THE IMPACT OF SIMULATION-BASED LEARNING PRACTICE ON STUDENT LEARNING OUTCOME IN ENGINEERING EDUCATION AT HIGHER EDUCATION INSTITUTIONS IN MALAYSIA

LEE HOR YAN

MASTER OF BUSINESS ADMINISTRATION

(CORPORATE MANAGEMENT)

UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF BUSINESS AND FINANCE

MARCH 2025

APPROVAL SHEET

This thesis/dissertation entitled "**THE IMPACT OF SIMULATION-BASED LEARNING PRACTICE ON STUDENT LEARNING OUTCOME IN ENGINEERING EDUCATION AT HIGHER EDUCATION INSTITUTIONS IN MALAYSIA** " was prepared by LEE HOR YAN and submitted as partial fulfilment of the requirements for the degree of Master of Business Administration (Corporate Management) at Universiti Tunku Abdul Rahman.

Approved by:

(Dr. Wei Chooi Yi)
Professor/Supervisor
Centre for Learning and Teaching
Faculty of Business and Finance
Universiti Tunku Abdul Rahman

Date: 28th March 2025

FACULTY OF BUSINESS AND FINANCE

UNIVERSITI TUNKU ABDUL RAHMAN

Date: 28th MARCH 2025

SUBMISSION OF THESIS/DISSERTATION

It is hereby certified that Lee Hor Yan (ID No: 22ABM07000) has completed this thesis/dissertation entitled "**The Impact of Simulation-based Learning Practice on Student Learning Outcome in Engineering Education at Higher Education Institute in Malaysia**" under the supervision of Asst. Prof Cr. Wei Chooi Yi from the Centre of Learning and Teaching (CLT) , Faculty of Business and Finance.

I understand that the University will upload softcopy of my thesis/dissertation in pdf format into UTAR Institutional Repository, which may be made accessible to UTAR community and public.

Your truly,

Lee Hor Yan

DECLARATION

I LEE HOR YAN hereby declare that the thesis/dissertation is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

Horyan

(LEE HOR YAN)
Date 28th March 2025

THE IMPACT OF SIMULATION-BASED LEARNING PRACTICE ON STUDENT LEARNING OUTCOME IN ENGINEERING EDUCATION AT HIGHER EDUCATION INSTITUTIONS IN MALAYSIA

By

LEE HOR YAN

A Thesis submitted to

Faculty of Business and Finance

Universiti Tunku Abdul Rahman,

in partial fulfilment of the requirements for the degree of

Master of Business Administration

(Corporate Management)

MARCH 2025

ABSTRACT

THE IMPACT OF SIMULATION-BASED LEARNING PRACTICE ON STUDENT LEARNING OUTCOME IN ENGINEERING EDUCATION AT HIGHER EDUCATION INSTITUTIONS IN MALAYSIA

LEE HOR YAN

This study explores the impact of Simulation-Based Learning (SBL) on student learning outcomes in engineering education at Malaysian higher education institutions (HEIs) aligning to Malaysia’s workforce demands of Industry 4.0. This research examines how SBL influences cognitive and practical skills across various engineering disciplines, in fostering problem-solving, critical thinking, and hands-on experience. Utilizing Kolb’s Experiential Learning Theory (ELT), this study investigates the role of SBL tools in enhancing reflective observation, a key stage in Kolb's cycle, and its impact on student learning outcomes. The findings are based on a quantitative survey of engineering educators across multiple institutions, assessing the implementation and effectiveness of SBL in improving educational experiences. Despite challenges in inconsistent implementation and resource limitations, the study demonstrates that SBL, when paired with effective teaching practice, institution support and SBL tools capabilities, can significantly enhance students' ability to apply theoretical knowledge in real-world engineering scenarios. This research provides insights into how SBL can be optimized to bridge the skills gap in Malaysia’s engineering education system, supporting the development of a highly skilled, industry-ready workforce.

ACKNOWLEDGEMENT

I would like to extend my sincere gratitude to everyone who has supported and guided me throughout the process of completing this thesis. Without their encouragement and assistance, this project would not have been possible.

Firstly, I would like to express my heartfelt thanks to my advisor, Dr Wei Chooi Yi, for their invaluable guidance, patience, and insight throughout my research journey. Her expertise and dedication inspired me to reach beyond my limits and accomplish my goals.

I would like to acknowledge the support of my friends and colleagues, who were always willing to listen and offer their help whenever needed.

Lastly, I would like to extend my thanks to everyone who contributed directly or indirectly to this work. Your support has been an invaluable asset, and I am truly grateful to have had you all by my side.

Thankyou

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

Computation Fluid Dynamics	HEI
Computer Aided Modeling	CAD
Department of Statistics Malaysia	DOSM
Dependent Variable	DV
Electric Vehicle	EV
Electronic Computer Engineering Technology	ECET
Experiential Learning Cycle	ELC
Experiential Learnning Theory	ELT
Finite Volume Method	FVM
Foreign Direct Investment	FDI
Heat Ventilation, Air conditioning	HVAC
Higher Learning Institution	HLI
Immersive Simulation Based learning	ISBL
Independent Variable	IV
Malaysia's Education Blueprint	MEB
Malaysian Qualification Register	MQA
Ministry of Education	MOE
Noise, Vibration, Harshness	NVH
Printed Circuit Board	PCB
Return of Investment	ROI
Science, Technology, Engineering, and Mathematics	STEM
Simulation Based Learning	SBL
Social Science and Humanities	SSH
Statistical Package for Social Science	SPSS
Student Learning Outcome	SLO
Universiti Kebangsaan Malaysia	IKM
Universiti Sains Malaysia	USM
Universiti Tunku Abdul Rahman	UTAR

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.0 Background of the Study

Malaysia's 13th National Plan aims to boost digital adoption, and Higher Education Institutions (HEI) are tasked with preparing graduates skilled for Industry 4.0 sectors such as automation, renewable energy, biomedical healthcare, oil and gas, electronics, semiconductors, and more (Loheswar, 2024). To establish Penang as the "Silicon Valley of the East," Malaysia make effort in Government-to-Government mechanism to leverage technology and skill transfer, which has encouraged Foreign Direct Investment (FDI) to support job creation and national income. Initiative by the government includes grants and tax exemption to local manufacturers for research and development initiatives. This strategy aims to create job opportunities, accelerate technological advancement, and align with Malaysia national dream to become high-income nation status by 2028, run by highly skilled workforce (Goh & Baker, 2024; MIDA, 2024; BERNAMA, 2024; MalayMail, 2024).

However, a skills gap persists, as tech-driven employers seek graduates with practical design abilities, technical skills, and problem-solving capabilities. Many graduates remain unprepared for the workforce, prompting some FDI firms to prioritize international hires or sponsor international students for

Malaysian placements, increasing competition for local engineering graduates (Nor et al., 2020; Tan et al., 2017).

It is important for Malaysian HEI to innovate, improve by incorporating assistive tools such as engineering simulations, which help develop employability skills. Recent findings by scholars highlight that simulation-based learning (SBL), using simulation software tools, can bridge the skills gap by providing practical design experience and modeling, as well as offering cost-effective learning solutions (Kong et al., 2024). Simulations could be an effective tool to facilitate the learning of complex skills across various engineering field and practices, supporting SBL during various stages of skill development (Chernikova et al., 2020). Engineering simulation software allows students to conceptualize new ideas, test new designs, diagnose issues in existing ones, and simulate challenging conditions or parameters that are unobservable by naked eyes. This experiential virtual approach enhances students' visualization, analysis, and prediction of product behavior in three-dimensional (3D), providing better alignment with ready skills to propose and operate SBL tools during their career that could help their employer in improving return of investment (ROI), solve complex engineering problems , improve time to market and efficiency (Chernikova et al., 2020).

Despite these benefits, the adoption of SBL in Malaysian institutions remains uneven due to the lack of standardized curricular requirements, especially in interdisciplinary fields such as Electric Vehicles (EV), automotive, biomedical, mechatronics, and robotics, where testing and prototyping costs are high and time-consuming.

1.1 Engineering Simulation Tools and Applications

Simulation in industrial engineering was conceptualized during the 1930s by mathematicians Stanislaw Ulam and John von Neumann , who identified the potential of the "Roulette Wheel" technique for solving complex problems. This method involved merging probabilities of separate events to predict outcomes of entire sequences. Hence, potentially improve production capacity and efficiency, reduce material cost, labor cost and speed to market (UTH, 2000). The emergence of analog and digital computers in the early 1950s further refined simulation capabilities, but the lengthy time required to generate results due to the hardware technology limitation that time limited their practicality.

Standing strong until now , IBM emerged in year 1961 as a technology leader by introducing the "Gordon Simulator" to Norden Systems, a design company. This innovation enabled engineers to construct models, simulate problems, and obtain answers within six weeks, considered as an early version of Computer Aided Modeling (CAD) tool, is a significant improvement over earlier methods. However, simulation was still not widely applied in industrial engineering, as it was often seen as a tedious process requiring long hours at computer terminals and extensive debugging (UTH, 2000). The introduction of spreadsheet tools in the late 1970s began to change this perception, but only the advocates practiced the usage.

Around the year 1984, the first simulation language designed and developed specifically for modeling manufacturing systems, marking a new era in the use of simulation tools. The power of simulation became apparent in the mid-1990s, as it was increasingly integrated into the engineering design cycle (UTH, 2000). Today, simulation is a tool that is used widely in industrial engineering, contributing to every stage of the design process—from ideation and three-dimensional computer-aided design (CAD) to testing, validation, and compliance. It also supports manufacturing and assembly processes by identifying accurate product construction methods, functionality, and life-cycle predictions.

Modern engineering simulation is based on predictive analytic combined with deep learning to address various types of "working physics." These tools use data-driven solutions derived from vast amounts of high-fidelity data provided by experts over the years of research and trials. For example, they can translate 3D digital designs (CAD) into outputs with physical meaning by employing numerical algorithms to solve complex equations. These simulations aim to replicate real-world conditions, significantly reducing the time required for physical testing and prototyping while minimizing costs, labor, material usage, and time to market. Advanced simulation techniques also support multiphysics approaches, where different physical phenomena are coupled to solve complex interactions such as Mechanical-Fluid, Mechanical-electronics and more (Massobrio, 2023).

Engineering simulation tools run on computational clusters, enabling the analysis of complex models with high precision and accuracy. Global brands leading the engineering simulation industry today include NASTRAN, ANSYS, COMSOL Multiphysics, MATLAB, SolidWorks, Dassault Systèmes, Cadence, Siemens and more (Massobrio, 2023). These tools provide a wide range of solvers that can be applied to multiphysics phenomena across various industries.

Table 1.0 : Shows the capabilities and applications of simulation solvers (ANSYS, 2024)

Physics	Solvers Capabilities	Application & Industry
Mechanical	Non-Linear Statics Linear Dynamics Impact & Crash	Industries: Automotive, Aerospace, Heavy Machinery Applications: Vehicle crash testing, structural integrity analysis, machinery failure simulation.
	Noise, Vibration Harshness (NVH)	Industries: Automotive, Aerospace, Electronics Manufacturing Applications: Acoustic optimization, vibration reduction in vehicles and machinery.
	Printed Circuit Board (PCB) Reliability Robust Design Optimization	Industries: Electronics Manufacturing, Product Design Applications:

		Reliability testing of PCBs, optimization of product casing designs.
	Multi-Body Dynamics Manufacturing Solutions	Industries: Automotive, Metal Forming Applications: Kinematic analysis, sheet metal welding, metal forming processes.
	Materials (Creep Fatigue, Vibro Acoustics)	Industries: Biomedical, Healthcare Applications: Prosthetics development, fatigue analysis in medical devices.
Computation Fluid Dynamics (CFD)	Conjugate Heat Transfer , Heat Ventilation, Air conditioning (HVAC) & Electronics Cooling	Industries: Energy, Electronics Manufacturing Applications: Cooling system optimization, thermal management in electronics.
	Multi-phase Multi-species Flows Thermal Management	Industries: Chemical Processing, Battery Manufacturing Applications: Flow dynamics in chemical reactors, battery thermal regulation.
	External & Internal Aerodynamics Subsonic/Transonic/Supersonic Flows	Industries: Aerospace, Automotive Applications: Aircraft and vehicle aerodynamics, wind tunnel simulation.
	Aero-Vibro Acoustics Fluid-Structure Interaction	Industries: Defence, HVAC Systems Applications: Noise control in HVAC systems, vibration analysis in defense equipment.
	Combustion & Reaction Chemistry	Industries: Energy, Water Management

	Hydraulic & Turbomachinery	Applications: Combustion systems, water pumping solutions.
Photonics & Optics	Modeling Nanophotonic Devices Optical Waveguide Design	Industries: Photonic Integrated Circuits, Optical Communications Applications: High-speed data transmission, photonic chip design.
	Optical Design & Vision Simulation (Light Dispersion, CMOS Image Sensing, LIDAR)	Industries: Imaging & Sensing Systems, Autonomous Vehicles, Robotics Applications: Virtual reality systems, LIDAR for self-driving cars, robotic vision.
Electronics	Electromagnetic Simulation (High and Low Frequency) RF & Signal Integrity	Industries: Consumer Electronics, Telecommunications Applications: RF antenna design, thermal management of electronics systems.
	Electronics Cooling Reliability Prediction Sensors	Industries: Biomedical Devices, Automotive Applications: Electronics in medical devices, sensor reliability testing.
Semiconductors	Power Integrity & Reliability Electrothermal Simulation	Industries: Semiconductor Manufacturing, IC Design Applications: Validation of IC designs, electrothermal effects analysis.
Electromechanical	Electric Machine Design Electric Powertrain	Industries: Automotive, Industrial Automation Applications: Generator design, actuator performance optimization.
Acoustic	Sound Production	Industries: Consumer Electronics,

		Automotive Applications: Acoustic tuning in devices, noise reduction in vehicles.
3D Modeling	3D CAD Modeling Development & Assemblies 2D to 3D Conversion	Industries: Product Design, Manufacturing Applications: Prototype development, detailed 3D modeling for production.
Human Body Modeling	High-Fidelity Human Body Modeling	Industries: Ergonomic Studies, Healthcare Applications: Human body interaction analysis, ergonomic product design.

1.1.1 The Role of Simulation-Based Learning Across Engineering Education in Higher Education Institutes

It is evident that in the “Science, Technology, Engineering, and Mathematics” (STEM) fields , students must tackle complex, real-life system models, including automation machines and processes, the human body, integrated circuits, and more. Traditional methods, which rely heavily on human skills, experience and knowledge to address uncertainties, pose risks of inaccuracies. Simulation-Based Learning (SBL) has emerged as an essential tool for understanding and analyzing these systems.

To effectively operate simulation tools and achieve meaningful and reliable outcomes, students must be trained in critical skills such as a deep understanding of materials, fluid dynamics, and mesh construction (Massobrio, 2023). Furthermore, a study by Campos et al. (2020) highlights the growing academic interest in "simulation education," which has seen significant growth over the past decades and is projected to continue attracting relevance in future research studies , emphasizing SBL potentials in engineering studies.

Taher and Khan, (2015) highlights that SBL implementation in engineering studies able to connect the learning environment with real-world applications through visually simulate scenarios that are hard to replicate in traditional physical lab environments. For instance, constructing a Printed Circuit Board (PCB) or assembling surface-mount chips in the lab can be challenging due to facility availability , or performing a crash test analysis for vehicles , which would pose safety risk, compliance issues and cost, when conducted physically in academic settings (Jaiswal et al. , 2022) Visually representative analysis outcome by problem-solving oriented simulations enable critical and analytic thinking strategies, enhancing students' cognitive, problem-solving skills, and creativity. They are also cost-effective compared to maintaining and updating physical lab equipment, and they eliminate safety concerns associated with hands-on experiments (Taher & Khan, 2015).

Taher and Khan (2015) explored three instructional designs for integrating simulation-based experiments into education, supported hybrid instructional delivery as a result which demonstrated effectiveness in improving student learning outcomes, particularly in Electronic Computer Engineering Technology courses. Meanwhile, Lateef (2021) emphasized that simulation is a technique, not merely a technology, designed to replicate and amplify real-world experiences with virtually immersive ones. It has the potential to replicates substantial aspects of real-world events in an controlled interactive manner, making it particularly valuable in fields like biomedical engineering address ethical tensions and practical dilemmas during learning of inexperience student practitioners.

CAD 3D modeling and mechanical simulation in silico clinical trials for the design and development of prostheses and implants enable analysis of fatigue performance under diverse conditions, including electromagnetic emissions and radiation level. These simulations ensure durability and reliability before tailored device construction and actual surgical implantation, allowing researchers to observe and study the device's viability within the human body and its impact on health (Ginestra et al., 2016 ; Favre et al., 2021). Simulation-Based Learning (SBL) also plays a vital role in biomedical research, particularly in drug delivery systems. It facilitates the examination of transient blood flow in arteries and the study of airborne transmission of virus-laden droplets. By using computational fluid dynamics (CFD) tools, such as ANSYS Fluent, SBL predicts drug flow rates, pressure, and shear forces encountered during drug delivery through infusion sets. This approach provides a risk-free, near-real-life environment for research student to learn and gain hands-on experience without ethical and practical concerns to test on actual human (ANSYS, 2024e).

Simulation-Based Learning (SBL) has established itself as a transformative educational approach, with its growing adoption in STEM education highlighting its effectiveness in enhancing learning outcomes and equipping students to tackle real-world challenges. Its versatility is evident across various engineering disciplines, where it enables students to engage with complex concepts and practical applications in innovative and impactful ways.

1.2 Problem Statements

Despite the SBL potentials, the implementation and results measurement of SBL have not been deeply studied. Besides, although initiatives to integrate technology-enabled learning, such as UTMDigital and simulation labs at UTeM (UTMDigital, 2024; UTeM, 2024), disparities in resource allocation, faculty training, and policy consistency persist, hindering the widespread adoption of Simulation-Based Learning (SBL) (Ma'aruf & Phuah, 2016; Anis et al., 2018).

A significant barrier to the effective implementation of Simulation-Based Learning (SBL) in Malaysia is financial constraints and awareness of the importance of keeping up with the technological advancement. Many institutions, after making an initial investment in campus-wide or individual licenses, may continue using outdated simulation software due to limited funding and budgetary challenges. This approach, often characterized by the mindset of "use until it becomes unusable before seeking alternatives," reflects difficulties in securing ongoing financial support and a lack of awareness regarding the importance of staying current with technological advancements. Studies in a similar position as engineering schools, healthcare schools, especially in biomedical engineering, highlight that financial support often comes from internal institutional mechanisms, restricting access to updated technologies , further challenges the formal assessments of simulation effectiveness (Ismail et al., 2019).

Scholars like Negahban (2004) have explored immersive simulation-based learning (SBL) as a solution to address the high costs and maintenance challenges of engineering equipment, enabling students to safely conduct experiments and research without extensive prior experience in handling lab equipment.

Traditional physical lab approaches often restrict the learning experience, especially with the shift towards remote education and in studying complex, unobservable phenomena such as nanoscale effects, chemical reactions, thermodynamics, and electricity. These limits students' critical thinking ability, conceptual understanding and problem-solving ability. While Negahban (2004) immersive SBL findings, shows that SBL had positively motivate students in engineering lessons but have conflicting effects on student learning experience and learning outcome. The challenges in implementing simulation-based learning (SBL) in Malaysia's education system may stem from a lack of formal assessments of simulation effectiveness, as this area remains under-researched and less proven in supporting learning outcomes.

To further justify Negahban (2004) findings, Ma and Nickerson (2006) argued that despite extensive research on laboratory-based learning in education, there remains lack of a common view on the effectiveness of different type of lab-based education ; physical, remote and simulation labs, which utilize SBL. Their findings highlight inconsistent definitions and a lack of standardized criteria for evaluating the effectiveness and impact of laboratory-based learning, including simulation-based learning (SBL), on students' learning outcomes. This inconsistency particularly affects the assessment of key educational objectives, such as fostering conceptual understanding, design skills, teamwork, and professional competencies among students. In addition, Ma and Nickerson (2006) found that respondents held differing beliefs about the effectiveness of simulated labs with SBL, argued that simulated labs tend to focus on conceptual understanding and professional skills, but not able to fully addressing design skills, which they believe are more effectively taught in physical labs.

On contrary, scholars such as Razali and Shukor (2005) supports that SBL had significantly enhances students' understanding of the connection between theoretical concepts and real-life engineering applications. They highlight that equipment and cost constraints often hinder effective teaching of both theory and practice. SBL, however, serves as an effective teaching aid by providing accurate visualizations, improving cognitive understanding, and helping students grasp the the physics phenomenal and components involved, ultimately enhancing their ability to acquire the necessary engineering knowledge and skill.

In conclusion, while immersive simulation-based learning (SBL) has shown potential in overcoming challenges such as high costs, equipment limitations, and safety risks in engineering education, its effectiveness and adoption remain a subject of debate among educators. This research objective is to address these gaps, emphasizing the role of SBL, and examine its impact on student learning outcomes, ultimately supporting its broader implementation in engineering education.

1.3 Research Questions

1. What are the impact of practicing SBL across various engineering disciplines on student's learning outcome in Malaysian higher education?

2. How do the extend of implementation of practicing SBL across various engineering disciplines influence student's learning outcome in Malaysian higher education institutes?

3. How do the capabilities of simulation tools used in SBL influence student's learning outcome in Malaysian higher education institutes?

1.4 Research Objectives

This study's goal is to investigate the impact of simulation-based learning (SBL) on student learning outcomes and identify the barriers to its broader implementation across Malaysian institutions using David Kolb's Experiential Learning Theory (ELT). The research aims to provide insights for industry stakeholders, educators, and policy-makers. By evaluating SBL's role in fostering practical skills and addressing existing gaps in engineering education, the study aims to support to enhance workforce readiness in alignment with Malaysia's Industry 4.0 objectives. Below are the research objectives for this study:

1. To examine the impact of practicing simulation-based learning across various engineering disciplines on student's learning outcome in Malaysian higher education.

2. To examine the impact of extend of implementation of practicing simulation-based learning across various engineering disciplines on student's learning outcome in Malaysian higher education.

3. To examine how the capabilities of simulation tools used in SBL influence student's learning outcome in Malaysian higher education institute.

1.5 Significance of Study

This study aligns which Malaysia's Education Blueprint (MEB) 2015–2025, which emphasizes bridging literacy gaps and equipping students with both theoretical knowledge and technical vocational skills to create a highly skilled and literate workforce by focusing on "high-tech, high-touch" interventions (Ministry of Education, 2015).

Although scholars have identified both the advantages and limitations of implementing and adopting Simulation-Based Learning (SBL) in educational programs, fewer research has been carried out to assess SBL's effectiveness and its proven impact on student learning outcomes. While some scholars focus on SBL as a cost-effective alternative to expensive equipment and a means to bridge gaps in engineering education, others argue that SBL may merely function as a supplementary teaching tool without addressing critical educational objectives.

Similarly, the lack of organizational resources, knowledge awareness and insufficient teacher training further impede the integration of advanced simulation technologies into curricula (Benchadlia et al., 2023). These challenges ultimately limit students' exposure to cutting-edge tools, leaving them underprepared for competitive job markets especially in engineering field where it being driven by constant technological advancements and innovation.

Current policies also lack comprehensive frameworks for evaluating SBL's effectiveness or establishing benchmarks for simulation tools. This results in inconsistent assessments of critical educational outcomes such as conceptual understanding, professional skills, and practical design capabilities (Ma & Nickerson, 2006). These disparities limit the potential of SBL to foster interdisciplinary learning and real-world problem-solving.

To address these challenges, this study employs theoretical framework ; Kolb's Experiential Learning Cycle (Kolb, 1984) . By mapping SBL practices across the four stages; Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. This research provides a structured approach to enhancing student learning outcomes (SLO). For example, simulation tools offers accurate , realistic and safe environments for experimentation with minimal cost for maximized value, enabling students to apply theoretical knowledge to solve engineering challenges effectively (Negahban, 2004).

The findings of this study will guide policymakers in developing standardized guidelines for SBL integration in Malaysia Higher Education Institute.

Aligning SBL practices with Kolb's framework can address employer concerns about graduate competencies, particularly in problem-solving and design skills, while preparing students for the demands of Industry 4.0. It will serve as solid prove that SBL could improve students quality and highly competitive engineering workforce as well as the potential of SBL being the central piece of both education and industrial engineering that could drive the national dream (MOE, 2015).

Ultimately, this research supports Malaysia's aspirations to become a globally competitive, highly skilled nation. By equipping students with both technical expertise and practical problem-solving abilities, the study contributes to producing graduates who are better prepared to meet industry demands and drive national progress.

This study is significant as it aligns with Malaysia’s Education Blueprint (2015–2025) by promoting a highly skilled workforce through Simulation-Based Learning (SBL). Recognized for its potential in engineering education, SBL is examined using Kolb’s Experiential Learning Cycle to assess its impact on student learning outcomes while addressing challenges like resource limitations and inconsistent evaluation. The findings will help policymakers standardize SBL integration, ensuring graduates are industry-ready and supporting Malaysia’s vision of becoming a technology-driven nation.

CHAPTER II

LITERATURE REVIEW

2.0 Introduction

This chapter provides a literature review of Kolb's Experiential Learning Theory (ELT) application in Simulation-Based Learning (SBL) using Kolb's Experiential Learning Cycle (ELC). The discussions highlight the theoretical foundation of Kolb's framework, emphasizing the role of Reflective Observation as a mediating factor in translating learning through simulation experiences into measurable learning outcomes. This chapter also explores the foundational theories that influenced Kolb's model, evaluates its role and applicability in education, identifies gaps in its integration with engineering education in HEI in Malaysia.

2.1 Underlying Theory

Kolb's Experiential Learning Theory

Kolbs's Experiental Learning Theory (1984) developed by psychologist David A. Kolb, is rooted in the idea that knowledge is acquired through a process where knowledge is created through the transformation of experience by considering the interconnected elements in the learner's experience, perception, cognition and behaviour during the learning process. Kolb's theory emphasize on learner's internal cognitive processes during learners attempts in making sense of new information, focusing on three key concepts; learning through experience , four learning styles and learning as a continuous process (Murrell & Claxton, 1987).

2.1.1 Kolb's Experiential Learning Cycle

Within Kolb's Experiential Learning theory that highlights the concept of experiential learning, and learning as a continuous cycle of experience, reflection, conceptualization and experimentation. Hence, formed Kolb's four stage learning cycle consists of Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation. Kolb's identified four learning styles; diverging, assimilating, converging and accommodating based on preferences for different stages of the learning cycle, the whole process highlights how learners move through different stages to develop deeper understanding of concepts and apply their knowledge effectively , creating new information inputs on top of reinforcing or relearning from past experience, knowledge to improve a learner's learning process (Kolb , 1983.& Kolb et al., 2016)

2.1.1.1 The Influences on Kolb's Theory

In Kolb's written creation; "Experiential learning: Experience as The Source of Learning and Development", Kolb's expanded on his theory by integrating elements from the learning models of Kurt Lewin, Jean Piaget and John Dewey, each contributing distinct perspectives to the experiential learning process. He identified commonalities in the nature of experiential learning, emphasizing the roles of feedback, judgment, and internal reflection in the learning process.

Kurt Lewin (1994) influence Kolb's ELC through his view in conceptualizing learning as a four-stage cycle. Starting with concrete experience, which triggers the second stage of observation and reflection. During this stage, learners gather information and derive insights from their experiences. The third stage involves forming abstract concepts and generating ideas based on past experiences and personal perceptions. These concepts are used to define the current situation and guide future actions. Finally, in the fourth stage, learners test the implications of these concepts through active experimentation and assesses how well the outcomes align with desired goals.

Lewin's utilized the concept of trial and error whereby each stage builds on the previous one through an endless feedback loop, creating a dynamic process of action, evaluation, and adaptation. By leveraging these feedback loops, learners refine their understanding and approach, fostering personal and professional growth through transformation of feeling to satisfied internal desire of concrete experience into higher-order meaningful actions (Kolb, 1984; Choi, 2014).

Although there are similarities with Lewin's concept of learning, John Dewey's influenced Kolb's ELC by emphasizing learning by doing as logical process that integrates immediate experience, concepts, observations, and actions. This process is driven by a continuous cycle of impulses arising from experiences, with ideas directing these impulses. Reflection or mediated experiences, in Dewey's view, is not merely an internal process but involves acquiring information through active participation or social interaction, engaging with third-party perspectives, and adapting to the surrounding environment. Dewey argued that the learning process should involve observation and judgment before intervention to achieve a desired end goal, advocating for progressive education that prioritizes experiential and adaptive learning through democratic inquiry (Kolb, 1984; Main, 2023; Cloke, 2023)

Lastly, Jean Piaget's influenced Kolb's ELC model by emphasizing learning and cognitive development comprehensive framework of stages-in-order, that spans from early childhood to adulthood (Kolb, 1984). Piaget emphasized the ability to conceptualize and test actions to achieve desired results during the learning process. This repetitive practice fosters the development of logical and scientific thinking at each stage of human development. From a childhood development perspective, Piaget explained that learning varies among individuals, with the degree of understanding influenced by the quantity and complexity of experiences and the evolution of new ideas built on prior knowledge (Okstate, 2024).

Piaget's highlights constructive learning process that differs from Kolb's and Lewin's learning cycles. Piaget proposed that learning begins with schemas, which are mental frameworks for organizing information, followed by three processes of adaptation: assimilation, accommodation, and equilibration (Pakpahan & Saragih, 2022). He further outlined the four stages of cognitive development starting with sensorimotor, preoperational, concrete operational, and formal operational. That learning process starts with the recognition and differentiation of experiences based on reward and punishment, enable learning through internal reflection based on categorize experiences, adaptation to situations, and evolve their understanding as their brain develops during growth (Gowrie, 2024).

Leveraging these theories, Kolb concluded that learning is a process and not in terms of outcome as knowledge will not remain stagnant at the point it was initially learnt. New knowledge will be gain continuously as a result of act of understanding, invention through the interaction processes of assimilation and accommodation., formed and reformed through experience (Choi, 2014). Hence, he formed his theory that propose a four-stage process that forms a complete cycle; concrete experience, reflective observation, abstract conceptualization and active experimentation (Kolbs, 1984).

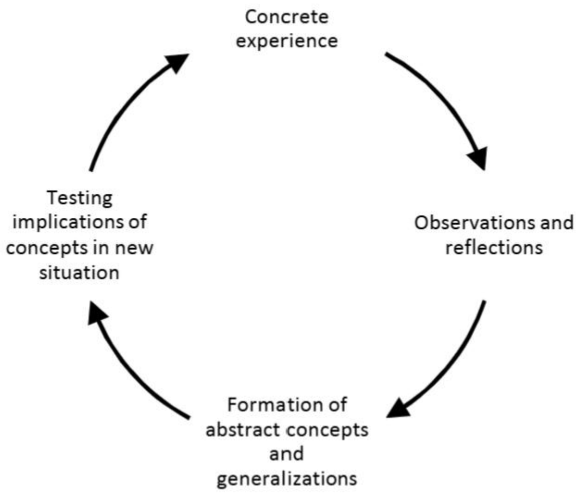


Figure 1.0: The Kolb's Experiential Learning Cycle adapted from Kolb, 1984.

Table 2.0 : Shows the previous SBL Studies in influencing Student's Learning Outcome using Kolb's Experiential Learning Cycle Framework

Source	Theoritical Framework	Findings
Camperos et al. 2023	Kolb's ELC	Integration of SBL with experiential learning to enhance user understanding of system behavior, optimize decision-making in a digital environment, and improve learning productivity through a structured simulation cycle.
Panungkas et al. 2019	Kolb's ELC	Experiential learning enhances student achievement, knowledge, and skills through direct engagement, improving conceptual understanding, self-efficacy, and cognitive development, making it a suitable approach for mechanical engineering education in Indonesia.
Singh-Pillay, 2024	Kolb's ELC	Integration of SBL in academic curriculum, helps teaching lecturers in fostering learning, unlearning, and relearning through the SBL teaching method, and enhance conceptual understanding, spatial–visual skills, and active engagement of the students, especially in resource-limited educational contexts.

2.2 Reflection Observation Stage as Mediator in Translating Simulation Experience into Measurable Learning Outcome

According to Choi (2014), Reflection is key process to proof the success of Kolb's Experimental Learning Cycle as described in Dewey's Model of Learning as a process of act and thinking to gain or search for new positive experience in resolving negative experience such as doubt, perplexity, mental difficulty and perplexity. During this process, reappraisal of other tasks and planning of new experiences may be triggered, hence simulate the a repetitive continuous learning cycle that further improve and reinforce former positive experience, hence could positively impacts learning outcomes. While Kolb emphasized that learning should not be reduced to behavioral outcomes, Choi (2014) argued that reflective observation can contribute to measurable learning outcomes. Drawing on Jarvis (1987) study, Adult Learning in Social Context, Choi (2014) noted that the degree of reflection and active involvement significantly influences the learning outcomes, resonating with Piaget's findings that individual differences shape the effectiveness of experiential learning processes.

Simulation-based learning (SBL) leverages reflective observation as a foundation for effective knowledge acquisition. By focusing on learning through cognitive experiences, SBL allows learners to absorb knowledge and practice skills in a visually represented two-dimensional (2D) or three dimensional (3D) Graphics, realistic yet simulated environment. This approach bridges gaps in solving complex problems, particularly those involving abstract concepts or engineering challenges that are difficult to test in real-life settings or are imperceptible to the naked eye (Landriscina, 2013 & Jones & Alinier, 2009).

Kolb's Experiential Learning Cycle's (ELC) structured framework provides a guided reflection throughout the learning process. By completing all four stages of the cycle, students can demonstrate their learning outcomes, including the ability to identify solutions and apply knowledge to achieve desired results (Kolb, 1984).

1. **Concrete Experience**: Students engage directly with a task, scenario, or situation, gaining hands-on experience during SBL lectures
2. **Reflective Observation**: Students review and reflect on their SBL experiences, utilizing prior knowledge and past experiences to analyze the task and consider multiple aspects, including emotional responses . This reflective process bridges the gap between concrete simulation experiences and measurable learning outcomes by fostering internal feedback, critical thinking, and problem-analysis skills. It sets the foundation for developing innovative solutions in the subsequent stage, contributing to improved academic performance.
3. **Abstract Conceptualization**: Students form conclusions based on their reflections, developing theories or conceptual models to understand and approach the task.

4. **Active Experimentation**: Students apply their newly acquired knowledge and test their theories to achieve desired outcomes, iterating the process to refine their understanding and skills through assignments, evaluation tests or examinations. These outcomes are could be measurable through academic grades evaluations or examinations results (Jones-Roberts & Bechtold, 2024).

2.3 Research Framework

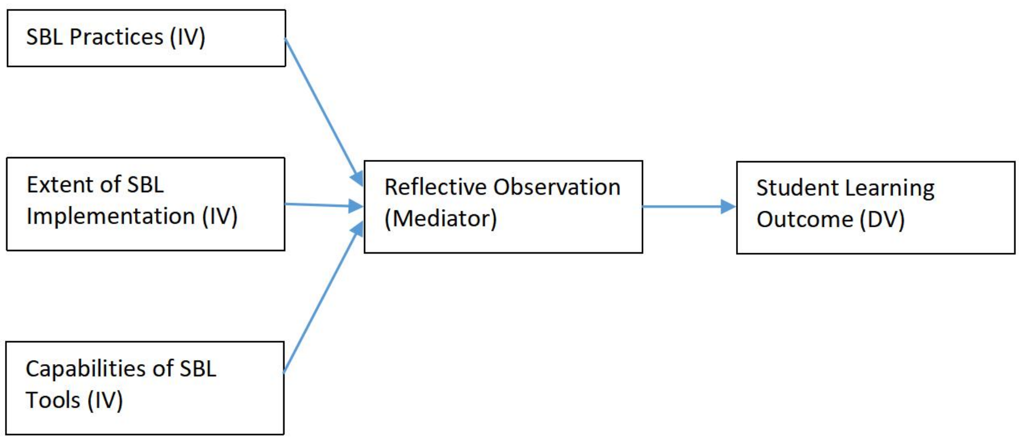


Figure 2.0 : Shows the conceptual model of relationship between Kolb's Learning Cycle,with Reflective Observation stage as mediator, and student learning outcomes in the context of Simulation-Based Learning (SBL)

Although Kolb's ELC provides an efficient framework to understanding the learning process, it does not explicitly address the outcomes of applying this theory in real-life experimental contexts, particularly in Simulation-Based Learning (SBL). Several gaps emerge when applying Kolb's framework to

SBL. For instance, while the cycle is well-suited for understanding learning processes, it does not directly measure learning outcomes in SBL environments.

Developed decades ago, Kolb's Learning Cycle lacks emphasis on the role of technology in facilitating the learning process. This under explored area is significant in the context of visual and interactive SBL tools, which are being increasing integrated into modern education. Moreover, Kolb's framework was initially designed with a focus on social sciences and humanities (SSH) studies, leaving a gap in its contextual adaptation for STEM education. This divide between technical and social sciences may stem from the specialized focus of researchers, who often view these fields as distinct, overlooking the potential for cross-disciplinary applications (Olmos-Penuela et al. , 2014) .

Another limitation is the under-explored role of reflective observation as a stage for achieving measurable outcomes. While Kolb believed that the learning process should not be strictly goal-oriented, recent studies (e.g., Choi, 2014; Queen's University, 2021) have demonstrated the potential of reflective observation to yield quantifiable academic and skill-based outcomes. Without this focus, Kolb's framework remains underutilized as a transformative tool for modern education and policy development, especially in modern data-driven decision making practice.

Kolb’s Learning Cycle has the potential to evolve into a comprehensive guideline for measuring the impact of experiential learning, aided by SBL in terms of academic performance and skill development. To address these gaps, the new conceptual model integrates SBL into Kolb’s framework, emphasizing the technological dimension and amplifying the role of reflective observation as a transformative mediator. This approach aims to make Kolb’s theory more relevant to modern education by linking experiential learning stages to measurable learning outcomes.

Specifically tailored for engineering education, this model leverages SBL to enhance problem-solving capabilities in real-world engineering scenarios. By addressing the interaction between students and technology, the model provides a structured approach to evaluate learning outcomes in STEM education.

2.3.1 Hypotheses Development

Based on past studies by Clark & Dickerson (2018) and Hui et al. (2021), the hypothesis was formulated that the integration of simulation-based learning (SBL) positively influences reflective observation, which in turn enhances student learning outcomes in engineering programs. Clark & Dickerson (2018) specifically explored how post-exam reflective exercises using simulation tools helped students critically assess their mistakes and improve their performance in subsequent exams, suggesting that such reflection contributes to deeper learning. Similarly, Hui et al. (2021) found that SBL fosters creative self-efficacy and promotes deeper, reflective learning, further supporting the idea that reflective practices facilitated by simulation positively impact student outcomes.

Building upon these findings, Kumar & Milanovic (2022) hypothesized that a systematic, simulation-supported approach leads to increased student engagement, study time, and confidence across various engineering disciplines, underlining the importance of simulation in fostering reflective thinking and improving learning.

Thus, for this research, the hypothesis is formulated as follows:

Hypotheses 1 (H1) : The practice of SBL across various engineering disciplines positively impacts Reflective Observation , leading to improved student learning outcomes in engineering programs.

This hypothesis is supported by Taher and Khan (2015), highlights the effectiveness of Kolb's Experiential Learning Cycle (ELC) in simulation-based methods in the Electronic Computer Engineering Technology (ECET) program . The case study employed Kolb's cycle by integrating lectures, hands-on practice, and simulation labs involving 24–29 undergraduate students.

Students first engaged in lectures on circuit building using bread-boarding and Multisim-8 simulation software, gaining concrete experiences (The Engineer Solution, 2020).

Following this, students practiced circuit-building in class and participated in simulation labs aligned with each lecture topic. These activities facilitated reflective observation, where students analyzed their experiences, connected them to prior knowledge, and critically evaluated their tasks. This stage enabled cognitive retention and iterative improvement, progressively preparing students for the abstract conceptualization stage, where they formulated new ideas and strategies.

To measure learning outcomes, three tests were administered, focusing on the student's academic grades and lecturer observations. Comparisons between students taught with and without simulation tools revealed that simulation-based learning not only reinforced theoretical knowledge but also significantly enhanced practical skills. The findings highlight that reflective observation acts as a crucial mediator, linking experiential learning stages to measurable academic performance. This underscores how Kolb's cycle, particularly the reflective observation stage, fosters deeper understanding and application of knowledge, making it an indispensable framework in simulation-based learning environments for technical education.

Meanwhile, a similar study conducted by Panungkas et al. (2019) supported SBL can improve students' learning outcomes and encourage the development of cognitive and psychomotor skills using Kolb's Experiential Learning Cycle (ELC) framework in mechanical engineering programs. The study highlights that learning can occur not only in classrooms but also outside them. It highlights Reflection Observation process that integrates both internal and external reflection through observation and judgment, facilitated by social interactions such as practicing, embedding experiences into long-term memory, engaging in conversations and interactions, which aligns with the Lewin's concept of learning.

According to Panungkas et al. (2019) , his study to determine the effectiveness of active learning modules in teaching heat transfer using finite element methods with SolidWorks software (Watson & Brown, 2021). The research conducted using a post-test and pre-test group design. Applying theory of Kolb's ELC stages: Concrete Experience, where students engaged in question-and-answer sessions with the instructor; Reflective Observation, where students learned through module-based activities; Abstract Conceptualization, involving discussion and presentations; and Active Experimentation, where students applied their reflective observations and abstract ideas in practical tasks evaluated through academic grades.

Reflective Observation was emphasized as the stage where learners connect hands-on experiences to abstract concepts, proven through the average pre and post quiz evaluation, found that students gained heightened awareness of challenges related to the abstraction of real-world problems and the interpretation of simulation results. These findings agree the effectiveness of SBL, in its role in fostering Reflective Observation, which improve cognitive and psychomotor skills, ultimately contributing to improved learning outcomes.

The above study demonstrates that SBL enhances learning outcomes by improving academic performance and fostering conceptual understanding through cognitive visualization. However,as the past studies focus on implementation of SBL as a value added teaching tool to address specific teaching gaps, such as enhancing students' self-learning independence and compensate the unavailability of sufficient lab facilities and equipment. It does not place sufficient emphasis on developing design skills which are crucial for problem-solving and technological innovation. Therefore, these findings support with H1.

In addition, previous studies by Kumar and Milanovic (2022) and Chernikova et al. (2020) have proposed various hypotheses on the impact of simulation-based learning (SBL) in improving student learning outcomes across diverse educational disciplines.

Kumar & Milanovic (2022) proposed that a systematic and widespread implementation of SBL across engineering curricula leads to increased student engagement, study time, and confidence. Their research demonstrated that integrating SBL into multiple courses using different simulation tools enhances student participation and inquiry-based learning, making it a scalable and effective alternative to traditional lab-based education.

Chernikova et al. (2020) further expanded on the impact of SBL by hypothesizing that simulation is one of the most effective methods for developing complex problem-solving skills in higher education. Their meta-analysis of 145 empirical studies provided strong evidence that SBL significantly contributes to skill development across various fields, such as medical and teacher education. The study also emphasized that the degree of SBL implementation, along with structured scaffolding, plays a critical role in improving learning outcomes, particularly for students with varying levels of prior knowledge.

These findings collectively suggest that the extent to which SBL is implemented in higher education institutions plays a crucial role in fostering reflective observation, which in turn enhances student learning outcomes.

Thus, for this research, the hypothesis is formulated as follows:

Hypotheses 2 (H2) : The extent of implementation of simulation-based learning (SBL) in higher education institutions positively impacts Reflective

Observation, leading to improved student learning outcomes in engineering programs.

Panungkas et al. (2019) highlight that engineering education in Indonesia emphasizes leadership development through direct experience (Concrete Experience), enabling students to excel in their careers by engaging in experience-based learning such as SBL. This approach fosters higher-order cognitive skills, particularly analytical thinking (Reflective Observation) and concept application (Active Experimentation) to address real-world challenges.

However, the extent of SBL implementation is hindered by several challenges, including: insufficient educational infrastructure, such as a lack of high-performance computers capable of running simulations, which limits SBL availability. Lack of experienced educators and skill competencies, due to limited technology training from industry experts. In addition, poor classroom management and outdated curricular may not effectively integrate SBL, thereby reducing student exposure and engagement.

These barriers negatively impact students' learning experiences, as limited exposure to SBL leads to insufficient input for Reflective Observation, ultimately influencing learning outcomes. The shift from conventional learning (effective for lower cognitive skills) to SBL (which enhances higher cognitive skills) requires pedagogical adaptation, which remains a challenge.

Panungkas et al. (2019) further explain that the depth and breadth of SBL integration in higher education curricula significantly influence students' learning opportunities, self-learning abilities, and learning readiness. Their study found that 75% of knowledge gained through experiential learning is retained, compared to only 5% in conventional learning.

By expanding SBL adoption, students develop superior affective, cognitive, psychomotor, and competitive abilities, reinforcing student-centered learning that enhances knowledge acquisition, skill development, and leadership capabilities, ultimately improving workplace readiness.

In addition, a study by Singh-Pillay (2024) in his article "Exploring Science and Technology Teachers' Experiences with Integrating Simulation-Based Learning" agrees that the depth and breadth of SBL integrated into engineering academic curriculum able to maximize education benefits. Singh-Pillay highlights the challenges and successes encountered during implementation as well as the degree of SBL integration among educators, limited by resources availability, institutional support, and personal proficiency with the simulation tools.

In Singh-Pillay (2024) study, well-implemented SBL in teaching encourage problem-based learning rather than traditional passive one-way teaching, thus improve in active engagement , conceptual understanding and spatial ability of learners. However, quality education through SBL can only be achieved if teachers are adequately trained, possessing the necessary skills, knowledge, and readiness to implement it effectively. To address this, Kolb's Experiential Learning Cycle was applied in teacher training and exposure to SBL. Although teachers initially faced challenges in upskilling and adopting SBL, Singh-Pillay (2024) findings indicate positive feedback, particularly during the Reflective Observation stage. At this stage, many teachers acknowledged how transformative SBL is, prompting them to look into their current teaching methods, recognizing areas for improvement.

Further experimentation with SBL revealed significant benefits for students. Teachers observed that students were better equipped to overcome challenges and performed better in spatial visualization assessments. Some teachers noted that SBL helped reduce material wastage, an issue that was previously unavoidable with manual design methods due to the difficulty novice learners faced in accurately visualizing dimensions and results. Additionally, another teacher highlighted how SBL allowed students to manipulate variables repeatedly in ecological studies, enabling them to observe relationships between variables in a controlled, simulated environment, something that would be difficult to achieve in physical experiments (Singh-Phillay, 2024 ; Carlisle et at., 2015 ; Fongamut et al., 2022).

SBL helps students focus directly on the concepts being explored, reinforcing their learning process. The study ultimately demonstrated significant improvements in student learning outcomes, affirming the effectiveness of well-integrated SBL in higher education curricula. A study conducted by Fang et al. (2010) examined the effects of Simulation-Based Learning (SBL) on Engineering Workshop Practice by comparing student learning outcomes between SBL-integrated classes which combined SBL with instructor-led teaching and non-SBL classes which relied solely on traditional classroom instruction. The study evaluated factors such as interactivity, communication, independence, and work pace among students.

Their findings revealed that students in SBL-integrated workshops demonstrated higher levels of learning independence and were more likely to engage with instructors for topic-related inquiries. In contrast, students in non-SBL classes exhibited stronger peer-to-peer collaboration and required more hand-holding and repetitive clarification from instructors. This suggests that SBL fosters a more task-oriented learning environment, helping students familiarize themselves with workshop tools and procedures, making instruction more effective.

However, the study also uncovered an interesting trend that students in SBL classes were less likely to actively participate in classroom discussions compared to those in non-SBL classes, despite both groups performing equally well in answering questions correctly. This could be attributed to SBL students relying more on individual reflective observation, which may condition them to be more introverted and feel less need for open discussion.

Another key finding was that SBL students exhibited a faster work pace. With SBL aiding in the visualization of machine parts and complex motor skills, students spent less time seeking clarification from peers and were able to process information more efficiently (Fang et al., 2011). While these studies provide positive insights into the effectiveness of SBL, they primarily compare SBL versus (vs.) non-SBL implementation in a single engineering program rather than evaluating the extent of SBL integration across an entire engineering curriculum. Given that engineering courses encompass multiple disciplines, further research is needed to assess how a broader implementation of SBL impacts different engineering fields. Additionally, the study does not explore the implications of self-directed learning using SBL versus a hybrid approach that combines SBL with traditional classroom instruction, which could further refine our understanding of its benefits and limitations. Hence, the above findings supported H2.

Previous studies have explored the impact of simulation-based learning (SBL) on student learning outcomes across various disciplines. Kong et al. (2024) hypothesized that replacing traditional lab sessions with process simulation enhances learning by bridging theory and practice. Their study on CHEMCAD integration in Chemical Engineering Thermodynamics showed improved student comprehension and real-world application.

Similarly, Eppes et al. (2011) formulated the hypothesis that engineering curricula often lack multiphysics design and research experiences, limiting graduates' adaptability in addressing interdisciplinary engineering challenges. They emphasized that exposure to sophisticated computational techniques, including multiphysics simulation, is often restricted to postgraduate studies, leaving undergraduate students with minimal interdisciplinary experience. This gap underscores the importance of implementing comprehensive simulation tools that encourage students to reflect on and integrate diverse engineering principles.

Khalil et al. (2024) further expanded on the effectiveness of SBL by investigating the role of MonsoonSIM in Malaysian higher education institutions. Their hypothesis suggested that SBL enhances students' learning experiences and knowledge acquisition,

Thus, for this research, the hypothesis is formulated as follows:

Hypotheses 3 (H3) : The capabilities of simulation tools used in simulation-based learning (SBL) positively impacts Reflective Observation, leading to improved student learning outcomes in Malaysian higher education.

According to Bouchrika (2025) , the Co-Founder and Chief Data Scientist from academic research portal Research.com, industrial standard simulation tools must possess below capabilities :

- Intuitive and user friendly interface
- Customizable features for different engineering application
- Scalability and supporting high-performance computing
- Multi physic integration for multiphysic scenarios
- Quality support and trainings
- Affordable cost and flexibility of licensing models

These capabilities reflect the quality, versatility, and functionality of simulation tools used in SBL and their ability to provide realistic, interactive, and diverse scenarios, which are crucial for enhancing student learning outcomes (Bouchrika, 2025).

In addition, Bouchrika (2025) had suggested a few simulation software that is capable and reliable up to industry required standard; ANSYS Fluent , ASPEN HYSYS , Honeywell Unisim, COMSOL Multiphysics, Arena Simulation and more. He highlighted the capabilities of simulation tools such as manufacturing, automotive healthcare sectors and more in simulating process, reliability testings that eventually reducing risk , wastage and cost, improve planning and efficiency.

Simulation tools provides environment where students can test, modify, and validate their engineering solutions through various solvers. In addition, with the availability of comprehensive training resources, free student version and user-friendly interfaces ensures that students can fully engage in experiential learning, leading to higher academic performance and problem-solving skills (ANSYS How To, 2024; AIC, 2024). Students able to analyze and internalize their experiences to reinforce conceptual understanding and problem-solving skills. The capabilities of these tools directly impact how effectively students engage with real-world scenarios in engineering education, ultimately influencing their learning outcomes.

A case study by Crha el at. (2021) on the comparative analysis of CFD simulation tools in engineering education; COMSOL Multiphysics and ANSYS Fluent for hydrodynamics simulations demonstrated how tool capabilities directly affect learning outcomes. The users of shared his experience, highlighting that COMSOL Multi physics provides higher accuracy through 2D rotational symmetry, closely aligned with physical experimental results, enabling the researcher to acquired accurate factual data analysis to proof his active experiment and acquired a desirable learning outcome. On the other hand, ANSYS Fluent shown better computational efficiency due to its Finite Volume Method (FVM) to not able to generate desired results for his learning curve during his observation and reflection stage (Hussian, 2021).

In addition, Verner et al. (2024) further reinforces H3 in his studies that demonstrate the utilization of combining use of multiple simulation tools to compensate individual tool limitations to enhance reflective observation of students during SBL classes. Student version of the SBL tools such as Onshape and Blender comes with limited capabilities; Onshape , a CAD modeling software that enable students to design and develop 3D designs in a collaborative learning environment but without simulation solvers.

Hence, Blender with simulation solvers utlitized to enable the simulation of rigid body motion of the student's designs, allowing them to validate mechanical behaviour. The combination used of different SBL tools leverage usage based on its relevancy to the academic subject. Contributing to their observation and reflection stage, students able to use Blender to analyze simulation outputs of their own designs done using OnShape, and justify their design decisions . Then, students reinforcing their understanding of engineering concept during the conceptualization stage, leading to better Active Experimentation output hence learning outcome as per required by the academic standard. Thus, the findings consistent with H3.

2.4 Review of Past Studies on SBL Variables

2.4.1 IV 1 : Simulation-Based Learning (SBL) Practice

The practice of Simulation-Based Learning (SBL) has been widely studied in engineering education, with a particular focus on its role in enhancing learning through Kolb's Experiential Learning Cycle (ELC). Taher and Khan (2015) demonstrated how integrating SBL into the Electronic Computer Engineering Technology (ECET) program facilitated student learning through hands-on practice and reflective observation. Their study found that students who engaged in simulation tools, such as Multisim-8, performed better in both theoretical understanding and practical application.

Similarly, Panungkas et al. (2019) examined the effectiveness of active learning modules using SolidWorks for heat transfer simulations. Their findings reinforced the role of Reflective Observation in bridging experiential learning with cognitive and psychomotor skill development. The results revealed that students exhibited greater analytical thinking and knowledge retention when learning occurred in an interactive SBL environment.

While these studies affirm SBL's impact on student learning outcomes, they predominantly focus on its implementation as a supplementary teaching tool rather than a core component of engineering education. Additionally, there is limited research on SBL's effectiveness in fostering design and innovation skills, which are crucial for problem-solving in real-world engineering challenges.

2.4.2 IV 2: Extent of Implementation of SBL

The degree to which SBL is integrated into higher education significantly influences its effectiveness. Panungkas et al. (2019) highlighted that in Indonesia, engineering education's reliance on SBL varies depending on institutional resources, faculty expertise, and curriculum design. Their study found that while 75% of knowledge gained through experiential learning is retained, barriers such as inadequate computing infrastructure, limited faculty training, and outdated curricula hinder widespread adoption.

Singh-Pillay (2024) further explored how resource availability and institutional support impact SBL implementation. His study emphasized that well-structured SBL programs encourage problem-based learning, increasing student engagement and spatial ability. However, he noted that successful implementation requires faculty to be well-trained in simulation tools, underscoring the need for professional development programs.

Fang et al. (2010) provided additional insight by comparing student performance in SBL-integrated engineering workshops versus traditional classroom settings. Their findings showed that students in SBL classes demonstrated higher learning independence and efficiency but engaged in fewer peer discussions. This suggests that while SBL enhances individual cognitive processing, it may require additional pedagogical strategies to foster collaborative learning.

While these studies illustrate the benefits of SBL, they primarily focus on its implementation within specific courses rather than across entire curricula. Further research is needed to assess how broader SBL integration impacts learning outcomes across multiple engineering disciplines.

2.4.3 IV 3: Capabilities of Simulation Tools in SBL

The capabilities of simulation tools used in SBL play a crucial role in determining the effectiveness of experiential learning. Bouchrika (2025) outlined key features that industrial-standard simulation tools must possess, including user-friendly interfaces, customizable features, scalability, multi-physics integration, and affordability. He identified software such as ANSYS Fluent, ASPEN HYSYS, Honeywell Unisim, and COMSOL Multiphysics as industry-standard tools that enhance learning through realistic simulations.

A study by Crha et al. (2021) compared the effectiveness of COMSOL Multiphysics and ANSYS Fluent in hydrodynamics simulations, demonstrating that tool-specific capabilities significantly impact learning outcomes. Students using COMSOL benefited from higher accuracy in 2D rotational symmetry simulations, while ANSYS Fluent offered better computational efficiency through the Finite Volume Method (FVM). This highlights how selecting the right tool for specific applications can influence students' understanding and problem-solving abilities.

Verner et al. (2024) further emphasized the importance of combining multiple simulation tools to compensate for individual tool limitations. Their study examined the use of Onshape for CAD modeling alongside Blender for rigid body motion simulations. This hybrid approach enabled students to validate mechanical behaviors effectively, reinforcing their conceptual understanding during the Reflective Observation stage of Kolb’s ELC.

These studies collectively suggest that the selection and combination of simulation tools directly affect student engagement and learning outcomes. However, further research is needed to explore the impact of emerging technologies, such as AI-driven simulations and virtual reality, in enhancing SBL experiences in engineering education.

These past studies demonstrates that SBL practice, its extent of implementation, and the capabilities of simulation tools each play a critical role in shaping student learning outcomes. While existing research highlights the benefits of SBL in fostering experiential learning, challenges such as faculty training, resource availability, and curriculum integration must be addressed to maximize its potential.

In a nutshell, past researches shows that SBL improves theoretical understanding and practical skills but is often supplementary rather than central to teaching. Its implementation varies due to resource constraints and faculty expertise, with well-structured programs enhancing problem-solving and engagement. The effectiveness of SBL also depends on simulation tools, with industry-standard software like ANSYS and COMSOL playing a key role. While SBL offers significant benefits, challenges in faculty training, curriculum integration, and emerging technologies need further exploration.

CHAPTER III

RESEARCH METHODOLOGY

3.0 Research Design

This chapter outlines the research design used to examine the relationship between Simulation-Based Learning (SBL) variables and the role mediator factor, Reflective Observation from Kolb's Experiential Learning Cycle (ELC), in influencing engineering students' learning outcomes in Malaysian Higher educational institutions (HEI).

To achieve this objective, a quantitative survey approach will be employed to collect empirical data for statistical analysis. This study investigates three key independent variables (IVs):

> **IV1: SBL Practice** – To assess the direct and indirect impact of practicing SBL on student learning outcomes in HEIs in Malaysia.
>
> **IV2: Extent of SBL Implementation** – To assess the direct and indirect impact of the level of SBL integration on student learning outcomes in HEIs in Malaysia.
>
> **IV3: Capabilities of Simulation Tools** – To assess the direct and indirect impact on the capabilities of simulation software influence student learning outcomes in HEIs in Malaysia.

By analyzing these variables, this study aims to determine both their direct and indirect effects on student learning outcomes. Additionally, it will explore the mediating role of Reflective Observation, assessing how it influences the relationship between the IVs and student learning outcomes.

Cross-sectional study design will be implemented, where data will be collected at a single point in time over a period of several weeks (Oruganti et al , 2025). This approach is suitable for examining the extent of SBL implementation, the effectiveness of Reflective Observation as a mediator, and the impact on student learning outcomes within various engineering disciplines. The survey instrument will be distributed to engineering teaching lecturers across multiple institutions to gather diverse perspectives on SBL's effectiveness.

A quantitative method was chosen because structured, closed-ended survey questions provide measurable, objective data that facilitates statistical analysis. This method allows for the identification of trends, patterns, and relationships between variables, making it well-suited for testing hypotheses related to Kolb's Experiential Learning Cycle. Additionally, a deductive approach will be applied, where existing theories and prior research on SBL, Kolb's Learning Cycle, and student learning outcomes guide hypothesis formulation and data interpretation.

This research design is particularly effective in addressing the study's variables by enabling structured data collection to test relationships between SBL variables, Reflective Observation, and learning outcomes. It also able to compare across different engineering programs to assess variations in SBL implementation and its impact. Hence, allowing generalization of findings to the broader population of engineering teaching lecturers in Malaysia through systematic sampling techniques.

To illustrate the rationale behind this research methodology, Table 3.0 presents a selection of previous studies that have utilized quantitative methods to apply deductive reasoning in testing Kolb's Experimental Learning Cycle in SBL contexts. By adopting this research design, this study aims to provide data-driven insights to improve SBL integration in Malaysian higher education,

Table 3.0 : Shows the previous studies that have utilized quantitative methods to apply deductive reasoning in SBL contexts.

Source	Methodology	Remarks
Taher & Khan	Quantitative & Qualitative	Quantitative survey were used to investigate the impact of using SBL on students' problem-solving skills
Nowparvar, 2022	Quantitative	Quantitative survey were used to study the effectiveness of immersive simulation-based learning (ISBL) modules for learning and teaching engineering economy concepts.
Alenzi, 2019	Quantitative	Quantitative survey were used study the impact os simulation on teching effectiveness and student learning performance

3.1 Sampling and Data Collection Procedure

To identify data to be sampled for this research, a list of Malaysia Higher Education Institutes will be identified and compiled from various sources online such as Malaysian Qualifications Agency or Ministry of Higher Education website (MOHE) website , shown in Appendix 1(MQA, 2009 & MOHE, 2025) , categorized by states.

A close-ended survey approach is designed to accumulate data using cross-sectional studies, by gathering data once over a period months. A self-administered questionnaire will be designed using Microsoft Forms due to its analytic features and user-friendly interface. Researchers will contact the teaching lecturers and professors through email and the survey link will be included within the email content including asking their consent to participate this survey. Across a twelve week period , responds acquired will filtered to discard erroneous or incomplete answers , and valid responses will be retained for data analysis.

3.2 Target Population of 6,100 Engineering Lecturers in Malaysia

This research focuses on a specific group of participants which are the teaching lecturers of any engineering or engineering related courses or subjects, with academic level from diploma level and above, such as degree and master courses that requires student-teachers interaction, academic grading and evaluation. Insights from this group are crucial as, brings to the table a wealth of experience in monitoring, guiding, understanding Malaysia education requirement, student's behaviour, performance and the employment market requirement to mentor talents that could drive innovation in Malaysia technology.

3.3 Sampling Frame

The sampling frame for this study will encompass 30 Malaysia's Higher Education Institutes with engineering schools across states, focusing on same count of selected public and private science or research institutes which is Malaysian Qualifications Register (MQA) approved to ensure quality and credibility of education system being delivered such as Universiti Kebangsaan Malaysia (UKM), Sunway University , Universiti Sains Malaysia (USM), Universiti Tunku Abdul Rahman (UTAR) and more as shown in Appendix 1. The contact details of the teaching lecturers or professors is openly available through respective institute's online website directory and at least 20 teaching lecturers from each institute, 2 to 5 from each engineering program based on are invited to participate. The survey results will then trimmed down to the required sample size (USMC, 2025 & UPM, 2025).

To ensure inclusive representation across various engineering applications, the sampling frame will categorize Higher Education Institutions (HEIs) based on factors such as engineering programs that incorporate SBL and lecturers who use SBL in their teaching. Within the questionnaire, filtering questions will be included as mandatory to determine which engineering programs the respondents teach and whether they have implemented SBL. This approach ensures a diverse range of experiences and perspectives on student learning outcomes, gathered from lecturers and professors who have integrated SBL across different engineering disciplines in Malaysia.

By employing a stratified sampling approach, this study aims to capture insights from a broad spectrum of Malaysian HEIs, thereby reflecting the value and effectiveness of SBL in engineering education.

3.4 Sample Size

This research targets teaching lecturers involved in engineering or engineering-related courses as categorized in Table 3.2, regardless of their nationality, gender, ethnicity, income, or age. According to the Department of Statistics Malaysia (DOSM, 2023), the total number of academic staff in Malaysia was 31,631. However, no specific breakdown is available for engineering-related faculty members. Based on the available data in Appendix 1, the researcher estimates a ballpark figure of 6,100 engineering academic staff in Malaysia. (DOSM, 2025)

To determine the appropriate sample size for this study is determined using Krejcie and Morgan’s (1970) sample size determination table, which provides pre-calculated values based on different population sizes at a 95% confidence level and a 5% margin of error, common criteria for behavioral research. For a population of 6,100, the table recommends a sample size of 362 respondents. Therefore, this study will use a sample size of 362 participants, ensuring statistical reliability in analyzing the relationship between SBL variables and learning outcomes .

3.5 Sampling Technique

Non-probability sampling technique, such as quota and stratified systematic sampling, will be utilized in this study to ensure a representative selection of the participants from the different engineering disciplines and institutions implementing SBL. Total of 15 private and 15 public universities and colleagues is selected and population are divided into homogeneous subgroups based on key characteristics on type of engineering program, type of SBL tools used and it's engineering applications. Systematic sampling will be employed within each subgroup to ensure unbiased selection process while maintaining proportional representation.

In addition, stratified systematic sampling reduces sampling error by ensuring each subgroup is adequately represented (Creswell & Creswell, 2018) at the same time enhance efficiency by selecting participants at regular intervals from a list for a structured and evenly distributed sample across the targeted institutions. With this approach, this study aims to capture diverse perspectives on how SBL affects student learning outcomes within Kolb's Experiential Learning Framework, particularly in fostering Reflective Observation as mediators in learning outcome.

Table 3.1 highlights sample respondents selected grouped into categories.

Code	Engineering programs
EE	Electronics & Electrical Engineering
ME	Mechanical Engineering
CS	Civil & Structural Engineering
BE	Biomedical Engineering
MC	Mechatronics Engineering
IE	Industrial Engineering
CE	Chemical Engineering

Any programmers which are an extension or a branch variation of above categories will be sorted into the categories that share the highest relevancy to simplify data analysis.

3.6 Data Collection Method

The instrument for this study will be close-ended questions to explore the teaching lecturer's view on the implementation of SBL in influencing student's learning outcome of the engineering course by factoring the relationship between the IVs and the Mediator.

The questions will be designed with pre-set options available for selection, either single responds from a drop-down menu or multiple selections for Section A. The rest of the questionnaire will be designed with 5 points scale [1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree] to gauge to extend of agree to disagree on each statement.

E-questionnaire will be created using Microsoft Forms online with responds being gathered through the platform that provides a live results and the data set can be exported into excel for further analysis using Statistical Package for Social Sciences (SPSS). A short survey link could be generated by Microsoft Forms and further distributed through email or WhatsApp. Respondent could contact the researcher by replying the email if they required clarification. Follow-up communications will be managed, and responses will be monitored and tracked in real-time. The researcher will obtain the email database or phone number from fore-mentioned databases .

Ethical approval will be acquire from the studied university with a personal data protection statement attached to the questionnaire to protect the personal biography information of the respondents. All data given by the respondents will be treated as private and confidential , and used for academic purpose only. Compulsory written consent is to be acquired from all respondents to ensure respondents sought to ensure all respondents that the participation is a voluntary process prior answering the survey and their right to withdraw from the survey at will. The significance of the study will be highlighted to encourage participation. Approximately four working weeks are estimated to be required to collect responses.

3.6.1 Development of Questionnaires

The respondents will be asked questions pertaining to their knowledge , observation and experience in relate to the context of how SBL affect the learning outcome of their students throughout the programme. A filtering question will be included in Section A to assess the respondent’s eligibility on their involvement in implementing SBL in their academic program. This section also gather information on the respondent’s demographics and teaching background.

Table 3.2 shows questionnaire divided into four sections

Section	Information	
A	DemoFigureic & Teaching Background	
B	Measuring Items related to the independent variable (IV)	IV 1: SBL Practice IV 2 : Extend of SBL Implementation IV 3 : Capabilities of SBL
C	Measuring Items related to the Mediator	M : Reflective Observation
D	Measuring Items related to the dependent variable (DV)	DV : Student Learning Outcome

Table 3.3 shows the questions constructed for the questionnaire

Section	Questions	
A	1. Gender 2. Age 3. Education Level 4. Institute of Higher Education 5. Type of Institute that you’re currently teaching 6. Institute of Higher Education that you are currently teaching 7. Engineering Program(s) taught? 8. Which Engineering Program(s) implemented SBL ? * 9. Which SBL Tools are used in your teaching? 10. Which SBL Solvers / Application do you use?	
B	SP: SBL Practice (Tan et al. , 2009 ; Magana, 2017 & Feijoo-Garcia et al., 2024)	1. Students’ performance will improve when SBL integrated with traditional lab methods 2. Students able to make useful associations between course works and projects during SBL activities 3. Students able to use SBL Tools to solve engineering problems 4. Student able to make informed decisions when solving engineering design challenges through SBL

	EI: Extend of SBL Implementation (Panungkas et al. 2019 ; Singh-Pillay,2024 & Tan et al. , 2009)	1. SBL is consistently implemented across relevant engineering programs 2. There is sufficient institutional support for the implementation of SBL in relevant engineering programs 3. SBL is integrated across multiple subjects throughout the relevant engineering programs 4. There are adequate training for teaching lecturers to effectively integrate SBL into their lessons. 5. The institute curriculum is aligned with industry-relevant SBL practices and SBL tools
	CS: Capabilities of SBL (Dr Bouchrika, 2025)	1. User friendly interface of Simulation Tool enhances student's learning experience 2. Customization features of Simulation Tool for different engineering application improves student's learning outcome 3. Scalability of the Simulation Tool positively impacts students' ability to solve engineering problems of their giving tasks 4. Integration of multi physics solvers enhances student's understanding of interdisciplinary engineering scenarios 5. Availability of quality accessible of learning materials improve student engagement with SBL 6. Affordability of licensing models influence the adoption and effectiveness of SBL in engineering education
C	RO: Reflective Observation (Fang et al. , 2010)	1. SBL enhance student's familiarity with assignments, improving learning process. 2. SBL increase student's engagement in instructor-led discussions 3. SBL encourage students to develop independent problem-solving skills 4. SBL improves student's efficiency in completing tasks and assignments 5. SBL improve students understanding through the

		course.
D	SLO: Student Learning Outcome (Taher & Khan, 2015 & Panungkas et al. 2019)	1. SBL practice in engineering programme improves overall student's learning outcome 2. More in-depth, structured implementation of SBL throughout relevant engineering programs will enhance student's learning outcome 3. Capabilities of the simulation tools directly influence student learning outcome 4. SBL foster reflective observation, allowing students to critically apply knowledge, leading to improved academic performance.

3.7 Pre-Testing & Pilot Test

This study conducted a pre-test by administering the questionnaire to teaching lecturers randomly selected from various engineering programs at Universiti Tunku Abdul Rahman (UTAR). Preference was given to engineering lecturers holding key academic positions, such as heads of programs or deans, from the Faculty of Engineering and Green Technology (which offers Electrical Engineering and Industrial Engineering programs) and the Lee Kong Chian Faculty of Engineering and Science (which offers Civil Engineering, Computer Science, Electrical Engineering, and Mechanical Engineering programs). These experts were selected due to their crucial roles in curriculum development and their alignment with industry and Ministry of Education (MOE) requirements, ensuring that engineering graduates meet workforce demands.

Their insights contributed to refining and enhancing the questionnaire's relevance. Additionally, since the pre-test respondents were from the same institution as the research study, their familiarity with the context fostered trust and openness in providing constructive feedback. Two experts were selected from each faculty, and feedback was also received from an Associate Professor with an Industrial Engineering background. The professor highlighted a flaw in Question Seven regarding the drop-down options for universities, which was a technical limitation of Microsoft Forms. Consequently, necessary improvements and edits were made to address this issue.

Following the pre-test, a pilot test was conducted with 40 respondents to evaluate the reliability of the questionnaire. According to Isaac and Michael (1995) and Hill (1998), a pilot sample size between 30 and 50 is generally recommended for reliability testing in behavioral research. Cronbach's Alpha scores for all variables exceeded the 0.6 threshold according to Table 3.4, confirming the internal consistency and reliability of the instrument , no items removed upon pilot test analysis.

Table 3.4 shows Pilot Test reliability statistics of the IVs , Mediator and DV

Variable's name	No. Of Items	Cronbach's Alpha Score
IV1 : SBL Practice	4	.749
IV2 : Extend of SBL Implementation	5	.815
IV3 : Capabilities of SBL Tools	6	.749
IV4 : Mediator Factor : Reflective Observation	5	.906
DV : Student Learning Outcome	4	.875

3.8 Field Work of Main Survey

Upon finalizing the research questionaire based on the feedback improvement from both pre-test and pilot study participants, ethical clearance will be applied by academic supervisor and the data collection will commence once ethical approval was obtained.

E- questionaire will be distributed during the break of the first trimester, to optimize response rates and prevent respondents from being overwhelmed by numerous emails, three rounds of follow-up will be scheduled, one week apart, targeting those who have not yet responded. Here is the link to the E-Questionaire https://forms.office.com/r/p66sA8NRHi , and a visual copy included in Appendix 4.

The distribution of e-questionnaires will be halted once required count of completed questionnaire are collected.

3.9 Data Analysis Tool

As this study utilized quantitative method to study the relationship between independent (IV), the mediator (M) and dependent variables (DV) , statistical tool Statistical Package for the Social Sciences (SPSS) version 29 will be use to acquire in-depth analysis of the data sets.

Descriptive statistics will be used to examine the data demographic and teaching background. Statistical methods is a suitable method to analyse statistical raw data to evaluate the reliability of the findings (Alenzi, 2019). Reliability or internal consistency of the questionnaire items such as the IV , DV and the mediator will be evaluated using Cronbach's Alpha coefficient. A value more than .70, indicates satisfactory internal consistency (Heale & Twycross, 2015; Martini et al., 2015) This suggests that the questionnaire instrument was suitable for collecting data to assess the impact of SBL on student's learning outcome with Reflective Observation as mediator.

Quantile-Quantile (Q-Q) plot is utilized to assess whether the variables follows the normal distribution. The Q-Q plot visually compares the sample quantiles of the variable against the theoretical quantiles of a normal distribution. If the data points align closely along a straight line, it indicates that the variable is normally distributed. Conversely, deviations from this line suggest departures from normality.

All hyphotheses will be tested using multiple linear regression model with R-Square and R-value column value to measure the contextual effects of the IVs and the DV. This analysis significantly influenced the student's learning outcome by controlling each IVs' effects. According to Cohen, West, and Aiken (2014), the R-value used to test the model's fit for the collected data, while the R-square value determines the extent to which variations in the DV can be explained by variations in the IVs. The model is considered acceptable if the R-value exceeds 0.70. Additionally, model coefficients, including p-values, are utilized for further analysis. The p-value is used to test the statistical significance of these associations, confirming or rejecting the hypotheses. If the p-value is less than 0.05, the hypothesis is confirmed; otherwise, if it exceeds 0.05, the hypothesis is rejected (Cohen et al., 2014).

Multicollinearity will be accessed using Variance Inflation Factor (VIF), ensuring the reliability of each variable. The Analysis of Variance (ANOVA) test is used to determine whether there are statistically significant differences between the means of different groups. In the context of this study, ANOVA helps assess the impact of the independent variables ; IV1 : SBL Practice (SP) , IV2 : Extent of SBL Implementation (EI), IV3: Capabilities of Simulation Tools (CS). Besides, ANOVA also examines whether these IVs have significant effects on student learning outcomes (DV) and whether the differences in learning outcomes across different levels of these IVs are statistically significant. ANOVA also assess whether the Mediator; Reflective Observation (RO) influences the relationship between IVs and DV, by comparing variations in student learning outcomes with and without the mediator.

The hypotheses (H1 , H2 and H3) will be tested using ANOVA, to related to the study, by identifying Null Hypothesis where there is no significant difference in student learning outcomes across different levels of SBL practice, SBL implementation, and simulation tool capabilities. On the other hand, with Alternative Hypothesis, means at least one of the IVs significantly influences student learning outcomes. If the ANOVA test yields a p-value < 0.05, the null hypothesis is rejected, indicating that at least one IV has a statistically significant effect on student learning outcomes.

3.10 Chapter Summary

To summarize this chapter, the research methodology used to examine the impact of Simulation-Based Learning (SBL) on student learning outcomes in Malaysian Higher Education Institutions (HEIs), with Reflective Observation as a mediating factor. A quantitative survey approach is employed, using a structured questionnaire distributed to engineering lecturers across 30 HEIs. The study follows a cross-sectional design with stratified sampling to ensure diverse representation, targeting 362 respondents for statistical reliability. Data is collected via Microsoft Forms and analyzed using SPSS. A pre-test and pilot test confirm the reliability of the questionnaire, and ethical considerations, including data privacy and consent, are strictly followed throughout the research process.

CHAPTER IV

RESULTS AND DISCUSSION

4.0 Introduction

This chapter shows the survey data analysis findings and results of the study on the impact of SBL on student learning outcomes in engineering education at Malaysian HEI. It begins with descriptive statistics to outline the demographic stratification, followed by inferential analysis to support hypothesis testing.

4.1 Descriptive Results: Respondents' Demographic Profiles

The proportion of female respondents is slightly higher than the male respondents at 58.6% against 41.4% as shown in Table 4.1 could be due to gender disparity in the Higher Education Institutions (HEI) in Malaysia with studies suggested that females values academic education more compare to males (Ahmad , 2009). Most educators that responded are aged 35 and above with age range 40 to 45 the highest responds at 39.8%.

In addition, the proportion of Doctor of Philosophy and higher qualifications is significantly higher than than Master Degree by 93.6% against 6.4% in Table 4.1 in teaching academics although Master Degree served as minimal requirement in most higher learning institute teaching profession. But as higher ranking universities in Malaysia is majority research basis, a Doctorate Degree or higher would bring higher value in teaching specialized subjects (Dzulkefli, 2022).

The respondents from both Private and public institute are almost fairly distributed, private at 48.9% to Public 51.1% due to targeted stratified sampling method according quota set for this study , deviation would due to unavailability of stratified engineering course within the selected institute, which could be due to lack of enrollment demand , available of educators talent and financial restriction to build up the program.

Table 4.1 : Descriptive Statistical Results

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Gender					
• Female		212	58.6	58.6	58.6
• Male		150	41.4	41.4	100.0
	Total	362	100.0	100.0	
Age					
• 25 - 30		1	0.3	0.3	0.3
• 31 - 35		14	3.9	3.9	4.1
• 36 - 40		93	25.7	25.7	29.8
• 41 - 45		144	39.8	39.8	69.6
• 46 - 50		84	23.2	23.2	92.8
• 50 and above		26	7.3	7.3	100.0
	Total	362	100.0	100.0	
Education Level					
• Master Degree Holder		23	6.4	6.4	6.4
• Doctor of Philosophy and above		339	93.6	93.6	100.0

	Total	362	100.0	100.0	
Type of Institute					
• Private		177	48.9	48.9	48.9
• Public		185	51.1	51.1	100.0
	Total		100.0	100.0	
HEI that you are currently teaching (Private)					
• i-CATS UC					
• INTI		12	3.3	6.7	6.7
• LUC		11	3.0	6.1	12.8
• QIU		11	3.0	6.1	19.0
• SU		12	3.3	6.7	25.7
• SunUni		6	1.7	3.4	29.1
• Taylor's		14	3.9	7.8	36.9
• TARUMT		12	3.3	6.7	43.6
• UCSI		13	3.6	7.3	50.8
• UC TATI		12	3.3	6.7	57.5
• UOSM		12	3.3	6.7	64.2
• UNITEN		10	2.8	5.6	69.8
• UTP		12	3.3	6.7	76.5
• UTAR		14	3.9	7.8	84.4
• UOW		16	4.4	8.9	93.33
		12	3.3	6.7	100.0
	Total	179	49.4	100.0	
Institute of Higher Education that you are currently teaching (Private)					
• UKM		14	3.9	7.7	7.7
• UM		14	3.9	7.7	15.3
• UMK		11	3.0	6.0	21.3
• UMP		14	3.9	7.7	29.0
• UniMAP		14	3.9	7.7	36.6
• UPSI		10	2.8	5.5	42.1
• UPNM		10	2.8	5.5	47.5
• UPM		13	3.6	7.1	54.6
• USIM		6	1.7	3.3	57.9
• USM		14	3.9	7.7	65.6
• UniSZA		11	3.0	6.0	71.6
• UTeM		12	3.3	6.6	78.1
• UTM		14	3.9	7.7	85.8
• UiTM		12	3.3	6.6	92.3
• UTHM		14	3.9	7.7	100.00
	Total	183	50.6	100.0	

Figure 4.0 to 4.3 present the statistical distribution of engineering programs, SBL adoption, tool preferences, and solver applications among lecturers in Malaysian HEIs, based on SPSS frequency percentages. Figure 4.0 shows that the majority of respondents teach Mechanical Engineering (26%), Electrical and Electronics (21%), and Mechatronics programs (22%). This could be attributed to the long-standing technological frameworks of these fields, which serve as the foundation for advancing engineering education. Civil & Structural, Chemical, and Biomedical Engineering follow, though with smaller representation. Additionally, some lecturers may be teaching multiple interrelated subjects, reflecting the interdisciplinary nature of these fields.

Figure 4.0 shows Statistic Distribution of Engineering Programs Taught by Lecturers in HEI.

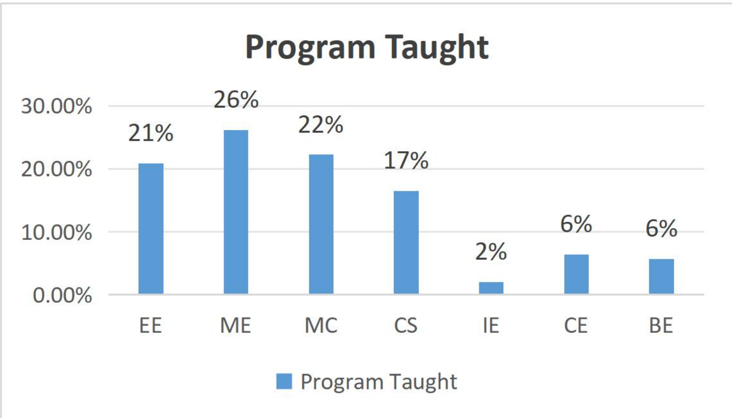


Figure 4.1 reveals that SBL is predominantly implemented in Mechanical Engineering (30%), followed closely by Electrical and Electronics (26%) and Mechatronics (16%). Civil Engineering (15%) and other programs like

Biomedical, Chemical, and Industrial Engineering show lower SBL adoption. This disparity could stem from the perceived necessity of SBL in disciplines requiring complex simulations, expensive lab equipment, or the visualization of phenomena not easily observable with the naked eye.

Figure 4.1 shows Statistic Distribution of Engineering Programs Implemented SBL

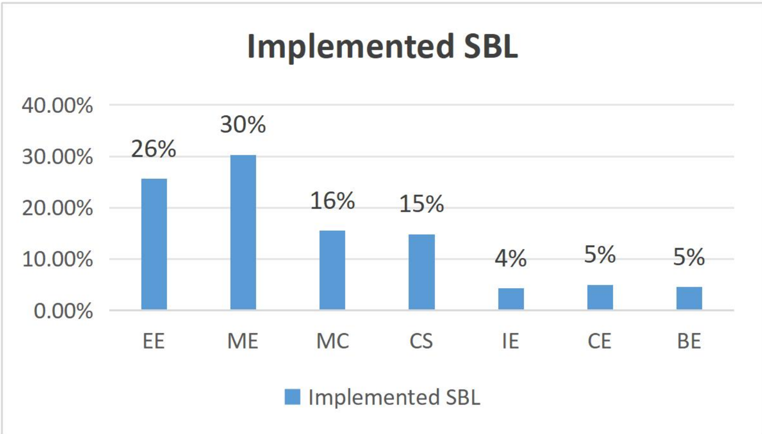


Figure 4.2 indicates that ANSYS is the most frequently used SBL tool (26%), closely followed by SolidWorks (25%) and Autodesk (18%), with other tools comprising the remaining 14%. Interestingly, some educators use multiple tools to leverage their unique capabilities, enhancing the learning experience by providing diverse simulation outcomes.

Figure 4.2 shows Statistic Distribution of SBL Tools used in throughout the Engineering Programs

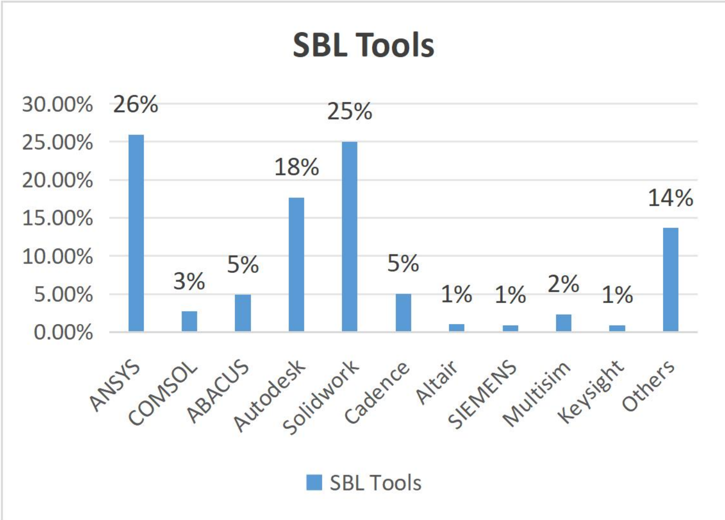
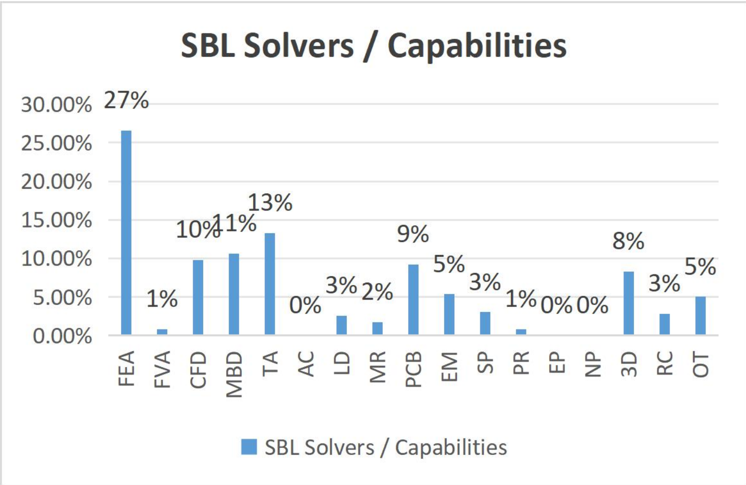


Figure 4.3 highlights the primary applications of SBL tools, with Finite Element Analysis (FEA) leading at 27%, followed by Thermal Analysis (13%), Multibody Dynamics (11%), and Computational Fluid Dynamics (CFD) (10%). Applications like PCB Circuit Design and 3D Design/Modeling are moderately represented, often overlapping with Mechanical and Electronics Engineering. Notably, the use of SBL for Signal and Power Integrity and Electromagnetic Simulation is relatively low, despite the high proportion of respondents teaching Electrical and Electronics subjects. This may indicate either a lack of awareness or limited access to tools capable of handling these specialized simulations.

Figure 4.3 shows Statistic Distribution of SBL Solvers or Capabilities used in throughout the Engineering Programs



Overall, the data highlights a growing trend in the adoption of SBL, particularly in programs where complex simulations and virtual experimentation provide significant educational value. However, gaps remain in broader implementation across other engineering disciplines.

4.2 Inferential Statistical Results

The collected data was confirmed reliable through a reliability test, achieving Cronbach's Alpha scores for all variables that exceeded the 0.6 threshold (Ursachi et al., 2015, as shown in Table 4.2, indicating acceptable internal consistency.

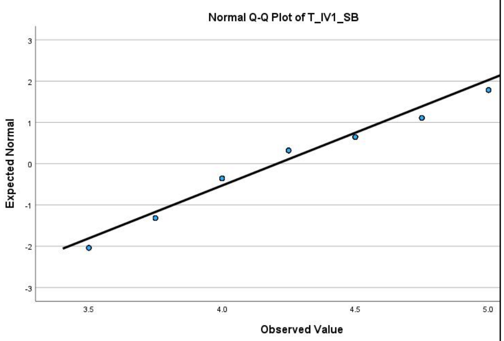
Table 4.2 shows Reliability Test Results of Studies Variable in the Survey

Variable's name	No. Of Items	Cronbach's Alpha Score
IV1 : SBL Practice	4	.772
IV2 : Extend of SBL Implementation	5	.861
IV3 : Capabilities of SBL Tools	6	.746
IV4 : Mediator Factor : Reflective Observation	5	.929
DV : Student Learning Outcome	4	.843

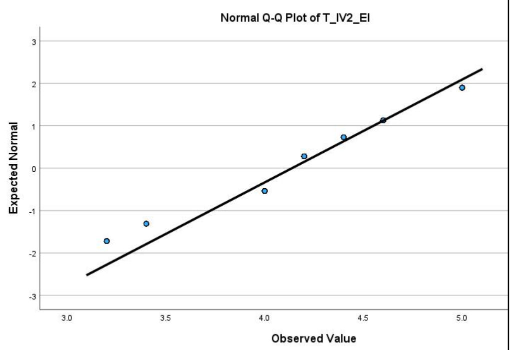
To ensure that assumptions of normality were not violated, Q-Q plots were generated for each studied variable. As shown in Figure 4.3, the data points align closely with the reference line, indicating that the assumption of linearity in respondents' ratings holds true across all variables.

Table 4.3 shows The studied variables' Q - Q Plot

IV1 : SBL Practice

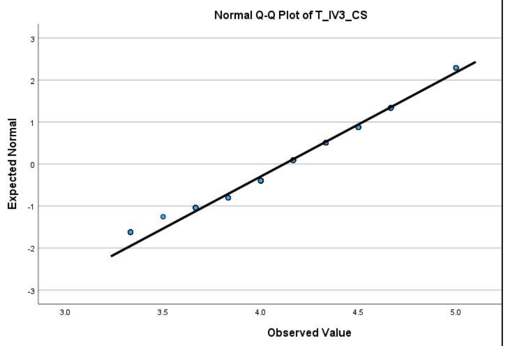


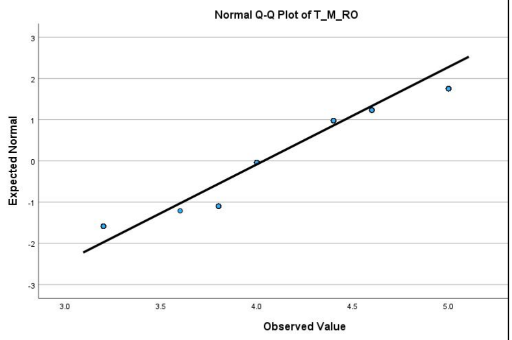
IV 2: Extend of Implementation



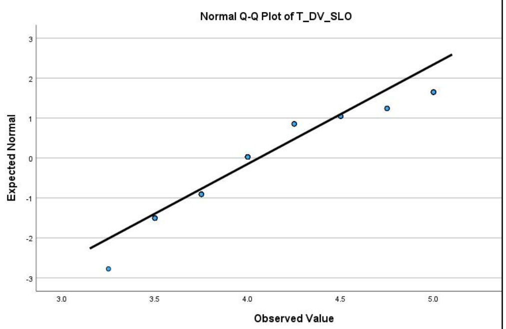
IV3 : Capabilities of SBL Tools

M : Reflective Observation





DV : Student Learning Outcome



Examining the bivariate correlation between independent and dependent variables allowed for the assessment of relationship strength over time ; whether strong, moderate, or weak. The correlation coefficient value between each IV and DV should be above 0.6 to demonstrate acceptable correlation. While IV2 and IV3 showed high correlation with the dependent variable, the Mediator (M) demonstrated moderate correlation, and IV1 showed weak correlation in, as detailed in Table 4.4.

Table 4.4 shows Co-relations Results

Correlations

		IV1_SP	IV2_EI	IV3_CS	M_RO	DV_SLO
IV1_SP	Pearson Correlation	1	.678**	.625**	.637**	.354**
	Sig. (2-tailed)		<.001	<.001	<.001	<.001
	N	362	362	362	362	362
IV2_EI	Pearson Correlation	.678**	1	.924**	.785**	.738**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001
	N	362	362	362	362	362
IV3_CS	Pearson Correlation	.625**	.924**	1	.633**	.618**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001
	N	362	362	362	362	362
M_RO	Pearson Correlation	.637**	.785**	.633**	1	.758**
	Sig. (2-tailed)	<.001	<.001	<.001		<.001
	N	362	362	362	362	362
DV_SLO	Pearson Correlation	.354**	.738**	.618**	.758**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	
	N	362	362	362	362	362

**. Correlation is significant at the 0.01 level (2-tailed).

A multiple linear regression analysis was conducted, accompanied by preliminary statistical tests to validate the hypotheses. Table 4.5 shows that IV1 and IV3 negatively affect students' learning outcomes, while IV3 shows high collinearity. This could be due to high multicollinearity causing IV3 appear redundant, difficult to detect unique contribution.

Table 4.5 Shows Excluded Variables from Regression Model

Excluded Variables[a]								
						Collinearity Statistics		
Model		Beta In	t	Sig.	Partial Correlation	Tolerance	VIF	Minimum Tolerance
1	T_IV1_SP	-.272[b]	-5.882	<.001	-.296	.540	1.853	.540
	T_IV3_EI	-.429[b]	-4.766	<.001	-.244	.147	6.803	.147
2	T_IV3_CS	-.433[c]	-5.045	<.001	-.258	.147	6.803	.130
a. Dependent Variable: T_DV_SLO								
b. Predictors in the Model: (Constant), T_IV2_EI								
c. Predictors in the Model: (Constant), T_IV2_EI, T_IV1_SP								

Table 4.6 shows that Model 3, which includes IV1, IV2, and IV3, explains the highest proportion of variance in students' learning outcomes, with an R Square of .782 and Adjusted R Square of .612. However, the marginal increase in Adjusted R Square compared to Model 2, coupled with the high collinearity observed for IV3, suggests that the additional complexity may not significantly enhance the model's predictive power. Therefore, while Model 3 is statistically significant (Sig. = 0.000), Model 2 may offer a more interpretable fit.

Table 4.6 shows Regression Summary Result

Model Summary[d]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.738[a]	.545	.543	.27148
2	.765[b]	.585	.582	.25963
3	.782[c]	.612	.609	.25122
a. Predictors: (Constant), T_IV2_EI				
b. Predictors: (Constant), T_IV2_EI, T_IV1_SP				
c. Predictors: (Constant), T_IV2_EI, T_IV1_SP, T_IV3_CS				
d. Dependent Variable: T_DV_SLO				

Table 4.7 shows ANOVA Result

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	31.724	1	31.724	430.447	<.001[b]
	Residual	26.532	360	.074		
	Total	58.256	361			
2	Regression	34.056	2	17.028	252.605	<.001[c]
	Residual	24.200	359	.067		
	Total	58.256	361			
3	Regression	35.662	3	11.887	188.357	<.001[d]
	Residual	22.594	358	.063		
	Total	58.256	361			

a. Dependent Variable: T_DV_SLO
b. Predictors: (Constant), T_IV2_EI
c. Predictors: (Constant), T_IV2_EI, T_IV1_SP
d. Predictors: (Constant), T_IV2_EI, T_IV1_SP, T_IV3_CS

The ANOVA results in Table 4.7 show that all three models significantly predict students' learning outcomes (p < .001). Table 4.8 further reveals that IV2 has the strongest positive impact on students' learning outcomes, with a highly significant t-value and large Beta coefficient. IV1 and IV3 also have statistically significant relationships with the DV, but their effects are negative. Additionally, the high VIF values for IV3 and IV2 suggest the presence of multicollinearity, which may affect the stability of the estimates.

Table 4.8 shows Coefficients

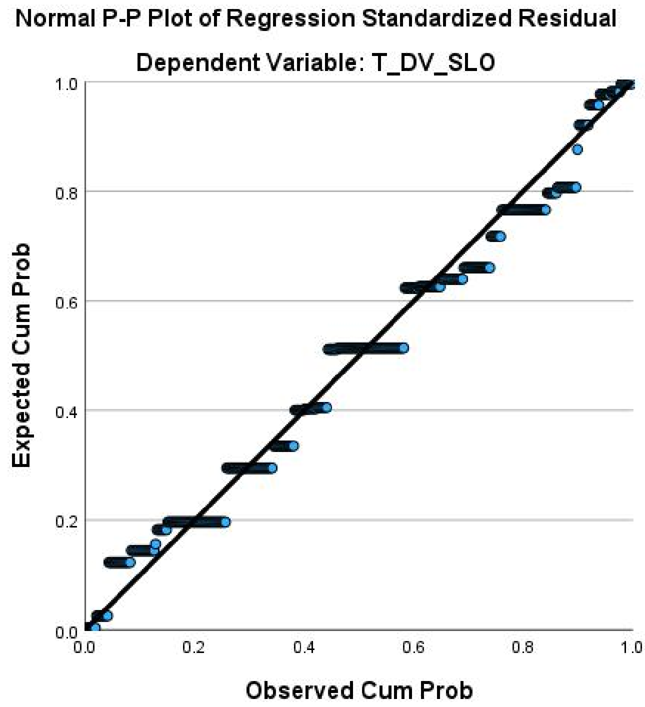
Coefficients[a]								
		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	1.085	.144		7.531	<.001		
	T_IV2_EI	.719	.035	.738	20.747	<.001	1.000	1.000
2	(Constant)	1.517	.156		9.716	<.001		
	T_IV2_EI	.899	.045	.923	19.928	<.001	.540	1.853
	T_IV1_SP	-.280	.048	-.272	-5.882	<.001	.540	1.853
3	(Constant)	1.684	.155		10.888	<.001		
	T_IV2_EI	1.289	.089	1.324	14.506	<.001	.130	7.687
	T_IV1_SP	-.281	.046	-.274	-6.114	<.001	.540	1.853
	T_IV3_CS	-.431	.085	-.433	-5.045	<.001	.147	6.803

a. Dependent Variable: T_DV_SLO

In Model 3, all predictors showed statistical significance. IV2 positively influenced students' learning outcomes, while IV1 and IV3 had negative impacts. Notably, IV2 exerted the strongest positive influence, as reflected by its highest unstandardized coefficient (1.289) and standardized Beta value (1.324).

Finally, the P-P Plot of Regression (Figure 4.2) shows the points which are closely following the reference line, indicating the residuals reasonably meet the normality assumption. This supports the validity of the regression model and its suitability for predicting students' learning outcomes.

Figure 4.4 shows the P - P Plot of Regression



4.3 Mediator Effect on Variables

Analysis direct and Indirect effect of independent variables mediated by mediator in influencing dependent variable Student Learning Outcome with PROCESS Model 4 . The confidence level for all confidence intervals is set at 95%, with 5,000 bootstrap samples use to compute percentile bootstrap confidence intervals.

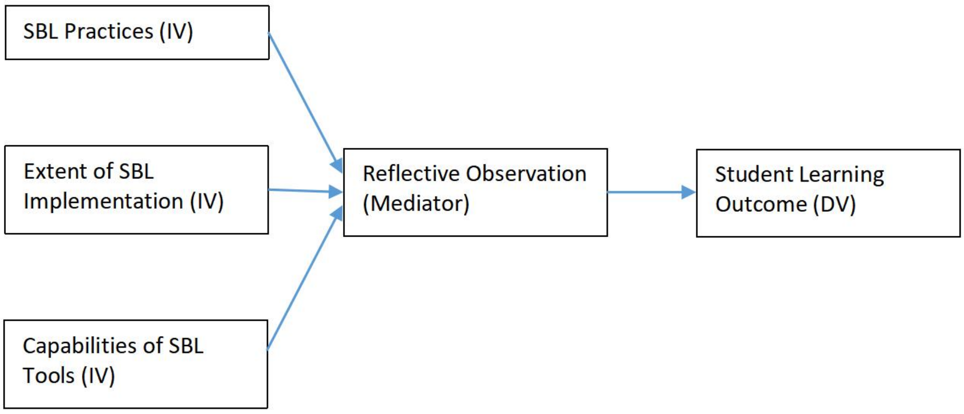


Figure 4.5 shows Conceptual Model

Table 4.9 shows Mediation Analysis using PROCESS on SP > M > SLO

Outcome Variable :M						
Model Summary						
R	R-sq	MSE	F	df1	df2	p
.6372	.4060	.1068	246.0886	1.0000	360.0000	.0000
Model						
	coeff	se	t	p	LLCI	ULCI
constant	1.1322	.1859	6.0919	.0000	.7667	1.4977
Variable SP	.6900	.0440	15.6872	.0000	.6035	.7765

Outcome Variable : SLO						
Model Summary						
R	R-sq	MSE	F	df1	df2	p
.7759	.6021	.0646	271.6012	2.0000	359.0000	.0000
Model						
	coeff	se	t	p	LLCI	ULCI
constant	1.5693	.1518	10.3406	.0000	1.2709	1.8678
Variable SP (SP > SLO)	-.2233	.0444	-5.0324	.0000	-.3106	-.1360
Variable M (M > SLO)	.8500	.0410	20.7453	.0000	.7695	.9306
Direct and Indirect Effects of SP on SLO						
Direct Effect (SP > SLO)						
Effect	se	t	p	LLCI	ULCI	
-.2233	.0444	-5.0324	.0000	-.3106	-.1360	
Indirect Effect (M > SLO)						
	Effect	BootSE	BootLLCI	Boot ULCI		
Variable M	.5866	.0563	.4819	.7012		

Table 4.9 presents the findings on Simulation-Based Learning (SBL) practices across various engineering disciplines and their impact on student learning outcomes (SLO). The results indicate that while the direct effect of SBL Practice (SP) on SLO is negative and significant (-0.2233, $p < .001$), the indirect effect through Reflective Observation (M) is positive and significant (Effect = 0.5866, BootCI = [0.4819, 0.7012]). This suggests that SBL practice alone may not lead to improved learning outcomes unless it facilitates Reflective Observation, which enhances learning effectiveness.

Table 4.10 : Mediation Analysis using PROCESS on EI > M > SLO

Outcome Variable :M						
Model Summary						
R	R-sq	MSE	F	df1	df2	p
.7845	.6155	.0692	576.2357	1.0000	360.0000	.0000
Model						
	coeff	se	t	p	LLCI	ULCI
constant	.7011	.1396	5.0226	.0000	.4266	.9756
Variable EI	.8056	.0336	24.0049	.0000	.7396	.8716
Outcome Variable : SLO						
Model Summary						
R	R-sq	MSE	F	df1	df2	p
.7922	.6276	.0604	302.5226	2.0000	359.0000	.0000
Model						
	coeff	se	t	p	LLCI	ULCI
constant	.7761	.1350	5.7501	.0000	.5107	1.0415
Variable SP (EI > SLO)	.3637	.0506	7.1881	.0000	.2642	.4632
Variable M (M > SLO)	.4408	.0493	8.9478	.0000	.3439	.5377

Direct and Indirect Effects of SP on SLO						
Direct Effect (EI > SLO)						
Effect	se	t	p	LLCI	ULCI	
.3637	.0506	7.1881	.0000	.2642	.4632	
Indirect Effect (M > SLO)						
	Effect	BootSE	BootLLCI	Boot ULCI		
Variable M	.3551	.0585	0.2452	.4741		

The analysis from Table 4.10 reveals that since both the direct effect (B = 0.3637, p < .001) and the indirect effect (0.3551, BootCI = [0.2452, 0.4741]) are significant, this indicates partial mediation. This means that while the extent of SBL implementation (EI) directly enhances student learning outcomes (SLO), Reflective Observation (M) also plays a crucial mediating role in further improving SLO

Table 4.11 shows Mediation Analysis using PROCESS on CS > M > SLO

Outcome Variable :M						
Model Summary						
R	R-sq	MSE	F	df1	df2	p
.6334	.4012	.1077	241.1579	1.0000	360.000	.0000
Model						
	coeff	se	t	p	LLCI	ULCI
constant	1.2957	.1773	7.3096	.0000	.9471	1.6443
Variable CS	.6649	.0428	15.5293	.0000	.5807	.7491

Outcome Variable :M						
Model Summary						
R	R-sq	MSE	F	df1	df2	p
.6334	.4012	.1077	241.1579	1.0000	360.000	.0000
Model						
	coeff	se	t	p	LLCI	ULCI
constant	1.2957	.1773	7.3096	.0000	.9471	1.6443
Variable CS	.6649	.0428	15.5293	.0000	.5807	.7491

Outcome Variable : SLO						
Model Summary						
R	R-sq	MSE	F	df1	df2	p
.7785	.6061	.0639	276.1732	2.0000	359.0000	.0000
Model						
	coeff	se	t	p	LLCI	ULCI
constant	.7716	.1463	5.2728	.0000	.4838	1.0594
Variable SP (CS > SLO)	.2304	.0426	5.4056	.0000	.1466	.3143
Variable M (M > SLO)	.5796	.0406	14.2757	.0000	.4998	.6595

Direct and Indirect Effects of SP on SLO						
Direct Effect (CS > SLO)						
Effect	se	t	p	LLCI	ULCI	
.2304	0.426	5.4056	.0000	.1466	.3143	
Indirect Effect (M > SLO)						
	Effect	BootSE	BootLLCI	Boot ULCI		
Variable M	.3854	.0476	.2958	.4823		

Lastly, Table 4.11 how that the capabilities of simulation tools (CS) used in SBL significantly influence student learning outcomes (SLO). Both the direct effect (B=0.2304,p<.001B = 0.2304, p < .001B=0.2304,p<.001) and the indirect effect (0.3854,0.3854,0.3854, BootCI = [0.2958, 0.4823]) are significant, this indicates partial mediation. This suggests that while more capable simulation tools (CS) directly enhance student learning outcomes (SLO), Reflective Observation (M) plays a crucial role in further strengthening this effect

In short, the results indicate that Reflective Observation (M) plays a key mediating role in the relationship between SBL factors and student learning outcomes (SLO). Overall, these findings highlight the importance of Reflective Observation in maximizing the benefits of SBL on student learning.

4.4 Summary of Confirmation of Current Hypotheses

As shown in Table 4.12, all hypotheses, are supported to varying degrees, indicating that SBL Practices (IV1), Extent of SBL Implementation (IV2) and Capabilities of SBL Tools (IV3) positively influence student learning outcomes through the mediating effect of Reflective Observation.

Table 4.12 : Confirmation of Current Hypotheses

Details of Hypotheses	**Remarks**
H1 : The practice of SBL across various engineering disciplines positively impacts Reflective Observation , leading to improved student learning outcomes in engineering programs.	Partial Supported
H2 : The extent of implementation of simulation-based learning (SBL) in higher education institutions positively impacts Reflective Observation, leading to improved student learning outcomes in engineering programs.	Fully Supported
H3 : The capabilities of simulation tools used in simulation-based learning (SBL) positively impacts Reflective Observation, leading to improved student learning outcomes in Malaysian higher education.	Fully Supported

H1 is partially supported because while SBL Practice (SP) has a significant indirect positive effect on SLO through M, its direct effect is negative, suggesting full mediation. H2 and H3 are fully supported, as both the extent of SBL implementation (EI) and the capabilities of simulation tools (CS) significantly improve SLO, both directly and through M, indicating partial mediation.

4.5 Chapter Summary

In conclusion, the findings confirm that Reflective Observation plays a crucial mediating role in transforming SBL practices, implementation, and tool capabilities into meaningful improvements in student learning outcomes. While the research model is fully supported for H2 and H3, the partial mediation observed in H1 suggests that the effectiveness of SBL practices is highly dependent on the presence of Reflective Observation. This reinforces the importance of structured reflection in enhancing simulation-based learning experiences in engineering education.

CHAPTER V

CONCLUSION AND IMPLICATIONS

5.0 Introduction

This chapter presents the overall conclusions derived from the study, highlighting the key findings and their implications for engineering education in Malaysian higher education institutions. The study aimed to examine the impact of Simulation-Based Learning (SBL) Practices, Extent of SBL Implementation, and Capabilities of SBL Tools on student learning outcomes, with Reflective Observation as a mediating factor. The findings confirm that while all three independent variables contribute to learning outcomes, their effectiveness is significantly enhanced when students engage in reflective observation.

The chapter also outlines major findings, discusses their theoretical and practical implications, and provides recommendations for educators and policymakers to optimize SBL in engineering education. Lastly, it suggests future research directions to further improve SBL effectiveness. By addressing these aspects, this chapter aims to provide a comprehensive understanding of the study's contributions, as well as actionable strategies for improving engineering education through simulation-based methodologies.

5.1 Summary of Major Findings

The findings of this study confirm that Reflective Observation plays a crucial mediating role in enhancing student learning outcomes. The independent variables and their corresponding hypotheses—SBL Practices (H1), Extent of SBL Implementation (H2), and Capabilities of SBL Tools (H3)—are supported to varying degrees, indicating that their influence on student learning outcomes primarily occurs through the mediation of Reflective Observation.

Hypothesis One (H1): The practice of SBL across engineering disciplines does not have a direct positive impact on student learning outcomes. Instead, Reflective Observation fully mediates this relationship. This suggests that while students engage in SBL activities, academic performance does not improve automatically. However, dedicated participation in SBL fosters skill acquisition and deeper understanding, which in turn can enhance learning outcomes over time.

Hypothesis Two (H2): Unlike H1 and H3, the extent of SBL implementation has both a direct and indirect positive impact on student learning outcomes. The results confirm that greater adoption of SBL across Higher Education Institutions (HEIs) improves learning outcomes, especially through Reflective Observation. This highlights the importance of institutional support, faculty engagement, and structured integration of SBL into curricula. Expanding SBL implementation across HEIs encourages more frequent and effective practice, leading to better learning experiences and improved academic performance.

Hypothesis Three (H3): Similarly, the capabilities of SBL tools do not directly improve student learning outcomes. The results indicate that Reflective Observation is necessary for students to effectively benefit from the tools. This implies that proper application, hands-on training, and relevant instructional support are essential for students to maximize the learning potential of simulation tools. Without active reflection and engagement, advanced simulation capabilities alone are not sufficient to enhance academic performance.

In conclusion, the study underscores the importance of Reflective Observation as a key mechanism in making SBL practices, tools, and implementation effective in improving student learning outcomes. Without it, the direct influence of SBL components remains limited, reinforcing the need for structured reflection and institutional backing to maximize the benefits of SBL in higher education.

5.2 Discussion of Major Findings

This study investigates the impact of Simulation-Based Learning (SBL) on student learning outcomes in Malaysian engineering education disciplines, guided by Kolb's Experiential Learning Theory (ELT). The findings confirm that Reflective Observation plays a crucial mediating role in improving learning outcomes, supporting Choi's (2014) study, which emphasizes the importance of reflection in validating Kolb's Experiential Learning Cycle. Reflection serves as a critical cognitive process, as described in Dewey's Model of Learning, where thinking and acting help resolve negative experiences, such as doubt, perplexity, and mental difficulty. The study aligns with ELT, reinforcing that without structured reflection, SBL remains incomplete. Prior research supports that SBL alone is insufficient unless students actively reflect on their experiences.

To further explore how the study's findings achieve the research objectives, the discussion is categorized as below.

5.2.1 Impact of SBL Practices on Learning Outcomes

The study fulfills Objective 1 by examining the effect of SBL practices on student learning outcomes. The results indicate that SBL practices positively influence Reflective Observation, which subsequently enhances student learning outcomes. However, SBL practices alone do not directly improve academic performance. Instead, repeated engagement with SBL, including experimentation and structured reflection, allows students to develop problem-solving skills, gain deeper insights into engineering concepts, and create innovative solutions. Kolb (1984) and Schön (1987) argue that without reflection, experiential learning remains superficial. This study reinforces that structured reflection must be integrated into SBL practices to maximize learning outcomes.

Supporting studies by Panungkas et al. (2019) and Taher and Khan (2015) highlight that improved student learning outcomes arise not solely from practicing SBL but from understanding and applying the concepts through structured learning processes. The findings indicate that student performance improves when SBL is integrated with traditional lab methods, enabling them to use SBL tools effectively for solving engineering problems. However, no evidence suggests that SBL alone enables students to make informed decisions in solving complex engineering design challenges without complementary learning methods.

Since the direct effect of SBL practice on learning outcomes is not significant, Hypothesis 1 is only partially supported. This suggests that merely integrating SBL into teaching does not guarantee better student performance. Several external factors, such as individual learning pace, familiarity with SBL tools, and the availability of sufficient practice may affect the effectiveness of SBL practices in enhancing academic outcomes. Nevertheless, when implemented effectively, SBL fosters deeper understanding, retention, and engagement, ultimately leading to improved academic performance (Kumar & Milanovic, 2022).

5.2.2 Extent of SBL Implementation Influences Reflective Observation and Learning Outcomes

The study fulfills Objective 2 by examining the impact of SBL implementation across different engineering disciplines. The results confirm that a higher extent of SBL implementation positively influences Reflective Observation and directly improves student learning outcomes. This suggests that successful SBL integration depends on structured teaching practices, self-learning opportunities, and resource availability rather than just access to sophisticated tools.

Panungkas et al. (2019) highlight challenges in SBL implementation, such as insufficient educational infrastructure and a lack of high-performance computing resources, which restrict SBL availability. Furthermore, a shortage of experienced educators and skills training limits Reflective Observation, ultimately affecting learning outcomes. Wang et al. (2020) and Boud et al. (2013) found that well-implemented SBL frameworks enhance student engagement and knowledge retention. Institutions that integrate SBL systematically, providing well-trained educators and accessible learning materials and help students become independent problem-solvers, leading to better academic performance.

The findings align with prior research indicating that institutional support is essential for effective SBL adoption. Singh-Pillay (2024) highlights that faculty training and adequate infrastructure are crucial for successful implementation. Moreover, research by Negahban (2024) and Labuschagne (2025) underscores the necessity of a structured framework to integrate SBL into curricula, enhancing student engagement, performance, and the overall learning experience.

5.2.3 Capabilities of SBL Tools and Learning Outcomes

The study fulfills Objective 3 by examining the role of simulation tool capabilities in student learning outcomes. Salas et al. (2009) and de Jong et al. (2013) argue that advanced simulation tools alone do not guarantee better learning outcomes; instead, they must be complemented by relevant applications and training.

Crha et al. (2021) emphasize that the relevance of SBL tool capabilities is crucial for solving intended problems. Verner et al. (2024) further highlight the effectiveness of combining multiple simulation tools to compensate for individual tool limitations, enhancing students' reflective observation. The study findings suggest that although SBL tool capabilities indirectly improve learning outcomes through Reflective Observation, their direct effect on student learning is negative. This suggests that highly advanced tools may cause cognitive overload if students lack adequate training and guidance, reducing their ability to engage effectively in the learning process.

Bouchrika (2025) argues that while advanced simulation tools contribute to a dynamic learning environment, their impact on student learning outcomes is not always significant. Without proper instructional support, students may struggle to operate these tools effectively, leading to frustration and diminished learning efficiency.

Since students derive greater learning benefits when they actively reflect on their simulation experiences, the presence of Reflective Observation as a mediator improves learning outcomes. The findings suggest that while high-tech tools enhance learning, their impact is maximized when paired with structured reflection and pedagogical strategies (Grieve, 2019; Tercete et al., 2017; Jamil & Isiaq, 2019).

Overall, the findings underscore the importance of Reflective Observation as a mediating factor in improving student learning outcomes. While SBL practices and tool capabilities alone may not directly enhance academic performance, their impact is significantly strengthened when paired with structured reflection. The extent of SBL implementation, on the other hand, has a direct and positive effect on learning outcomes, emphasizing the need for institutional support and structured educational strategies to maximize the benefits of SBL in engineering education.

5.3 Implications

5.3.1 Implications for Policymakers and HEIs

The findings highlight the importance of adopting standardized SBL practices across engineering disciplines to improve student learning outcomes. The inferential results indicate that the extent of SBL implementation (IV2) in terms of both its breadth and depth which significantly influences Student Learning Outcomes (SLO). However, its effectiveness is often constrained by organizational support, particularly in terms of resources and technical know-how. To address these challenges, government grants and infrastructure investments are crucial, especially for high-performance computing facilities and accessible simulation software licenses. Aligning educational policies with industry standards will also help graduates better meet the demands of Industry 4.0 by ensuring they develop practical skills in simulation-based methodologies.

For SBL to reach its full potential, continuous reskilling and upskilling of educators is essential. Educators need to adopt innovative teaching methods that integrate SBL effectively into their classrooms, keeping pace with technological advancements and producing industry-ready graduates. Beyond just using the tools, educators should be trained to leverage SBL in real-world engineering scenarios, moving beyond textbook-based instruction to foster problem-solving and critical thinking skills.

Policymakers should support HEIs in developing structured frameworks for integrating SBL into engineering curricula, ensuring that educators receive adequate training in simulation tool usage. Furthermore, fostering partnerships with industry players is key. Collaborative projects, work-based learning opportunities, extended internships, and industrial engagement would able to help to bridge the gap between academic theory with industry practice. These partnerships would not only help develop a more relevant curriculum but also ensure access to cutting-edge tools that mirror those used in the workplace, thereby enhancing graduate employability and ensuring students are equipped with the practical skills needed in the engineering sector.

In summary, policymakers and HEIs must work hand-in-hand to enhance SBL implementation through adequate funding, educator training, and industry collaboration. This will ensure a future-ready workforce that thrives in the evolving landscape of engineering and technology.

5.3.2 Implications for Literature

This research contributes to the growing body of knowledge surrounding experiential learning by providing empirical evidence that SBL practices and implementation extent positively impact Reflective Observation and student learning outcomes. The findings align with Kolb's Experiential Learning Theory, particularly highlighting the Reflective Observation phase as a crucial mediator in transforming SBL experiences into meaningful learning outcomes. However, the lack of a significant impact from simulation tool capabilities challenges the assumption that advanced tools alone enhance learning outcomes, suggesting that other factors such as instructional quality and student engagement may play a more substantial role.

5.3.3 Limitations

Despite presenting valuable insights, this study encounters several limitations that warrant consideration. Firstly, the focus on engineering education in Malaysia limits the generalizability of the findings to other disciplines and geographical contexts. Secondly, the study utilized a cross-sectional research design by capturing data at a single point in time. Thus prevents the observation of long-term impacts and the potential evolution of learning outcomes. Furthermore, the study relied on quantitative methods, which, while insightful, may not fully capture the nuances of students' experiences with simulation tools. Lastly, the study found that negative co-efficient of simulation tool capabilities and student learning outcomes, suggesting the need for further investigation.

In summary, future research should embrace broader contexts, adopt longitudinal designs, integrate qualitative methods, and delve deeper into the nuanced roles of simulation tool capabilities. Doing so would pave the way for more comprehensive insights and actionable recommendations to further enhance simulation-based learning in engineering education.

5.4 Recommendation for Future Studies

The findings highlight the need for standardized SBL practices across engineering disciplines to enhance student learning outcomes. The extent of SBL implementation significantly influences student performance, but its effectiveness depends on institutional support, including resource allocation and technical expertise. Future research should examine the impact of government policies, funding mechanisms, and industry-academic collaborations on SBL adoption. Additionally, studies should investigate how policy frameworks can better align educational strategies with Industry 4.0 demands, ensuring graduates develop relevant simulation-based competencies.

5.4.1 Expanding Research Across Disciplines and Contexts

This study focused on engineering education in Malaysia, limiting its generalizability. Future research should explore SBL implementation across diverse academic fields such as aerospace, biomedical, biosciences, petroleum engineering, geology, and defense-related disciplines. Conducting cross-disciplinary and cross-regional studies will provide deeper insights into discipline-specific challenges and benefits, allowing for more tailored SBL strategies. Comparative studies between developing and developed nations could further identify best practices and contextual constraints in implementing SBL effectively.

5.4.2 Longitudinal Studies to Assess Long-Term Impact

This research used a cross-sectional design, capturing data at a single point in time. To understand the long-term effects of SBL, future studies should adopt longitudinal research designs to track students over extended periods. Such studies would reveal how SBL influences knowledge retention, skill development, and career readiness. Additionally, comparative studies between SBL-integrated and non-SBL courses could provide stronger empirical evidence of its effectiveness in fostering higher-order thinking and problem-solving skills.

5.4.3 Integrating Qualitative Approaches for Deeper Insights

While this study relied on quantitative methods, future research should incorporate qualitative methodologies such as in-depth interviews, focus groups, and classroom observations. These approaches would provide richer insights into students' experiences, challenges, and perceptions of SBL. Understanding how students engage with SBL tools, their reflective practices, and the barriers they face will help refine instructional strategies. Future studies should also explore the emotional and cognitive aspects of learning through simulations, enhancing the human-centered approach to SBL implementation.

5.4.4 Addressing the Impact of Simulation Tool Complexity

This study found a negative coefficient between simulation tool capabilities and student learning outcomes, suggesting potential challenges such as cognitive overload or insufficient training. Future research should investigate how tool complexity, user proficiency, and accessibility influence learning outcomes. Studies should explore how user-friendly interfaces, adaptive learning technologies, and initial hand-holding sessions can enhance student engagement with SBL tools. Further research should also examine how the combination of multiple simulation tools can mitigate individual tool limitations and maximize learning effectiveness.

To summarize, in order to optimize the effectiveness of SBL, future research should focus on policy implications, expanding disciplinary scope, adopting longitudinal studies, integrating qualitative methodologies, investigating pedagogical factors, and addressing simulation tool complexities. Addressing these areas will provide a more comprehensive understanding of SBL's role in engineering education and beyond, leading to more effective implementation strategies that support student learning and professional readiness.

5.5 Conclusion

he findings of this study support Kolb's Experiential Learning Cycle, particularly through the research framework with Reflective Observation as a mediator, confirming the importance of Reflective Observation in bridging the gap between SBL experiences and student learning outcomes. The inferential analysis demonstrated that SBL Practices and the Extent of SBL Implementation positively influenced Reflective Observation, ultimately enhancing learning outcomes. However, the lack of impact from simulation tool capabilities indicates that merely providing advanced tools does not guarantee improved outcomes; rather, the way SBL is practiced and integrated into the curriculum holds greater significance.

Kolb's theory remains a suitable framework for understanding the learning process in SBL contexts, especially given the confirmed role of Reflective Observation. Nonetheless, the findings suggest that additional theoretical perspectives might be needed to capture the complexities surrounding technology adoption in education. Moving forward, institutions should focus on strengthening SBL practices and ensuring comprehensive implementation to maximize learning benefits. This research serves as a foundation for future exploration, advocating for broader adoption of SBL across engineering education to align with the skills demanded by Industry 4.0.

References

Ahmad, N. (2009). Gender differences and trends in the participation of Malaysians in education: Implications on employment outcomes. *ResearchGate*. https://www.researchgate.net/publication/265472046_Gender_Differences_and_Trends_in_the_Participation_of_Malaysians_in_Education_Implications_on_Employment_Outcomes

Al-Damook, A. (2021). *Comsol vs. Ansys Fluent: User perspectives*. ResearchGate. https://www.researchgate.net/post/Comsol_Vs_Ansys_Fluent

Alenzi, A. (2019). *A study on the effectiveness of interactive simulations in engineering education*. *International Journal of Information Technology & Education, 8*(3), 1-10. https://aircconline.com/ijite/V8N3/8319ijite01.pdf

Ameed, A. (2015). *Comparison of Comsol, Abaqus, and Ansys: Features and ease of use*. ResearchGate. https://www.researchgate.net/post/What_are_the_main_differences_between_comsol_abacus_and_ansys_Which_one_is_easiest_to_learn_and_work_with_it

Anis, A. M., Islam, R., & Abdullah, N. A. (2018). *Challenges faced by Malaysian private HLIs in providing quality education: A thematic analysis*. ResearchGate. https://www.researchgate.net/publication/325745109_Challenges_face d_by_Malaysian_private_HLIs_in_providing_quality_education_a_thematic_analysis

ANSYS How To. (2024). *ANSYS how-to tutorials*. YouTube. https://www.youtube.com/@AnsysHowTo

ANSYS. (2024a). *Engineering simulation software products*. https://www.ansys.com/products#t=ProductsTab&sort=relevancy&layout=card&numberOfResults=21

ANSYS. (2024b). *Orthopedic applications*. https://www.ansys.com/applications/orthopedic

ANSYS. (2024c). *Cardiovascular applications*. https://www.ansys.com/applications/cardiovascular

ANSYS. (2024d). *Students explore biomedical research with ANSYS CFD*. https://www.ansys.com/blog/students-explore-biomedical-research-with-ansys-cfd

ANSYS. (2024e). *Digital system prototyping for medical devices*. https://www.ansys.com/content/dam/product/platform/wp-digital-system-prototyping-medical-devices.pdf

Benchadlia, M., Sahli, W., & Othman, M. F. (2023). *Simulation-based learning in nursing education: A systematic review*. *The Open Nursing Journal, 17*, e187443462307030. https://opennursingjournal.com/VOLUME/17/ELOCATOR/e187443462307030/FULLTEXT/

Bouchrika, S. (2025). *Best computational modeling and simulation software*. Research.com. https://research.com/software/best-computational-modeling-and-simulation-software

Camperos, C., Pérez, R., & Mendoza, L. (2023). *Simulation-based learning for technical education: A case study*. *Journal of Public Policy and Workforce*, 8(4), 15780-10131. https://journalppw.com/index.php/jppw/article/download/15780/10131/19383

Campos, F., Martínez-Abad, F., & Olmos-Migueláñez, S. (2020). *Impact of simulation-based learning on educational outcomes in engineering studies*. *International Journal of Educational Technology in Higher Education, 17*(1), 1-21. https://educationaltechnologyjournal.springeropen.com/articles/10.1186/s41239-020-0181-y

Carlisle, D. L., Tyson, J. F., & Nieswandt, M. (2015). Fostering spatial skill acquisition by general chemistry students. *Chemistry Education Research and Practice*, *16*(3), 478–517. https://doi.org/10.1039/C4RP00228H

Chernikova, O., Heitzmann, N., Stadler, M., Holzberger, D., Seidel, T., & Fischer, F. (2020). Simulation-Based Learning in Higher Education: A Meta-Analysis. *Review of Educational Research*, *90*(4), 499–541. https://doi.org/10.3102/0034654320933544

Choi, B. (2014). *Learning from experiences of project successes and failures in the workplace*. ResearchGate. https://www.researchgate.net/publication/334558140_Learning_from_Experiences_of_Project_Successes_and_Failures_in_the_Workplace

Clark, R. M., & Dickerson, S. J. (2018). *The Use of SPICE Simulation to Promote Reflection and Metacognition in a Microelectronics Course*. https://strategy.asee.org/the-use-of-spice-simulation-to-promote-reflection-and-metacognition-in-a-microelectronics-course

Cloke, H. (2023). *John Dewey's influence on modern education. Growth Engineering*. https://www.growthengineering.co.uk/john-dewey/

Cohen, P., West, S. G., & Aiken, L. S. (2014). *Applied multiple regression/correlation analysis for the behavioral sciences*. Psychology Press.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage Publications.

Crha, J., Novotny, M., & Bartlova, M. (2021). *A comparison of CFD solvers for geoscience applications: The case of a single rising bubble. Minerals, 11*(5), 452. https://www.mdpi.com/2075-163X/11/5/452

DOSM. (2015). *Lecturers in Malaysian universities: A statistical overview*. Department of Statistics Malaysia. https://open.dosm.gov.my/data-catalogue/lecturers_uni

Dzulkefli, M. (2022). How to become a lecturer in Malaysia. EduAdvisor. https://eduadvisor.my/articles/how-to-become-a-lecturer-in-malaysia#:~:text=While%20a%20master's%20degree%20is,lecturers%20with%20experience%20in%20research

Eppes, T., Milanovic, I., & Russell, I. (2011). Multiphysics modeling with high priority research applications. *Global Engineering Education Conference*, 59–64. https://doi.org/10.1109/EDUCON.2011.5773113

Fang, L., Tan, H. S., Thwin, M. M., Tan, K. C., & Koh, C. (2011). The value simulation-based learning added to machining technology in Singapore. *Educational Media International*, *48*(2), 127–137. https://doi.org/10.1080/09523987.2011.576526

Fang, N., Zhang, L., & Liu, H. (2010). *The effects of simulation-based learning on engineering workshop practice*. ResearchGate. https://www.researchgate.net/publication/265238623_The_Effects_of_Simulation-based_Learning_on_Engineering_Workshop_Practice

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2007). *G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences*. *Behavior Research Methods, 39*(2), 175-191. https://doi.org/10.3758/bf0319314

Favre, P., Maquer, G., Henderson, A. D., Hertig, D., Ciric, D., & Bischoff, J. E. (2021). In Silico Clinical Trials in the Orthopedic Device Industry: From Fantasy to Reality? *Annals of Biomedical Engineering*, 1–14. https://doi.org/10.1007/S10439-021-02787-Y

Feijoo-Garcia, B., Gonzalez, L., & Martinez, J. (2024). *Sustainability in engineering education: Integrating simulation-based learning for future workforce development*. *Sustainability, 16*(7), 2633. https://www.mdpi.com/2071-1050/16/7/2633

Feng et al.. (2021). *Embedding ensemble learning into simulation-based optimisation: a learning -based optimisation approach for contruction planning*, 30 (1), 259-295. https://www.emerald.com/insight/content/doi/10.1108/ecam-02-2021-0114/full/pdf?title=embedding-ensemble-learning-into-simulation-based-optimisation-a-learning-based-optimisation-approach-for-construction-planning

Fongsamut, K., Tanasittikosol, M., & Phaksunchai, M. (2022). Effectiveness of the simulation-based learning (SBL) assisted with scaffolding approach to address students' misconceptions about projectile motion. *Physics Education*, *58*(2), 025002. https://doi.org/10.1088/1361-6552/aca57d

Ginestra, P., Ceretti, E., & Fiorentino, A. (2016). *Potential of modeling and simulations of bioengineered devices: Endoprostheses, prostheses and orthoses*. *230*(7), 607–638. https://doi.org/10.1177/0954411916643343

Gowrie, N. (2024). *Piaget's theory of cognitive development*. *Gowrie NSW*. https://www.gowriensw.com.au/thought-leadership/piaget-theory#:~:text=Piaget%20grouped%20cognitive%20development%20into,operational:%20ages%2012%20and%20up

Grieve, S. M. (2019). *Cognitive Load Theory Principles Applied to Simulation Instructional Design for Novice Health Professional Learners*. https://nsuworks.nova.edu/cgi/viewcontent.cgi?article=1079&context=hpd_pt_stuetd

Heale, R., & Twycross, A. (2015). *Validity and reliability in quantitative studies*. *Evidence-Based Nursing, 18*(3), 66-67.

Hill, R. (1998). What sample size is "enough" in internet survey research? *Interpersonal Computing and Technology: An Electronic Journal for the 21st Century, 6*(3-4), 1-10.

Hui, A. N. N., Eason, M. S., Cheung, R. C. C., Lai, L. C., Lau, D., & Lam, T. H. S. (2021). *The Relationships Among Simulation-Based Learning, Creativity, and the Learning Approach in Higher Education* (pp. 89–104). Springer, Cham. https://doi.org/10.1007/978-3-030-72216-6_6

Hurrell, D. (2024). *90+ Simulation-Based Learning Benefits and Challenges for eLearning*. *Neovation*. https://www.neovation.com/learn/90-simulation-based-learning-benefits-and-challenges-for-elearning#:~:text=Accessibility%3A%20Some%20learners%20may%20have,transferable%20to%20real%2Dworld%20situations.

Hussain, A. (2021). *Comsol vs. Ansys Fluent: Performance in simulation modeling*. ResearchGate. https://www.researchgate.net/post/Comsol_Vs_Ansys_Fluent

Isaac, S., & Michael, W. B. (1995). *Handbook in research and evaluation: A collection of principles, methods, and strategies useful in the planning, design, and evaluation of studies in education and the behavioral sciences* (3rd ed.). EdITS Publishers.

Ismail, S., Salleh, M., & Sulaiman, N. (2019). *Assessing simulation-based learning effectiveness in medical education*. *Medicine and Health UKM, 14*(2), 1-10. https://www.medicineandhealthukm.com/sites/medicineandhealthukm.com/files/article/2019/5_ms412_pdf_56973.pdf

Jaiswal, A., Gupta, A., & Kumar, A. (2022). *Virtual crash test analysis of modern cars through ANSYS software*. ResearchGate. https://www.researchgate.net/publication/361808096_Virtual_Crash_Test_Analysis_of_Modern_Car_through_ANSYS_Software

Jamil, G., & Isiaq, S. O. (2019). Teaching technology with technology: approaches to bridging learning and teaching gaps in simulation-based programming education. *International Journal of Educational Technology in Higher Education*, *16*(1), 1–21. https://doi.org/10.1186/S41239-019-0159-9

Jones, I., & Alinier, G. (2009). *Introduction of a new reflective framework to enhance students' simulation learning: a preliminary evaluation*. https://uhra.herts.ac.uk/handle/2299/6147

Jones-Roberts, C., & Bechtold, C. (2024). Experiential Learning in Higher Education. *Journal of Technology-Integrated Lessons and Teaching*, *3*(2), 53–63. https://doi.org/10.13001/jtilt.v3i2.8587

Khalil, A. M., Lee, K. L., Kamaruzzaman, Z. A., & Ong, C. A. (2024). Effectiveness of simulation-based learning in Malaysian higher education: a case study of MonsoonSIM. *Asian Education and Development Studies*. https://doi.org/10.1108/aeds-09-2023-0125

Kim, H. Y. (2015). Statistical notes for clinical researchers: Assessing normal distribution (2) using skewness and kurtosis. *Korean Journal of Anesthesiology, 68*(4), 283–286. https://pmc.ncbi.nlm.nih.gov/articles/PMC4667138/

Kolb, D. A. (1983). *Experiential Learning : Experience as the Source of Learning and Development*. https://www.amazon.com/Experiential-Learning-Experience-Source-Development/dp/0132952610

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. ResearchGate. https://www.researchgate.net/publication/235701029_Experiential_Learning_Experience_As_The_Source_Of_Learning_And_Development

Kolb, D., Lewin, K., Piaget, J., & Dewey, J. (2016). *Experiential learning theory is a cycle learning theory introduced by American educational theorist*.

Kong, Z. Y., Omar, A. A., Lau, S. L., & Sunarso, J. (2024). Introducing process simulation as an alternative to laboratory session in undergraduate Chemical Engineering Thermodynamics course: A case study from Sunway University Malaysia. *Digital Chemical Engineering*, 100167. https://doi.org/10.1016/j.dche.2024.100167

Kumar, S., & Milanovic, I. (2022). *Simulation-Supported Engineering Curriculum*. 1–6. https://doi.org/10.1109/WEEF-GEDC54384.2022.9996267

Labuschagne, M. (2025). How can we ensure quality simulation based education? *Acta Ophthalmologica*, *103*(S284). https://doi.org/10.1111/aos.16923

Landriscina, F. (2013). *Simulation-Based Learning* (pp. 99–146). Springer, New York, NY. https://doi.org/10.1007/978-1-4614-1954-9_5

Lateef, F. (2010). *Simulation-based learning: Just like the real thing*. *Journal of Emergency Trauma and Shock, 3*(4), 348-352. https://pmc.ncbi.nlm.nih.gov/articles/PMC2966567/

Ma, J., & Nickerson, J. V. (2006). *Hands-on, simulated, and remote laboratories: A comparative literature review*. ResearchGate. https://www.researchgate.net/publication/220566688_Hands-on_simulated_and_remote_laboratories_A_comparative_literature_review

Ma'aruf, S. A., & Phuah, K. T. (2016). *Exploring the adoption of simulation-based learning in engineering education*. *Berjaya Journal of Services & Management, 6*, 3-15. https://journal.berjaya.edu.my/wp-content/uploads/2019/10/July-2016_3-15.pdf

Magana, A. J. (2017). *Modeling and simulation in engineering education: A learning progression approach*. ResearchGate.

https://www.researchgate.net/publication/318322929_Modeling_and_Simulation_in_Engineering_Education_A_Learning_Progression

Main, M. (2023). *John Dewey's theory of experiential learning*. *Structural Learning*. https://www.structural-learning.com/post/john-deweys-theory

Martini, R., Rios, J., Polatajko, H., Wolf, T., & McEwen, S. (2015). *The performance quality rating scale (PQRS): Reliability, convergent validity, and internal responsiveness for two scoring systems*. *Disability and Rehabilitation, 37*(3), 231-238.

Massobrio, G. (2023). *What is engineering simulation and how does it work?*. *Neural Concept*. https://www.neuralconcept.com/post/what-is-engineering-simulation-and-how-does-it-work#:~:text=Engineering%20simulations%20are%20based%20on,and%20time%2Dconsuming%20physical%20testing.

Medicine and Health UKM. (2019). *Title of the Article*. *Medicine and Health*, *14*(2), 1-10. https://www.medicineandhealthukm.com/sites/medicineandhealthukm.com/files/article/2019/5_ms412_pdf_56973.pdf

Ministry of Education Malaysia (MOE). (2015). *Malaysia Education Blueprint 2015–2025 (Higher Education)*. https://www.kooperation-international.de/uploads/media/3._Malaysia_Education_Blueprint_2015-2025__Higher_Education__.pdf

MOHE. (2025). *Public universities in Malaysia*. Ministry of Higher Education Malaysia. https://mohe.gov.my/en/institutions/public-university

MQA. (2009). *Accredited engineering programs in Malaysia*. Malaysian Qualifications Agency. https://www2.mqa.gov.my/mqr/english/eakrbyipta.cfm

Murrell, P. H., & Claxton, C. S. (1987). Experiential Learning Theory as a Guide for Effective Teaching. *Counselor Education and Supervision*, *27*(1), 4–14. https://doi.org/10.1002/J.1556-6978.1987.TB00735.X

Negahban, S. (2024). *Advancing simulation-based learning for industrial applications*. *Simulation, 50*(2), 223-238. https://journals.sagepub.com/doi/10.1177/00375497241229757

Negahban. (2024). *Simulation in engineering education: The transition from phhysical experimentation to digital immersive simulated environment*, *100* (7), 695-708. https://journals.sagepub.com/doi/pdf/10.1177/00375497241229757

Nickerson & Ma. (2006). *Hands-on, simulated, and remote laboratories: A comparative literature review, 38*(3). *ResearchGate*. https://www.researchgate.net/publication/220566688_Hands-on_simulated_and_remote_laboratories_A_comparative_literature_review

Nowparvar, S. (2022). *Simulation in STEM education: Enhancing conceptual understanding*. National Science Foundation. https://par.nsf.gov/servlets/purl/10328375

Okstate. (2024). *Jean Piaget's cognitive development theory. Oklahoma State University Open Library*. https://open.library.okstate.edu/foundationsofeducationaltechnology/chapter/2-cognitive-development-the-theory-of-jean-piaget/#:~:text=Basically%2C%20this%20is%20a%20%E2%80%9Cstaircase,of%20childhood%2C%20but%20only%20approximately.

Oruganti, S. K., Karras, D., Thakur, S., Chaithanya, J. K., Metta, S., & Lathigara, A. (Eds.). (2025). *Digital transformation and sustainability of business* (1st ed.). CRC Press. https://doi.org/10.1201/9781003606185

Pakpahan& Saragih (2022). Theory of cognitive development by Jean Piaget. ResearchGate. https://www.researchgate.net/publication/362524801_Theory_Of_Cognitive_Development_By_Jean_Piaget

Panungkas, C., Rahmat, A., & Sutopo, W. (2019). *Kolb's experiential learning for vocational education in mechanical engineering: A review*. ResearchGate. https://www.researchgate.net/publication/334057529_Kolb's_experiential_learning_for_vocational_education_in_mechanical_engineering_A_review

Queen's University. (2021). *Simulation experiential learning faculty toolkit.* Queen's University. https://www.queensu.ca/experientiallearninghub/sites/qelhwww/files/uploaded_files/Simulation%20Toolkit/Simulation%20EL%20Faculty%20Toolkit%20%20Final%20Final%20April%208.pdf

Razali, Z. B., & Shukor, S. A. A. (2005). *Title of the Article*. *Institution Name*. https://research.utm.my/wp-content/uploads/sites/80/2013/02/ICT-Zol-Bahri-Razali-Shazmin-Aniza-Abdul-Shukor_ok.pdf

Singh-Pillay, A. (2024). *Exploring science and technology teachers' experiences with integrating simulation-based learning*. *Education Sciences, 14*(8), 803. https://www.mdpi.com/2227-7102/14/8/803

Taher, M., & Khan, R. (2015). *The impact of simulation-based learning on student engagement and learning outcomes*. *QScience Proceedings: Experiential Learning Conference*, 2015(ELC2014), 58. https://www.qscience.com/content/papers/10.5339/qproc.2015.elc2014.58

Talah, H. (2016). *Sampling methods in research methodology: How to choose a sampling technique for research*. *International Journal of Academic Research in Management (IJARM), 5*(2), 18-27.

Talan, T. (2021). *Effectiveness of simulation-based learning in engineering education: A meta-analysis study*. *ERIC*, EJ1286535. https://files.eric.ed.gov/fulltext/EJ1286535.pdf

Tan, J., Khoo, M., & Lee, W. (2009). *Enhancing student learning through simulation-based instructional design*. CDIO. https://cdio.org/files/document/file/B1.1_0.pdf

Tercete, G. M., Amann, K. A. P., & Maia, R. F. (2017). SimStructure: 3D simulation Tool to Evaluate the Learning Aspects of Students in an Engineering Course. *International Journal of Education*, *02*. https://www.iaras.org/iaras/journals/caijels/simstructure-3d-simulation-tool-to-evaluate-the-learning-aspects-of-students-in-an-engineering-course

Universiti Sains Malaysia (USM). (2025). *Gender statistics*. USM Kanita. https://kanita.usm.my/index.php?view=article&id=170:gender-statistics&catid=47#:~:text=Doctor%20of%20Philosophy%20(PhD)%20Level,PhD%20population%20in%20recent%20years

University of Houston (UTH). (2000). *Simulation in education and training: A review*. https://uh.edu/~lcr3600/simulation/contents.html

UPM. (2025). *Biomedical engineering at UPM*. University Putra Malaysia. https://sgs.upm.edu.my/content/biomedical_engineering-60115

Ursachi, G., Horodnic, I. A., & Zait, A. (2015). How Reliable are Measurement Scales? External Factors with Indirect Influence on Reliability Estimators. Procedia Economics and Finance, 20, 679-686. https://doi.org/10.1016/s2212-5671(15)00123-9}

UTeM. (2024). *Simulation Lab Facilities at UTeM*. Universiti Teknikal Malaysia Melaka. https://ceria.utem.edu.my/lab-emd-home.html

UTMDigital. (2024). *UTM Digital Official Website*. Universiti Teknologi Malaysia. https://digital.utm.my/

Verner, I., Waks, S., & Kolberg, E. (2024). *Simulation-based learning for engineering design education: A case study using Onshape and Blender*. *Procedia Computer Science, 299*, 102789. https://www.sciencedirect.com/science/article/pii/S1877050924002898

Watson, K. A., & Brown, A. O. (2012). *Ac 2012-3043: finite element analysis learning modules for an undergraduate heat transfer course: implementation and assessment*.

Zainal Abidin, M. J., Hassan, R., & Luan, W. S. (2017). *Exploring acceptance of game-based learning from Malaysian government professionals' perspectives*. ResearchGate. https://www.researchgate.net/publication/325481245_Exploring_Acceptance_Of_Game_Based_Learning_From_Malaysian_Government_Professionals'_Perspectives

Appendixes

Appendix 1 shows list of Malaysia's Higher Education Institutes being sampled with website link to their respective directories.

No.	Institute	Directory URL	No.of Engineering Academic Staff
1	University Teknologi Petronas (UTP)	https://www.utp.edu.my/directories/Pages/academic.aspx	236
2	i-CATS University College (i-CATS UC)	https://staff.icats.edu.my/Directory/index	26
3	Lincoln University College (LUC)	https://www.online.lincoln.edu.my/applyonline/vwlect_detls.aspx	-
4	Southern University College (SU)	https://playground.southern.edu.my/feit-lecturers/	20
5	Univeristi Tunku Abdul Rahman (UTAR)	https://www2.utar.edu.my/staffListSearchV2.jsp?searchDept=LKC+FES&searchDiv=All&searchName=&searchExpertise=&submit=Search&searchResult=Y	301
6	University College TATI (UC TATI)	https://uctati.edu.my/eDirectory/#/main	114
7	INTI International College (INTI)	https://newinti.edu.my/campuses/inti-international-university/academic-staff/	12
8	Quest International College (QIU)	https://qiu.edu.my/all-experts/	-
9	Tunku Abdul Rahman University of Management (TARUMT)	https://www.tarc.edu.my/staffDirectory.jsp?cat_id=FDAA0D41-8967-4EAD-BE89-9BE26F147C47&fmenuid=5B689C00-D205-4D5C-A521-A77CB5420C2A&fdept=FOET&fbrncd=KL&fdivcd=	75
10	Sunway College (SunUni)	https://sunwayuniversity.edu.my/staff-profiles/school/School%20of%20Engineering%20and%20Technology	97
11	Taylor's University (Taylor's)	https://university.taylors.edu.my/en/study/explore-all-programs/engineering/staff-directory-for-school-of-engineering.html	50
12	University College Sedaya International (UCSI)	https://www.ucsiuniversity.edu.my/staff/faculty-of-engineering-technology-and-built-environment/all/faculty-of-engineering	105
13	Universiiti Kebangsaan Malaysia (UKM)	https://appsmu.ukm.my/edirektori/carian	527

14	Universiti Malaya (UM)	https://www.um.edu.my/list-staff.php?kodPTJ=K&kodJAB=K08	300
15	Universiti Malaysia Kelantan (UMK)	http://ecomm.umk.edu.my/staff_directory.jsp	55
16	Universiti Malaysia Pahang (UMP)	https://directory.ump.edu.my/	503
17	Universiti Malaysia Perlis (UniMAP)	https://direktori.unimap.edu.my/DIREKTORI/index.jsp?ABC=DEF	731
19	Universiti Pertahanan Nasional Malaysia (UPNM)	https://directory.upnm.edu.my/carianptj.php?ptj=6200&jbt=Fakulti%20Kejuruteraan	104
20	Universiti Putra Malaysia (UPM)	https://eng.upm.edu.my/jabatan-2156	308
21	Universiti Sains Islam Malaysia (USIM)	https://www.usim.edu.my/ms/direktori-telefon-emel-staf/	44
22	Universiti Sains Malaysia (USM)	https://directory.usm.my/	896
23	Universiti Sultan Zainal Abidin (UniSZA)	https://www.unisza.edu.my/staff-directory/	58
24	Universiti Teknikal Malaysia Melaka (UTeM)	https://portal.utem.edu.my/oas/directory/stafsearch_smsm.asp?mysearch=	537
25	Universiti Teknologi Malaysia (UTM)	https://www.utm.my/directory/faculty	719
26	Universiti Teknologi MARA (UiTM)	https://engineering.uitm.edu.my/index.php/about-us/staff-directory/academician	127
27	Universiti Tun Hussein Onn Malaysia (UTHM)	https://telefon.uthm.edu.my/fakulti/senarai2/21	117
28	Universiti Southampton Malaysia (UOSM)	https://www.southamptonmalaysia.edu.my/about/meet-our-team/academics/our-lecturers	26

Appendix 2 Master Copy of the Finalized Questionnaire

UNIVERSITI TUNKU ABDUL RAHMAN (UTAR)

FACULTY OF BUSINESS AND FINANCE

Master in Business Administration (Corporate Management)

The Impact of Simulation-Based Learning Practice on Student Learning Outcomes in Engineering Education at Higher Institutions in Malaysia

<u>Survey Questionnaire</u>

Dear Respondents,

I am currently undergoing a Master of Business Administration (Corporate Management) program studying at the University Tunku Abdul Rahman (UTAR), Faculty of Business and Finance. This study is undertaken to fulfil my dissertation of the programme.

The main objective of the study is to evaluate the impact of Simulation-based Learning (SBL) on student learning outcomes across engineering disciplines, assess the extent of its implementation in Malaysian higher education institutions, and examine how the capabilities of simulation tools influence learning effectiveness.. I sincerely hope that you can spare a few minutes to complete this questionnaire. Your responses are utterly important for me in completing my study. However, your participation is on a voluntary basis.

The information gathered and acquired through this questionnaire will be used solely for academic purposes. I firmly assure you that all information provided to this study will be kept PRIVATE AND CONFIDENTIAL. I truthfully appreciate your cooperation in completing this questionnaire. Thank you for your precious time and participation in this study.

Yours sincerely,

Name: LEE HOR YAN

Student ID: 22ABM07000

Contact details: countesskiev@1utar.my

Appendix 3

PERSONAL DATA PROTECTION NOTICE

Please be informed that in accordance with Personal Data Protection Act 2010 ("PDPA")
which came into force on 15 November 2013, Universiti Tunku Abdul Rahman ("UTAR")
is hereby bound to make notice and require consent in relation to collection, recording,
storage, usage and retention of personal information.

1. Personal data refers to any information which may directly or indirectly identify a
person which could include sensitive personal data and expression of opinion. Among
others it includes:

a) Name
b) Identity card
c) Place of Birth
d) Address
e) Education History
f) Employment History
g) Medical History
h) Blood type
i) Race
j) Religion
k) Photo
l) Personal Information and Associated Research Data

2. The purposes for which your personal data may be used are inclusive but not limited
to:

a) For assessment of any application to UTAR
b) For processing any benefits and services
c) For communication purposes
d) For advertorial and news
e) For general administration and record purposes
f) For enhancing the value of education
g) For educational and related purposes consequential to UTAR
h) For replying any responds to complaints and enquiries
i) For the purpose of our corporate governance
j) For the purposes of conducting research/ collaboration

3. Your personal data may be transferred and/or disclosed to third party and/or UTAR
collaborative partners including but not limited to the respective and appointed
outsourcing agents for purpose of fulfilling our obligations to you in respect of the
purposes and all such other purposes that are related to the purposes and also in

providing integrated services, maintaining and storing records. Your data may be
shared when required by laws and when disclosure is necessary to comply with applicable laws.
4. Any personal information retained by UTAR shall be destroyed and/or deleted in
accordance with our retention policy applicable for us in the event such information
is no longer required.5. UTAR is committed in ensuring the confidentiality, protection, security and accuracy
of your personal information made available to us and it has been our ongoing strict
policy to ensure that your personal information is accurate, complete, not misleading
and updated. UTAR would also ensure that your personal data shall not be used for
political and commercial purposes.

Consent:

6. By submitting or providing your personal data to UTAR, you had consented and
agreed for your personal data to be used in accordance to the terms and conditions
in the Notice and our relevant policy.
7. If you do not consent or subsequently withdraw your consent to the processing and
disclosure of your personal data, UTAR will not be able to fulfill our obligations or to
contact you or to assist you in respect of the purposes and/or for any other purposes
related to the purpose.
8. You may access and update your personal data by writing to us at
.

Acknowledgment of Notice

[ ] I have been notified and that I hereby understood, consented and agreed per UTAR above notice.
[ ] I disagree, my personal data will not be processed.

…………………………

Name:

Date:

Appendix 2 shows Master Copy of the Finalized Questionnaire (Continued)

Section A: Demographic Profile & Teaching Background

The following questions refer to the respondent's demographic profile & Teaching Background. Please tick the option that can best describe your demographic profile and teaching background.

Gender:
- ☐ Male
- ☐ Female

Age:
- ☐ 25 - 30
- ☐ 31 - 35
- ☐ 36 - 40
- ☐ 41 - 45
- ☐ 46 - 50
- ☐ 50 and above

Education Level
- ☐ Diploma
- ☐ Degree Holder
- ☐ Master Degree Holder
- ☐ Doctor of Philosophy and above

Type of Institute
- ☐ Private
- ☐ Public

Institute of Higher Education that you are currently teaching (Private)

☐ i-CATS University College (i-CATS UC)	☐ INTI International College (INTI)	☐ Lincoln University College (LUC)
☐ Quest International University (QIU)	☐ Southern University College (SU)	☐ Sunway University College (SunUni)
☐ Taylor's Universiti (Taylor's)	☐ Tunku Abdul Rahman University of Management (TARUMT)	☐ University COllege Sedaya International (UCSI)
☐ University College TATI (UC TATI)	☐ Universiti Southampton Malaysia (UoSM)	☐ Universiti Tenaga Nasional (UNITEN)
☐ Unversiti Teknologi Petronas (UTP)	☐ Univeristi Tunku Abdul Rahman (UTAR)	☐ University of Wollongong (UOW)

Institute of ☐ Universiiti ☐ Universiti Malaya ☐ Universiti

Higher Education that you are currently teaching (Public)	☐ Kebangsaan Malaysia (UKM)	☐ (UM)	☐ Malaysia Kelantan (UMK)
	☐ Universiti Malaysia Pahang (UMP)	☐ Universiti Malaysia Perlis (UniMAP)	☐ Universiti Pendidikan Sultan Idris (UPSI)
	☐ Universiti Pertahanan Nasional Malaysia (UPNM)	☐ Universiti Putra Malaysia (UPM)	☐ Universiti Sains Islam Malaysia (USIM)
	☐ Universiti Sains Malaysia (USM)	☐ Universiti Sultan Zainal Abidin (UniSZA)	☐ Universiti Teknikal Malaysia Melaka (UTeM)
	☐ Universiti Teknologi Malaysia (UTM)	☐ Universiti Teknologi MARA (UiTM)	☐ Universiti Tun Hussein Onn Malaysia (UTHM)
Engineering Program(s) taught	☐ Electronics & Electrical Engineering	☐ Civil & Structural Engineering	☐ Mechatronics Engineering
	☐ Mechanical Engineering	☐ Biomedical Engineering	☐ Industrial Engineering
	☐ Chemical Engineering	☐ Others	☐
Which Engineering Program(s) implemented SBL?	☐ Electronics & Electrical Engineering	☐ Civil & Structural Engineering	☐ Mechatronics Engineering
	☐ Mechanical Engineering	☐ Biomedical Engineering	☐ Industrial Engineering
	☐ Chemical Engineering		
Which SBL Tool(s) are used in your teaching?	☐ ANSYS	☐ COMSOLE Multiphysics	☐ ABACUS (Dassault System)
	☐ Autodesk	☐ Solidwork	☐ Cadence
	☐ Altair	☐ Multisim	☐ Others
Which SBL	☐ Finite Element Analysis	☐ Linear Dynamics	☐ Electric Powertrain

Solver(s) / Application(s) do you use?		Finite Volume Analysis		Multiphase Reaction		Nanophotonics , Lumerical or Optics
		Computation Fluid Dynamics		Printed Cirsuit Board (PCB) design		3D Design & Modeling / High-Fidelity Human Body
		Muti-Body Dynamics		Electromagnetic Simulation		Reaction Chemistry
		Thermal Analysis / Heat Transfer		Signal/ Power Integrity		Others
		Acoustics		PCB Reliability Prediction		

Section B: Independent Variable

Please take a moment to read and respond to the statements below regarding the impact of simulation-based learning (SBL) practice on student learning outcomes in engineering education at higher institutions in Malaysia. Indicate your level of agreement with each statement by choosing a number on a 5-point scale: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

This study provides insights into optimizing SBL adoption, improving instructional quality, and bridging the skills gap for Industry 4.0. is crucial to understanding their collective impact on student learning outcomes in engineering education. SBL Practice examines how hands-on engagement with simulation tools enhances conceptual understanding and problem-solving skills. The extent of SBL implementation assesses the depth and breadth of its integration across engineering program, identifying gaps that may hinder its effectiveness. Lastly, evaluating the capabilities of SBL tools, such as their user-friendliness, computational power, and multidisciplinary adaptability, helps determine their role in maximizing learning efficiency

No.	Items	1 Strongly	2 Disagree	3 Neutral	4 Agree	5 Strongly
SBL Practice						
SP1	Students' performance will improve when SBL integrated with traditional lab methods					
SP2	Students able to make useful associations between course works and projects during SBL activities					
SP3	Students able to use SBL Tools to solve engineering problems					
SP4	Student able to make informed decisions when solving engineering design challenges through SBL					
Extend of SBL Implementation						
EI1	SBL is consistently implemented across relevant engineering programs					
EI2	There is sufficient institutional support for the implementation of SBL in relevant engineering programs					
EI3	SBL is integrated across multiple subjects throughout the relevant engineering programs					
EI4	There are adequate training for teaching lecturers to effectively integrate SBL into their lessons					
EI5	The institute curriculum is aligned with industry-relevant SBL practices and SBL tools					
Capabilities of SBL Tools						
CS1	User friendly interface of Simulation Tool enhances student's learning experience					
CS2	Customization features of Simulation Tool for different engineering application improves student's learning outcome					
CS3	Scalability of the Simulation Tool positively impacts students' ability to solve engineering problems of their giving tasks					
CS4	Integration of multi physics solvers enhances student's understanding of interdisciplinary engineering scenarios					
CS5	Availability of quality accessible learning materials improve student engagement with SBL					
CS6	Affordability of licensing models influence the adoption of SBL in engineering education					
Mediator Factor : Reflective Observation						
RO1	SBL enhance student's familiarity with assignments, improving learning process					
RO2	SBL increase student's engagement in instructor-led discussions					
RO3	SBL encourage students to develop independent problem-solving skills					
RO4	SBL improves student's efficiency in completing tasks and assignments					

RO5	SBL improve students understanding through the course					
Students Learning Outcome						
SLO1	SBL practice in engineering programme improves overall student's learning outcome					
SLO2	More in-depth and structured implementation of SBL throughout relevant engineering programs will enhance student's learning outcome					
SLO3	Capabilities of the simulation tools directly influence student learning outcome					
SLO4	SBL foster reflective observation, allowing students to critically apply knowledge, leading to improved academic performance					

Thank you very much for your willingness to participate in answering the questionnaire

Appendix 3 shows ethical approval letter from UTAR

UNIVERSITI TUNKU ABDUL RAHMAN DU012(A)

Wholly owned by UTAR Education Foundation Co. No. 578227-M

Re: U/SERC/56(A)-611/2025

24 Mac 2025

Dr Wei Chooi Yi
Department of Finance
Teh Hong Piow Faculty of Business and Finance
Universiti Tunku Abdul Rahman
Jalan Universiti, Bandar Baru Barat
31900 Kampar, Perak

Dear Dr Wei,

Ethical Approval For Research Project/Protocol

We refer to your application for ethical approval for your research project (Master student's project) and are pleased to inform you that your application has been approved under Expedited Review.

The details of your research project are as follows:

Research Title	The Impact of Simulation-Based Learning Practice on Student Learning Outcomes in Engineering Education at Higher Institutions in Malaysia
Investigator(s)	Dr Wei Chooi Yi Lee Hor Yan (UTAR Postgraduate Student)
Research Area	Business Administration
Research Location	Malaysia
No of Participants	362 participants (Age: 21 - 80)
Research Costs	Self-funded
Approval Validity	24 March 2025 - 23 March 2026

The conduct of this research is subject to the following:

(1) The participants' informed consent be obtained prior to the commencement of the research,

(2) Confidentiality of participants' personal data must be maintained; and

(3) Compliance with procedures set out in related policies of UTAR such as the UTAR Research Ethics and Code of Conduct, Code of Practice for Research Involving Humans and other related policies/guidelines.

(4) Written consent be obtained from the institution(s)/company(ies) in which the physical or/and online survey will be carried out, prior to the commencement of the research.

Kampar Campus : Jalan Universiti, Bandar Barat, 31900 Kampar, Perak Darul Ridzuan, Malaysia
Tel: (605) 468 8888 Fax: (605) 466 1313
Sungai Long Campus : Jalan Sungai Long, Bandar Sungai Long, Cheras, 43000 Kajang, Selangor Darul Ehsan, Malaysia
Tel: (603) 9086 0288 Fax: (603) 9019 8868
Website: www.utar.edu.my

Should you collect personal data of participants in your study, please have the participants sign the attached Personal Data Protection Statement for your records.

The University wishes you all the best in your research.

Thank you.

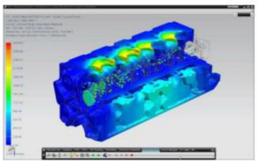
Yours sincerely,

Professor Ts Dr Faidz bin Abd Rahman
Chairman
UTAR Scientific and Ethical Review Committee

c.c Dean, Teh Hong Piow Faculty of Business and Finance
Director, Institute of Postgraduate Studies and Research

Kampar Campus : Jalan Universiti, Bandar Barat, 31900 Kampar, Perak Darul Ridzuan, Malaysia
Tel: (605) 468 8888 Fax: (605) 466 1313
Sungai Long Campus : Jalan Sungai Long, Bandar Sungai Long, Cheras, 43000 Kajang, Selangor Darul Ehsan, Malaysia
Tel: (603) 9086 0288 Fax: (603) 9019 8868
Website: www.utar.edu.my

Appendix 4 shows E-Questionnaire



Simulation-based Learning in Engineering Education at Higher Institutions in Malaysia

Dear Respondents,

I am currently undergoing a Master of Business Administration (Corporate Management) program studying at the University Tunku Abdul Rahman (UTAR), Faculty of Business and Finance. This study is undertaken to fulfil my dissertation of the programme.

The main objective of the study is to evaluate the impact of Simulation-based Learning (SBL) on student learning outcomes across engineering disciplines, assess the extent of its implementation in Malaysian higher education institutions, and examine how the capabilities of simulation tools influence learning effectiveness.
I sincerely hope that you can spare a few minutes to complete this questionnaire. Your responses are utterly important for me in completing my study. However, your participation is on a voluntary basis.

The information gathered and acquired through this questionnaire will be used solely for academic purposes. I firmly assure you that all information provided to this study will be kept **PRIVATE AND CONFIDENTIAL**. I truthfully appreciate your cooperation in completing this questionnaire.

Thank you for your precious time and participation in this study.

Yours sincerely,
Name: LEE HOR YAN
Student ID: 22ABM07000
Contact details: countesskiev@1utar.my
Phone : +6011 2890 8335

* Required

PERSONAL DATA PROTECTION STATEMENT

Please be informed that in accordance with Personal Data Protection Act 2010 ("PDPA") which came into force on 15 November 2013, Universiti Tunku Abdul Rahman ("UTAR") is hereby bound to make notice and require consent in relation to collection, recording, storage, usage, and retention of personal information.

Notice:

12. Extent of SBL Implementation *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly
SBL is consistently implemented across relevant engineering programs	○	○	○	○	○
There is sufficient institutional support for the implementation of SBL in relevant engineering programs	○	○	○	○	○
SBL is integrated across multiple subjects throughout the relevant engineering programs	○	○	○	○	○
There are adequate training for teaching lecturers to effectively integrate SBL into their lessons	○	○	○	○	○
The institute curriculum is aligned with industry-relevant SBL practices and SBL tools	○	○	○	○	○

13. Capabilities of SBL Tools *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly
User friendly interface of Simulation Tool enhances student's learning experience	○	○	○	○	○
Customization features of Simulation Tool for different engineering application improves stude nt's learning outcome	○	○	○	○	○
Scalability of the Simulation Tool positively impacts students' ability to solve engineering problems of their giving tasks	○	○	○	○	○
Integration of multi physics solvers enhances student's understanding of interdisciplinary engineering scenarios	○	○	○	○	○
Availability of quality accessible learning materials improve student engagement with SBL	○	○	○	○	○

	Strongly Disagree	Disagree	Neutral	Agree	Strongly
Affordability of licensing models influence the adoption of SBL in engineering education	◯	◯	◯	◯	◯

14. Mediator Factor : Reflective Observation *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly
SBL enhance student's familiarity with assignments , improving learning process	◯	◯	◯	◯	◯
SBL increase student's engagement in instructor-led discussions	◯	◯	◯	◯	◯
SBL encourage students to develop independent problem-solving skills	◯	◯	◯	◯	◯
SBL improves student's efficiency in completing tasks and assignments	◯	◯	◯	◯	◯
SBL improve students understanding through the course	◯	◯	◯	◯	◯

15. Students Learning Outcome *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly
SBL practice in engineering programme improves overall student's learning outcome					
More in-depth, structured implementation of SBL throughout relevant engineering programs will enhance student's learning outcome					
Capabilities of the simulation tools directly influence student learning outcome					
SBL foster reflective observation, allowing students to critically apply knowledge, leading to improved academic performance					

1. The purposes for which your personal data may be used are inclusive but not limited to:-

- For assessment of any application to UTAR
- For processing any benefits and services
- For communication purposes
- For advertorial and news
- For general administration and record purposes
- For enhancing the value of education
- For educational and related purposes consequential to UTAR
- For the purpose of our corporate governance
- For consideration as a guarantor for UTAR staff/student applying for his/her scholarship/ study loan

2. Your personal data may be transferred and/or disclosed to third party and/or UTAR collaborative partners including but not limited to the respective and appointed outsourcing agents for purpose of fulfilling our obligations to you in respect of the purposes and all such other purposes that are related to the purposes and also in providing integrated services, maintaining and storing records. Your data may be shared when required by laws and when disclosure is necessary to comply with applicable laws.

3. Any personal information retained by UTAR shall be destroyed and/or deleted in accordance with our retention policy applicable for us in the event such information is no longer required.

4. UTAR is committed in ensuring the confidentiality, protection, security, and accuracy of your personal information made available to us and it has been our ongoing strict policy to ensure that your personal information is accurate, complete, not misleading and updated. UTAR would also ensure that your personal data shall not be used for political and commercial purposes.

Consent:

1. By submitting this form you hereby authorise and consent to us processing (including disclosing) your personal data and any updates of your information, for the purposes and/or for any other purposes related to the purpose.

2. If you do not consent or subsequently withdraw your consent to the processing and disclosure of your personal data, UTAR will not be able to fulfill our obligations or to contact you or to assist you in respect of the purposes and/or for any other purposes related to the purpose.

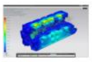
3. You may access and update your personal data by writing to us at: countesskiev@1utar.my

1. Acknowledgment of Notice

*

○ I have been notified by you and that I hereby understood, consented, and agreed per UTAR above notice.

○ I disagree, my personal data will not be processed. (If this is the answer, thank you for your time)



Simulation-based Learning in Engineering Education at Higher Institutions in Malaysia

Background & Significant of the Study

Malaysia's 13th National Plan emphasizes digital adoption and workforce readiness for Industry 4.0, requiring higher education institutions to equip graduates with relevant technical and problem-solving skills . However, despite foreign direct investments (FDI) strategies and grants aimed at fostering technological growth, a significant skills gap persists, leading employers to favor international hires over local graduates.

Simulation-Based Learning (SBL) has emerged as a transformative educational tool that bridges this gap by providing hands-on design experience, cost-effective training, and enhanced visualization of complex engineering concepts . Through the integration of simulation tools, students can conceptualize, test, and analyze real-world engineering scenarios, improving their employability and industry readiness.

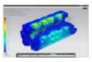
Despite these advantages, SBL adoption in Malaysian higher education remains inconsistent due to the lack of standardized curricula, particularly in interdisciplinary fields where prototyping and testing costs are prohibitive. This study investigates the impact of SBL on student learning outcomes, the extent of its implementation, and the role of simulation tool capabilities in Malaysian higher education.
This study aims to evaluate the impact of SBL on student learning outcomes across engineering disciplines, assess the extent of its implementation in Malaysian higher education institutions, and examine how the capabilities of simulation tools influence learning effectiveness.

This study is significant as it supports Malaysia's Education Blueprint (MEB) 2015–2025 by addressing the integration of Simulation-Based Learning (SBL) to enhance technical and vocational education, ensuring a highly skilled workforce for Industry 4.0 .

Despite the acknowledged advantages of SBL in bridging gaps in engineering education and reducing reliance on costly physical equipment, research on its effectiveness and structured implementation remains limited. Challenges such as inadequate organizational resources, lack of awareness, and insufficient faculty training further hinder its adoption . Moreover, existing policies fail to establish clear evaluation benchmarks for SBL's impact on conceptual understanding, professional competencies, and design skills .

By employing Kolb's Experiential Learning Cycle , this study provides a structured approach to assess how SBL enhances learning outcomes through hands-on experimentation, critical reflection, and applied problem-solving.

The findings will inform policymakers on standardizing SBL adoption across Malaysian higher education, aligning it with industry needs to produce graduates equipped with the skills necessary for real-world engineering challenges. Ultimately, this research underscores SBL's potential as a transformative tool in both education and industrial innovation, contributing to Malaysia's vision of becoming a global leader in engineering and technology.



Simulation-based Learning in Engineering Education at Higher Institutions in Malaysia

* Required

Demographic Profile & Teaching Background

The following questions refer to the respondent's demographic profile & Teaching Background. Please tick the option that can best describe your demographic profile and teaching background.

2. Gender *

- Male
- Female

3. Age *

- 25 - 30
- 31 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 above

4. Education Level *

- Diploma Holder
- Degree Holder
- Master Degree Holder

Doctor of Philosophy and above

Option 5

5. Type of Institute that you are currently teaching *

Private

Public

6. Institute of Higher Education that you are currently teaching (Public) *

Select Non-Applicable if you are teaching in Private University

Universiti Malaysia Pahang (UMP)

7. Engineering Program(s) Taught *

- [x] Electronics & Electrical
- [ ] Mechanical Engineering
- [ ] Mechatronics Engineering
- [ ] Civil & Structural Engineering
- [ ] Industrial Engineering
- [ ] Chemical Engineering
- [ ] Biomedical Engineering
- [ ] Other

8. Which Engineering Program(s) implemented SBL? *

- [x] Electronics & Electrical

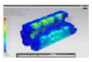
- [ ] Mechanical Engineering
- [ ] Mechatronics Engineering
- [ ] Civil & Structural Engineering
- [ ] Industrial Engineering
- [ ] Chemical Engineering
- [ ] Biomedical Engineering
- [ ] Other

9. Which SBL Tools are used in your teaching? *

- [ ] ANSYS
- [ ] COMSOLE Multiphysics
- [ ] ABACUS (Dassault System)
- [ ] Autodesk
- [x] Solidwork (Dassault System)
- [ ] Cadence
- [ ] Altair
- [ ] SIEMENS
- [ ] Multisim
- [ ] Keysight
- [ ] Other

10. Which SBL Solvers do you use? *

- [x] Finite Element Analysis (FEA)
- [ ] Finite Volume Analysis (FVA)
- [ ] Computation Fluid Dynamics (CFD)
- [ ] Muti-Body Dynamics
- [ ] Thermal Analysis / Heat Transfer
- [ ] Acoustics
- [ ] Linear Dynamics
- [ ] Multiphase Reaction
- [ ] Printed Cirsuit Board (PCB) design
- [ ] Electromagnetic Simulation
- [ ] Signal/ Power Integrity
- [ ] PCB Reliability Prediction
- [ ] Electric Powertrain
- [ ] Nanophotonics , Lumerical or Optics
- [ ] 3D Design & Modeling / High-Fidelity Human Body
- [ ] Reaction Chemistry
- [ ] Other



Simulation-based Learning in Engineering Education at Higher Institutions in Malaysia

* Required

Measuring Items Related to the Variables

Please take a moment to read and respond to the statements below regarding the impact of simulation-based learning (SBL) practice on student learning outcomes in engineering education at higher institutions in Malaysia. Indicate your level of agreement with each statement by choosing a number on a 5-point scale: [1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree]

11. SBL Practice *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly
Students' performance will improve when SBL integrated with traditional lab methods					
Students able to make useful associations between course works and projects during SBL activities					
Students able to use SBL Tools to solve engineering problems					
Student able to make informed decisions when solving engineering design challenges through SBL					