learning outcomes. This therefore, outlines that by undertaking work placements, students develop new engineering knowledge (conceptual and procedural knowledge domains), depending upon the interdisciplinary nature of the workplace.

Thus, students had access to interdisciplinary engineering knowledge and related skill development which were not available from their university studies. This aligns with the literature as stated in the works of Jackson (2013), Kaider and Bussey (2018), Keating et al. (2008), Merriam (2020), and Ruskin et al. (2018) who suggested that work placements (WIL) provides engineering knowledge and skill development which is not developed through the university studies alone. Participants I.4E.1 and I.4E.2 indicated that they developed additional engineering knowledge (conceptual knowledge domain) from work placements, which they were able to apply back in their university classroom learning and engineering projects. Such knowledge acquisition from work placements likely helped them to work more efficiently in their engineering projects. The learning progression between classroom learning and work placements, based on students' perceptions is shown in Figure 5.5.

Figure 5.5: Learning linkages between classroom learning and work placement.



Note: E1 = Classroom developed engineering/theoretical knowledge

E4 = Work placement developed engineering knowledge

Students developed foundational engineering concepts from classroom learning, which they then took into their work placements. These foundational engineering concepts (conceptual and procedural knowledge domains) can be considered as theoretical knowledge (E1) along with design and manufacturing knowledge, report writing skills, and specific conceptual knowledge (course specific). In work placements, students may have opportunities to relate classroom learned theory with the real-world applications available in the workplace and can thereby further develop a deeper understanding of engineering theory. Participant I.4E.3 indicated that in their work placement, they worked on fabrication and design works, which enhanced their theoretical understanding related to design and manufacturing concepts (conceptual and procedural knowledge domains).

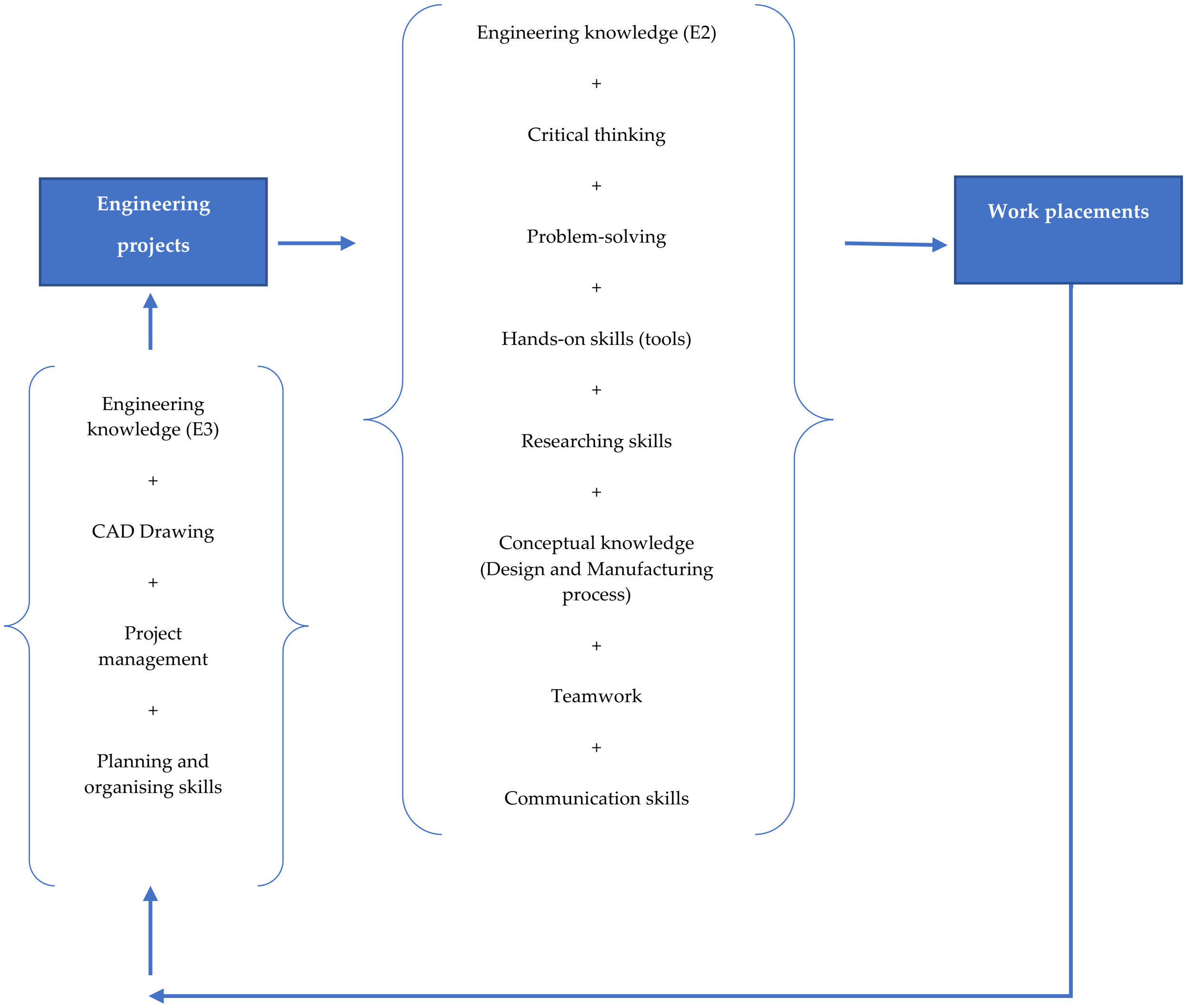
Additionally, students may have also developed new engineering knowledge from work placements, as workplaces are diverse in nature, comprising interdisciplinary engineering fields. Participant GC.1 shared that via work placement, he developed new knowledge around ISO Standards, technical drawing concepts, and 3D drawing concepts. Thus, the new engineering knowledge developed through work placements can be related to engineering knowledge E4, as shown in Figure 5.5. The works of Mutereko and Wedekind (2015), Winchester-Seeto et al. (2020), and Nuninger and Châtelet (2011) align with the findings of this study that work placements provide deeper understanding of prior acquired knowledge, and aid in development of new knowledge through engagement in work placements. Work placements provide opportunities for students to apply their previously developed classroom knowledge onto workplace application, encouraging students to relate theory with practise, thereby, enhancing their prior knowledge. Additionally, work placements also aid in developing new engineering knowledge (conceptual and procedural knowledge) by the work experience provided by the workplace, and is also dependant on the interdisciplinary nature of the workplace.

There is a progressive flow of conceptual and procedural knowledge from classroom learning to engineering projects and work placements, where the classroom developed knowledge is further developed and enhanced by practise in projects and work placements. This specifies that development of conceptual and procedural knowledge domains is facilitated between the experiences of classroom learning, engineering projects, and work placements. Additional to conceptual and procedural knowledge domains, the societal knowledge domain is also developed by these approaches, as here, the learning process happens with social interactions in an authentic learning environment. Students socially interact with their lecturers, peers, tools, machinery, and their environment, which facilitates in the development of social knowledge by sharing and collaborating concepts. Thereby, societal knowledge domain development is evident in the learning process of engineering projects and work placements.

One of the work placement supervisors I.WS.1 stated that students were able to reflect and apply their prior learning in engineering (conceptual knowledge domain) in our workplace, and they further developed understanding of those theories via practise. This suggests that there was flow of engineering knowledge from engineering projects to work placements. Additionally, as students work on real-world applications and/or industrial projects, they might develop additional engineering knowledge (E3) as shown in Figure 5.6, along with 3D Drawing capabilities, project management, and organising skills. The development of these skills is evidence that students develop the know-how of these skills (procedural knowledge domain) and knowledge of how to apply these skills in real world (technical knowledge domain). As these skills were developed in a social environment, an aspect of societal knowledge domain is also evident here. Students socially interact with tools and artefacts in the learning environment of projects and work placements, therefore, that aids in developing skills because of development of the societal knowledge domain. The learning process between engineering projects and work placements is shown in Figure 5.6.

As also indicated by one of the University lecturers I.LC.4, students may learn different engineering knowledge based on the discipline of the work placement. This new engineering knowledge (E3) will be student's learning outcomes from work placements, which they will then take back to their engineering projects for further application. This supports the theory of constructionism (Galbin, 2014; Kynigos, 2015), because successful students experience social interaction through a range of learning approaches: classroom learning (lectures, tutorials, assignments, seminars), engineering projects (technical projects in first, third and fourth years of engineering study), and work placements (400 hours of work placements in second and third years of engineering study) to develop engineering knowledge and skills.

Figure 5.6: Learning linkages between engineering projects and work placements.



Note: E2 = Engineering project developed engineering/theoretical knowledge

E3 = Work placement developed engineering knowledge

Through these social learning environments providing authentic learning experiences to students, knowledge is socially constructed through these approaches, which aids in developing students' overall knowledge and skills (also developing conceptual, procedural, societal, and technical knowledge domains). Similarly, as students apply their engineering knowledge to their tutorials, assignments, engineering projects and work placement applications, they action classroom learning further through application, reflection, and experience.

5.3.3 Real-World Application: Practical Engineering Knowledge

Barron and Wells (2013) and Ferns et al. (2014) indicated in their studies that both work placements and projects offer practical learning experiences to students through their authentic learning process. Work placements help students in developing their graduate profile through encouraging learning via application of engineering knowledge and skills, reflection, and work experience (Doolan et al., 2019b; Govender & Wait, 2017; Jackson et al., 2022; Khampirat, 2021; Male, 2017; Pažur Anicic & Divjak, 2022; Winchester-Seeto et al., 2020). Similarly, engineering projects apply strategy where universities align courses with real-world applications and students can develop their knowledge and skills (Bevinakoppa et al., 2016; Gewurtz et al., 2016; Karim et al., 2019; Kuppuswamy & Mhakure, 2020; Loyens et al., 2015; Pereira et al., 2017; Uziak, 2016).

Analysis of the findings indicate that current engineering students felt they enhanced their practical knowledge through participating in projects and work placements. They stated that projects were more related to their engineering context, as they were designed by staff and derived from the theories and concepts students learned from their classroom studies. Interestingly, the recent graduates also indicated that projects helped them understand core engineering knowledge and concepts the most. This indicates that projects aided in developing conceptual and procedural knowledge domains of students and graduates. On the other hand, graduates indicated that work placements did not help much to enhance their practical engineering knowledge. Most graduates indicated that they were required to do some non-technical work in their work placements, because of which, they could not develop and enhance technical practical knowledge. University lecturers and workplace supervisors agreed with the point that engineering projects enable students to deepen their engineering knowledge, both theoretically and practically. This is because engineering projects are designed based on the lecture tutorials covered in classroom learning or the University's engineering curriculum.

Each engineering project reflects the prior engineering theories learned in classroom learning. That is, engineering projects can be designed based on specific engineering theorems and concepts that students learned in their classroom. This may promote students to apply those specific engineering theorems and concepts to the project’s problem-solving process. Engineering concepts such as design and manufacturing, 3D or technical drawing, mathematics, statistics, and structures, which were learned in classroom teachings, were applied in engineering projects. Thus, engineering projects seemed to help students directly relate previously developed classroom engineering theories with practical knowledge, promoting linkage between theory and practise. Whereas for work placements, current students and recent graduates indicated that their work placements did not fully cover their mechanical engineering aspects. Some suggested that their placements were not very technical, as they were made to do office and administrative jobs.

However, there is a difference between projects and work placements, which students and graduates may not yet have identified. That is, engineering projects are restricted to the engineering curriculum. In contrast, the main aim of work placement is to enhance overall employability skills, and thereby, enhance students’ conceptual, procedural, societal, and technical knowledge domains. Through work placements, students and graduates work under expert supervision and get hands-on work experience, including developing technical and non-technical skills along with procedural and technical knowledge of the skills. In work placements, students have been exposed to all aspects of work, including technical and non-technical positions. By undertaking a range of higher and lower levels tasks, students may develop underlying skills. For example, by doing office-type tasks, students may enhance transferable skills such as communication, IT, time management, planning and organising, and presentation skills. From their work placement experience, students gain exposure to all aspects of work, including working in technical and non-technical positions. Development of these skills specifies that students develop the procedural knowledge (know-how), societal knowledge (knowledge developed due to social interactions), and technical knowledge (process and methods to apply skills) of these skills through work placement experiences. In this study, students and graduates expected to do only technical work during a work placement; however, this may indicate misconceptions of workplaces and a lack of awareness of the real-world nature of engineering workplaces.

Vaaland and Govender (2018), Batholmeus and Pop (2017), Jackson (2017), and Khampirat (2021) stated that work placements usually are directly related to the disciplinary context and, therefore, impart technical skills and knowledge. Findings of these researchers contradicts with the perceptions of students on work placement learning, as students did not identify links of prior classroom knowledge with workplaces. Engineering is a vast field, and within it comes mechanical engineering, which again has a vast variety of concepts and theories. It is unlikely that all content theories be available in one work placement, as work placements may be of a particular kind, focusing on a particular field. For example, workplaces under mechanical engineering include: manufacturing, building and construction, building services, product development, aviation, boat building and transport, agriculture, water and waste water, and the energy sector (Careers Govt NZ, 2021). Mechanical workplaces could be in any one of these fields and they may work on different mechanical engineering contents and theories. Therefore, it is unlikely that students will be exposed to a wide range of engineering concepts from one work placement. Each work placement will differ with the quantity of technical and non-technical work, depending upon the specific mechanical engineering field.

Work placement focuses on developing graduate learning outcomes in students, by blending theoretical concepts with practise-based learning, that is, working under supervision (Ferns et al., 2014). As work placements occur in authentic workplace surroundings, students get real exposure to the workplace setting and are able to practise working in a professional manner with engineers. This was illustrated in this study by Participant I.4E.2 who stated that his work placement provided him an opportunity to work on extensive tools and machinery, which were not available in the University's laboratory. Participant I.4E.1 stated that by working on some industrial projects in his work placement, he was able to master his 3D Designing and Drawing abilities via Solid Works and Auto-CAD software (procedural and technical knowledge). As Participant I.4E.1 received technically difficult designs to draw on software, it challenged him to work on them, with help from his supervisor (societal knowledge). This shows that Participant I.4E.1 worked in a social environment, utilising tools such as the computer and with colleagues, supervisor, and machinery, to satisfy his job role. This further supports the theoretical perspective and epistemology of constructionism in this study, as students construct their knowledge and skills by working socially in an authentic learning environment provided by work placements. This shows that both engineering projects and work placements provided students with the opportunity to develop practical engineering knowledge, which was not achieved by classroom learning alone. The learning process in engineering projects and work placements facilitated students' progressive learning through conceptual, procedural, societal, and technical knowledge domains.

5.3.4 Unexpected Holistic Nature of Applied Engineering (Lack of Awareness)

Engineering is a practical field where technological, scientific, and mathematical principles are applied to design solutions for problems (Bokova, 2010; Mannan, 2014). Due to the practical nature of engineering education, it requires professional training of engineering students during their undergraduate studies in order to support them to be work-ready graduates (Ali, 2014). The engineering students' professional training includes the development of technical and non-technical skills through engineering practise. Engineering students should be trained to deal with traditional engineering problems where human and environmental factors are major components (Kirn & Benson, 2018; Russell Iii et al., 2021; Subramaniam et al., 2020). In order to achieve this objective, active learning is introduced through several approaches, with PBL and WIL prominent (Bosman & Fernhaber, 2018; Murugesan, 2019). In this section, students' perceptions are discussed based on their experiences with engineering education, engineering projects, and work placements. Participants in this study identified a number of perceived limitations of each of the learning approaches undertaken in this programme. The limitations of the teaching and learning approaches as identified by the students are shown in Table 5.2.

Table 5:2: Students' identified limitations of classroom learning, engineering projects and work placements.

Serial No.	Approach	Limitations	Students' quotes
1.	Classroom learning (University)	No technical skills from university	"University was not able to provide some core technical skills, which was required in my work placement"
2.	Work placement	Non-technical context of work placement	"Sometimes work placements were not directly related to some engineering concepts"
3.	Work placement	No timeline in work placement	"There was no proper plan or schedule to show what work we will be doing this week or next week"
4.	Classroom learning (University)	No practical knowledge from classroom learning	"University did not provide much practical knowledge"
5.	Engineering projects (University)	No practical knowledge from projects	"Projects did not provide much practical knowledge"

The first limitation was that the university was not able to provide some core technical skills that were required in that student's work placement. University classroom learning provides the fundamental engineering concepts and theories (conceptual knowledge domain), which help students form their engineering knowledge foundation. After gaining this insight, students then undertake their engineering projects, where they apply classroom learned theories to given engineering problems. After this approach, students experienced work placements, where they worked under expert supervision, in authentic workplace settings. The hierarchical structure of the learning approaches, based on the participating university's engineering education curriculum is shown in Figure 5.7.

Figure 5.7: Hierarchy of learning approaches in engineering education.

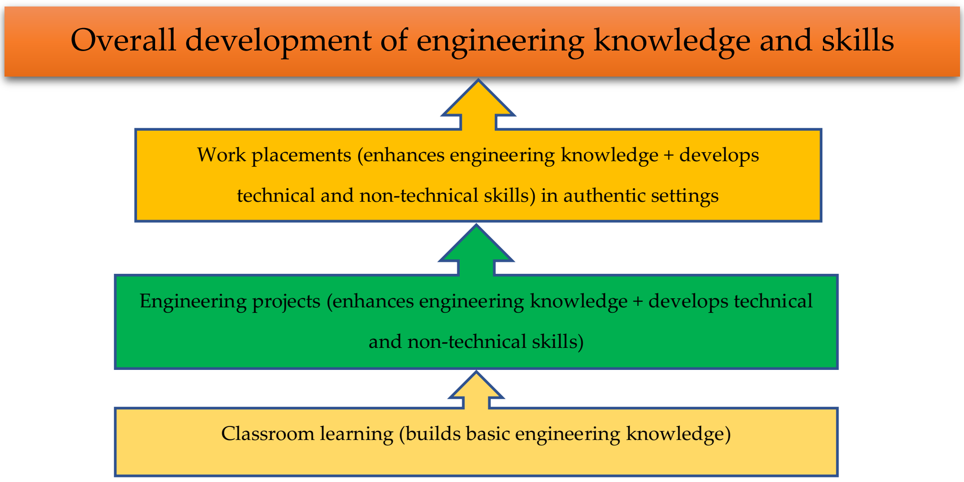


Figure 5.7 illustrates that classroom learning provides basic understanding of engineering concepts that are necessary for students to understand the key theoretical aspects of engineering, and thus develop their engineering knowledge foundation (conceptual and procedural knowledge). Classroom learning cannot include aspects of practical engineering knowledge; following Bloom's taxonomy stages, thus, engineering projects are introduced to facilitate higher learning through:

- creating problem statement,

- evaluating underpinning engineering theory/concept,
- analysing engineering concept along with problem statement to create design concepts,
- applying design concepts onto problem statement,
- understanding from the reflections based on application of design concepts onto the project's problem, and
- remembering the findings from their projects.

Learning through engineering projects offer opportunities for Bloom's taxonomy higher order learning (Figure 5.3). This learning from engineering is not only limited to development of engineering knowledge (conceptual knowledge domain), but also accompanies development of technical and non-technical skills such as teamwork, communication, and interpersonal skills (development of procedural, societal, and technical knowledge domains). The knowledge of how to apply these skills refers to the procedural knowledge domain, whereas the knowledge developed by applying teamwork, communication, and interpersonal skills in a social environment may be related to the societal knowledge domain. The practical knowledge associated with skills to apply in practical techniques relates to the technical knowledge domain. The development of procedural, societal, and technical knowledge domains together constitutes the development of technical and non-technical skills via engineering projects.

However, engineering projects are set within laboratory boundaries in the University setting, which therefore, pose limitations. Universities cannot provide heavy industrial based real projects within these settings, unless there is provision for alternative approaches such as Simulated WIL or work placements (Batholmeus & Pop, 2017; Bosco & Ferns, 2014; Jollands, 2016). The University in this study used work placements, where students are intended to work in real work environments, under supervision with the opportunity to relate engineering theory with real-world applications. The University in this study mainly provided engineering theory and concepts (conceptual knowledge domain) via classroom learning, followed by some opportunities for students to apply their previously learned engineering knowledge through engineering projects.

Through engineering projects, students further developed their engineering knowledge (conceptual knowledge domain) and acquired technical and non-technical skills (procedural, societal, and technical knowledge domains). But due to the scope and critical extent of the limitation of engineering projects, industrial level project exposure could not be provided within the University's laboratory setting. Participant I.GC.1 lacked understanding of this limitation of the University's engineering projects, therefore, he said that the University had not provided him with the technical skills (related to 3D drawing – ISO standards) that were needed in his work placement. Participant I.GC.1 may not have recognised that work placements were introduced so that students could learn interdisciplinary engineering knowledge and receive assistance in developing technical, non-technical, and employability skills, that could not be taught in classroom learning.

In Table 5.2, the second limitation identified was the non-technical context of work placement. This was exemplified by a student who stated that his work placement experience included working on non-technical work roles. The student indicated that his work role was non-mechanical engineering based, that is, his work role lacked aspects of mechanical engineering. The student also shared that not all classroom engineering concepts were reflected in his work placement. This again suggests the students' lack of awareness of the role of work placements, their procedures, and processes. Work placements provide students with opportunities to develop and enhance their technical and non-technical skills, for which they sometimes may be needed to do non-technical works. This student may have lacked the understanding of the importance of non-technical skills in engineering workplaces. Additionally, as this student was from the mechanical engineering department, he therefore, may have expected to do only mechanical-related work roles. Data from this study suggested that students did not fully understand the work placement process, and they had an over-expectation of covering all aspects of mechanical engineering from a single workplace and had the misconception that all mechanical engineering contexts can be covered from individual work placements. This suggests a lack of understanding and awareness of work placement structures. Each workplace may specialise in different aspects of mechanical engineering, thus, in one work placement, it is not possible to have access to all these aspects of mechanical engineering. If students have access to more variety of mechanical work placements, with more student-centred work roles there, then that would have benefitted students with more knowledge and skills acquisition, which is also supported by the works of Mackaway, Winchester-Seeto and Carter (2014), who stated that work placements offer students practical hands-on work experiences, which indirectly helped in developing their workplace knowledge and skills.

The third limitation identified was that there was no weekly schedule in the work placement. This was exemplified by a student who stated that in his work placement, there was no information on weekly scheduling or planning of work. This also suggests a lack of awareness of work placement activities, and possible over-expectation of work placements. Work placements, as stated before, are authentic work environments, where students work under professional guidance and supervision. Students may have expected that they will be briefed each and every time with the upcoming workloads and duties. Sometimes, students may need to initiate discussion with their supervisor to check what upcoming works are there for them.

By this, the supervisors may realise and understand students' interest, commitment, enthusiasm, and eagerness to work in that work placement.

In order to provide a wide exposure of tasks to students in a range of workplace contexts, it would be difficult to provide them with a pre-determined schedule or weekly plan. Workplaces may have crucial industrial projects underway, which may be subject to improvisations, complex scheduling, man-power requirements and other unknown factors. Depending upon these changing factors, it is not always possible to predict what each student's work will be for any specific week or for following weeks. Students may have raised the concern of no pre-determined workload schedule or weekly plan for them because of this lack of understanding of the complex nature of engineering practise, and awareness of how workplaces function. According to Rowe and Winchester-Seeto (2021), a detailed orientation and induction detailing the work placement process, work schedule, what to expect, how work placement works, and how workplace experiences will build their learning outcomes, are given to students prior to commencement of their work placements. Such a pre-activity approach would make students aware of the workplace learning process. Additionally, constructive feedback from academic and workplace or industrial supervisors would also facilitate students' learning progress, wellbeing, and enhance their overall learning process.

The fourth and fifth limitations indicate that both classroom learning and engineering projects did not provide opportunity for learning sufficient practical engineering knowledge. As suggested in Figure 5.7, classroom learning provided students with foundation engineering theories and concepts. Subsequently students start to build their core engineering knowledge. The literature states that methods used in the classroom for students' learning process are likely to be a blended form of teacher-centred and learner-centred learning. Teacher-centred is where the teacher is the master of the subject and students are presumed to be passive and copious recipients of knowledge from the teacher such as in lectures (direct face-to-face or via online delivery). Learner-centred is where the teacher is both a teacher and a learner, thereby shifting the instructional-based passive learning to students' active learning through approaches such as inquiry-based learning (Djenic & Mitic, 2017; Murugesan, 2019; Net, 2021) and experiential learning (Dewey, 1938b; Kolb, 1984b; O'Flynn et al., 2021; Rapaport, 2013).

In teacher-centred classroom learning, there is limited opportunity to develop Bloom's higher-level skills through intense practical learning. Much theoretical learning and understanding happens in the classroom through a teacher-centred approach. Despite ample evidence that student-centred learning is more effective (Al-khresheh, 2022; Bubnys, 2014; Lahdenperä, 2019), in order to complement this minimal uptake of practical engineering knowledge development, along with lecturing, experiential learning through engineering projects and work placements were considered to facilitate deployment of higher-level thinking and motivate students (Bevinakoppa et al., 2016; Govender & Wait, 2017; Pereira et al., 2017). While participating in projects, it was intended that students gain practical engineering knowledge, connect classroom learning with real-world applications or practise, and strengthen their understanding of engineering theories. However, some participants in this study indicated that they did not obtain much practical engineering knowledge from engineering projects. This suggests that students may have gained practical engineering knowledge but did not realise it. Students may not have identified a specific learning outcome as practical engineering knowledge, and, thereby, could have indicated that they did not experience development of practical engineering knowledge through projects. They also appeared to be unsuccessful in understanding that projects happen in university laboratory settings with several limitations such as a lack of:

- industry-level critical projects;
- industrial level machinery, tools, and equipment;
- highly skilled professionals/colleagues to work alongside;
- challenging engineering problem-solving opportunities.

Students were likely unsuccessful in understanding that to complement these shortfalls, work placements were introduced to provide students exposure to aspects that cannot not be replicated in a laboratory setting. The works of Batholmeus and Pop (2017), Bosco and Ferns (2014), and Jackson et al. (2022) also indicate that work placements provide students with industrial exposure that enhances their content knowledge and promotes skill development.

5.3.5 Impact of Assessment

In the theme of engineering knowledge development, a sub-theme emerged related to the significance of assessment structures and their processes in engineering education. Students had to do multiple assessments in work placements (WIL) and during engineering projects (PBL), in which one student indicated in the interview that he was overloaded with assessments, potentially affecting their ability to focus on the tasks at hand and their learning. Additionally, students also indicated in the survey that if the number of assessments were less, then that would have enhanced their learning experiences of engineering projects and work placements.

Clapp and Funch (2003), Subheesh and Sethy (2018), Ferns and Zegwaard (2014), and Bosco and Ferns (2014) define assessment as an internal part of the curriculum and teaching-learning process, through which students can be motivated to learn subject materials, which enables learning, and enhances their learning experience. Assessment acts as a progress checker, as students' learning progresses with feedback to help recognise and reflect on their learning progress and identify gaps to work on

(Kusurkar et al., 2022; Sievertsen, 2022). At university, students may have a variety of assessments such as written assignments, tutorials, tests, seminars, presentations, projects, and examinations (Sievertsen, 2022).

During engineering projects, students were also required to write a report, giving details of their overall project outcomes. Similarly, in work placements, students were required to complete a technical report, placement brief assessment, project identification report, skill reflection assignment, and workplace health and safety report. The challenge students faced was doing work placements full-time for 400 hours and completing their workplace assessments during a full-time work placement. Students felt challenged and had difficulty coping with their busy schedule. They indicated that if they had less assessments to complete then they could focus more on their work placements.

There are several possible explanations for this thinking. One is that the students lack understanding of the broader role and purpose of assessments. Kusurkar et al. (2022) state that students should be aware of the importance of assessments, as that awareness can be the motivating factor for students to undertake assessments seriously and progressively. This study interprets that students may have a lack of understanding of engineering education curriculum and learning practices. It could indicate the students' lack of resilience and self-discipline, or understanding of the apprenticeship model of learning, where it is typical for learners to study and undertake assessments along with full-time work. It could also indicate that the university has not provided a clear rationale to students for having these assessments. If students understood what these assessments assist them to achieve, their importance, and how they impact knowledge development through self-reflection, then that might help students appreciate the importance of doing assignments. The lecturers may help students to understand that assessments enable learning and aid in developing and progressing their learning experience.

Additionally, universities need to assess students, so to determine the academic grade for this course, including whether the students pass, this is achieved through assessments. Report writing is an important method to assess students' progression in education (Kusurkar et al., 2022; Luzan et al., 2021; Ozbicakci et al., 2012; Sievertsen, 2022; Subheesh & Sethy, 2020; Subheesh & Sethy, 2018), however, perhaps universities could work on establishing alternative authentic assessments based on reflections, portfolios, case studies, practical laboratory tests, and presentations to check students' knowledge application. These authentic assessments may be different compared to writing a report or assignment, as authentic assessments may assess students practically, check their knowledge, and how they apply that knowledge onto practical problem-solving. By placing students in problem-solving through projects, case studies, scenario-based, and reflection-based activities, students may be motivated to apply their learnings onto practical applications. This approach may aid students in building an interest towards authentic assessments including engineering training and practise, which may, therefore, enhance students' overall learning experience.

5.3.5.1 Recommendations for Improved Outcomes for Students

This study suggests that students in the study were likely not given a detailed explanation of the learning outcomes, how the workplace process happens, and cognitive objectives of work placements and engineering projects before their commencement. Additionally, this study suggests that students likely did not understand the types of skill developments projects and work placements facilitated, what to expect from these approaches, and how the assessment informs progression, and the role of self-reflection as well as the necessity of determining success or failure in the course. This study suggests that the University could provide an in-depth outline regarding the process and structure of the courses, requirements for students, assessment structures and purpose with clear success criteria, and clear progression across projects and work placements.

An additionally recommendation is a detailed orientation and induction before commencement of projects and work placements, stating the intended learning outcomes, processes, and procedures of assessments, how engineering projects and work placements assist students to gain an understanding of the whole learning process, thus avoiding over-expectations. This would help them to focus to intended learning outcomes from each approach to facilitate maximised learning experiences and better prepare students to become work-ready graduates. These approaches may also make students aware of how these processes aid in developing their conceptual, procedural, societal, and technical knowledge domains in engineering education. In the next section, the overall engineering knowledge development through classroom learning, engineering projects, and work placements are discussed.

5.3.6 Overall Engineering Knowledge Development through Engineering Projects and Work Placements

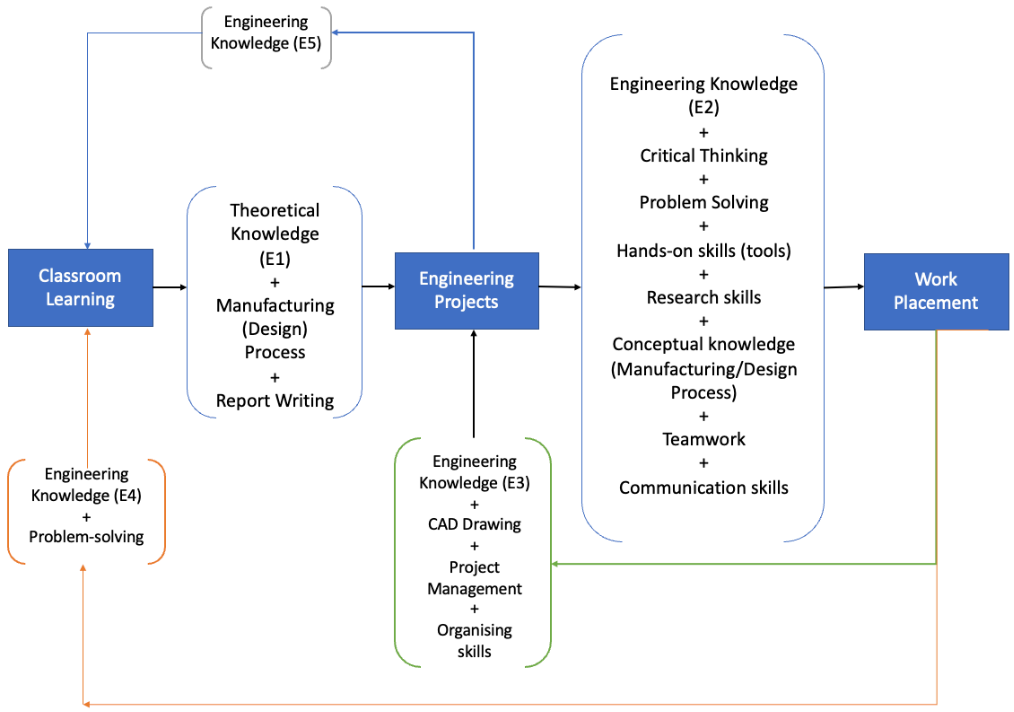
The perceptions of participants indicated that classroom learning, engineering projects and work placements, collectively worked together to provide and build engineering knowledge (conceptual and procedural knowledge domains) from each of the specific approaches. From classroom learning, students developed basic theoretical engineering knowledge (E1) and specific design and manufacturing knowledge (conceptual and procedural knowledge domains). With this knowledge, students proceeded to their engineering project, where they applied these classrooms learned concepts and knowledge onto their projects. This aligns with the findings of Bevinakoppa et al. (2016) and Chen (2008) who found that students were able to apply their previously developed classroom learnings onto their projects.

The artefacts that are important in classroom learning and engineering projects are lecturers, students, tutorials, assignments, written assessments, group discussions, presentations, and physical model prototyping. With these elements, students proceed to learning and building their own engineering knowledge (conceptual, procedural, and societal knowledge domains) via social interactions and reflections. This confirms that Vygotsky's Sociocultural Theory (Vygotsky, 1978b) can explain the learning process of classroom learning and engineering projects, because here, learning of the mind, mental processes, human activities takes place at the social level, which leads to the overall learning process (societal knowledge domain) of the students (Jeon, 2000). Additionally, constructionism is also evident because the engineering knowledge and development of skills happened when students interacted socially with their peers, lecturers, workplace supervisors, professional colleagues, tools, and machinery in their engineering projects and work placements (Galbin, 2014; Kynigos, 2015). By interacting with these artefacts in a social environment, students constructed their engineering knowledge and development of skills by work experience in work placements and by problem-solving in engineering projects with support from peers, colleagues, and experts such as lecturers and workplace supervisors. This relates to development of knowledge and skills in a social environment because of development of conceptual, procedural, societal, and technical knowledge domains in engineering projects and work placements.

Students work under the supervision of their lecturers in their classroom learning and engineering projects, who guide students through the process by the scaffolding of conceptual knowledge development. Lecturers give feedback to students on a regular basis which acts as a scaffold to help students develop their conceptual knowledge. This proceeds further to mediated action and reflection learning in engineering projects, as lecturers, peers, tools, and machinery socially construct knowledge (societal and technical knowledge domains) here, showing element of scaffolding learning. The knowledge constructed via social interaction and scaffolding reflects the alignment of engineering projects with Vygotsky's Sociocultural Learning Theory and Constructionism (Galbin, 2014; Kynigos, 2015; Mahn, 1996; Shabani et al., 2010; Vygotsky, 1978b).

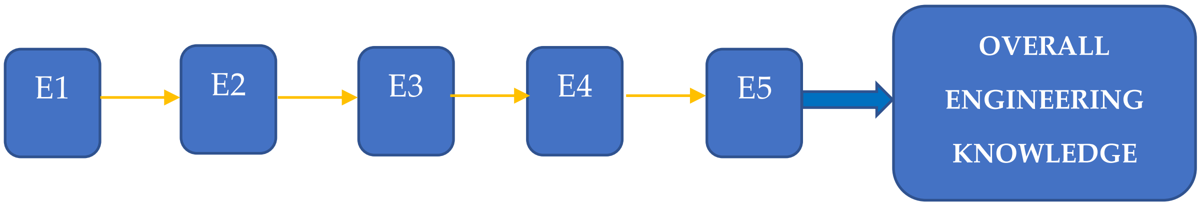
In engineering projects, students apply past engineering knowledge onto real-world applications, and thereby, likely understand the link between engineering concepts and practical examples. This, then, further enhances their understanding of classroom learned engineering theories and helps to enhance their practical engineering knowledge. Additionally, students also develop specific engineering knowledge (conceptual and procedural knowledge domains) via projects, which might be additional to their previously learned engineering knowledge, which they then take back to their classroom learning. Figure 5.8 shows that engineering knowledge E1 (basic foundational engineering knowledge) was transferred from classroom learning to engineering projects, and knowledge E5 (enhanced design and manufacturing knowledge and 3D technical drawing knowledge) back from engineering projects to classroom learning. This knowledge transfer between classroom learning and engineering projects, along with Vygotsky's theory suggests that engineering projects act as complementary support for the classroom learning, by providing the extra engineering knowledge that is generally not taught within the classroom learning space. The learning linkages between classroom learning, engineering projects, and work placements are shown in Figure 5.8.

Figure 5.8: Learning linkages between classroom learning, engineering projects, and work placements in building up the overall engineering knowledge and skills.



Similarly, between engineering projects and work placements there are learning linkages, both in terms of engineering knowledge and skill development. In engineering projects, students develop additional engineering knowledge E2 and E5 (enhanced design and manufacturing knowledge, 3D drawing knowledge, and interdisciplinary engineering knowledge – electrical, electronics, and computer science), which can be practical and interdisciplinary knowledge. Students were able to apply engineering knowledge E2 from engineering projects to work placements. The engineering knowledge E2 when applied onto work placements, enable students to develop new engineering knowledges E3 and E4 (interdisciplinary engineering knowledge, advanced 3D drawing knowledge, and software and programming knowledge) through social interactions with workplace supervisors, colleagues, projects, tools, equipment, and machinery. The engineering knowledge E3 and E4 are then taken back to classroom learnings and engineering projects, for further understanding, applications, reflections, and experience building. The overall engineering knowledge development through these approaches are presented in Figure 5.9.

Figure 5.9: Engineering knowledge development through classroom learning, engineering projects, and work placements.



Where the knowledge sources flow are as follows:

- E1 – from classroom learning to engineering projects,
- E2 – from engineering projects to work placements,
- E3 – from work placements to engineering projects,
- E4 – from work placements to classroom learning, and
- E5 – from engineering projects to classroom learning.

Figure 5.9 shows how the overall engineering knowledge (conceptual knowledge domain) is constructed throughout the engineering education through an interactive process between classroom learning, engineering projects and work placements. The combination of all specific learning events or outcomes (E1+E2+E3+E4+E5) forms development of students' overall engineering knowledge (conceptual knowledge) once they conclude their studies. Borikov et al. (2016), Craig (2017), and Ferns et al. (2014) indicated that students' overall knowledge development happens collectively through different aspects of the teaching and learning process, such as through classroom learning, problem-based learning, and work-integrated learning. In engineering education, classroom learning along with engineering projects and work placements work together to build up students' overall engineering knowledge, as also supported by the works of Mutereko and Wedekind (2015), Twigg et al. (2018), and Dahms (2014). The overall learning process in engineering projects and work placements happens in a social environment, where knowledge is constructed through concept development, social interactions, application, and practise. Through the application of prior knowledge in engineering projects and work placements, students indirectly develop their conceptual, procedural, societal, and technical knowledge domains, which indeed results in development of their overall engineering knowledge and skills. In the next section, discussions on engineering skill development are presented.

5.4 Engineering Skill Development

Engineering is a practical field, which requires a range of technical skills, to perform problem-solving of technical and non-technical issues (Patacsil & Tablatin, 2017). WIL and PBL are two approaches where students develop some content knowledge, which aid in the development of technical and non-technical skills (Dahms, 2014; Hoskyn et al., 2018; Khoo et al., 2020; Pereira et al., 2017). As stated in Chapter 2 Literature Review, technical skill is referred to as the ability to apply practical knowledge, to work with practical methods and tools related to a practical activity. These may occur through design, simulation and software use (Litchfield et al., 2016). The development of skills relates to the development of procedural knowledge (know-how), societal knowledge (social), and technical knowledge domains (Section 2.6) by undertaking engineering projects and work placements. Students work in a social environment (engineering projects and work placements), where they develop procedural knowledge of application of skills by practise and experience. Additionally, as students work socially within a group in engineering projects and work placements, they socially construct knowledge by sharing and collaborating with each other. This knowledge development is known as social or societal knowledge, which may also relate to development of skills via social interactions with colleagues, supervisors, tools, and machinery. Lastly, the knowledge of applying skills onto physical practices is referred to as technical knowledge. Students experience development of these knowledge domains in engineering by undertaking engineering projects and work placements, as these provide the social environment to apply engineering practise.

In this study, students' perceptions of essential engineering skills were collected and presented in Chapter 4 Findings. Each cohort's skills were compared with other skills and qualities. They were also compared across cohorts, and the results were presented in Tables 4.22, 4.23, 4.24, 4.25, 4.26, 4.27, 4.28, and 4.29. Firstly, the perceptions of students are discussed and then compared across cohorts and are presented in the next section.

5.4.1 Comparison of Skills and Qualities across Cohorts

The 2nd experience cohort indicated that analytical reasoning and employability skills were significantly more important than other skills, when compared with 4th- and 5th – Experience and graduate cohorts as seen in Table 4.22. The initial problem-solving experiences from the engineering projects, especially on interdisciplinary engineering problems, would have encouraged students to practise analytical skills. The works of Kirn and Benson (2018), Russell Iii et al. (2021), Bevinakoppa et al. (2016), and Barron and Wells (2013) indicated that students had to critically apply outside-the-box thinking and analytical reasoning to attempt solving the given project’s problem statement. Here, the 2nd-Experience cohort students had their first engineering project (Boat Race project) in their first year of study, where students might have undertaken problem-solving practically in university for the first time. Students had to apply analytical reasoning for selecting relevant engineering concepts, design and manufacturing concepts, and boat structures for the project. As students were exposed to this project's problem-solving in their first year of study, students, therefore, may have ranked analytical reasoning as a more important skill than others during their early years of study. Khoo et al. (2020) also indicated that lecturers consider analytical reasoning and problem-solving as more important skills than others, as these enable learning and motivate students to undertake self-learning and higher-order thinking.

Similarly, the work placement experiences would have motivated students to understand the importance of employability skills in the engineering field during their initial attempt at work placement. The works of Ornellas et al. (2019), Shekhawat (2020), Grace and Trede (2013), and Jackson and Collings (2017) also indicated that work placements help in developing students' employability or professional skills, as students work in authentic work environments under expert supervision. As students work alongside professionals and under expert supervision, on industrial projects in work placements, students develop professional skills through workplace experiences. Therefore, students develop a sense of professionalism and gain employability skills that are necessary for a specific job. This would have helped them understand the importance of employability skills in engineering work culture.

Some students indicated that they developed problem-solving skills from the Boat Race project that helped them tackle engineering problems in their work placement. Students practised how to understand those problems, analyse those problems, research to find relevant theories/examples, and define the required solution. Similarly, on comparing the responses of the 3rd-Experience with the 4th- and 5th-Experience cohorts concerning problem-solving, it was found that problem-solving was significantly more important for the 3rd-Experience cohort students. These students had completed two engineering projects and one work placement, which might be why they indicated problem-solving to be more critical. Also, the projects may have been fresh in the minds of the 3rd-Experience cohort, as they had just completed their second engineering project at that time. The two engineering projects gave them challenging engineering problems, and students had to bring innovative ideas to solve them, theoretically and technically (practically), and thereby, students had to apply problem-solving for this purpose. The lecturers also designed the projects so that it could give students challenging engineering problems, and encourage them to enhance their problem-solving skills (Khoo et al., 2020). These authors indicated that lecturers consider problem-solving skills to be more important than other skills, which also relates to the findings of this section. As students undertake more engineering projects, they further develop and practise through this approach more problem-solving skills.

The findings of Tuzlukova and Usha-Prabhukanth (2018) and Russell Iii et al. (2021) showed that working through problem-based learning approaches, students developed problem-solving skills via solving the given problem statement through projects. Furthermore, engineering projects were mostly based on targeted problems that aligned with students' classroom learned engineering concepts; therefore, students experienced more exposure to wider problem-solving in projects. On the other hand, work placements are more diverse in nature and may be interdisciplinary in engineering, therefore, they may not have targeted problems such as those encountered in engineering projects.

Additionally, the 2nd-Experience students gave more importance to fast learning and flexibility than the 5th-Experience and graduate cohorts. This might indicate that the 2nd-Experience students were still relatively new to engineering education and may have lacked a comprehensive understanding of engineering practise. This is supported by the works of Bennett et al. (2015), where they indicate that students in their first-year of study have little or no understanding regarding the realities of their degree programme and engineering work. In such a new environment, when students learn new engineering theories and technical works, it is understandable that they would give importance to fast learning and flexibility because they need to grasp new approaches and ideas effectively and apply those to their practical experiments.

With the yearly progression students make while completing more engineering projects and work placements, it can be seen that students likely develop a sound appreciation of technical and non-technical skills, based on their learning perceptions. Zegwaard and Hodges (2003) also indicated in their study that with yearly progression of students in their engineering degree, they develop understanding of the importance of skills similar to that of employers. As students progress through engineering projects and work placements, they develop a sense of important skills needed to be a successful engineer and develop work experiences, technical and non-technical skills, professionalism, and engineering practices. In the next section, a discussion around the comparison of skills within cohorts is presented.

5.4.2 Comparison of Skills within Cohorts

When the perceived importance of skills by the 2nd-Experience cohort are compared within the same cohort, some interesting findings were revealed. Firstly, problem-solving was perceived to be the most important skill. These 2nd-Experience cohort students only had one engineering project and one work placement experience. The engineering project (Boat Race) provided them with a challenging engineering problem, where students practised some skills. Participant I.1E.2 said, "Through the Boat Race project, I developed skills such as communication, teamwork, problem-solving, critical thinking, hands-on tools experience, design and manufacturing concepts." Through the Boat Race project, students practised problem-solving, and, this being their first experience of solving an engineering project, they found problem-solving to be an essential skill. They even used this in their first work placement where they could apply problem-solving in their work placement tasks. Bevinakoppa et al. (2016), Long et al. (2022), Nurkhin and Pramusinto (2020), and Pereira et al. (2017) suggest that Problem-Based Learning (engineering projects) encourages the use of problem-solving to efficiently solve the problems, and helps to understand the underlying theory. Additionally, the 2nd-Experience cohort students indicated that fast learning, initiative, adaptability, creativity, flexibility, and self-starter are other important skills (Table 4.24). The findings demonstrate that students felt these skills to be important due to the fact that they were new to engineering education, and as Bennett et al. (2015) suggest these students lacked the understanding of engineering works and engineering degree programmes at the early stage of their engineering study. Due to a lack of awareness of engineering experience, it is anticipated by this study that these students indicated the above skills as more important than others.

Another finding showed that these students valued team skills more than engineering work experience, employability skills, and planning and organising skills. As students completed the Boat Race engineering project in groups of three or four students, they could perceive that teamwork helped with brainstorming ideas, they could discuss project-related theories, clear doubts or queries, distribute workloads, and finalise relevant solutions for the project. Chowdhury and Murzi (2019) also found that teamwork is a key skill in engineering, as students need to practise problem-solving in groups in this programme, to solve authentic engineering problems. In this study, teamwork was extensively applied in engineering projects and work placements, because in both these approaches, students had to work in a team collaboratively and cooperatively. Additionally, these students did not have much experience with work placements, and maybe they did not yet know the importance of engineering work experience, employability skills, and planning and organising skills. This indicates that due to less engagement of these students with work placements, they may not have fully built an understanding of the importance of employability skills and engineering work experience.

In the 3rd-Experience cohort, students indicated that problem-solving was the most crucial skill, followed by logical thinking (Table 4.26, Section 4.8, Chapter 4). The students from this cohort experienced the Boat Race project, one work placement, and the design and manufacturing project. The students' and graduates' online survey and interview data show that they felt they developed several skills, with problem-solving being the most significant. A possible reason is that in both engineering projects (boat race and design and manufacturing), students were given authentic engineering problems, which they had to address and find solutions for while working in teams. This facilitated the use of problem-solving in engineering projects, and also in the work placement, which is a demanding skill in workplaces (Mohd-Yusof et al., 2013; Subramaniam et al., 2020). Participants I.1E.1, I.1E.2, and I.1E.3 indicated that by doing the Boat Race project, they improved their problem-solving skills by encountering the engineering problem projected by the boat race project. Participant I.3E.1 said that from the design and manufacturing project, he had to develop inventive ways to address multi-design projects requiring him to apply high problem-solving and critical thinking skills. The 3rd-Experience students indicated that all skills were important, but problem-solving skills and analytical thinking were significantly more important than others.

This study anticipates that this might be because these students had more project experiences than work placements, thereby, students may have less understanding of engineering work culture and requirements. This may also suggest that these students may not have had an opportunity to apply other skills such as critical thinking, planning and organising skills, time management, and project management. This study anticipates that with more work placement experiences, these students may understand the role and importance of more technical and non-technical skills. Zegwaard et al. (2017), Pažur Anicic and Divjak (2022), Jackson et al. (2022), Ferns et al. (2014), and Jackson and Collings (2017) found that by undertaking work placements, students develop the understanding of professionalism, work ethics, and workplace cultures, and also develop technical and non-technical skills as learning outcomes.

In the case of the 4th-Experience cohort, the students indicated that problem-solving skills, communication skills, critical thinking, engineering work experience, planning and organising skills, employability skills, self-management, teamwork, and adaptability as the most important skills (Table 4.27). This cohort of students has experienced boat race, design, and manufacturing projects, and two work placements. The two work placements will have informed the students' outlook in terms of engineering work practices and training. This can be evidenced by Participant I.4E.2 stating that by doing work placements, he developed skills such as teamwork, problem-solving, critical thinking, planning, and organising, and employability skills. When compared with the 3rd-Experience cohort, this finding from the 4th-Experience shows differences in the perception of importance. More work placements would provide students with additional exposure to real-world engineering workplaces, work practices, engineering training, and the development of technical and non-technical skills (Jones et al., 2015). Also, the findings demonstrate workplace supervisors may expect more efficient work from the 4th-Experience students, as this would be their second work placement experience. Since they already had their first work placement experience, the workplace supervisors may expect students to take more initiative, be self-starters, capable of handling technical works, competent with technical, non-technical, and professional skills.

This study sees here the difference the work placements create in students' overall outlook towards engineering education and development, considering the outcomes from the 2nd -, 3rd -, and 4th-Experience cohorts. Each cohort, when they progressed through the yearly learning approaches (projects and work placements), shows that students developed a greater understanding of essential skills and qualities that are significant for being a successful engineer. Jackson (2016), Mutereko and Wedekind (2015), Barron and Wells (2013), Bevinakoppa et al. (2016), and Zegwaard and Campbell (2014) indicated that work placements and projects not only helped in developing professionalism, but also aided in developing essential work skills and qualities, which are important for being a successful employee.

The 5th-Experience and graduate cohorts showed the same level of perceptions of importance of learning skills from engineering projects and work placements (Skill Tables 4.28 and 4.29). This is unsurprising because both cohorts had the same amount of exposure to both learning approaches. Both cohorts indicated that the following skills were more important than others: problem-solving, communication, critical thinking, engineering work experience, employability skills, planning and organising, self-management, logical thinking, teamwork, being technically minded, and adaptability. Seeing such a realistic change in the perceptions of importance of learning skills of the 5th-Experience and graduate cohorts with other remaining cohorts clearly shows that students' outlook likely changed as more engineering projects and work placements were undertaken.

Students initially developed problem-solving, critical thinking, teamwork, communication, and engineering knowledge/conceptual knowledge through engineering projects. With this development, they applied these to their work placements, where they further enhanced these skills and developed engineering work experience, employability skills, planning and organising skills, adaptability, being technically minded, and self-management. Participants I.GC.1 and I.GC.2 stated that they developed time management, project management, problem-solving, communication, and employability skills via work placements.

There is a continuous learning linkage between engineering projects and work placements, where the knowledge and skills developed in engineering projects were further used in work placements and vice-versa. In the following sub-section, the stakeholders' perceptions of learning through engineering projects and work placements are discussed against the second key theme of this study.

5.4.3 Perceptions of Learning through Engineering Projects and Work Placements

Students' perceptions of learning through engineering projects and work placements were collected, as shown in Table 5.3, where they indicate the type of skills they developed from both engineering projects and work placements. The responses show that most of the skills they developed were from both learning approaches (Table 5.3).

Table 5:3: Skills developed through engineering projects and work placements.

Serial No.	Skills	Engineering projects	Work placements
1.	Problem-solving	✓	✓
2.	Teamwork	✓	✓
3.	Critical thinking	✓	✓
4.	Communication	✓	✓
5.	Planning and organising (Project Management)	✓	✓
6.	Leadership qualities	✓	✓
7.	3D Designing Software (Auto-CAD, Solid Works)	✓	✓
8.	Hands-on tools experience	✓	✓
9.	Professional Ethics	X	✓
10.	Research skills	✓	X

Bevinakoppa et al. (2016), Dahms (2014), and Takahashi and Saito (2013) indicated with students' involvement in problem-solving the project, they developed technical and non-technical skills along with development of conceptual knowledge. As projects presented students with a problem statement, which students had to address through group works, they discussed the background of the problem statement and related conceptual theory. In this way, students develop conceptual knowledge by attempting to problem-solve the project, which aids in developing skills like problem-solving, critical thinking, communication, interpersonal skills, and teamwork. Students were encouraged to apply creative and critical-thinking skills by the given challenging problems through the project. This is exemplified by the statement of Participant (I.5E.2) who said that for addressing the challenging problems posed by projects, they had to bring up innovative and inventive methods to address those project problems and accordingly find a solution for those.

Lecturers stated that engineering project topics encouraged students' critical thinking and problem-solving practices. To solve a technical engineering problem (based on engineering concepts in recent classroom learning), students had to recall their prior engineering knowledge to find, match and research the relevant theory to the problem. In order to bridge several engineering theories with the engineering problem via projects, students were motivated to apply research skills, critical thinking, and problem-solving skills to address the problem(s) (Christiansen et al., 2013; Dahms, 2014; Loyens et al., 2015; Pereira et al., 2017). This development again happened in a social environment, where students interacted with their lecturers, classmates, project managers and laboratory equipment, machines, and tools.

This confirms that the theory of constructionism (Galbin, 2014; Kynigos, 2015) applies to this study, because by completing engineering projects and work placements, students construct their knowledge, and develop understanding and expertise of applying technical and non-technical skills. In work placements, Participant I.GC.1 stated that he worked on several industrial projects, in that he was designing several machine parts on 3D drawing software (Auto-CAD). Since he knew the basics of creating software from university studies (especially projects), he could grasp design information. As Participant I.GC.1 worked on industrial projects, he further developed his 3D drawing expertise with the help of his supervisor and colleagues. This again is evidence that this student further developed a technical skill by socially working in a workplace, thereby constructing knowledge and expertise around 3D drawing and software, satisfying the constructionism paradigm here.

Workplace supervisors supported this finding, stating that students already knew about 3D drawing from projects they did in university. Having an initial understanding and expertise in 3D drawing helped students start working without additional training, and they, thereby, began to work on several projects. Accordingly, they further developed their skills in 3D drawing by working on some critical industry projects. Similarly, working in a professional environment helped students develop their communication, problem-solving, critical thinking, professional ethics, and planning and organising skills (project management).

Both engineering projects and work placements allowed students to develop technical and non-technical skills. In addition, work placements provided more development of professional or employability skills. The overall skill development through engineering projects and work placements are presented in Figure 5.10.

Figure 5.10: Overall skill development through engineering projects and work placements.

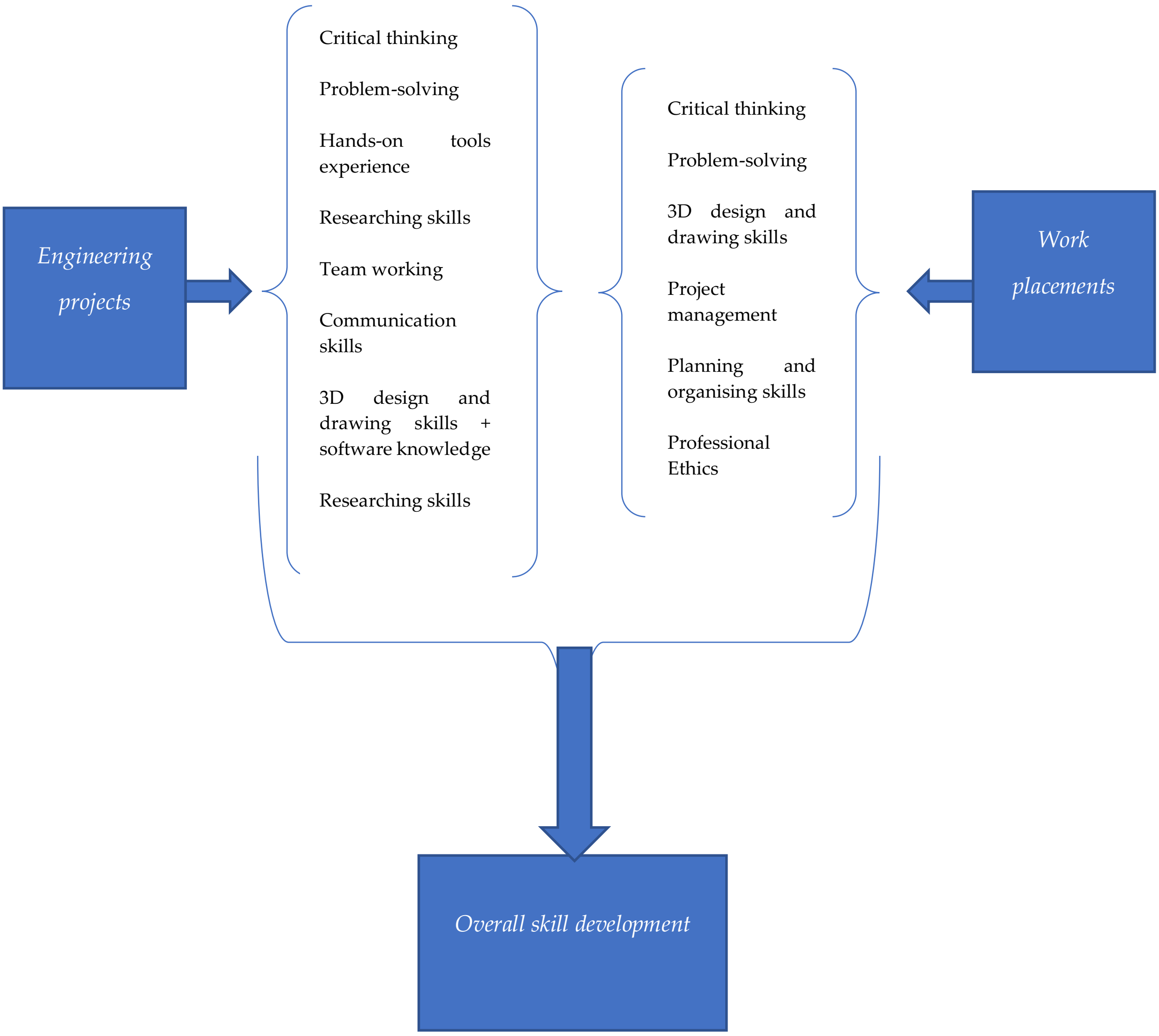


Figure 5.10 shows the different skills that engineering projects and work placements develop and how they add up to form the overall skill development in engineering students. These interconnections of learning between classroom learning, engineering projects, and work placements could be represented graphically, showing all the

learning outcomes of each approach and how they flow, which is presented later in this chapter.

5.5 More Challenging Projects and Work Placements Wanted

Engineering projects and work placements helped students to develop their engineering knowledge and aided in developing technical, non-technical or employability skills outside classroom boundaries (Jackson et al., 2022; Khampirat, 2021; Simanjuntak et al., 2021; Thorndahl & Stentoft, 2020; Xie et al., 2022). Work placements were diverse in nature, covering different aspects of mechanical engineering. Therefore, students had the opportunity to work in interdisciplinary engineering fields. For example, workplaces with heating, ventilation, and air conditioning (HVAC) have thermodynamics components, an essential core course in mechanical engineering, along with electrical wiring aspects relevant to electrical engineering. Their work is correlated with structures and construction, thus including aspects of civil engineering. When a student works in such a disciplinary workplace, along with mechanical engineering knowledge (thermodynamics) development, there student also get exposure to aspects of electrical and civil engineering concepts, enhancing knowledge outside their field of study. Likewise, from different types of interdisciplinary engineering workplaces, students may develop interdisciplinary engineering expertise from their work placement experience.

Similarly, engineering projects are purely based on classroom-taught engineering concepts and would mostly be interdisciplinary. Therefore, students may construct more engineering knowledge from projects rather than classroom learning. Based on these findings, it can be summarised that a more significant number of engineering projects may help students to relate engineering theory with practise and may also help them to develop technical and non-technical skills.

Each workplace may be based on one or more aspects of mechanical engineering. On the other hand, mechanical engineering work placements are diverse in nature, which may be based on factors such as design and manufacturing, building and construction, building services, product development, aviation, boat building and transport, agriculture, water and wastewater, and the energy sector. Therefore, it is not necessary that all elements be found in an individual workplace. For example, one participant indicated that when he worked in a design and manufacturing workplace, he gained insight into design and manufacturing concepts and related skills. That was the learning outcome from that workplace. For next time work placement, he was at a thermodynamic workplace where he gained knowledge and skills related to thermodynamics.

Work placements on different mechanical engineering aspects may help students gain a wide variety of mechanical engineering knowledge and related skill development. Based on this experience, this student may have realised that a single work placement could not cover all aspects of mechanical engineering. He also acknowledged that each work placement is based on specific mechanical engineering fields; from there, only related engineering knowledge and skills may be developed. Therefore, if students want to cover different aspects of mechanical engineering and related knowledge and skills, they will need more work placement experiences. This means that if students have the opportunity to do more targeted work placements based on different mechanical engineering fields, then that would be beneficial for broadening the students' knowledge of practise. The works of Blumenthal and Maccallum (2017), Cotter (2017), and Jackson (2017) indicate that work placements aid in developing a wide variety of knowledge and skills, which can be both technical and non-technical in nature. Thus, the findings demonstrate that a greater number and variety of mechanical engineering work placements may expose students to a variety of mechanical engineering knowledge and skills.

It can be summarised that a greater number of challenging engineering projects and work placements may help students to further develop their engineering knowledge and skill development. For example, in place of one large engineering project per year, the curriculum may be designed in such a way that it has two small projects per year with different challenging aspects. In this way, students have access to more complex tasks than before. Similarly, in work placements, the University may work on finding possible placements based on different aspects of mechanical engineering so that students may have work experience in various mechanical engineering fields. A viable option would be to broaden the range of exposure of work placements. For example, in place of two work placements of 400 hours each, the University and employers may look into providing three work placements of 300 hours each. Likewise, such options could be considered for further research scope and possible recommendations. The following section discusses a more advanced feedback system between work placement and the university.

5.6 More Contextual Feedback

Feedback is an essential factor of great importance in improving the learning experience for the students at higher education level (Al-Bashir et al., 2016). According to the works of Park et al. (2014), a feedback system can be used as an element of growth and development for students, and also as a tool to improve teacher's instruction. In engineering projects and work placements, feedback plays an important role to inform students' progress through the sessions, which indeed will help students to develop aspects of reflective learning (Bevinakoppa et al., 2016; Chen, 2008; Fleming & Eames, 2005; Govender & Wait, 2017).

In this study, several approaches were used to give feedback on students' performance during work placements. These included a technical report for projects, a technical report for work placements, a report for Health and Safety, and reflective assignments. These assessments showed what the students learned (actual achieved learning outcomes), how they managed challenges and problems, and what knowledge and skills were developed through these approaches.

In the earlier section, students indicated that they felt overloaded with too many assessments while doing engineering projects, work placements, and other courses. May be students did not realise that by completing assessments while doing work placements will help students to correctly reflect on their learning outcomes and aid in completing the assessments properly and accurately without missing any details. Completing assessments while doing work placements will also enable students' learning from work experiences and make them aware of the learning outcomes of the work placement. On the other hand, some student participants indicated that they needed a higher level of feedback from supervisors of projects and work placements. These two findings may be interpreted as students lacked awareness regarding the importance of assessments. They may not have understood that doing assessments was one of the forms of receiving feedback, checking on their academic performance, and enabling reflective learning. There may be other side of this findings too, that is, the assessment tasks and feedback do not achieve what they are designed to do and are actually pointless for the students, which may be the reason for students indicating over-assessment issue.

This could highlight shortcomings by the University to clarify the purpose and importance of each assessment. However, some students indicated that they benefitted from the feedback they received while doing their engineering projects and work placements, as it helped them understand their learning gaps. For example, one of the students indicated that formative feedback from their lecturer and project manager enabled him and his team to understand the 3D design and drawing concepts while doing his engineering projects. Feedback received assisted in the understanding of design errors in software and shortcomings in design concepts.

Similarly, in work placements, students were happy to receive feedback from their workplace supervisor, as it helped them to understand their operational errors and encouraged them to reflect on shortcomings. Some students also appreciated the feedback even when it was challenging feedback. They suggested that more contextual feedback from engineering projects and work placements should be there. Perhaps these students expected a one-on-one feedback system and progress checking for each student, possibly over-expecting without understanding the importance and role of the assessments.

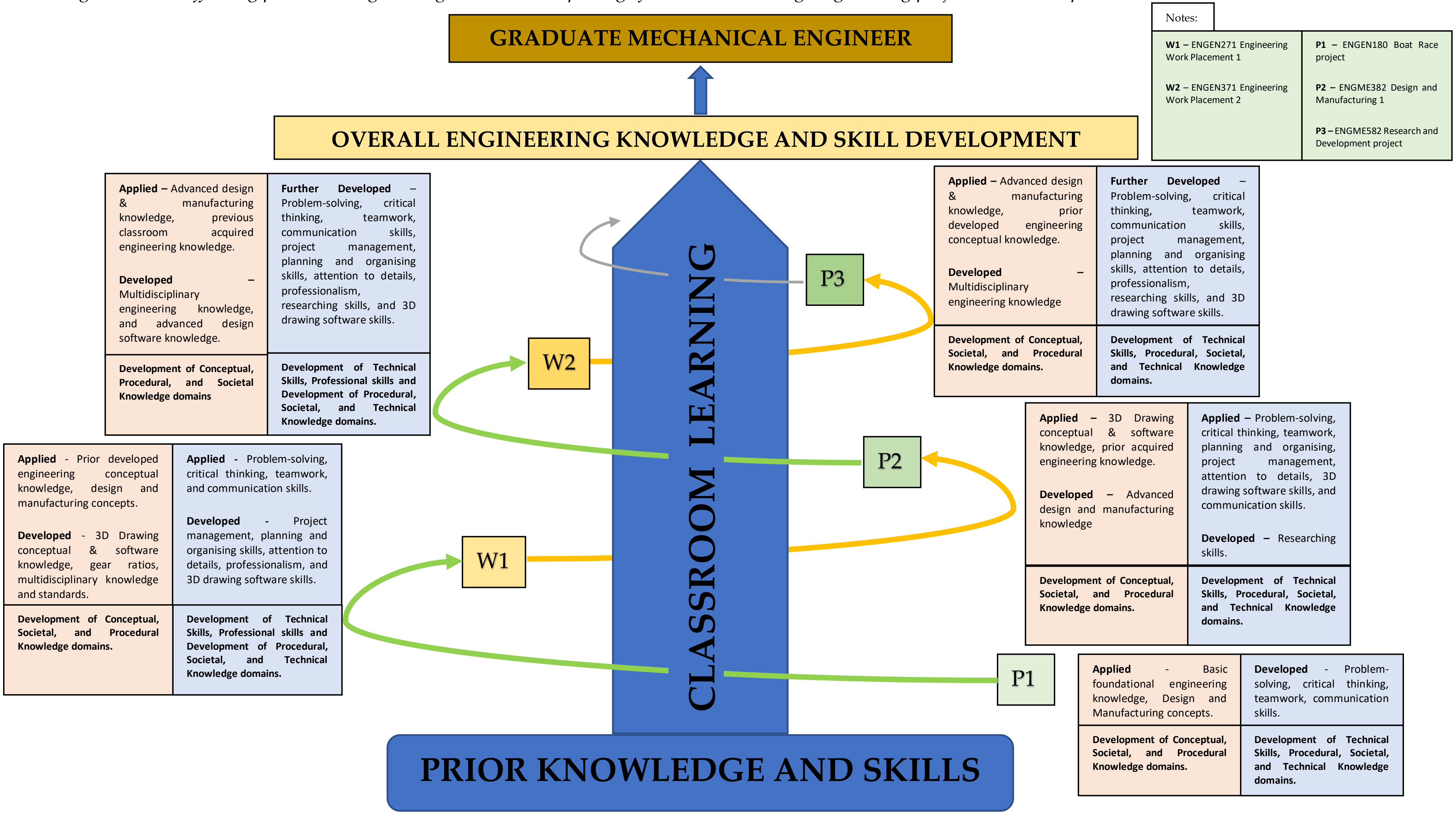
The findings and analysis indicate that due to a lack of understanding and awareness of the purpose of assessments and their significance, students suggested wanting more feedback. Undoubtedly, feedback is critical for informing students about their academic progress, evaluating their understanding, and checking on their learning outcomes. Both students and lecturers suggest that feedback enhances learning and teaching, respectively. This study strongly believes that feedback via assessments is essential to help students progress.

5.7 Learning Linkages between Engineering Projects and Work Placements

This section describes the learning linkages between engineering projects and work placements based on participants' perceptions as presented in Section 8.2.3, Chapter 4. There was a flow of learning starting from classroom learning to engineering projects and finally coming onto work placements. Each learning approach provides valuable input into students' overall knowledge and skill development, which is then utilised internally between those approaches, each accumulating and enhancing students' comprehensive knowledge and skill development as they progress through their programme.

The engineering projects (Boat Race – P1, Design and Manufacturing – P2, and Research and Development – P3) took students' previously acquired engineering knowledge and skills from classroom learning and projects and encouraged students to use them for problem-solving the projects. Accordingly, students further developed their conceptual engineering knowledge, and developed procedural knowledge regarding understanding and applications of technical and non-technical skills. These learning outcomes from engineering projects, enabled students to take it further into their work placements (W1 and W2). The work placements (W1 and W2) made students apply their previously developed classroom and project knowledge and skills onto workplace applications and industrial projects. This promoted further enhancement of students' conceptual engineering knowledge, and procedural knowledge regarding understanding and applications of technical, non-technical, and professional skills. These learning relationships constructed by engineering projects confirm that projects provide scaffolded learning support to work placements, and complementary learning support to classroom learnings, by providing necessary engineering knowledge, technical and non-technical skills. Similarly, the learning outcomes from work placements, brought students further back to their classroom learnings and engineering projects. These learning relationships with work placements again confirm that work placements provide complementary learning support to engineering projects by providing additional engineering knowledge and professional skills. These linkages are shown in Figure 5.11.

Figure 5.11: Scaffolding process in engineering education comprising of classroom learning, engineering projects, and work placements.



In summary, there are well-established learning linkages between engineering projects and work placements. Engineering projects provide complementary learning support and scaffolded knowledge to support work placements. At the same time, work placements provide complementary learning support to engineering projects. These are the overall learning linkages between engineering projects and work placements. The next section presents the linkage of key themes with research questions.

5.8 Linkage of Themes with Research Questions

This section presents the linkage of themes with the research questions of this study. The section is divided into three sub-sections, where the first sub-section presents the stakeholders' perceptions of learning through engineering projects and work placements. The second sub-section presents the scaffolding of the learning process between engineering projects and work placements. The third sub-section presents the complementary learning process between engineering projects and work placements.

5.8.1 Stakeholder's Perceptions of Learning through PBL and WIL

This section discusses and answers the first research sub-question based on the analysis from the themes. This research study shows that engineering projects provided students the opportunity to develop engineering knowledge, technical, and non-technical skills. Students bring classroom-acquired engineering knowledge (conceptual and procedural knowledge domains) to their engineering projects, which is further developed via problem-solving. Additionally, this process facilitated in the development of new engineering knowledge (conceptual and procedural knowledge domains) and skills (procedural and technical knowledge domains) from beyond their classroom learning, as engineering projects were interdisciplinary in engineering. Pereira et al. (2017) and Tse and Chan (2003) also stated that engineering projects provided development of engineering knowledge and skills that were outside the learning scope of the classroom. This was because, classroom learning mostly included theoretical tutorials via lectures, which may lack aspects of practical knowledge in classroom learning due to the non-availability of tools and heavy machinery in the class environment. In engineering projects however, students develop practical knowledge and skills by working on problem-solving the projects with the help of tools and heavy machinery in a practical environment (laboratory).

Students developed skills such as problem-solving, critical thinking, 3D drawing and designing abilities, 3D software expertise, and design and manufacturing analysis through engineering projects. Development of these skills relates to the development of procedural (know-how), societal, and technical knowledge domains through work placements. On the other hand, as the work placements were interdisciplinary, they aided development of new engineering knowledge outside classroom learning, engineering projects, and the engineering curriculum. As well as engineering knowledge development, students also enhanced their technical and non-technical skills during work placements. Technical skills included: problem-solving, critical thinking, 3D drawing and designing abilities, 3D software expertise, design and manufacturing analysis, software programming, and coding. Non-technical or professional skills included: teamwork, communication, project management, time management, planning and organising, professional ethics, and technical communication skills. Development of these skills also relates to the development of procedural, societal, and technical knowledge domains by undertaking work placements. Participants likely understood the importance of each of the main facets of engineering education, and how these pedagogies collectively worked together to develop the overall engineering education, technical and non-technical skills, thereby, making them work-ready graduates.

5.8.2 Scaffolding of Learning Process Between Engineering Projects and Work Placements

This section answers the second research sub-question. The classroom learning provided students with foundational engineering knowledge (conceptual and procedural knowledge domains), which was then further applied in their engineering projects. Engineering projects provided an opportunity for students to apply their acquired classroom learned engineering theories onto their projects, thereby, enabling them to relate theory with practise. This indeed helped them to develop and deepen their understanding and provided exposure to the interdisciplinary nature of mechanical engineering projects, which students then take back to their classroom learning, and further into work placements. Additionally, students also developed technical and non-technical skills (procedural and technical knowledge domains) through engineering projects.

Christiansen et al. (2013), Xie et al. (2022), Thorndahl and Stentoft (2020), and Loyens et al. (2015) indicated that problem-based learning approaches aid the development of knowledge and skills, which then flow back to students' classroom learning. Findings of these authors align with the findings of this study, as engineering projects aided the development of students' practical engineering knowledge (conceptual and procedural knowledge domains) and skills (procedural and technical knowledge domains) and enhanced their previous classroom knowledge by performing problem-solving of the project's engineering problem. Additionally, the lecturers in the engineering projects aided the scaffolding of learning, by themselves being a scaffolded support for students when they start to work on their projects. Based on Vygotsky's Zone of Proximal Development (ZPD), the lecturers act themselves as a scaffolded support, which is gradually reduced as students develop their engineering knowledge, skills, and ability to do the problem-solving process of the project. The lecturers support can be in different forms, such as providing feedback, problem-solving strategies, encouraging teamwork, guided instructions, segmenting tasks, and adjusting of support level based on students' needs. Moreover, the Figure 2.2 from Chapter 2 also supports that lecturers' scaffolded support exists between the authentic problem and students, which thereby forms the tripartite relationship in engineering projects (PBL). This outlines that there is scaffolding of learning within PBL or engineering projects through the lecturers between the authentic engineering problem and the students.

In work placements, students gained opportunities to apply and practise prior developed engineering knowledge and skills from classroom learnings and engineering projects. Participant I.5E.1 stated that by undertaking engineering projects, he developed intense manufacturing and design concepts and 3D drawing knowledge, which he could apply to his future studies and work placements. In work placements, he could apply prior engineering knowledge and skills onto real-world workplace applications, which then aided in further enhancing his previous engineering knowledge and skills. Additionally, as work placements were interdisciplinary, he and other students, therefore, developed interdisciplinary engineering knowledge (conceptual and procedural knowledge domains) from work placements. This newly developed engineering knowledge from the work placement was then taken back to students' classroom learnings and engineering projects. Similarly, the technical and non-technical skills developed from work placements was also taken back to students' upcoming engineering projects. Seeing such learning progression between engineering projects and work placements, this study interprets that engineering projects provide sequence of scaffolded learning support to work placements (Figure 5.12).

Figure 5.12: Engineering project scaffolding classroom learning and work placement.

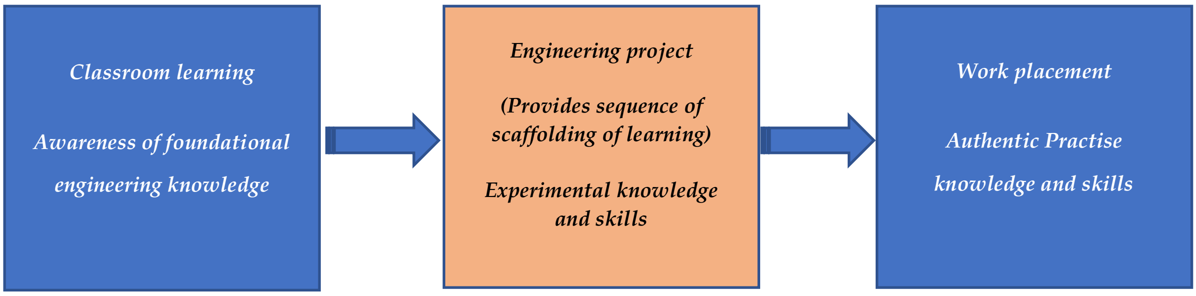
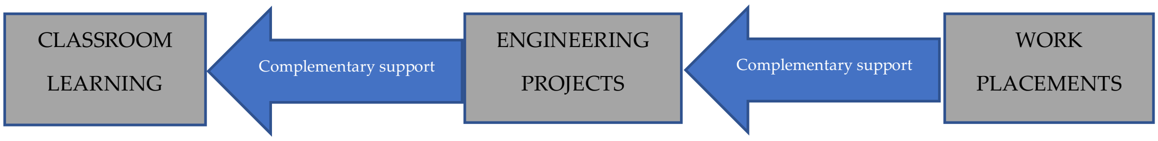


Figure 5.12 shows that classroom learning provides the development of foundational engineering knowledge, which thereby develop students' awareness of engineering concepts and theories. Students then take it further to engineering projects, where they apply their previously developed foundational engineering knowledge on projects problem-solving along with lecturers' support and guidance, and further develop their previous engineering knowledge and new interdisciplinary engineering knowledge. The overall engineering knowledge and skills developed from engineering projects can be termed as experimental knowledge and skills, as students develop these by undertaking projects (or practical experiments). This experimental knowledge and skills are then transferred to work placements, where students work in authentic practise and further develop their previous knowledge and skills. Examining this flow of engineering knowledge and skills, there seems to be an aspect of sequence of scaffolded learning between classroom learning, engineering projects and work placements. Classroom learning scaffolds engineering projects by providing students with basic foundational engineering knowledge, which students then apply in their projects. Similarly, engineering projects provide the scaffolded engineering knowledge and skills development along with lecturers' support for students to apply and work efficiently in their workplaces. In the next sub-section, the complementary learning process between engineering projects and work placements is discussed.

5.8.3 Complementary Learning Process Between Engineering Project and Work Placement

This section contributes to answering the third research sub-question. The classroom learning provided foundational engineering knowledge, which students applied and reflected in their engineering projects. On the other hand, engineering projects provided new engineering knowledge that may not have been covered in classroom learning, depending upon the interdisciplinary nature of the project. This new engineering knowledge was then transitioned to classroom learning by students, for further application, reflection, and experience-building. Additionally, students developed some technical skills from engineering projects (such as 3D drawing and design, problem-solving, critical thinking, and hands-on experiences of tools and machinery), which could not be developed from classroom learning because classroom learning lacked the aspects of practical learning, such as laboratory experiments, physical works, use of tools/machines, and practical problem-solving. These technical skills are transferable from engineering projects to classroom learning, where students can apply these skills on their present and future courses, and class tutorials. The engineering projects not only enhanced students' prior classroom knowledge, but also developed practical and interdisciplinary engineering knowledge, and technical skills by performing problem-solving via practical experiments. These project outcomes may not be developed from classroom learning as the classroom lacks the aspect of practical learning. The challenge to provide a practical learning environment is overcome by engineering projects, where students develop practical engineering knowledge and skills. Seeing this relationship, this study interprets that engineering projects provided complementary learning support to classroom learning (Figure 5.13).

Figure 5.13: Complementary learning support between classroom learning, engineering projects, and work placements.



Students took project-developed engineering knowledge and skills to their work placements, where they applied it to real-world applications. Thus, while working in a real engineering work environment, under expert supervision and with help from professional colleagues, students further developed their engineering knowledge and skill development. Depending upon the interdisciplinary nature of the work placement, students may develop new engineering knowledge that was not developed via their classroom learnings and engineering projects. Also, students further developed technical skills such as 3D drawing, problem-solving, critical thinking, and hands-on experiences of tools and machinery. Additionally, students through work placements, further develop non-technical skills such as communication, teamwork, and interpersonal skills. Also, students develop professional skills such as time management, planning and organising, and project management through work placement experiences, which are not developed through classroom learnings and engineering projects. Participants I.4E.3, I.4E.2, and I.4E.4 indicated that through work placements, they developed interdisciplinary engineering knowledge (electrical, electronics, and computer science), technical, and non-technical skills. The lack of engineering knowledge and skills that students did not develop through classroom and engineering projects, were developed by undertaking work placements. Work placements through authentic practise, aided in the development and enhancement of students' knowledge and skills. Observing this relation, this study interprets that the work placements provide complementary learning support to engineering projects and classroom learnings, as shown in Figure 5.11. In the next section, the chapter summary is presented.

5.9 Summary

This chapter answers the research questions by taking the key findings identified in Chapter 4 and discussing them in relation to current literature and the researcher's interpretations. The study explores the learning linkages between engineering projects and work placements by identifying four themes in this study, which are: 'Engineering knowledge enhancement', 'Engineering skill development', 'More challenging projects and work placements wanted', and 'More contextual feedback'. There was a significant difference between the findings of this research and current literature. The difference relates to students' perceptions of engineering projects providing more engineering knowledge than work placements. The findings of this study state that there is sequencing of scaffolding and complementary support between classroom learning, engineering projects, and work placements.

On the other hand, there is little research on how these approaches can be well used based on this relationship to enhance students' learning experience. This identified a research gap in the literature related to improving engineering education and the employability chances of students by understanding the learning linkages between engineering projects and work placements. This section also described how the technology education's knowledge domains (conceptual, procedural, societal, and technical) related to the learning process of engineering projects and work placements. The findings of this study show how these knowledge domains were developed from classroom learning, engineering projects, and work placements, and how they triangulated in developing students' overall engineering knowledge, technical, and non-technical skills in engineering education. The importance of these knowledge domains and how they were developed in projects and work placements were established in this section.

The need for more engineering projects and work placements was also discussed in this chapter. The study's findings aligns with the literature of Hills et al. (2011), Little and Harvey (2006), and Stirling et al. (2018) about engineering projects providing better understanding of theory with practise than work placements. Work placements mainly provided students with an opportunity to work in an authentic workplace, become familiarised with the professional work culture, and develop employability skills. The data indicated that students developed more engineering knowledge from engineering projects than from work placements. This might be because engineering projects were based on previously learned classroom engineering theories/concepts. This provided an easy understanding for students to link theory with practise and enhance their engineering knowledge.

This study's findings support the view that students use the knowledge gained from their classroom learning, engineering projects, and work placements to assist and inform their overall development of engineering knowledge and skills (technical and non-technical). This chapter identified that in engineering education-classroom learning, engineering projects, and work placements are critical factors needed in engineering knowledge and skill development. The following chapter, Chapter 6, concludes the findings from this study.

6 CONCLUSION

6.1 Introduction

This study aimed to investigate the stakeholders' views on the combined learning effects of engineering projects (PBL) and work placements (WIL) for preparing engineering students for professional practise. This chapter draws on collected data, literature, findings, and discussions to accomplish conclusions and identify implications and recommendations for engineering lecturers, workplace supervisors, and researchers in engineering education and work-integrated learning. The outcome of this study outlines the learning relationship between engineering projects and work placements, which was presented in Chapters 4 (Findings) and 5 (Discussion) of this thesis.

The following section will answer the research questions of this study regarding the learning effects between engineering projects and work placements.

6.2 Research Questions

The findings from this research allow for the research questions to be answered. The main research question was:

> *What are stakeholders' views on the combined learning effects of engineering projects (PBL) and work placements (WIL) for preparing engineering students for professional practise*?

The stakeholders (engineering students, recent graduates, lecturers, and workplace supervisors) could identify the actual learning outcomes from engineering projects and work placements in terms of developing engineering knowledge and technical and non-technical skills. They perceived a clear link between the learning in classroom studies, engineering projects, and work placements. Classroom learning provided the basic foundational engineering concepts to students, which then, after practise and application via classroom activities, aided in the formation of their base engineering knowledge. Students then applied this prior engineering knowledge to their engineering projects, where they further developed their abilities through problem-solving applications. Additionally, depending on the project's complexity and interdisciplinary engineering nature, students could develop additional new engineering knowledge not developed in their classroom learnings. Also, by solving the project's problem statement, students develop technical skills such as problem-solving, critical thinking, design and manufacturing abilities, 3D drawing skills, 3D software skills, and tools/machinery experiences, and non-technical skills like teamwork, communication, and interpersonal skills. This newly developed engineering knowledge; and technical and non-technical skills were then returned to classroom learnings and work placements.

In work placements, students further applied their engineering knowledge to real-world applications in the workplace, and that aided in developing a deeper understanding of classroom and engineering projects knowledge. Depending on the interdisciplinary nature of work placements, students could develop new engineering knowledge from work placements that were not developed from their classroom learnings and engineering projects. Students also further applied and practised engineering projects, developed technical skills, and developed some new technical skills from work placements. Students also developed employability skills such as: time management, project management, and planning and organisational skills from their work placements. This learning from work placements, regarding engineering knowledge, and learning technical and non-technical skills, was then transferred to future classroom learnings and engineering projects. This certainly shows clear learning linkages between engineering projects and work placements, which is further discussed in the sub-research questions below.

1. *What are stakeholders' perceptions of engineering students learning through engagement with PBL and WIL?*

The engineering students identified the learning outcomes from engineering projects and work placements. They perceived engineering projects as an approach where they could apply and practise their classroom-developed engineering knowledge in the project's problem-solving, which aided students in relating theory with practise. Students perceived engineering projects as an essential learning approach because engineering projects were designed based on the classroom learning engineering concepts and engineering curriculum. Accordingly, students developed engineering knowledge and technical and non-technical skills by problem-solving the engineering projects as a level that was required in their programme.

With work placements, students could apply and practise their previously developed engineering knowledge and skills in real-world engineering work environments, providing them with real industry exposure. As work placements provide students with industry work experience and the idea of different engineering career options, they perceive work placements as necessary for their learning. Thus, work placements allowed students to apply their previously developed technical and non-technical skills to workplace activities, which further aided in developing new skill sets, making students work-ready graduates.

Based on students' perceptions, this study interprets that engineering projects provided them with further development of classroom-acquired engineering knowledge, new engineering knowledge, and technical and non-technical skills. At the same time, work placements provided students with further development of classroom and engineering projects, acquired engineering knowledge, and developed more technical, non-technical, and employability skills. Students identified that these approaches are essential for developing their engineering knowledge and skill development in their engineering education.

2. *What, if any, scaffolding of learning occurs between PBL and WIL*?

The learning relationship between engineering projects and work placements was well identified via stakeholders' perceptions. Engineering projects provided additional engineering knowledge and development of technical and non-technical skills, which were not developed from classroom learnings. These learning outcomes from engineering projects were applied and practised in real-world applications via work placements. Students learned about other types of engineering beyond mechanical due to the interdisciplinary context of engineering projects. Students also practised problem-solving, critical thinking, communication, teamwork, 3D drawing skills, 3D software skills, design and manufacturing abilities, and tools/machinery experiences while problem-solving the projects. So, between classroom learning and work placements, engineering projects appear to offer scaffolded support, which developed essential engineering knowledge and skills to function effectively in work placements. Engineering projects provided sequencing of scaffolding of learning support to work placements, by providing students with the development of engineering knowledge and skills that were needed for students to excel in their work placements.

3. *What aspects of PBL and WIL are complementary (or not) in advancing student learning of the practise of engineering*?

The engineering projects provided the development of additional engineering knowledge and skill development, which were not developed in the classroom. Engineering projects provided complementary learning support to classroom learning. Similarly, when comparing classroom learning, engineering projects, and work placements, work placements provided additional new engineering knowledge that was not developed via classroom learning or engineering projects. Students could apply this newly developed engineering knowledge from work placements to their classroom learnings and engineering projects. This learning relationship between these three approaches indicates that work placements provided complementary learning support to both classroom learnings and work placements.

Similarly, work placements provided opportunities for students to practise previously developed technical and non-technical in real-world applications and aided in developing new technical and non-technical skills. These new technical and non-technical skills were not developed through classroom learning and engineering projects, so work placements provided an opportunity to ameliorate the shortfall in development. This also concludes that work placements provided complementary learning support to classroom learnings and engineering projects by providing opportunities to develop new technical, non-technical, and employability skills.

4. *How can understanding the synergies and differences between PBL and WIL inform and/or enhance the engineering curriculum*?

Students successfully identified their learning outcomes from engineering projects and work placements. Students perceived through engineering projects that they developed a much deeper understanding of classroom-learned engineering concepts because projects were designed and directly linked to classroom learnings and engineering curricula. Thus, projects showed a direct relationship to classroom learning, which aided students in relating those engineering concepts to practice, which benefitted students to deepen their understanding. Additionally, engineering projects were interdisciplinary, which aided in developing new engineering knowledge, and technical and non-technical skills, that were not developed via classroom learnings. Students understood these learning benefits from engineering projects and, therefore, they indicated that if the University could add more engineering projects into their curriculum, then that would greatly benefit students with the above-stated advantages.

Students had opportunities to experience a real-world engineering work environment to obtain exposure to engineering work culture and practices, and to work under expert supervision and with professionals, which aided in developing additional technical, non-technical, and employability skills in their work placements. Similarly, students successfully identified the learning benefits from work placements: the development of engineering knowledge and technical, non-technical, and employability skills. The findings demonstrate that this might be why students indicated they need more work placements, possibly enhancing their engineering knowledge and skill development.

6.3 Additional Findings Based on Researcher's Interpretation

This research study also identified additional findings based on researcher's interpretation, which are described below:

1. Students lacked some understanding, awareness, and preparation of engineering education practise, work placement processes, and assessment structures. Students indicated that they wanted more engineering-relevant work placements focused on core technical work roles only, as they perceived that they would only undertake technically-applied work roles during work placements. This indicated that students lacked some of the required awareness of normal workplace functions, purposes, and objectives. In order to develop employability skills in students, work placements provide students with a broad range of technical and non-technical works, as are typically expected in a workplace. This would aid in the development of technical and non-technical skills in students, along with developing employability skills. Students could not fully understand this overall learning outcome of work placement, and that may also indicate the University may have insufficiently prepared students for work placements through a lack of detailed orientations, induction, and providing students a detailed understanding of the intended learning outcomes of engineering projects and work placements. This may also indicate that the respective lecturers/course convenors/academic supervisors failed to

teach the students about the importance of engineering projects and work placements, how those works, their respective learning outcomes, and what to expect and not from these approaches.

2. Students indicated that if the number of assessments were fewer during their work placements, it would be beneficial for students to focus purely on work placements. This perception has validity, as assessments are completed whilst working full time. It also suggests a lack of awareness of the purpose of assessments. For example, assessments are intended for students to enhance their learning, to reflect on their learning, improve the self-awareness of their learning progress, and inform them of learning gaps and areas to focus on. Students lacked this awareness, and this suggests that the University did not impart this understanding to students via detailed instructions or orientation. This finding may also indicate that the assessment tasks and feedback do not achieve what they are designed to do and are pointless for the students, which may have made the students say the over-assessment was an issue.
3. Students suggested that universities add more engineering projects and work placements to engineering education programmes to enhance the overall engineering education experience. More such experiences could mean more exposure to real-world engineering applications and practise, developing engineering knowledge and skills, and practical hands-on experience. This demonstrates students' positive perceptions and benefits from these approaches. This outlines the students' needs, which Universities may address by providing more engineering projects and more work placement sessions to ensure that students maximise the benefits. There are some challenges that the university and employers may face, which are, firstly, more time that is required to accommodate a greater number of engineering projects and work placements. Secondly, adding more engineering projects and work placements may result in an extended programme structure. Thirdly, adding more

practical works via engineering projects and work placements may result in less time for theoretical classes. Students may lack an understanding of these challenges, which the University and employers may face.

4. Students lacked an understanding of the fact that to be a successful engineer, they need not only technical skills, but also non-technical skills. Students did not realise that engineer need proficiency in technical and non-technical related tasks. Students indicated that they expected to develop and enhance technical skills from work placements, but they did not expect to develop non-technical skills. Students gave more importance to technical skills and tasks, and seldomly thought about the non-technical skills and tasks. This also indicates their lack of understanding of engineering job roles, work culture, professionalism, and life-long learning skills. Students did not realise that the non-technical nature of some of the experiences was good, as these may aid in the development of non-technical or life-long learning skills, such as communication, interpersonal skills, and teamwork. This leads to students being poor at reflection and poor at the non-technical skills.

These findings have inferences for engineering lecturers and work placement supervisors because there are substantial learning outcomes and opportunities to develop engineering knowledge, technical and non-technical skills, employability skills, and professionalism from engineering projects and work placements. The university may consider refining its engineering curriculum in such a way that it focuses on developing engineering knowledge from classroom learning and engineering projects, and developing employability skills, professional ethics, and work experiences from work placements. In doing so, the University may utilise the clear distinction of learning outcomes of engineering projects and work placements to enhance the students' overall engineering degree study. In the next section, the impacts of this research on the literature are presented.

6.4 Impact of this Research on the Literature

The findings from this study provide information to fill identified research gaps, regarding the combined effects of engineering projects (PBL) and work placements (WIL) in engineering education. Studies by Jackson (2013), Kaider and Bussey (2018), , Kilpatrick et al. (2021), Ferns and Parrish (2021), and Billet (2021) showed that work-integrated learning (WIL) provided complementary support to classroom learning, by providing additional knowledge building, which was outside the scope of classroom learning outcome. Similarly, the words of Gita and Apsari (2017), Kaider and Bussey (2018), Ruskin et al. (2018), Yen et al. (2021), Savery (2021), and Hong and Lin (2022) stated that problem-based learning (PBL) provided scaffolded learning support across the whole education curriculum, by providing scaffolded knowledge building for classroom learning. These research studies show the linkages of WIL (via work placements) with classroom learnings, and PBL (via projects) with classroom learnings, but there are no research studies that explored learning linkages between engineering projects and work placements.

The research findings from this study explored the students' perceived learning outcomes of engineering projects and work placements and found that engineering projects provided complementary support of learning to classroom learnings, which matches the study findings of Gita and Apsari (2017), Niu et al. (2021), Karim and Ahmad (2022), Jafari and Salimi (2021), Hjorth and Hjorth-Anderson (2021), and Karim et al. (2019). This is because engineering projects were interdisciplinary, which aided in the development of new engineering knowledge outside the context of classroom learning. Additionally, by solving the project's engineering problem, students developed technical skills like problem-solving, critical thinking, design and manufacturing abilities, 3D drawing skills, 3D software skills, tools/machinery experiences, and technical skills like teamwork, communication, and interpersonal skills. These project-acquired learning outcomes were outside classroom learnings, and, therefore, students were able to take these further for application and development in their upcoming classroom learnings.

The actual learning outcomes from the engineering projects assisted the students to work efficiently, productively, and enthusiastically in their placements, as they had the knowledge and skills required to work in their technical and non-technical roles. The engineering projects provided students with essential engineering knowledge and technical and non-technical skills, which they could smoothly and successfully transfer to their work placements smoothly. Based on the findings, this study concludes that engineering projects provided scaffolded learning support to work placements by providing the necessary engineering knowledge and technical and non-technical skills for application in work placements. This study identified 'whether there is scaffolding of learning between engineering projects and work placements' as a potential research gap in this study, and findings from this study fills this research gap.

In work placements, students further developed previously acquired engineering knowledge and technical and non-technical skills by working on industry-based projects under expert supervision. As those industry projects were interdisciplinary, students developed new engineering knowledge, which was outside the scope of classroom learning and engineering projects. Additionally, students developed new non-technical and employability skills, such as planning and organising skills, time management, and project management from work placements. With these newly developed skills, students could reflect on their classroom learnings and engineering projects. Discovering this learning linkage, this study concludes that work placements provide complementary learning support to engineering projects by providing students with new engineering knowledge and technical and non-technical (employability) skills.

The findings demonstrate that this research establishes clear learning linkages between PBL via engineering projects and WIL via work placements (Figure 5.13, Section 5.7, Chapter 5), which would fill the identified research gap in the literature. Figure 5.13 shows the learning process flow between classroom learning, engineering projects, work placements, and respective learning outcomes from these approaches. This also shows how the learning outcomes from these approaches work together to develop students' overall engineering knowledge and technical, non-technical, and employability skills. This study shows that having such knowledge of the learning linkages between PBL and WIL may help educators design their engineering curriculum to benefit the most students in developing their overall engineering knowledge, technical abilities, and employability skills. In the next section, the impact of this research on education practise is described.

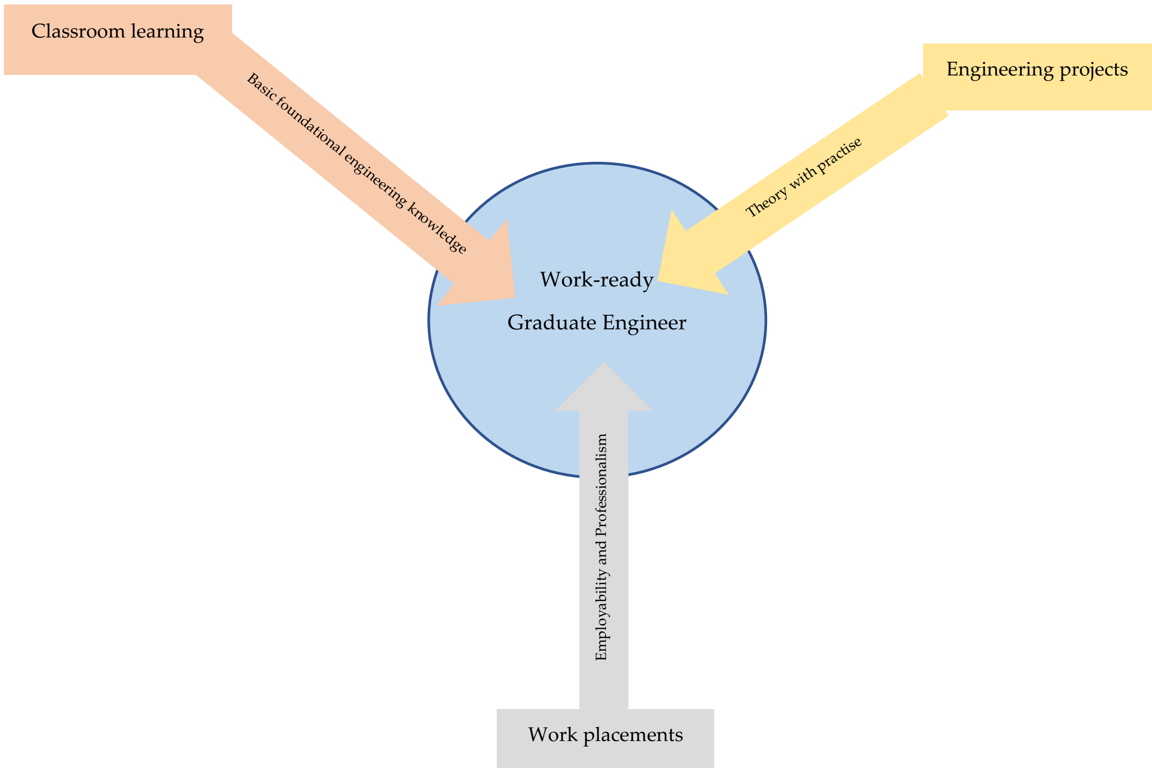
6.5 Implications for Engineering Education Practise

The research findings of this study identify the learning linkages between engineering projects and work placements based on participants' perceptions and the researcher's interpretations. Classroom learning only provides basic foundational engineering knowledge, whereas engineering projects provide theory with practise applications and aid in developing practical engineering knowledge. Work placements provide opportunities for enculturating students to develop employability and professionalism via work experiences. Such a clear distinction between these approaches may help the Universities to focus individually to enhance students specific outcomes. Figure 6.1 shows the triangulation process in developing a work-ready graduate in engineering education.

Particular emphasis on these teaching and learning approaches, along with more engineering projects and work placements may intensify the learning outcomes from these approaches. The teaching and learning approaches may be designed to focus on development of conceptual, procedural, societal, and technical knowledge domains, which may aid in the development of students' overall engineering knowledge and skills. Students may be aware that these learning approaches yield development in these knowledge domains, which indeed constructs their overall knowledge and skills. If the engineering curriculum is designed in this manner, then specific learning activities can be incorporated to focus mainly on the development of these knowledge domains through these approaches. For engineering projects, new learning activities can be designed to boost students' conceptual, procedural, societal, and technical knowledge domains, motivation to relate theory with practise, and apply engineering practise to real-world applications. Similarly, in work placements, new learning activities can be incorporated to enhance students' professional development, along with the development of knowledge domains.

The findings and interpretations suggest that by introducing more engineering projects into the engineering curriculum may help students to benefit with a deeper understanding and development of engineering knowledge. Similarly, instead of two work placements of 400 hours each, the University and employers could provide three different variety of work placements of 250 or 300 hours each. This could benefit students to enhance their engineering knowledge and develop employability skills and professionalism. Students' specific progression via these approaches can be monitored and focused, and accordingly, students' overall academic and professional development can be aided by the revised and restructured curriculum. The triangulation of classroom learning, engineering projects, and work placements, in the making of work-ready graduates is shown in Figure 6.1.

Figure 6.1: Triangulation of classroom learning, engineering projects, and work placements in engineering education.



If engineering projects and work placements are increased in number and complexity in engineering education, then this would substantially develop students' engineering knowledge, skills, technical abilities, and professionalism. This means, more engineering projects and work placements provide more opportunities for students to develop their conceptual, procedural, societal, and technical knowledge domains. Currently, students have four engineering projects and two work placements in their four-year engineering education programme.

The findings demonstrate that more engineering projects and work placements would mean more opportunities for students to develop their engineering education to become successful graduate engineers, however this would need to be balanced against cost and time. This study proposes that if there was a small project in each semester, that is, a total of eight projects across the whole engineering degree, then this would aid in strengthening students' understanding of engineering concepts. Similarly, if there is a total of three or four work placements across the curriculum, this would provide more opportunity for students to work in industry and develop employability skills and professionalism well before graduation.

The findings demonstrate that if educators and higher education institutions practise their teaching and learning by focusing individually on specific outcomes via these approaches, then this would benefit the students by enhancing their overall engineering education experience making them employable, work-ready graduates. In the next section, the limitations of this study are described.

6.6 Limitations of this Study

This research study had several limitations.

1. The research context was restricted to undergraduate mechanical engineering students from one university (University of Waikato) within a Western cultural context (New Zealand context). Therefore, it may not be generalisable to all disciplines and cultural contexts. Several international students were included in the study; however, this does not provide a wide cultural context.

2. Due to the impact of the COVID-19 pandemic, the number of student participants was less than anticipated. The work here did use triangulation to limit the impact of the small number of participants on the study findings.

3. The student cohort is predominantly made up of male students, reflecting the one-sided gender distribution of the mechanical engineering cohort. Female students are underrepresented in engineering and may hold different views about their engineering learning experience (Chopra et al., 2020).

4. This study is based on the perception data on how students think they have learned through engineering projects and work placements. Further testing can validate the students' perceptions.

These are the main limitations of this study and formulate essential recommendations for further research.

6.7 Future Research Directions

This research study established the combined learning linkages between engineering projects and work placements in mechanical engineering while indicating aspects of Vygotsky's (1978) constructivist learning theory in engineering education. The learning development in this study occurred in three different learning approaches: classroom learning, engineering projects, and work placements, with the help of tools and artefacts. The latter two approaches are social and collaborative in nature.

While investigating the learning linkages between these approaches, the study had several challenges, which might have limited the scope of the outcomes of this study. The challenges can be considered future recommendations for the researchers in this field of integration of engineering projects and work placements. The following were challenges identified in this study and are recommendations for further research:

1. This study focused on mechanical engineering; therefore, a study similar to this present study should be carried out that would involve other engineering disciplines and other fields of education, and related stakeholders. This would provide a more inclusive understanding of the integration of engineering projects and work placements in engineering education. This would generalise the findings in work-integrated learning and strategies to incorporate engineering projects (PBL) integration and work placements (WIL).

2. This study was limited in sample size due to the impact of COVID-19 during the data gathering stages. A similar study should be carried out involving a

larger sample of students, recent graduates, lecturers, and workplace supervisors to confirm the findings of this thesis. A larger sample will provide wide-angled perceptions of engineering practise via these approaches and will help triangulate the learning linkages of WIL and PBL in engineering education.

3. This study presents an opportunity for researchers to further inspect the learning linkages between engineering projects and work placements in developing students' professional identity, work ethics, work experiences, professionalism, work readiness, self-confidence, and self-efficacy. These attributes are important for being a successful engineering graduate and, thus, are crucial for further research options involving problem-based learning and work-integrated learning.

4. Another potential area of further research is to consider contextual and institutional differences in engineering, such as in other university environments and higher education institutions such as polytechnics, engineering colleges, and trades institutes, where different perspectives may be obtained. A significant difference between universities and polytechnics may be that universities' engineering curricula are based on the Washington International Engineering Accord, while polytechnics are based on the Dublin and Sydney International Engineering Accord. The level of qualification should also be considered, other than a bachelor's degree. Other course structure could be investigated, for example, other degrees such as, diploma in engineering, a post-graduate diploma in engineering, a graduate diploma, trades certifications, and apprenticeship. Additionally, along with contextual differences, country and cultural differences could also be considered to widen the demographic views and inputs to enrich the research findings.

5. Another potential area for future research may also include experimental design to test the effects of learning through sequencing PBL and WIL models. It may also include investigating learning outcomes in iterative sequencing of these and other WIL models.

The section above has indicated some potential areas for further research in the field of Work-Integrated Learning and engineering education.

6.8 Final Comments

This study emphasises what happens in classroom learning, engineering projects, and work placements and indicates the actual learning outcomes from these approaches based on stakeholders' perceptions. The integration and combined learning effects of engineering projects and work placements can be beneficial for the students in developing their engineering knowledge, technical and non-technical skills, employability skills, and overall professionalism. This study also identified that technology education's knowledge domains could be related to the learning process of engineering education, specifically with engineering projects and work placements. The overall engineering knowledge and skill development of students occurred due to the development of conceptual, procedural, societal, and technical knowledge domains through the application of classroom learning, engineering projects, and work placements. This study also identified that engineering projects provided scaffolded learning support to work placements in developing engineering knowledge and promoting the linkage of theory with practise. In comparison, work placements provided complementary learning support to engineering projects, developing students' employability skills and professionalism. This study identified the specific outcomes from these approaches and suggested development of a future framework to utilise each of these approaches individually to enhance specific outcomes to boost students' overall progress in engineering education.

7 REFERENCES

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8 APPENDICES

APPENDIX A

LETTER TO THE DEAN, SCHOOL OF ENGINEERING, University of Waikato

RESEARCH TITLE: An investigation into students' views of off-campus Work-Integrated Learning and on-campus Practical Projects in preparing them for engineering practise.

Research Scholar: Siju Joseph Thomas

Dear Professor Mark Dyer,

The purpose of this letter is to seek your consent for the staff and students at your faculty to participate in a study which aims to survey and interview Mechanical engineering stakeholders (constituting employers on the Cooperative Education Unit’s database who receive students for work placements, recent student alumni from the past five years, current students and lecturers at your faculty) and to gain their perceptions of the effectiveness of Work-Integrated Learning (Work placements) and Practical projects in the engineering student’s education and employment.

Obtaining this data will provide valuable information on how Work placements and Practical projects prepare engineering students for their education and employment, and whether they are able to meet employer’s expectations. This data would help to provide an understanding as to which approach would better prepare students in their education and employment.

The findings can also be used to improve university curricula, teaching and learning process, and assessment.

The following research questions are intended to be addressed through the surveys and interviews:

Main Research Question: An investigation into students' views of off-campus Work-Integrated Learning and on-campus Practical Projects in preparing them for engineering practise.

Sub-Research Questions:

Q.1. Does the Practical Projects prepare the engineering students of 1st year for their Work-Integrated Learning in 2nd year?

Q.2. Does the Work-Integrated Learning prepare the engineering students of 2nd year for their advanced Practical Projects in 3rd year?

Q.3. Which was most effective for preparing students for engineering practise based on students' views?

With your consent, I would like to collect data from volunteer academic staff and students at your faculty through an online survey, and later by interview.

With your support,

- I would also like to request assistance from your office to provide the email contact of staff who teach courses in 1st, 2nd, 3rd and 4th year of mechanical engineering students, and
- Data base of students including that of recent alumni for the past three years, and current students of 1st, 2nd, 3rd and 4th year of mechanical engineering classes, to participate in the online survey.

The survey should take no more than 10 minutes. All staff and students will be informed that they are free to decline the invitation to participate in the research project even though consent for the study has been given by yourself as Dean of the Engineering. Participation in the survey will be anonymous, but I would have personal details of the interested participants who would like to continue in this study and participate in individual interviews later in the study. No one else but the researcher would be able to access personal details of the participants.

The data collected will be confidential, used only for the purposes of the research, and stored securely and destroyed after five years. Students' participation or non-participation will not influence their standing in their academic programme nor grades in anyway. Likewise, lecturer's participation or non-participation will not influence their employment status in anyway.

A copy of the final research report will be made available to you/the Faculty of Engineering and Science and will be posted on the Cooperative Education Unit.

I would appreciate your approval for this project to be proceeded within your faculty. If you have any queries about this project you may contact the Chief Supervisor Associate Professor Wendy Fox (wendy.fox-turnbull@waikato.ac.nz) and co-supervisor, Dr Karsten Zegwaard (karsten.zegwaard@waikato.ac.nz).

Thank You.

Yours sincerely,
Siju Joseph Thomas
PhD Scholar, Faculty of Education, University of Waikato.

Permission Form – Dean of the School of Engineering,

The University of Waikato

RESEARCH TITLE: An investigation into students' views of off-campus Work-Integrated Learning and on-campus Practical projects in preparing them for engineering practise.

Research Scholar: Siju Joseph Thomas

In signing this form, I acknowledge that:
This form will be held for five years. The data gathered will be kept securely for the same length of time.

- I have been given and have understood an explanation of the research project.
- I have had an opportunity to ask questions and have them answered.
- I give permission for the investigator:
    - To access the current student database, including 2nd, 3rd and 4th year of mechanical engineering students, and recent alumni for the past five years, and
    - To access database of staff who teach courses in 2nd, 3rd and 4th year of mechanical engineering classes.

Signed: ________________________

Name: _________________________

Date: __________________________________

APPENDIX B

LETTER TO ALUMNI OFFICE, University of Waikato

RESEARCH TITLE: An investigation into students' views of off-campus Work-Integrated Learning and on-campus Practical Projects in preparing them for engineering practise.

Research Scholar: Siju Joseph Thomas

Dear Alumni Officer,

The purpose of this letter is to seek your consent for getting e-mail addresses of the recent Mechanical engineering graduates (within 3 years of graduation) from the Faculty of Engineering and Science, to invite them for an online survey and focus-group interview, to gain their perceptions of the effectiveness of Work-Integrated Learning (Work placements) and Practical projects in the engineering student's education and employment.

Obtaining their views will provide valuable information on how Work placements and Practical projects prepare engineering students for their education and employment, and whether they are able to meet employer's expectations. This data would help to provide an understanding as to which approach would better prepare students in their education and employment.

The findings can also be used to improve university curricula, teaching and learning process, and assessment.

The following research questions are intended to be addressed through the survey and focus-group interview:

Main Research Question: An investigation into students' views of off-campus Work-Integrated Learning and on-campus Practical Projects in preparing them for engineering practise.

Sub-Research Questions:

Q.1. Does the Practical Projects prepare the engineering students of 1st year for their Work-Integrated Learning in 2nd year?

Q.2. Does the Work-Integrated Learning prepare the engineering students of 2nd year for their advanced Practical Projects in 3rd year?

Q.3. Which was most effective for preparing students for engineering practise based on students' views?

With your consent, I would like to email addresses of the recent graduates and collect data through an online survey, and later by interview.

The survey should take no more than 10 minutes. The recent graduates will be informed that they are free to decline the invitation to participate in the research project. Participation in the survey will be anonymous, but I would have personal details (name and email address) of the interested participants who would like to continue in this study and participate in focus-group interview later in this study. No one else but the researcher would be able to access personal details of the participants.

The data collected will be confidential, used only for the purposes of the research, and stored securely and destroyed after five years.

A copy of the final research report will be made available to you/the Alumni office and will be posted on the Cooperative Education Unit.

I would appreciate your approval for getting the email addresses of the recent graduates. If you have any queries about this study, you may contact the Chief Supervisor Associate Professor Wendy Fox (wendy.fox-turnbull@waikato.ac.nz) and co-supervisor, Dr Karsten Zegwaard (karsten.zegwaard@waikato.ac.nz).

Thank You.

Yours sincerely,

Siju Joseph Thomas
PhD Scholar, Faculty of Education,

University of Waikato.

Permission Form – Alumni Office,
The University of Waikato

RESEARCH TITLE: An investigation into students' views of off-campus Work-Integrated Learning and on-campus Practical projects in preparing them for engineering practise.

Research Scholar: Siju Joseph Thomas

In signing this form, I acknowledge that:

- I have been given and have understood an explanation of the research project.
- I have had an opportunity to ask questions and have them answered.
- I give permission for the investigator:
    - To access recent graduates' email addresses and contact them for inviting them for an online survey and focus-group interview.

Signed: ________________________

Name: _________________________

Date: __________________________________

APPENDIX C

LETTER TO THE PILOT STUDY STUDENTS – SURVEY INVITATION

Dear students,

I invite you to participate in an online survey as part of a research study for my PhD programme at the University of Waikato. The purpose of this study is to learn about **AN INVESTIGATION INTO STUDENTS' VIEWS OF OFF-CAMPUS WORK-INTEGRATED LEARNING AND ON-CAMPUS PRACTICAL PROJECTS IN PREPARING THEM FOR ENGINEERING PRACTISE.** The research is being conducted under the supervision of Associate Professor Wendy Fox-Turnbull and Dr Karsten Zegwaard.

You are being invited to take part in this research because you study in the field of Engineering in the Faculty of Engineering and Science, University of Waikato and your knowledge and experience would be a good contribution to the present research study. The survey may take 2-5 minutes to complete. I would like to invite you to respond to this survey by clicking the link below:

URL for survey link

- I understand that you are very busy and thank you in advance for your time in helping in this important research. I would like to draw your attention to the following considerations:
- Your participation in this research is completely voluntary
- If you do not wish to answer any questions, you may skip it and move on to the next question
- The survey data would be kept anonymous, and confidential, and stored safely.
- The findings may be included in my thesis which will be lodged in the University of Waikato Research Commons when it is completed. If you wish to view findings from the survey, you will find the university link at the end of the survey
- This proposal has been reviewed and approved by the Waikato University Ethics Committee, to make sure that research participants are protected from harm.
- If you have any questions, or need more details about this research, please contact me, Siju Joseph Thomas, sjt39@students.waikato.ac.nz, 0220137293. If I am unable to resolve your concerns, you may contact my Chief supervisor, Associate Professor Wendy Fox-Turnbull, wendy.fox-

turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

- If you would be prepared and willing to help me further in the next phase, in individual interviews focusing on your experiences of Work placement and Engineering project for your professional learning in engineering education, please indicate your interest by clicking on the link below and I will follow up to set up the next phase of your involvement.
- Given to the sensitive nature of the material, participants would not be offered summary of the survey results.

URL for survey

Thank You.

Yours sincerely,

Siju Joseph Thomas

PhD Scholar, Faculty of Education,

University of Waikato.

Consent Form

I have read the attached letter of information and I understand that:

1. I have been given a full explanation of this study, the aim of study and future benefits to engineering education, students, universities, employers and communities.
2. I understand what I am required to do in this research.
3. I understand that participation is voluntary, and you may withdraw at any time without penalty.
4. I understand that any information or opinions provided will be kept confidential to the researcher and transcribers of interviews and that any published or reported results will not disclose the participants or their institution.
5. I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after 5 years.
6. I understand the risks associated with staff and students taking part in this process and how they will be managed.
7. I understand that I can contact the researcher Mr. Siju Joseph Thomas at sjt39@students.waikato.ac.nz or on phone and WhatsApp 0220137293.
8. I understand that if any unresolved issues exist, I can contact the study project Chief supervisor Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

By signing below, I agree to give consent to be involved in the project under the conditions set out above.

Name: ____

Signed: _______________________________________

Date:____

Email address (for semi-structured interview contact)

____

Please email this form to the researcher at: sjt39@students.waikato.ac.nz

APPENDIX D

LETTER TO THE PILOT STUDY STUDENTS – INTERVIEW INVITATION

Dear Students,

I invite you to participate in an online survey as part of a research study for my PhD programme at the University of Waikato. The purpose of this study is to learn about **AN INVESTIGATION INTO STUDENTS' VIEWS OF OFF-CAMPUS WORK-INTEGRATED LEARNING AND ON-CAMPUS PRACTICAL PROJECTS IN PREPARING THEM FOR ENGINEERING PRACTISE.** The research is being conducted under the supervision of Associate Professor Wendy Fox-Turnbull and Dr Karsten Zegwaard.

The survey may take 2-5 minutes to complete. I would like to invite you to respond to this survey by clicking the link below:

URL for survey link

- I understand that you are very busy and thank you in advance for your time in helping in this important research. I would like to draw your attention to the following considerations:
- Your participation in this research is completely voluntary
- If you do not wish to answer any questions, you may skip it and move on to the next question
- The survey data would be kept anonymous, and confidential, and will be stored safely.
- The findings may be included in my thesis which will be lodged in the University of Waikato Research Commons when it is completed. If you wish to view findings from the survey, you will find the university link at the end of the survey
- This proposal has been reviewed and approved by the Waikato University Ethics Committee, to make sure that research participants are protected from harm.
- If you have any questions, or need more details about this research, please contact me, Siju Joseph Thomas, sjt39@students.waikato.ac.nz, 0220137293. If I am unable to resolve your concerns, you may contact my Chief supervisor. Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.
- If you would be prepared and willing to help me further in the next phase, in individual interviews focusing on your experiences of Work placement and Engineering project for your professional learning in engineering education,

please indicate your interest by clicking on the link below and I will follow up to set up the next phase of your involvement.

- Given to the sensitive nature of the material, participants would not be offered summary of the survey results.

URL for interview indication

Thank You.

Yours sincerely,

Siju Joseph Thomas,

PhD Scholar, Faculty of Education,

University of Waikato.

Consent Form

I have read the attached letter of information and I understand that:

1. I have been given a full explanation of this study, the aim of study and future benefits to engineering education, students, universities, employers and communities.
2. I understand what I am required to do in this research.
3. I understand that participation is voluntary, and you may withdraw at any time without penalty.
4. I understand that any information or opinions provided will be kept confidential to the researcher and transcribers of interviews and that any published or reported results will not disclose the participants or their institution.
5. I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after 5 years.
6. I understand the risks associated with staff and students taking part in this process and how they will be managed.
7. I understand that I can contact the researcher Mr. Siju Joseph Thomas at sjt39@students.waikato.ac.nz or on phone and WhatsApp 0220137293.
8. I understand that if any unresolved issues exist, I can contact the study project Chief supervisor Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

By signing below, I agree to give consent to be involved in the project under the conditions set out above.

Name: ____

Signed: _______________________________________

Date:____

Email address (for semi-structured interview contact)

____

Please email this form to the researcher at: sjt39@students.waikato.ac.nz

APPENDIX E

LETTER TO THE CURRENT STUDENTS – SURVEY INVITATION

Dear students,

I invite you to participate in an online survey as part of a research study for my PhD programme at the University of Waikato. The purpose of this study is to learn about **AN INVESTIGATION INTO STUDENTS' VIEWS OF OFF-CAMPUS WORK-INTEGRATED LEARNING AND ON-CAMPUS PRACTICAL PROJECTS IN PREPARING THEM FOR ENGINEERING PRACTISE.** The research is being conducted under the supervision of Associate Professor Wendy Fox-Turnbull and Dr Karsten Zegwaard.

You are being invited to take part in this research because you study in the field of Mechanical Engineering in the Faculty of Engineering and Science, University of Waikato and your knowledge and experience would be a good contribution to the present research study. The survey may take 2-5 minutes to complete. I would like to invite you to respond to this survey by clicking the link below:

URL for survey link

- I understand that you are very busy and thank you in advance for your time in helping in this important research. I would like to draw your attention to the following considerations:
- Your participation in this research is completely voluntary
- If you do not wish to answer any questions, you may skip it and move on to the next question
- The survey data would be kept anonymous, and confidential, and stored safely.
- The findings may be included in my thesis which will be lodged in the University of Waikato Research Commons when it is completed. If you wish to view findings from the survey, you will find the university link at the end of the survey
- This proposal has been reviewed and approved by the Waikato University Ethics Committee, to make sure that research participants are protected from harm.
- If you have any questions, or need more details about this research, please contact me, Siju Joseph Thomas, sjt39@students.waikato.ac.nz, 0220137293. If I am unable to resolve your concerns, you may contact my Chief supervisor, Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

- If you would be prepared and willing to help me further in the next phase, in individual interviews focusing on your experiences of Work placement and Engineering project for your professional learning in engineering education, please indicate your interest by clicking on the link below and I will follow up to set up the next phase of your involvement.
- Given to the sensitive nature of the material, participants would not be offered summary of the survey results.

URL for interview indication

Thank You.

Yours sincerely,

Siju Joseph Thomas

PhD Scholar,Faculty of Education,

University of Waikato.

Consent Form

I have read the attached letter of information and I understand that:

9. I have been given a full explanation of this study, the aim of study and future benefits to engineering education, students, universities, employers and communities.
10. I understand what I am required to do in this research.
11. I understand that participation is voluntary, and you may withdraw at any time without penalty.
12. I understand that any information or opinions provided will be kept confidential to the researcher and transcribers of interviews and that any published or reported results will not disclose the participants or their institution.
13. I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after 5 years.
14. I understand the risks associated with staff and students taking part in this process and how they will be managed.
15. I understand that I can contact the researcher Mr. Siju Joseph Thomas at sjt39@students.waikato.ac.nz or on phone and WhatsApp 0220137293.
16. I understand that if any unresolved issues exist, I can contact the study project Chief supervisor Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

By signing below, I agree to give consent to be involved in the project under the conditions set out above.

Name: ______________________________________

Signed: _____________________________________

Date:_______________________________________

Email address (for semi-structured interview contact)

____

Please email this form to the researcher at: sjt39@students.waikato.ac.nz

APPENDIX F

LETTER TO THE RECENT GRADUATES – SURVEY INVITATION

Dear Alumni (University of Waikato),

I invite you to participate in an online survey as part of a research study for my PhD programme at the University of Waikato. The purpose of this study is to learn about **AN INVESTIGATION INTO STUDENTS' VIEWS OF OFF-CAMPUS WORK-INTEGRATED LEARNING AND ON-CAMPUS PRACTICAL PROJECTS IN PREPARING THEM FOR ENGINEERING PRACTISE.** The research is being conducted under the supervision of Associate Professor Wendy Fox-Turnbull and Dr Karsten Zegwaard.

You are being invited to take part in this research because you graduated in Mechanical Engineering from the Faculty of Engineering and Science, University of Waikato and your knowledge and experience would be a good contribution to the present research study. The survey may take 2-5 minutes to complete. I would like to invite you to respond to this survey by clicking the link below:

URL for survey link

- I understand that you are very busy and thank you in advance for your time in helping in this important research. I would like to draw your attention to the following considerations:
- Your participation in this research is completely voluntary
- If you do not wish to answer any questions, you may skip it and move on to the next question
- The survey data would be kept anonymous, and confidential, and will be stored savely.
- The findings may be included in my thesis which will be lodged in the University of Waikato Research Commons when it is completed. If you wish to view findings from the survey, you will find the university link at the end of the survey
- This proposal has been reviewed and approved by the Waikato University Ethics Committee, to make sure that research participants are protected from harm.
- If you have any questions, or need more details about this research, please contact me, Siju Joseph Thomas, sjt39@students.waikato.ac.nz, 0220137293. If I am unable to resolve your concerns, you may contact my Chief supervisor. Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

- If you would be prepared and willing to help me further in the next phase, in individual interviews focusing on your experiences of Work placement and Engineering project for your professional learning in engineering education, please indicate your interest by clicking on the link below and I will follow up to set up the next phase of your involvement.
- Given to the sensitive nature of the material, participants would not be offered summary of the survey results.

URL for interview indication

Thank You.

Yours sincerely,

Siju Joseph Thomas,

PhD Scholar, Faculty of Education,

University of Waikato.

Consent Form

I have read the attached letter of information and I understand that:

9. I have been given a full explanation of this study, the aim of study and future benefits to engineering education, students, universities, employers and communities.
10. I understand what I am required to do in this research.
11. I understand that participation is voluntary, and you may withdraw at any time without penalty.
12. I understand that any information or opinions provided will be kept confidential to the researcher and transcribers of interviews and that any published or reported results will not disclose the participants or their institution.
13. I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after 5 years.
14. I understand the risks associated with staff and students taking part in this process and how they will be managed.
15. I understand that I can contact the researcher Mr. Siju Joseph Thomas at sjt39@students.waikato.ac.nz or on phone and WhatsApp 0220137293.
16. I understand that if any unresolved issues exist, I can contact the study project Chief supervisor Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

By signing below, I agree to give consent to be involved in the project under the conditions set out above.

Name: ____

Signed: _______________________________________

Date:____

Email address (for semi-structured interview contact)

____

Please email this form to the researcher at: sjt39@students.waikato.ac.nz

APPENDIX G

LETTER TO CURRENT STUDENTS – INTERVIEW INVITATION

Dear students,

I would like to invite you to participate in individual and focus-group interviews, which are expected to last 30-40 minutes each. I would like to audio-record our conversation, with your agreement, so that I can analyse our conversation later. The information recorded will be confidential and it will only be accessible to me. I will provide you with a transcription of the interview if requested, for you to check for accuracy and to make any changes to what you have said within two weeks of receiving it and then returning to me by email.

- Your participation in this research is completely voluntary, and you can decline to be involved further in this study without any consequence.
- You are free to withdraw from the study at any time up until data analysis commences. If there is a withdrawal, the data gathered from you will be destroyed.
- Additionally, if you do not wish to answer any questions in the interview, you may skip it and move on to the next question.
- All the information you provide will remain confidential and only be used for research purposes, and in publications related to this research. Any data pertaining to you will be reported anonymously in such a way that it is unlikely to be traceable to you.
- However, every reasonable effort will be made to ensure your anonymity, and you will not be identified in any reports and publications without your explicit permission.
- The findings may be included in my thesis which will be lodged in the University of Waikato Research Commons when it is completed. The data collected for the purpose of this study will remain confidential to my supervisors and me. The transcript of your interview and its audio recording will be stored in a locked space in my office. Electronic data will be kept on a password protected device. The data will be stored for a minimum of five years and after that will be destroyed. This proposal has been reviewed and approved by the Waikato University Ethics Committee, to make sure that research participants are protected from harm.

I would appreciate your participation in this interview. If you have any questions, or need more details about this research, please contact me, Siju Joseph Thomas, sjt39@students.waikato.ac.nz, 0220137293. If I am unable to resolve your concerns, you may contact my Chief supervisor, Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

Thank You.

Yours sincerely,

Siju Joseph Thomas,

PhD Scholar, Faculty of Education,

University of Waikato.

Consent Form

I have read the attached letter of information and I understand that:

1. I have been given a full explanation of this study, the aim of study and future benefits to engineering education, students, universities, employers and communities.
2. I understand what I am required to do in this research.
3. I understand that participation is voluntary, and you may withdraw at any time without penalty.
4. I understand that any information or opinions provided will be kept confidential to the researcher and transcribers of interviews and that any published or reported results will not disclose the participants or their institution.
5. I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after 5 years.
6. I understand the risks associated with staff and students taking part in this process and how they will be managed.
7. I understand that I can contact the researcher Mr. Siju Joseph Thomas at sjt39@students.waikato.ac.nz or on phone and WhatsApp 0220137293.
8. I understand that if any unresolved issues exist, I can contact the study project Chief supervisor Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.
9. I understand that I can get summary of the results of the study if I provide my email address.

By signing below, I agree to give consent to be involved in the project under the conditions set out above.

Name: ______________________________________

Signed: _____________________________________

Date:_______________________________________

Email address (for semi-structured interview contact and/or report of findings)

____

Please email this form to the researcher at: sjt39@students.waikato.ac.nz

APPENDIX H

LETTER TO RECENT GRADUATES – INTERVIEW INVITATION

Dear Alumni (University of Waikato),

I would like to invite you to participate in a Focus-group interview, which is expected to last 30-40 minutes. I would like to audio-record our conversation, with your agreement, so that I can analyse our conversation later. The information recorded will be confidential and it will only be accessible to me. I will provide you with a transcription of the interview if requested, for you to check for accuracy and to make any changes to what you have said within two weeks of receiving it and then returning to me by email.

- Your participation in this research is completely voluntary, and you can decline to be involved further in this study without any consequence. You are free to withdraw from the study at any time up until data analysis commences. If there is a withdrawal, the data gathered from you will be destroyed.
- Additionally, if you do not wish to answer any question in the interview, you may skip it and move on to the next question. All the information you provide will remain confidential and only be used for research purposes, and in publications related to this research.
- Any data pertaining to you will be reported anonymously in such a way that it is unlikely to be traceable to you. However, every reasonable effort will be made to ensure your anonymity, and you will not be identified in any reports and publications without your explicit permission.
- The findings may be included in my thesis which will be lodged in the University of Waikato Research Commons when it is completed. The data collected for the purpose of this study will remain confidential to my supervisors and me. The transcript of your interview and its audio recording will be stored in a locked space in my office. Electronic data will be kept on a password protected device. The data will be stored for a minimum of five years and after that will be destroyed. This proposal has been reviewed and approved by the Waikato University Ethics Committee, to make sure that research participants are protected from harm.

I would appreciate your participation in this interview. If you have any questions, or need more details about this research, please contact me, Siju Joseph Thomas, sjt39@students.waikato.ac.nz, 0220137293. If I am unable to resolve your concerns, you may contact my Chief supervisor, Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

Thank You.

Yours sincerely,

Siju Joseph Thomas,

PhD Scholar, Faculty of Education,

University of Waikato.

Consent Form

I have read the attached letter of information and I understand that:

1. I have been given a full explanation of this study, the aim of study and future benefits to engineering education, students, universities, employers and communities.
2. I understand what I am required to do in this research.
3. I understand that participation is voluntary, and you may withdraw at any time without penalty.
4. I understand that any information or opinions provided will be kept confidential to the researcher and transcribers of interviews and that any published or reported results will not disclose the participants or their institution.
5. I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after 5 years.
6. I understand the risks associated with staff and students taking part in this process and how they will be managed.
7. I understand that I can contact the researcher Mr. Siju Joseph Thomas at sjt39@students.waikato.ac.nz or on phone and WhatsApp 0220137293.
8. I understand that if any unresolved issues exist, I can contact the study project Chief supervisor Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.
9. I understand that I can get summary of the results of the study if I provide my email address.

By signing below, I agree to give consent to be involved in the project under the conditions set out above.

Name: ______________________________________

Signed: _____________________________________

Date:_______________________________________

Email address (for semi-structured interview contact and/or report of findings)

____

Please email this form to the researcher at: sjt39@students.waikato.ac.nz

APPENDIX I

LETTER TO THE LECTURERS

Dear lecturers,

I invite you to participate in an individual interview as part of a research study for my PhD programme at the University of Waikato. The aim of this study is - **AN INVESTIGATION INTO STUDENTS' VIEWS OF OFF-CAMPUS WORK-INTEGRATED LEARNING AND ON-CAMPUS PRACTICAL PROJECTS IN PREPARING THEM FOR ENGINEERING PRACTISE.** The research is being conducted under the supervision of Associate Professor Wendy Fox-Turnbull and Dr Karsten Zegwaard.

You are being invited to take part in this research because you are lecturers of the Mechanical Engineering program, in the Faculty of Engineering and Science, University of Waikato and your knowledge and experience would be a good contribution to the present research study. The interview may take 15–30 minutes to complete.

- I understand that you are very busy and thank you in advance for your time in helping in this important research. I would like to draw your attention to the following considerations:
- Your participation in this research is completely voluntary
- If you do not wish to answer any questions, you may skip it and move on to the next question
- The interview data would be kept anonymous, and confidential, and stored safely.
- The findings may be included in my thesis which will be lodged in the University of Waikato Research Commons when it is completed. If you wish to view findings from the interview, you can mail me to get the findings
- This proposal has been reviewed and approved by the Waikato University Ethics Committee, to make sure that research participants are protected from harm.
- If you have any questions, or need more details about this research, please contact me, Siju Joseph Thomas, sjt39@students.waikato.ac.nz, 0220137293. If I am unable to resolve your concerns, you may contact my supervisor Associate Professor, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

Thank You.

Yours sincerely

Siju Joseph Thomas,

PhD Scholar, Faculty of Education, University of Waikato.

Consent Form

I have read the attached letter of information and I understand that:

1. I have been given a full explanation of this study, the aim of study and future benefits to engineering education, students, universities, employers and communities.
2. I understand what I am required to do in this research.
3. I understand that participation is voluntary, and you may withdraw at any time without penalty.
4. I understand that any information or opinions provided will be kept confidential to the researcher and transcribers of interviews and that any published or reported results will not disclose the participants or their institution.
5. I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after 5 years.
6. I understand the risks associated with staff and students taking part in this process and how they will be managed.
7. I understand that I can contact the researcher Mr. Siju Joseph Thomas at sjt39@students.waikato.ac.nz or on phone and WhatsApp 0220137293.
8. I understand that if any unresolved issues exist, I can contact the study project Chief supervisor Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.
9. I understand that I can get summary of the results of the study if I provide my email address.

By signing below, I agree to give consent to be involved in the project under the conditions set out above.

Name: ____

Signed: _______________________________________

Date:____

Email address (for semi-structured interview contact and/or report of findings)

____

Please email this form to the researcher at: sjt39@students.waikato.ac.nz

APPENDIX J

LETTER TO THE WIL SUPERVISORS

Dear WIL supervisor,

I invite you to participate in an individual interview as part of a research study for my PhD programme at the University of Waikato. The aim of this study is – **AN INVESTIGATION INTO STUDENTS' VIEWS OF OFF-CAMPUS WORK-INTEGRATED LEARNING AND ON-CAMPUS PRACTICAL PROJECTS IN PREPARING THEM FOR ENGINEERING PRACTISE.** The research is being conducted under the supervision of Associate Professor Wendy Fox-Turnbull and Dr Karsten Zegwaard.

You are being invited to take part in this research because you train students in Work placements, in the field of Mechanical Engineering and your knowledge and experience would be a good contribution to the present research study. The interview may take 15–30 minutes to complete.

- I understand that you are very busy and thank you in advance for your time in helping in this important research. I would like to draw your attention to the following considerations:
- Your participation in this research is completely voluntary
- If you do not wish to answer any questions, you may skip it and move on to the next question
- The interview data would be kept anonymous, and confidential, and stored savely.
- The findings may be included in my thesis which will be lodged in the University of Waikato Research Commons when it is completed. If you wish to view findings from the interview, you can mail me to get the findings
- This proposal has been reviewed and approved by the Waikato University Ethics Committee, to make sure that research participants are protected from harm.
- If you have any questions, or need more details about this research, please contact me, Siju Joseph Thomas, sjt39@students.waikato.ac.nz, 0220137293. If I am unable to resolve your concerns, you may contact my supervisor Associate Professor, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.

Thank You.

Yours sincerely,

Siju Joseph Thomas,

PhD Scholar, Faculty of Education, University of Waikato.

Consent Form

I have read the attached letter of information and I understand that:

17. I have been given a full explanation of this study, the aim of study and future benefits to engineering education, students, universities, employers and communities.
18. I understand what I am required to do in this research.
19. I understand that participation is voluntary, and you may withdraw at any time without penalty.
20. I understand that any information or opinions provided will be kept confidential to the researcher and transcribers of interviews and that any published or reported results will not disclose the participants or their institution.
21. I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after 5 years.
22. I understand the risks associated with staff and students taking part in this process and how they will be managed.
23. I understand that I can contact the researcher Mr. Siju Joseph Thomas at sjt39@students.waikato.ac.nz or on phone and WhatsApp 0220137293.
24. I understand that if any unresolved issues exist, I can contact the study project Chief supervisor Associate Professor Wendy Fox-Turnbull, wendy.fox-turnbull@waikato.ac.nz, or the School of Graduate Research by mail, SGR@waikato.ac.nz.
25. I understand that I can get summary of the results of the study if I provide my email address.

By signing below, I agree to give consent to be involved in the project under the conditions set out above.

Name: ____

Signed: _______________________________________

Date:____

Email address (for semi-structured interview contact and/or report of findings)

____

Please email this form to the researcher at: sjt39@students.waikato.ac.nz

APPENDIX K

APPROVED ETHICS APPLICATION

FEDU065/18

Approved: 13 August, 2018

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Ethics Research Application

An investigation into stakeholders' Views on the combined learning effects of practical projects (Problem-Based Learning) and work placements (Work-Integrated Learning) for preparing engineering students for professional practise in New Zealand

SIJU JOSEPH THOMAS

FACULTY OF EDUCATION

Overview

Principal Supervisor

Associate Professor Wendy Fox-Turnbull

Additional Personnel

N/A

Interest in Topic

I have been working as Lecturer in Electronics and Communication Engineering since 2016. I have spent mostly time in delivering lectures in Lecture rooms and Practical laboratories, and interaction with engineering students of 1st, 2nd and 4th year. This experience helps me to investigate how engineering student's learning can be improved by any other ways apart from classroom learning. At that point, I found interest in Work-Integrated learning and Problem based learning approaches. Problem based learning approach is prevalent in some or the other forms in the academic curriculums of the engineering students, in the form of their engineering projects, assignment, seminars, etcetera. So, through my research study, I would investigate which is more effective for the engineering student's education and employment. My Master's degree is purely on Electronics and Communication Engineering. Now my doctoral study is strongly related to my experience as Lecturer in engineering schools.

Details of the Project

Research questions

Overarching question:

What are stakeholders' views on the combined learning effects of practical projects (Problem-Based Learning) and work placements (Work-Integrated Learning) for preparing engineering students for professional practise?

Sub-questions:

1) What are stakeholders' perceptions of engineering student learning through engagement with PBL and WIL?
2) What, if any, scaffolding of learning occurs between PBL and WIL?
3) What aspects of PBL and WIL are complementary (or not) in advancing student learning of the practise of engineering?
4) How can understanding the synergies and differences between PBL and WIL inform and/or enhance the engineering curriculum.

Justification

The engineering graduates need to have strong hold on creativity, critical thinking, problem solving, communication and teamwork skills, but they usually lack it (Christensen, Henriksen, & Kolmos, 2006). If the students are provided an opportunity to undertake learning with practise, then it may help them to integrate the classroom learned theories with the practise-based knowledge, furthermore enhancing better understanding, knowledge retention, and skill development. There are several approaches to learning with practise, among which emphasis will be given on Work-Integrated Learning (WIL) and Problem-Based Learning (PBL), as these two are part of the engineering education curriculum in New Zealand. WIL refers to on-campus learning combined with work experiences (off-campus learning) that relates theory with practise in academic learning curriculums (Drysdale, McBeath, Johansson, Dressler, & Zaitseva, 2016). PBL aims to integrate knowledge and skills based on analysis and problem solving, by promoting student's active engagements with learning, by making them solve problems (Delisle, 1997). As both PBL and WIL aims at enhancing the skills and knowledge of the student and increasing employment opportunities, but the knowledge and skills acquired in each of them could be different. Through conducting a comprehensive research study, clarity could be obtained on how they complement each other, and thus how they provide integrated learning linkage between WIL and PBL. This indeed will provide answers for the stated research questions.

Christensen, J., Henriksen, L. B., & Kolmos, A. (2006). Future Engineering Skills, Knowledge and Identity. In A. Kolmos (Ed.), Engineering Science, Skills and Bildung. Aalborg, Denmark: Publizon A/S.

Delisle, R. (1997). Why use problem-based learning in classrooms. In M. Bleich (Ed.), How to use Problem-based learning in classrooms. Virginia, USA: Association of Supervision and Curriculum Development.

Drysdale, M. T. B., McBeath, M. L., Johansson, K., Dressler, S., & Zaitseva, E. (2016). Psychological attributes and work-integrated learning: an international study. Higher Education, Skills and Work-Based Learning, 6(1), 20-34. doi:10.1108/heswbl-02-2015-0004

Place in which the research will be conducted

Pilot Study and Main Study - Faculty of Engineering and Science, University in New Zealand.

Procedure for recruiting participants

- **Pilot Study:**

Previously approved.

Main Study:

The researcher will send an email to the Dean of Faculty of Science and Engineering seeking appointment to talk about the proposed research. As soon as the Dean responds positively, the researcher will schedule a meeting with the Dean to explain, provide Information Letter (Appendix A) and seek written consent (Appendix A) for participation in the current research.

As the Dean provide with their consent, a copy of that will be given back to the Dean for reference. Since the Dean(s) are in position of authority of the contact information, contact details (Names and Email addresses) of the lecturers, the WIL supervisors, recent graduates and current students (all Years) in the Mechanical Engineering department will be obtained. The researcher will send an invitation to the lecturers and WIL supervisors seeking their participation in the study. Respective informed letters and consent forms (Appendices I and J) will be sent as attachments via email. If the lectures and the WIL supervisors agree to participate, they will be requested to sign and return the respective consent forms. A copy of signed consent form will be provided to them for their reference. As the lecturers and WIL supervisors provide the written consent, their students will be contacted through the details provided by the Dean for their participation. The students and recent graduates (Alumni students) of the Mechanical Engineering department will be provided with the Information letter and consent form (Appendices E, F, G, and H). As the graduates and the current students agree to participate, they will be asked to return the sign consent form. A copy of signed consent form will be provided to the current students (all Years) and recent graduates (Alumni students) for their reference.

Procedures in which research participants will be involved - Indicate what activities you require participants to do in your study, and how much time will be needed for each participant. Consider use of bullet format to summarise this.

Main Study

- <u>Lecturers:</u>

The lecturers will be required to participate in semi-structured individual interviews (Appendix I and N). The interview will be conducted during the practical projects as per their convenient time and place. The interview will take approximately 15-30 minutes. The interview will be transcribed and provided to the lecturers for checking their inputs before any analysis takes place. Approximately, 15 minutes will be required from the lecturers to check the transcripts. The lecturers will also be asked to provide their course outline at the beginning of the semester.

Approximate Time:

Semi- structured Interview: 15-30min

Checking transcripts: 15 min

Also, from the lecturers of all Cohort's, their course outline will be collected in the beginning of their respective semester's, for document analysis.

- WIL supervisors:

  The WIL supervisors will be required to participate in semi-structured individual interviews (Appendix J and O). The interview will be conducted during the work placements as per their convenient time and place. The interview will take approximately 15-30 minutes. The interview will be transcribed and provided to the WIL supervisors for checking their inputs before any analysis takes place. Approximately, 15 minutes will be required from the lecturers to check the transcripts.

  Approximate Time:

  Semi- structured Interview: 15-30min

  Checking transcripts: 15 min

- Current Students:

  1. 2nd-Experience Cohort:

     The 2nd year Semester B students (50 students) will be required to participate in an online survey (Appendix E). The participants can participate in a survey as per their convenient time and place. Approximate time required to fill in the online survey is 5 minutes. After the online survey, representative random sampling will be done to invite 8-10 student participants to take part in focus group interviews. The interested participants will be provided with second information letter and consent form (Appendix G), in order to get their written consent. Two focus group interviews will be conducted using semi-structured interview schedule (Appendix M) at a time and place convenient to the participants. Each group will have 4-5 student participants. Each focus group will take approximately 30-40 minutes. The transcription of the focus group interview will not be provided as it is group data.

The students will also be observed during their practical project and work placement sessions. The observations (qualitative observation) will be made according to the schedule of these sessions. The researcher will not interfere with the scheduling of these sessions. As there is no prescribed time frame for these sessions, the researcher is in no position to provide approximate time required for the observations.

In addition to interviews and observations, students will also be required to provide with their written assignments for document analysis. The students' assignments will be collected in the end of their respective semesters.

Time Requirement:

Online Survey: 5 minutes

Focus-Group Interview: 30-40 minutes

Observation: As there is no prescribed time frame for these sessions, the researcher is in no position to provide approximate time required for the observations.

2. 3rd-Experience Cohort:

The 3rd year Semester B students (50 students) will be required to participate in an online survey (Appendix E). The participants can participate in a survey as per their convenient time and place. Approximate time required to fill in the online survey is 5 minutes. After the online survey, representative random sampling will be done to invite 8-10 participants to take part in focus group interviews. The interested participants will be provided with second information letter and consent form (Appendix G), in order to get their written consent. Two focus group interviews will be conducted using semi-structured interview schedule (Appendix M) at a time and place convenient to the participants. Each group will have 4-5 student participants. Each focus group will take approximately 30-40 minutes. The transcription of the focus group interview will not be provided as it is group data.

The students will also be observed during their practical project and work placement sessions. The observations (qualitative observation) will be made according to the schedule of these sessions. The researcher will not interfere with the scheduling of these sessions. As there is no prescribed time frame for these sessions, the researcher is in no position to provide approximate time required for the observations.

In addition to interviews and observations, students will also be required to provide with their written assignments for document analysis. The students' assignments will be collected in the end of their respective semesters.

Time Requirement:

Online Survey: 5 minutes

Focus-Group Interview: 30-40 minutes

Observation: As there is no prescribed time frame for these sessions, the researcher is in no position to provide approximate time required for the observations.

3. 4th-Experience Cohort

The 3rd year Semester C students (50 students) will be required to participate in an online survey (Appendix R). The participants can participate in a survey as per their convenient time and place. Approximate time required to fill in the online survey is 5 minutes. After the online survey, representative random sampling will be done to invite 8-10 participants to take part in focus group interviews. The interested participants will be provided with second information letter and consent form (Appendix G), in order to get their written consent. Two focus group interviews will be conducted using semi-structured interview schedule (Appendix M) at a time and place convenient to the participants. Each group will have 4-5 student participants. Each focus group will take approximately 30-40 minutes. The transcription of the focus group interview will not be provided, as it is group data.

The students will also be observed during their practical project and work placement sessions. The observations (qualitative observation) will be made according to the schedule of these sessions. The researcher will not interfere with the scheduling of these sessions. As there is no prescribed time frame for these sessions, the researcher is in no position to provide approximate time required for the observations.

In addition to interviews and observations, students will also be required to provide with their written assignments for document analysis. The students' assignments will be collected in the end of their respective semesters.

Time Requirement:

Online Survey: 5 minutes

Focus-Group Interview: 30-40 minutes

Observation: As there is no prescribed time frame for these sessions, the researcher is in no position to provide approximate time required for the observations.

4. 5th-Experience Cohort

The 3rd year Semester B students (50 students) will be required to participate in an online survey (Appendix E). The participants can participate in a survey as per their convenient time and place. Approximate time required to fill in the online survey is 5 minutes. After the online survey, representative random sampling will be done to invite 8-10 participants to take part in focus group interviews (Appendix L). The interested participants will be provided with second information letter and consent form (Appendix G), in order to get their written consent. Two focus group interviews will be conducted using semi-structured interview schedule (Appendix M) at a time and place convenient to the participants. Each group will have 4-5 student participants. Each focus group will take approximately 30-40 minutes. The transcription of the focus group interview will not be provided as it is group data.

The students will also be observed during their practical project and work placement sessions. The observations (qualitative observation) will be made according to the schedule of these sessions. The researcher will not interfere with the scheduling of these sessions. As there is no prescribed time frame for these sessions, the researcher is in no position to provide approximate time required for the observations.

In addition to interviews and observations, students will also be required to provide with their written assignments for document analysis. The students' assignments will be collected in the end of their respective semesters.

Time Requirement:

Online Survey: 5 minutes

Focus-Group Interview: 30-40 minutes

Observation: As there is no prescribed time frame for these sessions, the researcher is in no position to provide approximate time required for the observations.

- Recent Graduates (Alumni Cohort):

The recent graduates (50 students), who graduated in the last three years, will be required to participate in an online survey (Appendix F). The participants can participate in a survey as per their convenient time and place. Approximate time required to fill in the online survey is 5 minutes. After the online survey, representative random sampling will be done to invite 8 participants to take part in focus group interviews (Appendix H). The interested participants will be provided with second information letter and consent form (Appendix H), in order to get their written consent. Each focus group will take approximately 30-40 minutes. The transcription of the focus group interview (Appendix M) will not be provided as it is group data.

Time Requirement:

Online Survey: 5 minutes

Focus-Group Interview: 30-40 minutes

Procedures for handling information and materials produced in the course of the research. (Must be kept for at least five years.)

The types of data will include audio recording of individual interviews and their transcripts, electronic copy of online surveys, copy of participants' personal contact details, course outline from lecturers, assignments from students and researcher's notes. Hard printed copies of all research materials will be kept securely in a locked cabinet in my office; files containing electronic data will be stored in my personal computer in my office and will be password-protected and encrypted. All materials will be securely stored for five years after the completion of the study. After that period, all hard-printed copies will be shredded and electronic files will be completely deleted. The research data will be shared with the Supervisory Panel only. However, the personal information of participants will remain anonymous and confidential to me.

Ethical Issues

*** Access to participants**

1) I have had no contact with the potential participants. Hence, I will seek permission from potential participants (Mechanical engineering – recent graduates, current students, lecturers and WIL supervisors).
2) For the Main Study, the following procedure will be followed to access participants.

For conducting the main study, the researcher will send an email to the Dean of Faculty of Science and Engineering seeking appointment to talk about main study of the research. As soon as the Dean responds positively, the researcher will schedule a meeting with the Dean to explain, provide Information Letter (Appendix A) and seek written consent (Appendix A) for participation in the main study of the research.

As the Dean provide with their consent, a copy of that will be given back to the Dean for reference. Since the Dean(s) are in position of authority of the contact information, contact details (Names and Email addresses) of the lecturers, the WIL supervisors, recent graduates and current students (all Years) in the Mechanical Engineering department will be obtained. The researcher will send an invitation to the lecturers and WIL supervisors seeking their participation in the study. Respective informed letters and consent forms (Appendices I and J) will be sent as attachments via email. If the lectures and the WIL supervisors agree to participate, they will be requested to sign and return the respective consent forms. A copy of signed consent form will be provided to them for their reference.

As the lecturers and WIL supervisors provide the written consent, their students will be contacted through the details provided by the Dean for their participation. The students and recent graduates (Alumni students) of the Mechanical Engineering department will be provided with the Information letter and consent form (Appendices E, F, G, and H). As the graduates and the current students agree to participate, they will be asked to return the sign consent form. A copy of signed consent form will be provided to the current students (all Years) and recent graduates (Alumni students) for their reference.

*** Informed consent**

Participation in this research will be voluntary and, therefore, the informed consent of participants will be essential (Appendix C, D, E, F, G, H, I, J). They will be provided with the information letter that will state the research aim and purpose of the study, the procedures, the potential risks and benefits of their participation. The researcher will provide his contact details if they have any questions to ask about the study and raise concerns if they have.

*** Anonymity/Confidentiality**

All participants, including recent graduates, current Mechanical engineering students, Mechanical engineering lecturers and WIL supervisors, will be assigned pseudonyms that will be used for data coding and reporting on the study findings. Data will be used only for doctoral study and publication. Participants will be explained that all measures will be taken to protect their identities and keep the information they will provide confidential. Participants will be informed that the researcher will do everything possible to maintain full confidentiality and anonymity but this cannot be guaranteed. The details of the lecturer and his/her subject course, would be kept anonymous, as sharing such details may uncover their identity. Also, the workplace Industrial details will be kept anonymous, because of the sensitive nature of the workplace operations. The workplace details would not be pin pointed, or openly directed, that it may lead to their identification. The workplace details will be encoded for their identification, which will be known only to the researcher.

*** Potential harm to participants**

The following ethical principles have to be strictly followed behind my research activities: permission of people involved in the research, their wellbeing, respect, no emotional harm, and accurate representing of findings.

As a researcher, I have to remember that expected benefits of the research must never be at the cost of respect of interview participants. Their dignity, autonomy, and equality have to be upheld throughout the whole research process.

I do not anticipate any potential risks for participants during and after study. I will use pseudonymous in raw data as well as in report. However, regardless the situation, names of all participants and information they will provide will remain fully confidential. Also, the details of the workplace industries will be kept anonymous, and I would also not assign any direct pin-point details about them, which may indirectly lead to their identification.

The details of the industries in any documents would not be recognised, and they will be coded for their representation.

*** Participants' right to decline to participate and right to withdraw/withdraw data**

All participants are free to withdraw their participation before the commencement of data collection. If they decide to withdraw, they never need to provide any reasons for their withdrawal. After the qualitative individual interview, the participants are free to withdraw their data from the study after three weeks of data collection. For the Focus-Group interview, once the interview has been done, the participants cannot withdraw their data under any circumstances. The researcher will assure the participants that their comments / contributions in the focus-group interview will not be used for any publication purposes. In the case of quantitative survey, data cannot be withdrawn after the survey completion. Also, due to the sensitive nature of the study, the participants will not be offered the summary of the survey results.

*** Arrangements for participants to receive information**

All qualitative participants will have the opportunity to verify the accuracy of what has been transcribed from individual interviews and document analysis. As noted above, they can do so by reviewing the information from the transcript. Consent forms have detail explanation of this. I will also notify participants when transcripts are available to be checked. Each participant will have two week to make comments on the transcript. Given to the sensitive nature of the material, participants would not be offered summary of the survey results. Member checking will not available to members of focus-group interviews.

*** Use of the information**

The data will be used in the Doctoral thesis and this data may be included in the publication of academic courses and/or presented at conferences, in aspects related to the study. Data will not be used for any other purposes.

Conflicts of interest

None, I am not employed in any University in Hamilton or New Zealand.

*** Procedure for resolution of disputes**

If participants have any dispute in relation to my research, I will request participants to share to me in the first instance. If I am able to resolve them, then no further actions are needed. If not, then they may contact my PhD Chief supervisor, Associate Professor Wendy Fox-Turnbull, whose contact details are available in the information sheet, or the School of Graduate Research by mail - SGR@waikato.ac.nz.

Cultural and social considerations

New Zealand is a multi-cultural country with a number of ethnic groups. Research participants may be belong to Kiwi culture or may be from different and may have different religious beliefs and values. As a person born who grew up in India, I am engrossed with the cultures and customs of this country. Therefore, I do not anticipate any issues related to cultural insensitivity and/or disrespect. The research supervisors I will work with, are New Zealanders and well familiar with the culture and language. In an instance, where I am not familiar with the cultural practices and customs of a participant who I investigate, then I would ask my supervisor for their assistance, to ensure cultural and social practices are adhered to.

Language considerations

N/A

Other ethical concerns relevant to the research

N/A

Legal Issues

Copyright

The researcher will hold the copyright of any scholarly publication produced from the research unless relinquished to publishing company on publication.

Ownership of data or materials produced

Participants will own their own raw data. The researcher will own transcriptions, written notes made during the interviews, secondary data, the thesis, and other scholarly publications and/or presentations that get up from it.

Has this application in whole or part previously been applied and declined or approved by another ethics committee?

No

Any other legal issue relevant to the research

No**Research Timetable**

Proposed date of commencement of data collection

15 November, 2018

Expected date of completion of data collection

30 November, 2019

Informing Head(s) of School

Informing Head(s) of School

N/A

Additional Comments

My research study will be carried out in the Faculty of Engineering and Science, as the participants for surveys and interviews, i.e., the recent engineering graduates, current engineering students, engineering lecturers and engineering workplace supervisors, all are related to the Faculty of Engineering and Science. Thus, I have notified the Dean of Engineering and Science about my research intention and have also attached the information letter and consent form for the Dean hereby with this Ethics application. It is because of this reason that the above response is set to N/A, as I do not have any participants, courses or programmes associated with the Faculty of Education.

Applicant Agreement

Please copy the followings and ask your supervisor to sign the following support statement and upload it.

File Attachment : SC258R0222118070515250 (pdf)

Approval Date: 13 August, 2018

Chair: Sonja Arndt

APPENDIX L

SURVEY QUESTIONS

2nd-EXPERIENCE COHORT – 2nd Year Engineering Students

Work Placement is a period of supervised work, where you had the opportunity to experience working in a specific role with a company, through university's scheme of Work-Integrated Learning. You have had attended more than one Work Placement during your engineering education in University.

Practical Projects are the projects which you had participated during your engineering education, which included a couple of projects like Boat Race project, Cucumber Project, Engineering and Society group project, Engineering Mechanics group project, and Research and Development project

Classroom Learning is the classroom lectures that the students attend in university, where the lecturers bestow their knowledge and understanding of the subject to the students, so that the students develop knowledge and understanding of the same, and progress academically).

Q.1. Please specify your Gender.

a). Male

b). Female

c). Gender diverse

Q.2. Please specify your ethnicity.

Q.3. Please specify your Nationality.

Q.4. Please specify your Age range.

a). 14-19

b). 20-25

c). 26-31

d). 32-37

e). 38-43

f). 44-49

g). 50-55

h). 56-61

Q.5. Are you mostly full-time student or part-time?

Q.6. Are you working part-time during the year in any type of work? If yes, then please specify roughly how many hours a week?

Q.7. Are you working part-time in a workplace related to mechanical engineering?

a). Yes

b). No

Q.8. Please answer the following questions by ticking one response:

How important are the qualities for engineering? Please tick your responses.	Unimportant	Some importance	Moderately important	Important	Very Important
Intelligent					
Fast leaner					
Engineering knowledge					
Problem solving skills					
Good Communication skills					
Self-starter					
Work experience					
Logical abilities					

Hard worker					
Humble					
Team skills					
Adaptability					
Self-management					
Technically minded					
Studious					
Creative					
Critical thinking					
Planning and organising					
Artistic					
Analytical reasoning					
Employability skills					
Initiative					
Flexible					
Any comments	…………………………………………………………………………………………………..				

Q.9. Please answer the following question by ticking one response and writing an explanation:

Did Boat Race Project of 1st year help in any way in your Work Placement experience in 2nd year?	…………………… Yes …………………… No
Explain how.	……………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………

Q.10. Please answer the following question by ticking one response and writing an explanation:

Which project from First year of your engineering education do you remember the most? Please choose one from the following options.	ENGEN180 - (Boat Race) ________ ENGEN170 – (Engineering and Society Group Project) ________ ENGEN110 – (Engineering Mechanics Group Project) ________ None ________
Please provide reasons for your above answer	____ ____ ____

Q.11. Please respond to the following statement by ticking one option:

Activity	Very regularly	Reasonably regularly	Seldomly
I contributed ideas and facts during Work Placement			
I was able to understand the classroom taught theories during Work placement			
I used a variety of resources to understand working of different processes in the workplace.			
I learned more during Work Placement than doing classroom teaching			
I learned entirely different to that learned from Practical projects			
I helped efficiently in doing the team work			
I learned entirely different to that learned from classroom learning			
I was able to communicate professionally during Work placement			
Any comments	………………………………………………..		

Q.12. Recall your 1st year Boat Race Project. What were your expected outcomes (before) and actual outcomes (after) of Boat Race Project? Please tick your response(s). You can mark more than one answer.

	Expected outcome	Actual outcome
Obtain better understanding of classroom learned theories		
Obtain practical hands-on experience of engineering design		
Develop skills such as communication, team work, problem-solving, critical thinking and project management		
Get Academic Credit points to pass the course		
Nothing		
Others, please specify ……………………………………………………………………………………… ………………………………………………………………………………………………… ………………………………………………………………………………………………… ……………		

Q.13. Which of the following did you perceive as outcome of the Boat Race project? Please tick your response(s). You can mark more than one answer.

Problem solving skill	
Self-learning	
Team work	
Critical thinking	
Communication skills	
Leadership	
Better understanding of classroom learned theories	
Practical experience	
Others, please specify …… ……… ………………………………………	

Q.14. Reflect back on the Work Placement experience of 2nd year and consider the expected outcomes (before) and actual outcomes (after) of the following. Please tick your response(s). You can mark more than one answer.

	Expected outcome	Actual outcome

Obtain a future employment opportunity		
Obtain practical hands-on experience		
Develop employability skills such as communication, team work, problem-solving, critical thinking, project management, professionalism, leadership qualities and work-readiness.		
Get Academic Credit points to pass the course		
Nothing		
Others, please specify ………………………………………………………………………………………………… …… ………………………………………………………………………………………………		

Q.15. Which of the following skills did you perceive as an outcome of 2nd year's Work Placement? Please tick your response(s). You can mark more than one answer.

Communication skills	
Professional ethics	
Management skills	
Applications of theoretical studies	
Problem solving skills	
Self-learning	
Analytical and logical thinking	
Work experience	
Explore career options	
Knowledge retention	
Better understanding of classroom learned theories	
Others, please specify ……… …… ………………………	

Q.16. Please tick the aspects below that could have further enhanced your experience of the Boat Race project? You can mark more than one answer.

More genuine and challenging problem	

More support and guidance from Lecturer	
More preparation in Laboratories before the project begins	
More theory course work at classrooms	
Others, please specify …… …… ………………………………………	

Q.17. Please tick the aspects below that could have further enhanced your experience of the Work Placement? You can mark more than one answer.

More appropriate work placement	
More support from University	
More support from Industry/Workplace supervisor	
More guidance from University	
More preparation such as Induction course	
More theory course work at the University	
More communicational feedback from Industry to University	
Better ties up between University and Industry	
Others, please specify …… …… ………………………………………	

Q.18. This is a Pilot survey. Please provide comments about the survey, how understandable it was, clarity, or anything that seems missing.

Q.19. Please indicate if you would like to be part of a Pilot Focus-Group Interview?

a). Yes

b). No

Q.20. Please provide your full name.

Q.21. Please provide your email address.

3rd-EXPERIENCE COHORT – 3rd YEAR ENGINEERING STUDENTS

Work Placement is a period of supervised work, where you had the opportunity to experience working in a specific role with a company, through university's scheme of Work-Integrated Learning. You have had attended more than one Work Placement during your engineering education in University.

Practical Projects are the projects which you had participated during your engineering education, which included a couple of projects like Boat Race project, Cucumber Project, Engineering and Society group project, Engineering Mechanics group project, and Research and Development project

Classroom Learning is the classroom lectures that the students attend in university, where the lecturers bestow their knowledge and understanding of the subject to the students, so that the students develop knowledge and understanding of the same, and progress academically)

Q.1. Please specify your Gender.

a). Male

b). Female

c). Gender diverse

Q.2. Please specify your ethnicity.

Q.3. Please specify your Nationality.

Q.4. Please specify your Age range.

a). 14-19

b). 20-25

c). 26-31

d). 32-37

e). 38-43

f). 44-49

g). 50-55

h). 56-61

Q.5. Are you mostly full-time student or part-time?

Q.6. Are you working part-time during the year in any type of work? If yes, then please specify roughly how many hours a week?

Q.7. Are you working part-time in a workplace related to mechanical engineering?

a). Yes

b). No

Q.8. Please answer the following questions by ticking one response and writing an explanation.

Did you learn anything from Cucumber project that was different to classroom teaching?		Yes		No
Please explain how.	……………………………………………………………………………… ……………………………………………………………………………… ………………………………………………………………………………			

Q.9. Please answer the following questions by ticking one response and writing an explanation.

Do you think your 2nd year's Work placement helped you in any way in your 3rd year's Cucumber Project?		Yes		No
Explain how.	……………………………………………………………………………… ……………………………………………………………………………… ………………………………………………………………………………			

Q.10. Please respond to the following statement by ticking one option.

The following skills and qualities were developed through the Cucumber project.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Problem solving skill					
Team work					
Critical thinking					
Communication skills					
Logical Abilities					
Physical presentation					
Planning and Organising skills					
Leadership qualities					
Self-learning					
Professional Ethics					
Retention of information					
Logical Abilities					
Engineering knowledge					
Application of Information Technology					
Industrial and Technical exposure					
Idea of workplace environment					
Way of Professional working					
Professional social interaction					
Better understanding of classroom theories					
Available employment opportunities in the market					
Any comments	………………………………………………………………………………… …………………………………………………………………………………				

Q.11. Please respond to the following statement by ticking one option.

The 2nd year's Work placement helped you to enhance these skills in your 3rd year's Cucumber project.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Problem solving skill					
Team work					
Critical thinking					
Communication skills					
Logical Abilities					
Physical presentation					
Planning and Organising skills					
Any comments	………………………………………………………………………………….. …………………………………………………………………………………..				

Q.12. Please respond to the following statement by ticking one option.

The 1st year's Boat Race project helped you to enhance these skills in your 3rd year's Cucumber project.	Strongly Disagree	Disagree	Neutral	Agree	Strongl
Problem solving skill					
Team work					
Critical thinking					
Communication skills					
Logical Abilities					
Physical presentation					

Planning and Organising skills					
Any comments	……				

Q.13. Self-evaluate contribution in your Cucumber project experience. Please answer the following by ticking one response.

Activity	Very regularly	Reasonably regularly	Seldomly
I contributed ideas and facts for completion of the project			
I was able to understand the project based on the prior knowledge			
I used a variety of resources when doing the project			
I was able to learn more than from classroom learning			
I enhanced my problem-solving skills			
I helped my group efficiently in doing the team work			
I was able to understand the theory based on the project			
Any comments	…………………………………………………..		

Q.14. This is a Pilot survey. Please provide comments about the survey, how understandable it was, clarity, or anything that seems missing.

Q.15. Please indicate if you would like to be part of a Pilot Focus-Group Interview?

a). Yes

b). No

Q.16. Please provide your full name.

Q.17. Please provide your email address.

4th-EXPERIENCE COHORT – 3rd YEAR ENGINEERING STUDENTS

Work Placement is a period of supervised work, where you had the opportunity to experience working in a specific role with a company, through university's scheme of Work-Integrated Learning. You have had attended more than one Work Placement during your engineering education in University.

Practical Projects are the projects which you had participated during your engineering education, which included a couple of projects like Boat Race project, Cucumber Project, Engineering and Society group project, Engineering Mechanics group project, and Research and Development project

Classroom Learning is the classroom lectures that the students attend in university, where the lecturers bestow their knowledge and understanding of the subject to the students, so that the students develop knowledge and understanding of the same, and progress academically)

Q.1. Please specify your Gender.

a). Male

b). Female

c). Gender diverse

Q.2. Please specify your ethnicity.

Q.3. Please specify your Nationality.

Q.4. Please specify your Age range.

a). 14-19

b). 20-25

c). 26-31

d). 32-37

e). 38-43

f). 44-49

g). 50-55

h). 56-61

Q.5. Are you mostly full-time student or part-time?

Q.6. Are you working part-time during the year in any type of work? If yes, then please specify roughly how many hours a week?

Q.7. Are you working part-time in a workplace related to mechanical engineering?

a). Yes

b). No

Q.8. Please answer the following questions by ticking one response and writing an explanation.

Do you think your 3rd year's Work placement provided you something different from 3rd year's Cucumber project?		Yes		No
Please explain your above response.	……………………………………………………………………………… ……………………………………………………………………………… ………………………………………………………………………………			

Q.9. Please answer the following questions by ticking one response and writing an explanation.

Do you think your 1st year's Boat Race project's outcomes were enhanced in your 2nd year's work placement?		Yes		No
Please state how and reasons for your above response.	……………………………………………………………………………… ……………………………………………………………………………… ………………………………………………………………………………			

Q.10. Please answer the following questions by ticking one response and writing an explanation.

Do you think your 2nd year's Work placement experience helped you to progress well through your 3rd year's Cucumber project?		Yes		No
Please state how and reasons for your above response.	……………………………………………………………………………… ……………………………………………………………………………… ………………………………………………………………………………			

Q.11. Please answer the following questions by ticking one response and writing an explanation.

Do you think your 3rd year's Cucumber project experience helped you to progress well through your 3rd year's Work placement?		Yes		No
If yes, then please state reason	……………………………………………………………………………… ……………………………………………………………………………… ………………………………………………………………………………			

Q.12. Please respond to the following statement by ticking one option.

Which skills were enhanced through 3rd year's Work Placement and 4th year's R and D Project?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Problem solving skill					
Team work					
Critical thinking					
Communication skills					
Logical Abilities					
Physical presentation					
Planning and Organising skills					
Leadership qualities					
Self-learning					
Professional Ethics					

Retention of information					
Logical Abilities					
Engineering knowledge					
Application of Information Technology					
Industrial and Technical exposure					
Idea of workplace environment					
Way of Professional working					
Professional social interaction					
Better understanding of classroom theories					
Available employment opportunities in the market					
Professional social interaction					
Better understanding of classroom theories					
Available employment opportunities in the market					
Any comments	……………………………………………………………………………… ………………………………………………………………………………				

Q.13. Please respond to the following statement by ticking one option.

Practical Projects such as Boat Race and Cucumber Project provided these following outcomes.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Classroom theoretical knowledge					
Interdisciplinary knowledge					
Logical and Analytical thinking					
Contextual understanding					
Design and analyse engineering design					
Any comments	……………………………………………………………………………… ………………………………………………………………………………				

Q.14. Please respond to the following statement by ticking one option:

Activity	Very regularly	Reasonably regularly	Seldomly
I contributed ideas and facts during Work Placement			
I was able to understand the classroom taught theories during Work placement			
I used a variety of resources to understand working of different processes in the workplace.			
I learned more during Work Placement than doing classroom teaching			
I learned entirely different to that learned from Practical projects			
I helped efficiently in doing the team work			
I learned entirely different to that learned from classroom learning			
I was able to communicate professionally during Work placement			
Any comments	………………………………………………..		

Q.15. This is a Pilot survey. Please provide comments about the survey, how understandable it was, clarity, or anything that seems missing.

Q.16. Please indicate if you would like to be part of a Pilot Focus-Group Interview?

a). Yes

b). No

Q.17. Please provide your full name.

Q.18. Please provide your email address.

5th-EXPERIENCE COHORT – 4th YEAR ENGINEERING STUDENTS

Work Placement is a period of supervised work, where you had the opportunity to experience working in a specific role with a company, through university's scheme of Work-Integrated Learning. You have had attended more than one Work Placement during your engineering education in University.

Practical Projects are the projects which you had participated during your engineering education, which included a couple of projects like Boat Race project, Cucumber Project, Engineering and Society group project, Engineering Mechanics group project, and Research and Development project

Classroom Learning is the classroom lectures that the students attend in university, where the lecturers bestow their knowledge and understanding of the subject to the students, so that the students develop knowledge and understanding of the same, and progress academically)

Q.1. Please specify your Gender.

a). Male

b). Female

c). Gender diverse

Q.2. Please specify your ethnicity.

Q.3. Please specify your Nationality.

Q.4. Please specify your Age range.

a). 14-19

b). 20-25

c). 26-31

d). 32-37

e). 38-43

f). 44-49

g). 50-55

h). 56-61

Q.5. Are you mostly full-time student or part-time?

Q.6. Are you working part-time during the year in any type of work? If yes, then please specify roughly how many hours a week?

Q.7. Are you working part-time in a workplace related to mechanical engineering?

a). Yes

b). No

Q.8. Please answer the following questions by ticking one response and writing an explanation.

Do you think that the engineering discipline knowledge you gained during your 2nd and 3rd year's work placement was useful for your 4th year's Research and Development project?	| Yes | | No
Please explain your above response.	…………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………

Q.9. Please answer the following questions by ticking one response and writing an explanation.

Do you think that the engineering practical knowledge you gained during your 2nd and 3rd year's work placement was useful for your 4th year's Research and Development project?	| Yes | | No
Please explain your above response.	……………………………………………………………………………

	……………………………………………………………………………… ………………………………………………………………………………

Q.10. Please answer the following questions by ticking one response and writing an explanation.

Do you think your 3rd year's Cucumber project outcomes helped you to helped you to undertake the 4th year's Research and Development project?		Yes		No
Please explain your above response.	……………………………………………………………………………… ……………………………………………………………………………… ………………………………………………………………………………			

Q.11. Please respond to the following statement by ticking one option.

Which skills were enhanced through 3rd year's Work Placement and 4th year's R and D project?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Problem solving skill					
Team work					
Critical thinking					
Communication skills					
Logical Abilities					
Physical presentation					
Planning and Organising skills					
Leadership qualities					
Self-learning					
Professional Ethics					
Retention of information					
Logical Abilities					
Engineering knowledge					
Application of Information Technology					
Industrial and Technical exposure					
Idea of workplace environment					

Way of Professional working					
Professional social interaction					
Better understanding of classroom theories					
Any Comments	………………………………………………………………………………… ………………………………………………………………………………… …………………………………………………………………………………				

Q.12. Please answer the following questions by ticking one response.

Practical projects such as Boat Race and Cucumber Project provided these following outcomes.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Classroom theoretical knowledge					
Interdisciplinary knowledge					
Logical and Analytical thinking					
Contextual understanding					
Design and analyse engineering design					
Any Comments	……………………………………………………………………………… ……………………………………………………………………………………… ………………………………………………………………………………………				

Q.13. Please rank the following.

Please rank these terms based on how they prepared you throughout your engineering education, by clicking and dragging options in ranking order. Here, rank 1 means very important and rank 9 means least important.	…..................... work placement …..................... lectures …..................... lab sessions …..................... project sessions (Boat race, Cucumber and R & D projects) …..................... end of semester examinations ……………………… one to one interaction with teaching staff

	……………………… assignments ……………………… tests ……………………… group work
Please provide any additional comments	……………………………………………………………………… ……………………………………………………………………… ………………………………………………………………………

Q.14. This is a Pilot survey. Please provide comments about the survey, how understandable it was, clarity, or anything that seems missing.

Q.15. Please indicate if you would like to be part of a Pilot Focus-Group Interview?

a). Yes

b). No

Q.16. Please provide your full name.

Q.17. Please provide your email address.

ALUMNI COHORT – RECENT ENGINEERING GRADUATES

Work Placement is a period of supervised work, where you had the opportunity to experience working in a specific role with a company, through university's scheme of Work-Integrated Learning. You have had attended more than one Work Placement during your engineering education in University.

Practical Projects are the projects which you had participated during your engineering education, which included a couple of projects like Boat Race project, Cucumber Project, Engineering and Society group project, Engineering Mechanics group project, and Research and Development project

Classroom Learning is the classroom lectures that the students attend in university, where the lecturers bestow their knowledge and understanding of the subject to the students, so that the students develop knowledge and understanding of the same, and progress academically)

Q.1. Please specify your Gender.

a). Male

b). Female

c). Gender diverse

Q.2. Please specify your ethnicity.

Q.3. Please specify your Nationality.

Q.4. Please specify your Age range.

a). 14-19

b). 20-25

c). 26-31

d). 32-37

e). 38-43

f). 44-49

g). 50-55

h). 56-61

Q.5. During your engineering student life, were you full-time student or part-time?

Q.6. Were you working part-time during your engineering student life in any type of work? If yes, then please specify roughly how many hours a week?

Q.7. Did you work part-time in a workplace related to mechanical engineering during your engineering study?

a). Yes

b). No

Q.8. Please respond to the following statements by ticking one option.

The following qualities are relevant to engineering.	Unimportant	Of little importance	Moderately important	Important	Very important
Intelligent					
Fast leaner					
Engineering knowledge					
Problem solving skills					
Good Communication skills					
Self-starter					
Work experience					
Logical abilities					
Hard worker					
Humble					
Team skills					
Adaptability					
Self-management					

Technically minded					
Studious					
Creative					
Critical thinking					
Planning and organising					
Artistic					
Analytical reasoning					
Employability skills					
Initiative					
Flexible					
Any comments	………………………………………………………………………………………………… …………………………………………………………………………………………………				

Q.9. Please answer the following questions by ticking one response.

Practical projects such as Boat Race and Cucumber Project provided these following outcomes.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Classroom theoretical knowledge					
Interdisciplinary knowledge					
Logical and Analytical thinking					
Contextual understanding					
Design and analyse engineering design					
Any comments	……………………………………………………………………………… ………………………………………………………………………………				

Q.10. Please answer the following questions by ticking one response and writing an explanation.

Which project from First year of your engineering education do you remember the most?	ENGEN180 (Boat Race) ________ ENGEN170 – (Engineering and Society Group Project) ________ ENGEN110 – (Engineering Mechanics Group Project) ________ None ________
Please provide reasons for your above answer	____ ____ ____

Q.11. Please answer the following questions by ticking one response and writing an explanation.

Did Boat Race Project of 1st year help in any way in your Work placement experience in 2nd year in anyway?	…………………… Yes …………………… No
Explain why/why not.	…………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………

Q.12. Please answer the following questions by ticking one response and writing an explanation.

Do you think your 2nd year's Work placement helped you in any way in your 3rd year's Cucumber Project?		Yes		No
Explain how.	…………………………………………………………………………… ……. …………………………………………………………………………… ……. …………………………………………………………………………… …….			

Q.13. Please answer the following questions by ticking one response and writing an explanation.

Do you think your 3rd year's Cucumber project experience helped you to progress well through your 3rd year's Work placement? Please tick your response.		Yes		No
If yes, then please state reason	…………………………………………………………………………… ……. …………………………………………………………………………… ……. …………………………………………………………………………… …….			

Q.14.Please tick the aspects below that could have enhanced your experience of the practical projects in University? You can mark more than one answer.

More genuine and challenging problem	
More support and guidance from Lecturer	
More preparation in Laboratories before the project begins	
More theory course work at classrooms	
Others, please specify ……… ……… ………..............................	

Q.15.Please tick the aspects below that could have enhanced your experience of the work placements? You can mark more than one answer.

More appropriate work placement	
More support from University	
More support from Industry/Workplace supervisor	
More guidance from University	
More preparation such as Induction course	
More theory course work at the University	

More communicational feedback from Industry to University	
Better ties up between University and Industry	
Others, please specify …………………………………………………………………………………………………… ……… ………………………………………………………………………………………………………..............................	

Q.16. This is a Pilot survey. Please provide comments about the survey, how understandable it was, clarity, or anything that seems missing.

Q.17. Please indicate if you would like to be part of a Pilot Focus-Group Interview?

a). Yes

b). No

Q.18. Please provide your full name.

Q.19. Please provide your email address.

APPENDIX M

STUDENTS + GRADUATES INTERVIEW QUESTIONS

2nd-EXPERIENCE COHORT - FOCUS GROUP QUESTIONS

Q.1. What are your views on how the two approaches Work Placement and Practical Projects complement each other?

Q.2. Which project from 1st year of your engineering education you remember the most?

(Prompt questions based on participants' response)

- What made it so memorable?
- What skills were developed by participating in such group project?

Q.3. What was your experience of the recent Work Placement you had?

(Prompt questions based on participants' response)

- Did your learnings from 1st year's Boat Race project have any impact on your 2nd year's/recent work placement? How did it help?

Q.4. Do you think your learning outcomes from your 1st year's project were enhanced or developed in your 2nd year's work placement?

(Prompt questions based on participants' response)

- How did that work out? Please give some specific examples.

3rd-EXPERIENCE COHORT - FOCUS GROUP QUESTIONS

Q.1.What are your views on how the two approaches Work Placement and Practical Projects complement each other?

Q.2.How was your experience of 3rd year's Cucumber project?

(Prompt questions based on participants' response)

- How do you think the 1st year's project helped you to enhance your performance in your 3rd year's project?
- How do you think the 2nd year's Work Placement helped you to enhance your performance in your 3rd year's project?

Q.3. Did the 1st year's project and the 2nd year's Work Placement develop any skills and knowledge in common? Please give specific example.

(Prompt questions based on participants' response)

- How? Why?

Q.4. Do you think the engineering Work Placements and practical projects needs improvement?

(Prompt questions based on participants' response)

- Why so?
- What aspects need improvement? Why? How?

4th-EXPERIENCE COHORT - FOCUS GROUP QUESTIONS

Q.1. What are your views on how the two approaches Work Placement and Practical Projects complement each other?

Q.2. How was your experience of 3rd year's work placement?

(Prompt questions based on participants' response)

- How did your 2nd year's work placement enhance your performance in your 3rd year's work placement?

(From the above question, I would intend to ask about knowledge and skill development that happened through those sessions)

Q.3. Did the 1st year's Boat race project and the 3rd year's Cucumber project develop any skills and knowledge in common? Please give specific examples.

(Prompt questions based on participants' response)

- How that happened? Please explain that linkage between them.

Q.4. Do you think your present work placement experience and performance was improved because of the 2nd year's work placement or 3rd year's Cucumber project experience, or both?

(Prompt questions based on participants' response)

- If so, please explain how and why this occurred?

Q.5. Do you think work placements and practical projects need improvement?

- Why so?
- What aspects need improvement? Why? How?

5th-EXPERIENCE COHORT- FOCUS GROUP QUESTIONS

Q.1. What are your views on how the two approaches Work Placement and Practical Projects complement each other?

Q.2. How was your experience of 4th year's Research and Development project?

(Prompt questions based on participants' response)

- How was your 3rd year's Cucumber project was similar in operation to your 4th year's R & D project? How and why?
- What skills were improved from 1st year's Boat Race project to 4th year's R & D project (including 3rd year's Cucumber project)?

Q.3. Did the 2nd and 3rd year's work placement develop your skills and knowledge which helped you in your 4th year's R & D project?

(Prompt questions based on participants' response)

- How? Please explain the linkage that you identified?
- Do you find a relation between work placements undertaken in industry and practical projects undertaken in university? Did the skills and knowledge developed in practical projects assist you to carry out work in work placements or vice-versa?

Q.4.Do you think work placements and practical projects need improvement in any areas? Please state them and why you feel so that it needs improvement? How?

ALUMNI COHORT - FOCUS GROUP QUESTIONS

Think back to your years of Engineering Education at the University of Waikato

Work Placement is a period of supervised work, where you had the opportunity to experience working in a specific role with a company, through university's scheme of Work-Integrated Learning. You have had attended more than one Work Placement during your engineering education in University.

Practical Projects are the projects which you had participated during your engineering education, which included a couple of projects like Boat Race project, Cucumber Project, Engineering and Society group project, Engineering Mechanics group project, and Research and Development project)

Questions

Q.1. Which project from 1st year of your engineering education you remember the most? Please state reasons for this.

(Prompt questions based on participants' response)

- What aspects of it do you still remember?
- Do you think you developed any skills by participating in such group projects? If so, what? Why?

Q.2. Recall your 4th year's Research and Development project. Describe it.

- Do the 1st year's Boat Race and 3rd year's Cucumber project contributed anything in common to your 4th year's R & D project? How? Explain the linkage between them.

Q.3. Describe your experience of work placements you undertook in your 2nd and 3rd year?

- Do they provide and develop anything extra apart from classroom learning and practical projects activities? What aspects (skills and knowledge) did these include?

-Did you find a relation between work placements undertaken in industry and practical projects undertaken in university? Did the knowledge from practical projects help you to carry out work in work placements or vice-versa?

Q.4.Do you think work placements and practical projects need improvement in any areas? Please state them and why you feel so that it needs improvement? How?

APPENDIX N

LECTURER INTERVIEW QUESTIONS

3rd-EXPERIENCE COHORT – 3rd YEAR ENGINEERING STUDENTS

Q.1. Based on your observation, were the student's performance better in Cucumber project than their performance in Boat Race project? Explain why?

Q.2. Based on your assessment, do students understand and learned better by doing the Cucumber project than the 1st year Boat Race project?

Q.3. What knowledge and skills were developed throughout Cucumber project?

-Engineering and Scientific skills?

-Process skills?

-Generic skills like social and collaboration skills?

-Explain how?

Q.4. Do you think improved performance and motivation to learn in Cucumber project could come from past Boat Race project or Work placement? Why?

Q.5. According to your observation, do you think the current practices of practical projects in engineering education needs any improvement? If yes, then please explain why and how?

5th-EXPERIENCE COHORT – 4th YEAR ENGINEERING STUDENTS

Q.1. Based on your observations, do you think the students have developed any skills through the Practical project sessions in their engineering education? If so, what? Why? How?

Q.2. Does the students' overall performance improve after the Practical project sessions? Explain why.

Q.3. Do the students do better in their work placements after the practical project sessions? Explain why.

Q.4. Do you think that the acquisition of knowledge and skill development in the students could have been improved with some changes/improvisations in the Practical project approach? What? How? Why?

(If 3rd and 5th experience Cohort's lecturers are different)

Q.5. Give me your views of work placements and their relationship to achievement in:

-practical projects

-engineering education

Q.6. Give me your views of practical projects and their relationship to achievement in:

-work placements

-engineering education

APPENDIX O

WIL SUPERVISOR QUESTIONS

2nd-EXPERIENCE COHORT – 2nd YEAR ENGINEERING STUDENTS

(Have you had 2nd year students in your work placements?)

Q.1. Based on your observation, were the students able to relate their classroom taught theory with the real-life applications at the workplace? Explain how and the instances.

Q.2. Throughout the Work placement session, did you see improvements or progress in the performance of the students, in terms development of skills? If so, which skills are they? Explain how.

Q.3. Do you think the projects which students do in their universities can help them to enhance their performance in work placements? If so, explain why you think so.

Q.4.Apart from skill development, what other things the students learn from work placements?

Q.5. According to your observation, do you think the current practices of work placements need any improvement? If yes, then please explain why and how?

3rd-EXPERIENCE COHORT – 3rd YEAR ENGINEERING STUDENTS

(Have you had 2nd year students in your work placements?)

Q.1. Based on your observation, were the student's performance better in their present Work placement (3rd year) than students in their 2nd year? Explain why?

Q.2. Based on your assessment, how easily were the students able to adapt to the workplace environment and the professional ethics?

(If they had both) - Is there a difference between 2nd and 3rd year students?

Q.3. Do you think students' past knowledge and experience of work placement in their 2nd year of engineering education decided their performance of work placement in 3rd year? Explain why.

Q.4. Do you think students' past knowledge and experience of practical projects (instructed by the University in their 1st and 3rd year) decided their performance of work placement in 3rd year? Explain why.

Q.5. According to your observation, do you think the current practices of work placements needs any improvement? If yes, then please explain why and how?

(Alternatives if not had 2nd year students)

Q.1.Are you aware of any impacts of previous work placement experience on your 3rd year students? If so, what? How?

Q.2.Are you aware of any impacts of previous practical projects experience at university on your 3rd year students? If so, what? How?

APPENDIX P

Skill Reflection Assignment Instructions

School of Engineering

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

(Work Placement)

Skill Reflection Assignment

Due Date: Friday 17th of Jan, 2020, 11:55pm

Weighting: 20% of your total paper grade

Submission: Assignments must be submitted via Moodle by the due date

This assignment requires you to think about a three important skills you have developed during your placement. These skills need to be skills you see as being important for you as a professional. The skills can be transferable skills – that is, the skill can be something applied in a different context (i.e., do not feel limited to identifying skills only specific to a discipline).

We want you to think about:

- One technical skill

- Two behavioural skills.

For each skill:

- Describe what the skills is (*one, perhaps two, sentences*)
- Explain why this skill is important for you as a professional (*a paragraph*)
- Explain if it was a new skills or if it is a skill you already possessed and developed further (*a few sentences*)
- Describe how you learnt this skill and to what level you have obtained this skill, e.g., still need supervision, can do with little guidance, can do unsupervised, can teach others (*half a paragraph*)
- Discuss an example where you have used this skill (*a paragraph*)
- Explain if you need to develop this skill further and how you think you may do that (*half a paragraph*)

Use the template that has been provided on Moodle.

APPENDIX Q

Technical Report Instruction

School of Engineering

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

(Work Placement)

Technical Report

Due Date: Monday 2nd of March, 2020, 11:55pm. This is the first Monday of A Semester

Weighting: 35% of your total paper grade

Submission: Assignments must be submitted via Moodle by the due date

Contents

Important Notes

- This is a significant piece of assessment. You will need to start this assignment early to finish on time.

- Your workplace supervisor must check your report BEFORE submitting in case it contains confidential, sensitive, or erroneous information about the company or the work undertaken. You must allow time for your workplace supervisor to be able to read the report before the due date (you will need to plan and organise yourself). We recommend allowing about a week.

- If your report is deemed confidential, please talk to your Placement Coordinator. Confidential reports must not be submitted via Moodle, rather emailed directly to your WIL Coordinator or your Academic Supervisors. If the report is highly confidential, then it must only be handled by hard copy (to prevent automatic electronic backups being generated when, for example, emailing).

- The difference between a low quality report and a high quality report is that a high quality report will go *beyond merely describing* the tasks. A high quality report will show evidence of understanding of the engineering or science concepts and principles, discuss (not just describe) the purpose of the tasks and the meaning of the outcomes, and is able to explain why this work was undertaken (what was the purpose, where does it fit into the bigger picture).

- You must talk to your Academic Supervisor about the content and structure of the report before submitting the report. The report content instructions given here are only a guide, not a set rules, and the content and structure of your report needs to reflect the nature of your placement and your Academic Supervisors advice.

Any inquires about this assignment regarding content and grading, please contact your Academic Supervisor.

Technical Report

General Instructions

Page limit: There is no specific word or page limit, but typically your report will be up to 20 pages in length (excluding exec summary, table of contents, etc). Aim for concise and clear writing.

Academic Supervisor: Each student is appointed a member of the academic staff for you to ask for technical advice and to provide feedback on your report. Your Placement Coordinator will advise you in December who your Academic Supervisor will be. The Academic Supervisor will be your first point of contact if you have questions on the report. The second point of contact would be your Placement Coordinator.

Writing style: The report must be written in technical writing style. Avoid the use of first person style writing (e.g., I, me, we) – the occasional use in the introduction to describe your place within the project/process is permissible. The focus of the report is the work you have undertaken, the focus of the report is not you *per se.* Be accurate and precise with your writing, for example; when you say "a few readings" say how many; or "the material was heated" say to what temperature and for how long; or when referring to, for example, "Tank 1", give it a name the describes it, for example, "Fermentation Tank 1" (and remember, a name/title has capitals).

More information: The technical report writing lecture and workshop slides from 279 are available on Moodle. The report writing template and tutorial documents are also on Moodle.

Report: Front-End Content

Title
This is the project title or a succinct description of the tasks you did.
Please use the template provided.

Executive Summary
Do this last. If a manager could only read one page, this is the page! You need to summarise the key points of your report on half a page. Follow the report format, aims, methods, results and discussion, recommendations.

Acknowledgements
Acknowledge those who have helped in your placement – managers, supervisors, colleagues, and coordinators. As this is not a thesis, it needs to be brief and not too sentimental.

Table of Contents
Use the automatic formatting settings provided to you in the 279 technical report writing workshop.

List of Figures

The List of Figures are set out in numerical order with a brief caption for each Figure and the page number where it can be found. The 279 technical writing workshop will show you how to automate this process.

A figure is any visual presentation of results or illustration of concepts/methods, and includes graphs, images, diagrams of set-ups, drawings, maps, etc. The caption should be detailed enough that the reader can understand the figure without reading the main text. The caption should be no more than two sentences (and is located below the figure). Each Figure must be referred to in the text, preferably like 'The results clearly indicate a positive trend (Figure 1)', and not 'Figure 1 shows ….'.

List of Tables

The List of Tables are set out in numerical order with a brief caption for each Table and the page number where it can be found. The 279 technical writing workshop will show you how to automate this process.

A table presents lists of numbers or text in columns and rows, and should be used to illustrate differences, but not to represent relationships. The caption should be detailed enough that the reader can understand the table without reading the main text. The caption should be no more than two sentences (and is located ABOVE the table, not below). Each table must be referred to in the text, preferable like 'The results for the site at Mission Bay (Table 1)', and not 'Table 1 shows ….'.

Report: Introduction and Background

Introduction
This section should briefly introduce: What did you do? Who did you do it for? Why did you do it?

The first part needs to describe where your placement was located, what that organisation does, why you did this work, and where it fits into the bigger picture.

The introduction should contain all the background information a reader needs to understand the rest of the report. This means that all important concepts should be explained and all important terms defined and it should summarise the problem.

This section should end with a statement that defines your aims and goals for the work/project you undertook. It is typical to have about three aims/goals. It should also explain any ethical considerations relevant to the project and, if ethical approval was required, that it was obtained. The focus of the aims/goals is on the task rather than you as a student (e.g., not 'I hope to get work experience'. Instead, e.g., 'the aim was to understand soil compaction levels').

Background
Leads on from the Introduction and covers in detail the problem to be addressed. It also gives background on the subject, presents the theory behind your study and explains the science or engineering principles behind your placement. The report discusses previous research done on the topic and explains the important things others found and in some cases this will be fairly extensive and termed a 'literature review'.

Project or Research-Based Placements

For placements that were project or research based, follow this suggested structure:

Methods
This section should have enough information to enable others to repeat the experiment and reproduce the results, that is, a clear and repeatable description of how you tackled the project. Make sure to use the correct way to write scientific measurements, for example, 5 mL, 50 μm, etc. If you have substantive amounts of detailed methods, move these to the appendices and only present an overview of the methods (and refer to the appendices).

Results
This section of the report should describe the key results of the experiment without interpreting their meaning. Typically raw data is not included (add these as appendices) but the report should summarise the data with text and tables.

Discussion
Briefly restate problem or project aims, approach and results, and compare your results to others work. Then discuss (not describe) the meaning of your data, explain the significance of the meaning, and how have these answered (or not answered) the research goals/aims/research questions. It is important that you show that you understand the engineering or science concepts and knowledge that underpin what you are discussing and how these fit into the bigger picture.

Conclusions / Recommendations
Summarise and conclude the key outcomes of the work undertaken. Include recommendations on what could be done if you had more time/equipment for further trials. Also discuss what the implications of the results (your work) are for others – that is, how can other use what you have found and why should they.

References
As you will be relying on established methods and established knowledge to explain your results, you must supply the sources of such knowledge as a reference. Each reference must be used in the main body of the report (cited) and also be listed in the references list. There is a separate document for APA formatting on Moodle.

Appendices
Include important raw (unmodified) data as appendices. The appendix must be referred to in the text of the report. The information should be able to be checked and verified by another researcher.

Process-Based or 'Routine' Placements

For placements that are largely process-based or 'routine', follow this suggested structure:

These placements are not project based or research based, instead are where students contribute to ongoing repetitive work in the workplace such as a testing or maintenance cycle, production plant work, or construction (the latter may still fit into project type report). Often in these placement students largely do the same activity every day and do not collect data. This does not include, for example, monitoring placements, as data is collected and can be analysed from these placements through a Project or Research-Based technical report.

Processes (rather than Methods)
Describe how you undertook the process. What did it involve and what was the technique. Describe the technique (method) in enough details to understand how the work was undertaken (and any detailed calculations should be in the appendices). Where appropriate provide for example design brief, the concept plan(s), preliminary design, leading on to fault detection etc. Similarly, it also describes standard operating procedures for removal of components for cleaning, testing and refitting. What it should NOT be is a 'diary' or log of activities.

Outcomes (rather than Results)
How successful was the work you did? Can you explain the outcomes or end product of the work? Use pictures to show, for example, the re-fitted, refinished product, the new components that were designed or the graphics, web pages that were completed. You could describe and discuss 'numbers/data' such as how many errors were eliminated, or how much faster the process went after modifications.

Discussion
Restate the main aims/goals of the placement. Comment on the usefulness of your work and outputs. Discuss the purpose of your work to the overall function of your workplace and the applicability of your work to similar national or international industries. Mention any specific problems related to your work. This might be special conditions for working in a geothermal area, or working with fatty or oily substances that require specialised testing, materials, or methods. It is important that you show that you understand the engineering or science concepts and knowledge that underpin what you are discussing.

Conclusions / Recommendations
Restate the key outcomes/outputs. Discuss how the process could be improved to gain further insight or obtain better outputs. Discuss any recommendations and implications for the organisation or other relevant parties.

References
Even though you are largely describing processes, you will still be using established knowledge to describe these processes and in the discussion the purpose of the work. These sources of established knowledge needed to be references (cited) and also be listed in the references list. There is a separate document for APA formatting on Moodle.

Appendices
If you do have some raw data, include these as appendices. These must be referred to in the text of the report. You may also include additional pictures or figures that did not fit naturally into the main text but are still important to show.

APPENDIX R

Project Report and Interview Instructions

Overview

The project report and models are to be assessed based on the following aspects:

- **Design**
- **Manufacturing**
- **Health and Safety**
- **Finished Machine**

Design –. Two levels of design are being assessed; overall design as a functioning machine that meets the requirements and detail design of for example gearbox calculations, fixings, chassis, strength, weight etc.

Fail	C	B	A
No completed design and design concept cannot work. What detail work shown has many errors	Basic Design – has potential to meet the requirements but not convincing. Several design detail errors.	Good Design – close to meeting the requirements and could do so with some extra work. Some design detail errors.	Excellent Design - is complete and meets the requirements, with none or only a few minor detail errors.

Manufacturing – the manufacturing processes and execution are appropriate for the application.

Fail	C	B	A
Not much manufactured and what has been done	Adequate manufacturing. Machine	Good manufacturing - The machine is complete	Excellent manufacturing - The machine is complete

is inappropriate and of poor quality.	is mostly manufactured using appropriate processes. The machine is incomplete and is adequate quality (does the task).	but several components use inappropriate manufacturing processes and there is some poor execution and quality but works (does the task).	and appropriate processes are used for virtually all the machine and executed to a high quality.

Health and Safety – Can the machine be used without the risk of hurting the user?

Fail	C	B	A
No attention to health and safety has been considered.	Basic – Minimal consideration for health and safety. Many areas have not been considered or not well executed.	Good – Attention has been taken to make the machine safe, but a few areas have not been considered or not well executed.	Excellent – no finger traps or sharp edges. Guarding prevents contact with rotating shafts, chance of short circuits minimised or eliminated.

Finished Machine – Just like in industry, completing a machine for a show and tell with the client is important. This grade rewards those who have the machine completed and working by the assessment date and has a high weighting.

Fail	C	B	A
Incomplete machine not working	Completed but not working machine with some evidence of it working as required and to the rules.	Completed and partially working machine with evidence of it working as required and to the rules.	Completed and working machine with evidence of it working as required and to the rules.

Overall – Once the four assessment items are graded, they will be combined into a holistic overall grade. There is no specific weighting for each of the items, but the final machine that will completes the task effectively, meet the rules and aligns with the group's objectives, will be a significant factor in the final grade. This will appear as a line down the assessment sheet intercepting the overall grade line. After grading, all assessment sheets will be lined up from highest to lowest and the assessors will do a final check to make sure the grading has been fair. If there is a discrepancy, it will be discussed and changed once agreed by the assessors.

Some Do's and Don'ts at the Interview

Do's

Each group member must contribute during the interview – make sure each of you has something to talk about or demonstrate

Be prepared - have all your material well organised in a structured manner, so that you can give your narrative as smoothly as possible

Tell a story – all good stories have a beginning middle and end, remember this when planning your narrative

Concise – keep the narrative concise and on-topic with an emphasis on the important issues

Speak clearly – not mumbling or reading from scripts

Anticipate questions – try and think what questions will be asked and prepare appropriate responses

Improvisation - be prepared to improvise if you are asked an unexpected question

Time management – plan for a 20 minute interview including questions and align your material and narrative appropriately. Remember, the final proof has a higher weighting, so make sure you spend time on that part.

Practice – Spend some time as a group running through the material you are presenting and make sure everyone knows what they are doing.

Engage with the clients, treat them as people in a professional meeting, talk to them directly and concentrate during the interview

Focus – if you feel the interview is drifting, re-set and bring back on-topic

Don'ts

DO NOT READ FROM A SCRIPT, THIS IS AN ABSOLUTE NO-NO AT AN INTERVIEW!

Do not play with your phone – only use it when showing vids/pics

Do not talk to your group members during the interview unless it is important and relevant

Good luck

Engineering Team

Appendix A

ENGME380 Design and Manufacture Project

SDM Design Interview Assessment (20%)

Group __________

Names:

1.____

2.____

3.____

4.____

Design:

E D C C+ B- B B+ A- A A+

Manufacturing:

E D C C+ B- B B+ A- A A+

Health and Safety:

E D C C+ B- B B+ A- A A+

Finished Machine:

E D C C+ B- B B+ A- A A+

Overall:

E D C C+ B- B B+ A- A A+

Comments: