The Impact of Online Learning: Mechanical Engineering Education Perspectives

by

Dk Seri Rahayu binti Pg Ya'akub

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Wolfson School of Mechanical, Electrical & Manufacturing Engineering
Loughborough University
United Kingdom

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Abstract

An emerging issue in both the mechanical engineering field and almost all other study disciplines is online learning. Many universities have changed their teaching strategies and are investing heavily in the online presentation of coursework without much investment dealing with lecturers. The migration from a traditional learning technique to online learning has grown rapidly over time. However, the problem is whether all students are ready for the transition from traditional face to face learning to online learning. This research explores the impact of an online learning approach within the mechanical engineering context. The focus of this study was to identify the improvement in the satisfaction, performance and self-confidence of the mechanical students in learning the Mechanical Engineering Design module using the online method. There are four stages involved in this research work. The first stage was problem discovery involving review of related literature and a preliminary study conducted to investigate the student experiences and teacher perceptions on the existing learning techniques for the mechanical design process. This preliminary study also aimed to identify the difficulties and problems faced by students that have resulted in the suggestion of a learning approach using computer technology. The second stage involved the designing and developing of a new prototype web-based learning system. A System Development Life Cycle model (SDLC) was applied comprising four phases of a concept, design, coding and testing. The third stage was the implementation and data collection. A main study was conducted with 160 mechanical engineering students from three different levels of study at one of the universities in Brunei Darussalam. Finally, the fourth stage was data analysis using SPSS statistical software. Based on the main findings, a significant difference was found between the experienced and inexperienced students in terms of their learning satisfaction in using online learning. Significant differences were also identified in terms of time taken between the experienced and inexperienced students when using traditional and online techniques of learning to solve the simple task. Additionally, the findings also indicated that there were significant differences among the experienced and inexperienced students in terms of marks performance in solving complex tasks using the online web-based learning system. The study has shown that the online learning approach is expected to be useful as an additional learning tool to the existing traditional learning technique, particularly in the context of engineering education.

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List of Abbreviations

BEng	Bachelor of Engineering
BITNET	Because It's Time Network
CAD	Computer-Aided Drawing
CAT	Computer-Assisted Teaching
CSS	Cascading Style Sheets
DEMATEL	Decision Making Trial and Evaluation Laboratory
E	Experienced group
FD	Foundation Degree
FMEA	Finite Mode and Effect Analysis
HND	Higher National Diploma
HTML	Hyper Text Markup Language
I	Inexperienced group
ILT	Instructor-Led Training
IT	Information Technology
LMS	Learning Management System
MAR	Missing At Random
MCAR	Missing Completely At Random
MNAR	Missing Not At Random
O	Online learning
RO	Research Objective
RQ	Research Question
SDLC	System Development Life Cycle
SPSS	Statistical Package for the Social Sciences
STEM	Science, Technology, Engineering, and Mathematics
T	Traditional learning
USENET	Users Network
UTB	Universiti Teknologi Brunei
2D	2-Dimensional
3D	3-Dimensional

List of Symbols

Symbol	Description	Units
p-value	The attained level of significant	
df	Degree(s) of freedom	
F	F statistics variable	
M^a	Estimated marginal means for post-test	
η^2	Partial eta squared	
N	Population size	
t	t variable in paired sample T test	
n_s	Safety factor	
n_{sx}	Safety factor involving characteristics: quality material, control over load and accuracy of stress analysis	
n_{sy}	Safety factor involving characteristics: danger to personnel and economic impact	
P	Power	W or kW
T	Transmitted torque	N.mm or N.m
n	Rotational speed	rpm
F	Tangential force	N
d	Shaft diameter	mm or m
w	Width of key	mm or m
t	Thickness of key	mm or m
l	Length of keys	mm or m
l_c	Length of keys in compression stress mode	mm or m
l_s	Length of keys in shear stress mode	mm or m
A	Area	mm^2 or m^2
A_c	Compression area	mm^2 or m^2
A_s	Shear area	mm^2 or m^2
fs	Factor of safety (for design of keys)	
σ_c	Allowable compression stress	N/mm^2 or N/m^2 or Pa
τ	Allowable shear stress	N/mm^2 or N/m^2 or Pa
S_{yc}	Yield strength in compression	N/mm^2 or N/m^2 or Pa
S_{ys}	Yield strength in shear	N/mm^2 or N/m^2 or Pa
S_{yt}	Yield strength in tension	N/mm^2 or N/m^2 or Pa

Chapter 1. Introduction

1.1 Introduction

This chapter will begin by providing an overview of the background of the research. A statement of the research problems is then discussed. The key elements and identified research questions, aims and objectives of the research are also presented. This chapter concludes with a schematic flowchart to demonstrate how the thesis is structured.

1.2 Background of Study

Mechanical Engineering Design, also known as Mechanical Design or Machine Design, is one of the essential modules in a mechanical engineering course. This is because this module involves the structuring of almost all products containing necessary mechanical functions, ranging from the mechanical machinery for assembling and manufacturing to programming human interfaces of machines (Bach-y-Rita and Kercel, 2003). An individual learning mechanical design needs to be equipped with skills in simplicity, flexibility, creativity, and sustainability in a bid to help him/her design optimally. Moreover, it is crucial to a learner to be appropriately sophisticated and with enough and early exposure to complex mechanical systems (Wickert and Lewis, 2012). These aspects help to shape a learner into a good mechanical engineer from the earliest time possible.

One of the emerging issues in both the mechanical engineering field and almost all other study disciplines is the aspect of online learning. Online learning is the practice of distance learning by the use of the modern communication technology that helps learners acquire books, notes and related information without having to physically be in class (Moore and Kearsley, 2012). Consequently, it is also called e-learning. Mechanical engineering, being amongst the most commonly pursued courses in the world, currently employs online learning to enable efficient and easier training for students around the world.

The practice of online learning is a relatively new construct that has peaked in the past 10 to 15 years (Salmon, 2013). However, aspects of web-based and computer-aided instruction first emerged in the 1960s when early computer scientists and technology experts tried time sharing between computers (Rudestam and Schoenholtz-Read, 2010). According to Kearsley (2005), there were also experiments on dial-up connections between telephone lines as well as experimental connections between mainframe computers by the use of dumb terminals.

Rudestam and Schoenholtz-Read (2010) explain that the first known breakthrough in online sharing of resources is when the United States Government successfully oversaw the exchange of data through telephone lines between researchers using remote computers in 1969. Early computer networks such as the BITNET and USENET emerged as the technology of remote exchange of data advanced (Bidgoli, 2004). This research also argues that the emergence of electronic mail in 1972 was also crucial in the exchange of resources. However, the greatest facilitator of online communication is the Internet, which advanced greatly especially towards the end of the 20^{th} century (Poole et al., 2005). Today, online learning can happen internationally via websites, social media, and custom-made online forums. Despite the success of online learning, critics argue that online learning is hugely inappropriate for technical courses such as mechanical engineering. They suggest that online learning should be reserved for social and humanities courses instead of STEM courses.

This thesis, therefore, seeks to explore the impact of online learning on Mechanical Engineering Design by reviewing previous literature concerning this issue and to come up with a relevant conclusion concerning the impact of online learning. This research investigates the student experiences in attending a traditional learning technique and using the online learning system. Furthermore, this research focuses mainly on the feedback of mechanical students based on their experiences in learning a module of Mechanical Engineering Design using the online learning technique.

1.3 Problem Statement

As mentioned before, mechanical engineers play significant roles in designing and manufacturing from small individual parts into large mechanical systems. The designed products need to be produced with outstanding qualities of functional, aesthetic, manufacture and safe to operate, but this can only happen if analysis and design are performed efficiently. However, when designs become complex, the requirements for product specification become more challenging. When this issue occurs among mechanical students, they are likely to show less attention and try to ignore the importance of machine elements in their design. Hence, the students who are often faced with this problem would find that the products they designed cannot perform well, and some failed in operation. Also these problems generally result in the dissipation of time and effort during the design process.

Therefore, concerns with how students learn the module of Mechanical Engineering Design has given rise to this research. Many learning institutions have invested in different approaches and more favourable tools to increase the student attendance in lecture rooms. Methods such as introducing the course outline to students before the actual class learning to increase the students' activity, to give students a chance to present their views to the teaching panel and focusing on transformational learning such as group discussions and open class learning. However, studies show that many students prefer accessing course content online at their own preferred time (Allen et al., 2002). Universities and other institutions of higher learning are facing challenges in their bid to deliver quality skills to students who are anticipating in joining a very competitive workforce.

The migration from traditional learning methods to online presentation has rapidly grown over time. However, the big question is whether all students are now ready for online learning. The challenge of changing teachers' attitudes from the traditional face to face learning to the online mode of learning is critical since a teacher's attitude is transferred directly to the student (Ni, 2013). On the contrary, if teachers leave universities and other institutions of higher learning with negative attitudes towards online teaching, it will prove difficult to change the perception among the students.

Moreover, a deeper understanding of the need to migrate from traditional face to face methods of learning to online learning is crucial, not just for the teachers but also for the students involved (Zhang et al., 2004). In this research, a prototype web-based learning system is proposed and designed as to support student learning in mechanical design. This is to enhance the ability of mechanical students in solving the design problems. Further, this research investigates the comparison of students' satisfaction, performance and self-confidence in the learning of Mechanical Engineering Design module using online learning and traditional face to face learning.

1.4 Research Aim and Objectives

The aim of this research is to explore the impact of online learning on Mechanical Engineering Design among the experienced and inexperienced students, in the perspective of mechanical engineering education in Brunei Darussalam.

The following research objectives have been set to achieve the aim:

1. To explore the online learning techniques and related current issues within the context of engineering education, mainly in the area of mechanical engineering.

2. To investigate the experience of students and teacher perceptions on the existing learning technique for the mechanical design process, particularly in the module of Mechanical Engineering Design.

3. To design and create a prototype web-based online learning system.

4. To investigate the student experiences using the prototype web-based online learning system, and compare them with the traditional face to face learning method.

1.5 Research Questions

This research focuses on comparing the learning experiences between experienced and inexperienced students, in the traditional face to face mode of learning and online learning. Thus, this research explores the key elements with the identified main research questions as follows:

1. Views about attending the learning sessions:

   RQ1a: Will attending traditional learning sessions by experienced students improve learning satisfaction?

   RQ1b: Will attending traditional learning sessions by inexperienced students improve learning satisfaction?

   RQ1c: Is there any difference between experienced and inexperienced students in learning satisfaction after attending traditional learning sessions?

   RQ1d: Will using online learning sessions by experienced students improve learning satisfaction?

   RQ1e: Will using online learning sessions by inexperienced students improve learning satisfaction?

   RQ1f: Is there any difference between experienced and inexperienced students in learning satisfaction after using online learning?

2. Views about solving the assigned tasks:

RQ2a: Will solving the assigned tasks using traditional learning by experienced students improve learning satisfaction?

RQ2b: Will solving the assigned tasks using traditional learning by inexperienced students improve learning satisfaction?

RQ2c: Is there any difference between experienced and inexperienced students in learning satisfaction after solving the assigned tasks using traditional learning?

RQ2d: Will solving the assigned tasks using online learning by experienced students improve learning satisfaction?

RQ2e: Will solving the assigned tasks using online learning by inexperienced students improve learning satisfaction?

RQ2f: Is there any difference between experienced and inexperienced students in learning satisfaction after solving the assigned tasks using online learning?

3. Time taken to solve the assigned tasks:

RQ3a: Will using traditional learning by experienced students improve speed in solving the assigned tasks?

RQ3b: Will using traditional learning by inexperienced students improve speed in solving the assigned tasks?

RQ3c: Is there any difference between experienced and inexperienced students in speed in solving the assigned tasks using traditional learning?

RQ3d: Will using online learning by experienced students improve speed in solving the assigned tasks?

RQ3e: Will using online learning by inexperienced students improve speed in solving the assigned tasks?

RQ3f: Is there any difference between experienced and inexperienced students in speed in solving the assigned tasks using online learning?

4. Self-confidence to obtain the correct solutions for the assigned tasks:

RQ4a: Will doing the assigned tasks using traditional learning by experienced students improve self-confidence?

RQ4b: Will doing the assigned tasks using traditional learning by inexperienced students improve self-confidence?

RQ4c: Is there any difference between experienced and inexperienced students in self-confidence after solving the assigned tasks using traditional learning?

RQ4d: Will doing the assigned tasks using online learning by experienced students improve self-confidence?

RQ4e: Will doing the assigned tasks using online learning by inexperienced students improve self-confidence?

RQ4f: Is there any difference between experienced and inexperienced students in self-confidence after solving the assigned tasks using online learning?

5. Marks performance from solving the assigned tasks:

RQ5a: Will doing the assigned tasks using traditional learning by experienced students improve marks performance?

RQ5b: Will doing the assigned tasks using traditional learning by inexperienced students improve marks performance?

RQ5c: Is there any difference between experienced and inexperienced students in marks performance after solving the assigned tasks using traditional learning?

RQ5d: Will doing the assigned tasks using online learning by experienced students improve marks performance?

RQ5e: Will doing the assigned tasks using online learning by inexperienced students improve marks performance?

RQ5f: Is there any difference between experienced and inexperienced students in marks performance after solving the assigned tasks using online learning?

6. Satisfaction, performance and self-confidence when attending the learning sessions:

   RQ6a: Will attending traditional learning as the preferred learning approach by experienced students improve satisfaction, performance and self-confidence?

   RQ6b: Will attending traditional learning as the preferred learning approach by inexperienced students improve satisfaction, performance and self-confidence?

   RQ6c: Is there any difference between experienced and inexperienced students in satisfaction, performance and self-confidence with traditional learning as the preferred learning approach?

   RQ6d: Will using online learning as the preferred learning approach by experienced students improve satisfaction, performance and self-confidence?

   RQ6e: Will using online learning as the preferred learning approach by inexperienced students improve satisfaction, performance and self-confidence?

   RQ6f: Is there any difference between experienced and inexperienced students in satisfaction, performance and self-confidence with online learning as the preferred learning approach?

1.6 Thesis Outline

This thesis is divided into eight chapters and a schematic flowchart on how the thesis is structured, is presented in Figure 1.1. A brief explanation of each chapter is as follows:

Chapter 1: outlines an overview and background of the research. This chapter also describes the problem statements, key elements, research questions, aim and objectives of the research. Finally, this chapter presents a schematic flowchart on how the thesis is structured.

Chapter 2: discusses the finding in the literature review. This chapter includes the literature on the subjects that are significant to online learning in engineering education, especially in the field of mechanical engineering education. It also outlines and discusses the research gaps found from the previous studies presented in this chapter.

Chapter 3: defines and discusses the methodology and methods implemented to conduct the research. This chapter also describes the four stages that were applied in the study. The data collection activities are also presented in this chapter.

Chapter 4: demonstrates the approach used in conducting a survey and an informal interview for a preliminary study. This chapter discusses the outcomes and feedback from both questionnaires and informal interviews.

Chapter 5: presents the flowchart and layout of the design of a prototype web-based learning system. This chapter explains the overall process from creation to testing of the prototype system.

Chapter 6: presents and discusses a main study that has been conducted in Brunei Darussalam. The approach used in conducting a survey using questionnaire is also included. Data analysis is also explained and justified.

Chapter 7: interprets and discusses the findings of the quantitative data that has been presented in the previous chapter. This chapter also summarises the overall findings using tables.

Chapter 8: concludes the overall work done in this research by reviewing the main findings with respect to answer the research questions and the achievement of research objectives. This chapter concludes the research contributions, research limitations, and future research recommendations that could be carried out.

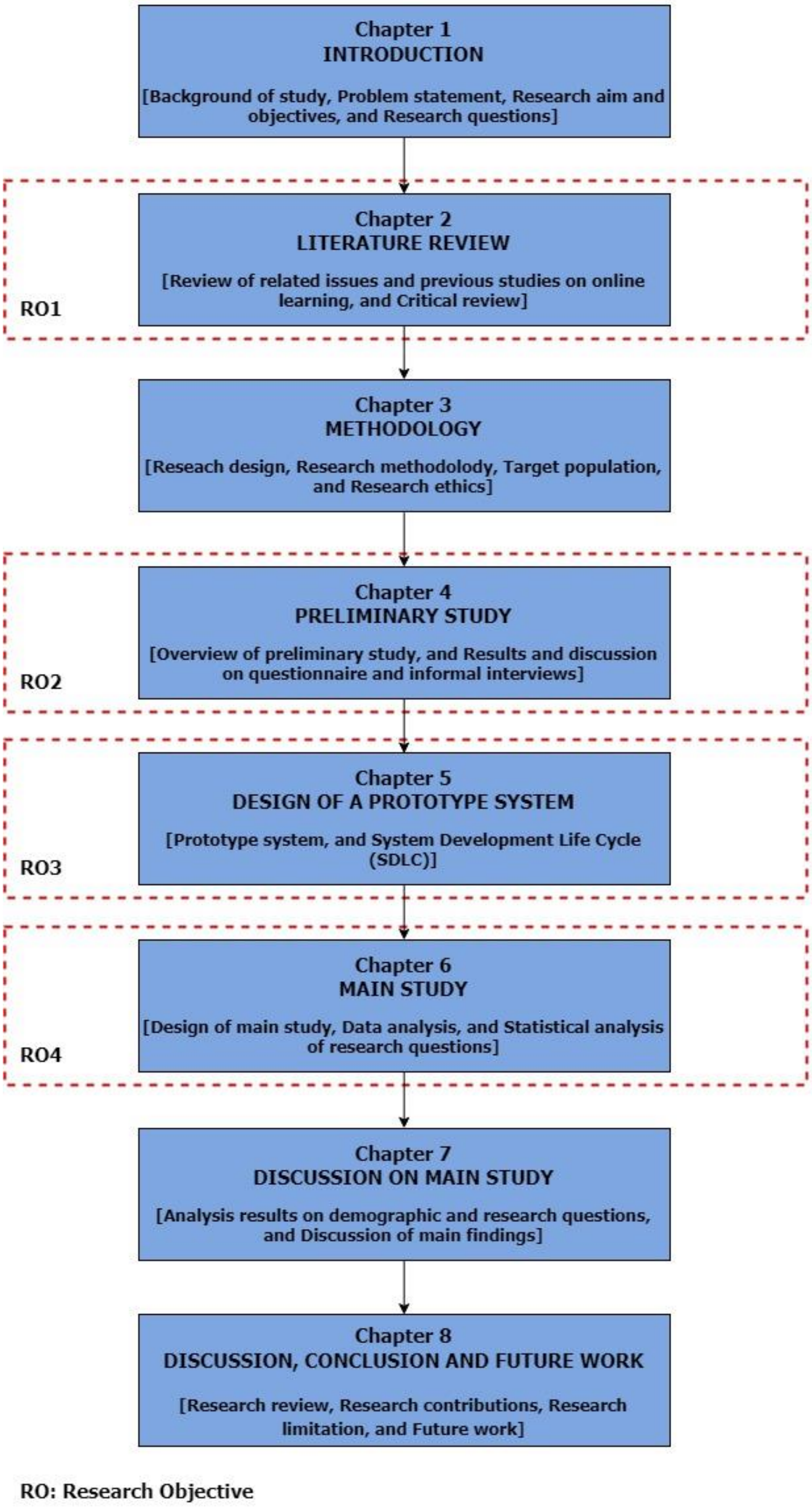


Figure 1.1: Thesis structure.

Chapter 2. Literature Review

2.1 Introduction

This chapter presents a detailed review of the previous literature that will lead to the formation of theoretical foundations for this study. The literature review associated with the study ensures that this research is solidly based on the knowledge and views provided by other researchers. Firstly, this chapter will present and discuss the knowledge of online learning from previous studies, including definitions, technologies and configurations, benefits and drawbacks. Then, the discussion will move to the importance, current trends, challenges and opportunities of online learning in engineering education, particularly in the field of Mechanical Engineering. This chapter will further review the findings of previous studies on online learning. Finally, this chapter will also conclude a summary of the critiques of the previous studies that are being presented. A conceptual model that guides the studies made in this research will also be presented.

2.2 Review on Online Learning

2.2.1 Definition and method

Carliner (2004) refers to online learning as the use of computers and related technologies to acquire and study educational materials as well as interact with tutors, instructors and fellow learners through discussion forums and/or online communication media. Moore and Kearsley, 2012 state that online learning is also referred to as distance learning or e-learning and that this practice entails using communication technology to learn without necessarily being in class or physically interacting with a teacher. Means et al. (2013) defines online learning as the learning that occurs completely over the internet where all instructions on the content that were assessed by the outcome measures were provided through the internet. Several terms have been used to refer the online learning in the research literature which include “online education”, “blended learning”, “computer-based learning”, “web-based learning”, “internet-based learning”, “virtual learning”, “cyber learning” and so forth (Sun and Chen, 2016).

There are various methods of online learning. According to Amit (2015), the most common methods of online learning include self-study, video/audio tapes, simulation, social learning, mobile learning and game-based learning. Bielawski and Metcalf (2003) also list Instructor-Led Training (ILT) as a major method of online learning. They further explain ILT as the use of rich media technologies to perpetuate and advance the typical, traditional classroom-based learning. This, according to Bielawski and Metcalf (2003), is the use of electronic media such as emails, internet resources, chat rooms, media streaming and related media to complement the traditional classroom methods such as the use of textbooks.

2.2.2 Technologies and configurations

Hockly (2012) refers online learning technologies and configurations as Learning Technologies, as the increasing assortment of hardware, platforms, systems, applications and software tools that are employed to administer, author and deliver quality online learning. Hardware is defined by Clements (2006) as the visible and tangible parts of a computer that can mess up and be destroyed if dropped onto the floor. In online learning, the main types of hardware required are the servers and the computer or related communication devices. Brosche and Feavel (2011) also state that software is necessary as a learning management system and to create a common database that connects concurrent users. According to this research, software also helps to create the bandwidth and to establish other server configurations. A bandwidth refers to a rate of data transfer which is the size of data that can be transmitted from one to the other within a certain period of time. Meanwhile, the server configurations is the arrangement of computer programs to provide service to other computer programs or the user.

To maintain the platforms and to ensure efficient feedback for students, support is also significant. A study by Anderson (2008) showed that having an excellent Learning Management System (LMS) is not enough by itself. Similar to the importance of having an excellent public relations department in business, running the system well is also crucial in ensuring that learners who use the system remain motivated and loyal to the online learning platform (Hartnett, 2016).

2.2.3 Benefits and drawbacks

Online Learning offers many benefits to the learner, to the tutor and the school facility and society as a whole. Appana (2008), explores some of these advantages. Investment in online learning, according to this research, enables an increased access to education and study materials due to the convenience that online learning offers to students. This paper further states that this convenience and availability allows the improvement of the quality of education as well as ensuring that students are well prepared and knowledgeable in a constantly changing society. On the other hand, Hickey (2002) states that online learning can be an avenue for profit making for the Learning Management System (LMS) provider as well as the instructors who work online. The research by Cook (2014) also evaluates the value of online learning. Cook suggests that online learning platforms are cheaper ways of learning due to the cost-lowering strategies they employ. For instance, the transport expenses and higher fees that a student would incur if he/she went to school are saved. Pearson (2010) also elaborated on further merits of online learning. In spite of also listing cost saving as one of these benefits, this research stated that online learning enables a student to learn anywhere, a quality offered by the convenience of online learning. Means et al. (2013) mentioned that online learning has become popular as it provides flexible access to the content and instruction at any time and any place. Additionally, Pearson stated that online learning enables a student to access the latest information, as compared to published literature which takes years to complete. This is similar to research by Kear (2011) which explained that online learning is time-saving as well.

Moore and Kearsley (2012) identified the beneficial reasons why the online learning is needed as follows:

- Enhances access to learning and teaching as a matter of equity
- Provides the opportunities to update skills at work
- Increases the cost effectiveness of education resources
- Improves the quality of previous educational structures
- Enhances the capabilities of the education system
- Balances inequality between age groups
- Delivers education campaigns to specific target audiences
- Provides emergency training for the main target areas

- Offers a combination of education with work and family life
- Enhances an international dimension to the educational experiences

Despite the benefits that online learning has, it has several demerits. Everley (2011) explains that the difficulty in identifying a fitting online course that impeccably suits the tastes and preferences of a learner forms one of the largest limitations of online learning. Mirikitani and Nikolaev (2010) on the other hand, found that the high costs of establishing the Learning Management System (LMS) is a major drawback of this learning method. According to this research, many resources are used to create and establish the software as well as to compute the learning algorithms. Since online learning involves very little supervision for learners, Journell (2012) found that students may underutilize the online facilities during an online course, therefore, leading to little academic development. This, in turn, causes poor academic performance.

Hartshorne et al. (2013) also explored the pitfalls of online learning. One of the pitfalls they explored is the inconvenience and unsuitability of online learning to classes of large numbers. Managing many students using online methods is very difficult according to this study. Moreover, Hendricks and Bailey (2016), while studying the same limitations, cited the lack of classroom interactions, collaboration and constant follow-up as some of the common drawbacks of online learning as a form of learning. This is closely related to previous stated work of Hartshorne et al. (2013) who listed the poor participation, disconnection of tutors and students and absence of feelings as further limitations of online learning methods.

Another issue is the growth of dropout rates in online courses that may be due to the students who do not recognise the effort, while the organisations are required to succeed in the online learning course (Wandler and Imbriale, 2017). Lee and Choi (2011) point out that the obvious reason for the dropout rates in online courses is due to the lack of self-regulated learner capabilities. However, the students on online learning courses are able to struggle with the need to become proactive, independent and reflective with the absence of traditional learning courses (Shea, 2017). In a study conducted by Miller and Shih (1999), it was reported that the college of agriculture teaching faculty considered off-campus distance education courses to be less rigid than the traditional on-campus courses.

2.3 Review on Online Learning in Mechanical Engineering Education

2.3.1 Importance of online learning

Online learning has been found to be crucial in almost all levels of study and disciplines, including mechanical engineering. According to Rasul (2012), this importance is derived from the numerous advantages that online learning has been found to offer learners, trainers, education facilities and society in general. One important aspect of online learning is that it enables the enhancement of a student's understanding of mechanical engineering as a course and its components (Inoue, 2007). This is made possible when a student sets out to study the course independent of tutors, therefore enhancing the learner's understanding (Palloff and Pratt, 2003). Consequently, a student's learning is assisted by this personal and independent indulgence.

Online learning also offers mechanical students a new, unique and different studying environment that helps to enhance the student's professional skills such as problem-solving (Rasul, 2012). Online learning also enables a student to develop his or her flexibility in the way he or she handles challenges. According to Inoue (2007), this skill is developed since online learning is uniquely personalized, therefore requiring a student to solve the problems presented to him or her independently. This environment may, therefore, enable the training of a qualified and self-reliant engineer upon completion of the course.

Most importantly, online learning equips a learner with the engineering skills to increase the design productivity by ensuring that production takes place thoroughly (Inoue, 2007). Rasul (2012) states that the final designed product is made appropriate by the engineer if he or she is keen on the identification and removal of errors, reduction of waste, underutilization of resources or misuse of energy. These mechanical engineering skills can be gained through training via online learning as well as learning in lecture rooms.

2.3.2 Current trends of online learning

Online learning has become one of the fastest growing trends in educational use of technology (Means et al., 2013). Learning Management Systems (LMS) are becoming more sophisticated with the day-to-day improvements in technology. Consequently, there are many emerging trends in online learning. Such trends include gamification, mobile learning, competency-based training, video-based training and big data (Roth, 2016). Mobile learning is being used by companies that want to ensure that their employees can access their resources from anywhere. Video-based training involves using videos during learning while competency-based learning involves the mapping of employees' careers in a bid to make their careers more successful. Gamification, on the other hand, involves offering workers gaming services during their breaks after hectic activities (Pande et al., 2016). Hence, gamification is a process of integrating the game mechanics to something existing in order to motivate participation, engagement, loyalty and encourage actions towards positive feedback (Guta, 2017). Big data, in term of the online learning or eLearning industry, is the data generated or created by students when they undergo the online learning courses (Pappas, 2014). Additionally, the use of web blogs and other user-friendly course management systems such as Blackboard and Moodle, have been widespread with the benefits of creating teacher-student environments as well as providing an easy and faster way for teachers to update their teaching contents without the help of system programmers (Anderson, 2008).

2.3.3 Challenges of online learning in Mechanical Engineering education

One of the greatest challenges that studying mechanical engineering online presents is the absence of the platform to conduct practicals, workshops, seminars and laboratory experiments (Thomson, 2011). According to a similar study by Morris (2015), this phenomenon is because online learning is home-based, and many students cannot afford to have their home-based labs or even conduct many of the necessary experiments at home. Thus, students who study engineering and many of the Science, Technology, Engineering, and Mathematics (STEM) courses through online platforms have these disadvantages as they learn using school-based systems. A general belief is that online learning is effective for students in full-time work, who strive to balance their commitments towards their jobs with those towards their education (Kim et al, 2005).

Research by Whiteside et al. (2017) observed that lack of teacher-student interaction is also a major challenge facing online engineering education. Mechanical engineering is amongst the most demanding courses in institutions of higher learning, meaning that students need their instructors' guidance more frequently than students on social sciences courses. However, online learning does not offer this chance, and it may take longer to give feedback to learners' queries. Similarly, Thomson (2011) stated that the technology is often faced with hitches which may impair learning and may be very frustrating.

Hartshorne et al. (2013), on the other hand, stated that since mechanical engineering has a large number of students, online learning is not the best since managing these learners is a difficult task. Nevertheless, computing technology still plays an important role in improving the teaching and learning methodology in the field of mechanical engineering (Hmelo et al., 1995; Cockman, 1998).

2.3.4 The opportunities for online learning in engineering education

There are several strategies that both learners and providers of online learning can use to make it more effective within the engineering education perspective. Thomson (2011) suggested that creating and maintaining an effective course site would be crucial to provide good support to learners as well as to provide timely feedback. This would ensure that learners of engineering, who are usually rushing to beat time deadlines, do not suffer delays from a malfunctioning site. Fandl and Smith (2014) recommend that it is crucial for instructors and online learners to maintain a close communication so that queries and feedback are offered smoothly and efficiently. This study stated that this close relationship ensures excellent performance for the learners.

Research by Palloff and Pratt (2007) recommends that personalization of the online learning process could be crucial in improving the quality of the learning process and improving the students' experience. This is because the course instructor can understand each of his/her student's strengths and weaknesses, therefore, improving the quality of service provided. Thomson (2011) also implies that this can be achieved by ensuring a prompt and frequent pattern that is motivating and positive enough to invoke proactivity and responsiveness from the online students.

2.4 Review on Previous Studies Related to Online Learning

Many earlier research studies have found that online learning is not significantly different from traditional classroom instruction in terms of learning outcomes (Cavanaugh, 2001; Machtmes and Asher, 2000; Zhao et al., 2005). However, according to a study by Means et al., (2013), students using online learning performed better than those in traditional face to face classes. They suggested that when comparing the online and traditional learning courses, student learning outcomes may be influenced by several factors, including the setting within which they are assessed (place and time) and the nature of the content such as subject area and type of learning.

A variety of learning environments have been developed to enhance the effectiveness of teaching and learning. In a study by Abdulrasool et al. (2010), the attitudes of teachers and students were analysed towards using the computer assisted instructions with the traditional teaching and learning methods for modules in mechanical engineering subject areas. This study found that a blended learning system consists of the integration of traditional teaching techniques and computers as an instructional medium has obtained better acceptance among teachers and students. Additionally, this study also concluded that the process of teaching and learning in the field of mechanical engineering subjects has also become more effective.

Similarly, a previous study by Deliktas (2008) stated that the use of computer technology as a teaching and learning approach helps to enhance the understanding of students and produce a convenient way of teaching. This study aimed to evaluate students' perceptions of learning modules of engineering mechanics using computer technology. Nevertheless, the technology-based learning methods cannot replace the traditional learning entirely but can be used significantly as support materials to enhance the students from lower order thinking to higher levels (Deliktas, 2008; Garland and Noyes, 2005). Ni (2013) also studied the effectiveness of online courses and compared them with traditional learning in terms of the interaction and performance of students. It was found that the students who are less likely to be active in the classroom setting can use online interaction to improve their learning.

A study by Spiceland and Hawkins (2002) explored the impact of learning in asynchronous learning courses as compared to traditional learning in terms of the student perceptions. As a result of this study, the learning outcomes with the positive attitude of students has shown results consistent with previous research. Figure 2.1 indicates that most students responded positively regarding whether they would take another online computer-assisted course. It was also found that mature students felt confident with and performed better when using online learning courses. Thus, there was no significant difference in learning performance. Additionally, this study concluded that the active learning formats in online learning enable students to enhance their work in their own time and at locations which they can control.

Question	Mean*	T-Value**
Gain new skills	3.88	7.63
Develop writing skills	3.68	5.63
Meet course objectives	3.57	5.09
Learn the material	3.34	2.96
Motivated to complete the assignments	3.65	4.75
Used the internet regularly	4.18	9.72
Would take another online computer-assisted course	4.32	11.59
Feel use of the internet is effective learning tool	4.40	16.59

*5 = fully agree; 1 = fully disagree

** = the response is significant at p = 0.05

Figure 2.1: Learning outcomes (Spiceland and Hawkins, 2002).

Obviously, students learn in various ways, but problems arise when the methods of teaching are often varied. Mismatches happen between learning and teaching styles in engineering education (Felder, 1988). Koh and Chua (2012) analysed the type of learning styles among mechanical engineering students from three different institutions (INTI Internatioanl University, TARC Tunku Abdul Rahman College and NUC Nilai University College) in Malaysia. The basic learning styles involved in the study were categorised into visual (V), auditory (A), kinesthetic (K), or combination of any two or three of these basic learning styles. As a result, this study identified that the majority of mechanical students from the three institutions had visual learning styles where learning is primarily based on “looking” as can be seen in Figure 2.2. However, online learning courses should be able to assist all types of learners (Zapalska and Brozik, 2006). Learners need to be exposed to various learning experiences so they can become more versatile online learners. Zapalska and Brozik (2006) also stated that the appropriate course design in online education can produce the ideal learning experiences for all types of learners.

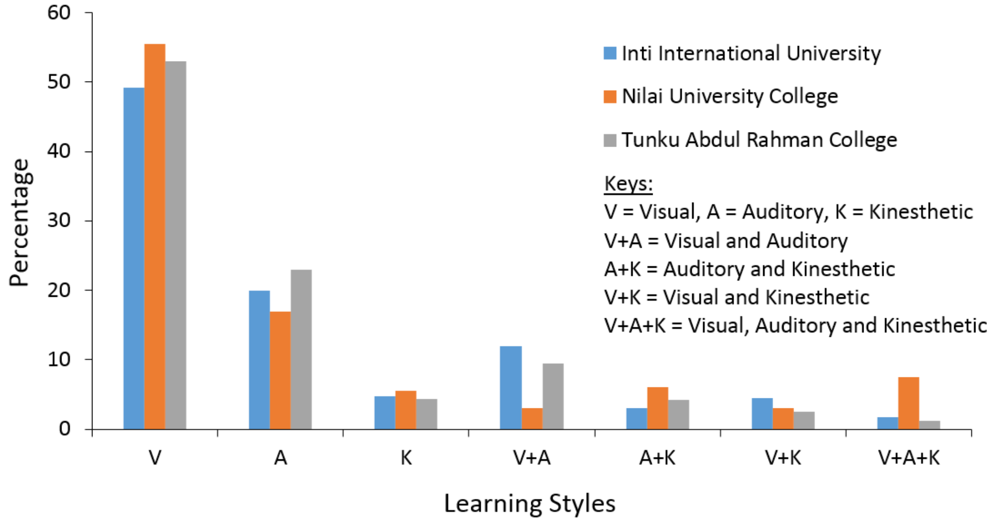


Figure 2.2: Comparison of the learning styles among mechanical students in three different institutions (Koh and Chua, 2012).

Evidently, the greatest motivation for online learners is that this practice offers appropriateness and accessibility by minimizing the distance that learners have to cover (Anderson, 2008). Kelly (2012) suggests that it is crucial to understand what propels online learners to seek these services in every course. It was proposed that naturally, learners love to engage in functions that are essential in enhancing their feelings of self-achievement and personal development. Hartnett et al. (2011) explained that the sense of motivation directly depended on the relative stability and personal characters of students. This research further stated that some online learners are intrinsically motivated while others depend on external motivational factors to propel them.

Similarly, Kim and Frick (2011) studied the changes that happen to a learner's motivation when they are studying online. While past research pinpointed lack of both time and motivation as the primary causes of changes in online settings, this paper specifically found out that the learners' age, competence, perceived relevance and familiarity with technology were the main factors that affected drastic changes in motivation. Since it is crucial for online tutors and instructors to keep their learners motivated, researchers have tried to explore how best to keep learners motivated.

Kelly (2012), explained that tutors needed to make learners feel empowered, useful, successful and interested. Similarly, online instructors are advised to give timely feedback on queries posted by their students, establish online discussion forums and maintain constant and relevant communication with their learners to keep them motivated (Morrison, 2012).Another study by Lee (2014) stated that it is crucial to investigate factors that related to the level of student satisfaction for online learning in order to boost student learning. It was found that the level of student satisfaction is associated with the up-to-date knowledge of the teaching on the teaching materials as well as clear instructions on the assignments and positive feedback. Figure 2.3 shows the conceptual model used in this study is based on the works by Piccoli et al. (2001) which consists of both human and design factors to lead to effective learning. Moreover, Ku et al. (2011) reported that the graduate students were less satisfied with online learning as they did not have the skills to use the technology. Nuangchalerm et al. (2011) also discovered that the student learning experiences were less effective when using online learning as the students had difficulty in contacting the technical assistance.

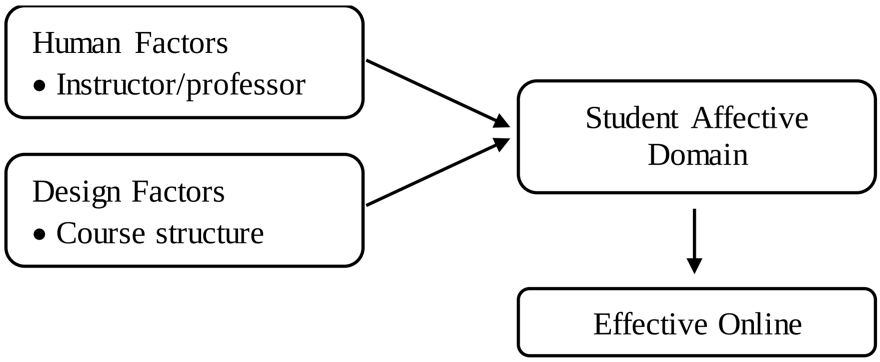


Figure 2.3: Conceptual model suggested by Piccoli et al. (2001).

Research by Karr et al. (2003) reported that students performed better on the analytical part of engineering mathematics using the online methods. However this study also found that there was little effect on the level of student performance between the traditional and online methods. This was because the students had chosen their learning methods based on their own preferences. On the other hand, Gurbuz and Birgin (2012) found that computer-assisted teaching was significantly more effective than the traditional techniques when remedying students' misconceptions.

In this study, computer-assisted teaching (CAT) was developed to rectify the misconceptions of students in the case of the concept of probability in mathematics. As shown in Figure 2.4, one of the analyses of score data obtained in the study indicated the mean significant of 0.446 with $p < 0.05$ which indicating the students in experimental groups benefited significantly from CAT than those in the control groups.

A comparison of post-test scores of groups on misconceptions related to the concept of equiprobability using ANCOVA.

Variable	Group	M^a	Std. error	Mean difference	*df*	*F*	*p*	Partial eta squared (η^2)
Equiprobability (E)	Experimental	2.506	0.131	0.446	1-34	5.915	0.020	0.148
	Control	2.060	0.127					

M^a : Estimated marginal means for post-test, Std. error : Standard error, *df* : degree(s) of freedom, *F* : F-statistics variable, *p* : probability value, Partial eta squared (η^2) : Default effect size measure

Figure 2.4: One of the data analyses that was obtained in the study conducted by Gurbuz and Birgin (2012).

Garland and Noyes (2005) commented that confidence in using ICT can lead to a higher positive attitude towards computers, and hence learning and related activities can also be enhanced. It was found in their study that student attitudes and confidence towards books and computer learning as learning tools varied significantly across the four different cohorts of school pupils, undergraduates, mature students (full-time) and mature students (distance learners) as shown in Figure 2.5. In addition, it was found that the confidence to learn from computers seems to be a better measure based on the attitudes toward computers and learning in education.

Wu et al. (2011) reported that online interaction via videoconferencing for English as a Foreign Language (EFL) could improve students' motivation, confidence and ability. Figure 2.6 shows the basic conceptual model developed in this study, where the arrow directions show the structural equation modelling (SEM) path and the thickness of the arrow indicates the relatively significant correlations. In this study, motivation is the indirect factor that influenced the ability and confidence of the students. It was also suggested that to enhance these three learning variables, the EFL instructors should involve formal and informal interaction with scenarios that are authentic, frequent and enjoyable. SEM is general statistical modelling technique used to represent the relationships between factor analysis and regression or path analysis (Hox and Bechger, 1998).

Attitude scores for books and computer, by cohort

	School pupils	*Level 1 undergraduates*	*Mature students (full-time)*	*Mature students (distance learners)*
Book attitude scores	58.98 (9.91)	54.55 (5.79)	59.44 (9.67)	41.46 (6.43)
Computer attitude scores	57.67 (6.26)	55.10 (5.53)	57.71 (8.43)	50.58 (6.26)

Computer confidence ratings, by cohort (means with standard deviation in parenthesis)

	School pupils	*Level 1 undergraduates*	*Mature students (full-time)*	*Mature students (distance learners)*
Confidence for general computer use	7.64 (1.71)	7.42 (1.55)	6.17 (2.66)	8.06 (1.55)
Confidence for learning from computers	7.05 (1.71)	7.15 (1.45)	5.70 (2.58)	6.89 (1.90)
Confidence for learning from books	7.98 (1.69)	8.45 (1.29)	8.56 (1.41)	8.77 (1.27)

Figure 2.5: Attitude scores and computer confidence ratings (Garland and Noyes, 2005).

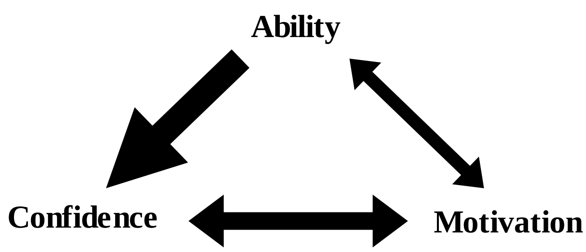


Figure 2.6: SEM path and degrees of relative significant correlation in learning (The thickness of arrow indicates the relatively significant correlations) (Wu et al., 2011).

Another study was concerned with the participation in online discussions that can enhance the students' learning and provide a virtual support environment. Davies and Graff (2005) revealed that active online interactions did not show significant improvements in student performance but less interactive students often failed because they felt depressed and isolated. Additionally, online courses often replaced the interactions in the classroom with the discussion boards, emails, synchronous chats and frequent electronic bulletin boards (Ni, 2013).

According to Nguyen (2015), researchers and educators are interested in the use of online learning in improving the student learning outcomes as well as resisting the reduction in resources, especially in higher education. Hence, his study reviewed the evidence of online learning effectiveness by categorising the findings and challenges into positive, negative, mixed and null findings. Table 2.1 shows a summary of the findings and challenges of online learning as compared to traditional learning.

Raspopovic and Jankulovic (2017) studied the quality of e-learning system through analysis of student satisfaction and the use of learning materials. This study aimed to determine the factors that influence the satisfaction of traditional and online students using the similar e-learning system. The analysis of three dimensions: use, user satisfaction and net benefits, have been conducted to analyse the use of learning materials and the overall satisfaction. From this study, the researchers concluded that the collaborative systems can be considered as supporting the students to build trust and teamwork in an online learning environment. In addition, they also proposed for future work that the model for the performance evaluation of student satisfaction for both traditional and online students should be grouped into four dimension groups including Institutional support, Instructors support, Personal or Interpersonal support, and Learning or Academic support.

Another recent study by Al-Samarraie et al. (2017) was to identify the key factors that affects the continuance satisfaction of instructors and students on using e-learning in the context of higher education. Hence, the researchers have identified 11 core factors from a systematic review that includes information quality, attitude, attainment value, intrinsic value, utility value, confirmation, system quality, usefulness, ease of use, task-technology fit, and social influence. The fuzzy decision making trial and evaluation laboratory (DEMATEL) approach was applied to study the data collected. An interview survey method was used to determine the factors that impact e-learning continuance. As a result, the information quality was the most significant effect factor that influences the e-learning continuance satisfaction of students and instructors. Inversely, both social influence and ease of use were being the least significant effect factors. Furthermore, this study has suggested for future work to the demographic backgrounds of different user groups and other modelling approaches to gather possible new factors related to e-learning continuance satisfaction.

Table 2.1: A summary list of findings from previous studies (Nguyen, 2015).

Findings	Outcomes
Positive	• Greatly satisfied with learning regardless of student background characteristics (Navarro and Shoemaker, 2000) • Stronger sense of community among students (Rovai and Jordan, 2004) • Reduction in withdrawal or failure (Riffell and Sibley, 2005) • Improved learning as measured by test scores (Harmon and Lambrinos, 2006) • Performed modestly better in learning (Means et al., 2010) • Improved task engagement and decreased attrition (Deterding et al., 2011; Huotari and Hamari, 2012; Kapp, 2012) • Improved perception of learning and motivation to learn (Feeley and Parris, 2012) • Learning improvement and cost saving (Bowen et al., 2012) • Positive effect on the quantity of students' contributions (Denny, 2013) • Student engagement with class materials (Nguyen, 2015)
Negative	• Differences in time devoted to class engagement resulting in differential outcome (Hiltz et al., 2000) • Significantly worse on tests in comparing learning outcomes in a microeconomics course (Brown and Liedholm, 2002) • Gender is a moderating variable for student learning outcomes (Figlio et al., 2010) • External validity treats: volunteer and grade incentive (Figlio et al., 2010)
Mixed	• Considerable diversity in the way students used the course materials (Brown and Liedholm, 2004) • Significantly more effective or less effective than face-to-face instruction (Lack, 2013) • Ubiquitous threat of selection bias and endogeneity of learning environment choice; Achievement difference are potentially biased to preference of learning which depend on the characteristics of the students; Certain groups or students benefit from online learning while others benefit from traditional learning (Nguyen, 2015)
Null	• No evidence to support the claim that media influence learning (Clark, 1994) • No significant difference in learning outcome - poor methodology, lack of control groups, random assignment; experimental controls for confounding variables and less discussion of attrition (Russell, 1999) • No significant difference in achievement, attitude and retention outcomes – asynchronous activities should be done at each persons' convenience (Bernard et al., 2004) • Overall mean effect size was close to zero (Zhao et al., 2005) • No significant difference in the learning of clinical skills (McCutcheon et al., 2015)

2.5 Critical Review

A personal summary of critiques of the previous studies presented in previous sections is as below:

The impact of the learning environment on learning outcomes is always explored by researchers of education. From the findings, it is clear that online learning has a positive impact on mechanical engineering and its related courses. Online learning can reap many benefits when learners are cooperative, self-driven and well-motivated. This, as discussed, is because online learning is home-based and usually takes place with very little supervision. The use of the internet to deliver online education has grown rapidly with the evidence of previous works that have been explored and discussed in this chapter. Additionally, online learning was found to have numerous benefits that outweigh its drawbacks. Designing an effective Learning Management Systems (LMS) is key to eliminating most of the drawbacks that accompany online learning.

For mechanical engineering, setting days that a learner can arrange to physically participate in practical and workshops could eliminate this problem. It is evident that an independent and self-driven learner can perform as exemplary as one in the classroom. Furthermore, online learning courses should able to assist all types of learners (Zapalska and Brozik, 2006). Therefore the learners need to be exposed to various learning experiences so they can become more versatile online learners.

Most previous studies found no significant difference in terms of student learning outcomes when comparing online learning and traditional face to face methods. The experimental tests carried out were mostly based on the same cohort of students and individual factors such as satisfaction, motivation, performance, confidence, and perceptions. Based on previous findings, a study on the relationship between satisfaction, performance and self-confidence of students in using online learning and compared to traditional learning, is felt to be necessary and forms the basis of the research described in this thesis. Future studies need to be designed to acquire students' perspectives, especially for those who are new to computer-based learning (Sun and Chen, 2016).

According to Clark (1994) and Bernard et al. (2004), there was no evidence that online learning is superior as a medium for learning. However, the idea of proposing more student-centred courses using online learning can perhaps improve the ability of students to work and think independently and prepare themselves for their future work environment. Therefore, with the emerging trends in online learning, it is motivating to investigate whether the positive attributes of online learning will continue to increase, especially in the perspective of higher education in mechanical engineering.

A conceptual model that has been proposed and developed to guide the main findings in this research is shown in Figure 2.7. The model shows the relationship between the three main factors, including satisfaction, performance and self-confidence of the student (indicated with arrows), which correlate to both learning experiences and learning outcomes. This study has assumed that the combination of these three factors will affect both learning experience and learning outcomes of students.

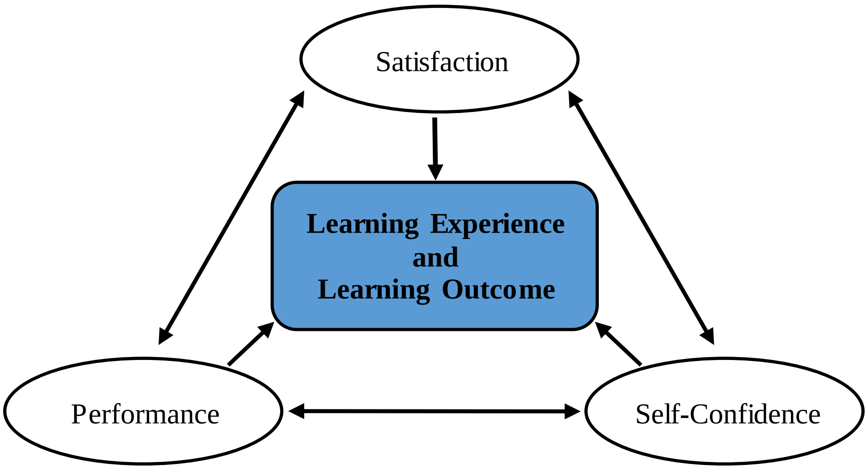


Figure 2.7: A conceptual model.

2.6 Summary

This chapter provided an overview of previous literature relating to online learning in general and in engineering education, especially in mechanical engineering. It started by reviewing the relevant literature associated with the related knowledge and findings in online learning. Then, this chapter continued with the discussion of previous studies on online learning in the field of engineering education. This chapter has helped to identify the research gaps and a conceptual model to guide the development of the research has also been proposed and discussed. A conceptual model was also discussed that illustrates the relationship between the three main factors, including satisfaction, performance and self-confidence of the student.

The next chapter will present the development of the methodology of this study. It will provide a detailed description of how the research was conducted and rationale for any decisions taken.

Chapter 3. Methodology

3.1 Introduction

This chapter presents a description of the research design and research methodology used in this research for ensuring the attainment of the research objectives and the reliability of final results. A research methodology was developed through different elements of research design and research methods that includes: philosophy, approach, strategy, choice of methods, time horizons, and techniques for data collection and data analysis. A research onion diagram was used to illustrate these elements, and the justifications for selected elements are also clarified. An overview of the stages for conducting this research is also presented in this chapter. Finally, it concludes with a discussion of research ethics concerning this research.

3.2 Research Design

Kumar (1999) defined a research design as a plan and strategy of investigation that is adopted by the researcher to answer the research questions validly, objectively, and economically. According to Saunders et al. (2009), a research design is an overall plan of how research will proceed to solve the research questions that have been raised. It provides the researcher with a clear view of the strategies and procedures to be applied in gaining the answer to the research question. In addition, research designs can help the researchers to make an informed decision about the research methodology (Saunders et al., 2009). Therefore the selection of research design needs to be done appropriately to achieve the valid and reliable findings.

In order to identify an appropriate research design for this research, two important aspects were taken into consideration that include: type of research and study designs. These aspects were chosen and clarified in accordance with an overview of the four stages of this research. The overall methodology will be discussed in the following section.

3.2.1 Type of research

According to Kumar (1999), the types of research can be defined on the basis of three different perspectives:

1. Applications of the findings of the study

   A research from the perspective of the application of its finding can be approached by two types of research: applied research and basic research (Neville, 2007). Applied research is designed for finding solutions to immediate problems of specific situations. Alternatively, basic research is a purely theoretical study to expand knowledge and understanding of certain phenomena as well as aiming for the generalisation and formulation of theory.

2. Objectives of the study

   Kumar (1999) classified four different types of research from the perspective of objectives:

   i. Descriptive research: refers to describing the prevalent aspects involving people, community, a situation, phenomenon or problem.
   ii. Correlational research: refers to exploring a relationship or association between two or more aspects of a phenomenon or situation.
   iii. Explanatory research: refers to explaining the formation of an interdependence that exists between two variables of a phenomenon or situation.
   iv. Exploratory research: refers to investigating the feasibility of performing a particular study of which the researcher has little or no prior knowledge, and known as a pilot study or feasibility study.

3. Mode of enquiry used in conducting the study

   From the perspective of the enquiry mode, a research study can be classified as quantitative research or qualitative research (Kumar, 1999). Quantitative research is a structured approach of enquiry used to quantify the variation in a situation, problem or issue. In a quantitative study, statistics are used to quantify the magnitude of relationships.

In contrast, qualitative research is an unstructured approach of enquiry that describes a situation, problem or issue. The analysis in qualitative research involves the formation of variations in situations or problems in the form of a description and without quantifying them. The selection between quantitative and qualitative research depends on the purpose of the researcher is enquiry and the intended use of the findings.

3.2.2 Study designs

An important requirement of research design is to determine the suitable study designs to use in quantitative or qualitative research types (Kumar, 1999). Some study designs that are commonly used in quantitative research can be categorised from the three different perspectives listed in Table 3.1. Study designs in each perspective are mutually exclusive, therefore only one type of study design from each perspective will be used in a research.

Table 3.1: Study designs in quantitative research based on the three perspectives (adapted from (Kumar, 1999)).

Perspectives	Study designs
Number of contacts with the population being studied	• Cross-sectional studies • Before-and-after studies • Longitudinal studies
Reference period (time-frame)	• Retrospective • Prospective • Retrospective-prospective
Nature of the investigation	• Experimental • Non-experimental • Quasi or semi-experimental

3.2.3 Overview of research stages

In achieving the research objectives, the research comprises four stages as shown in Figure 3.1.

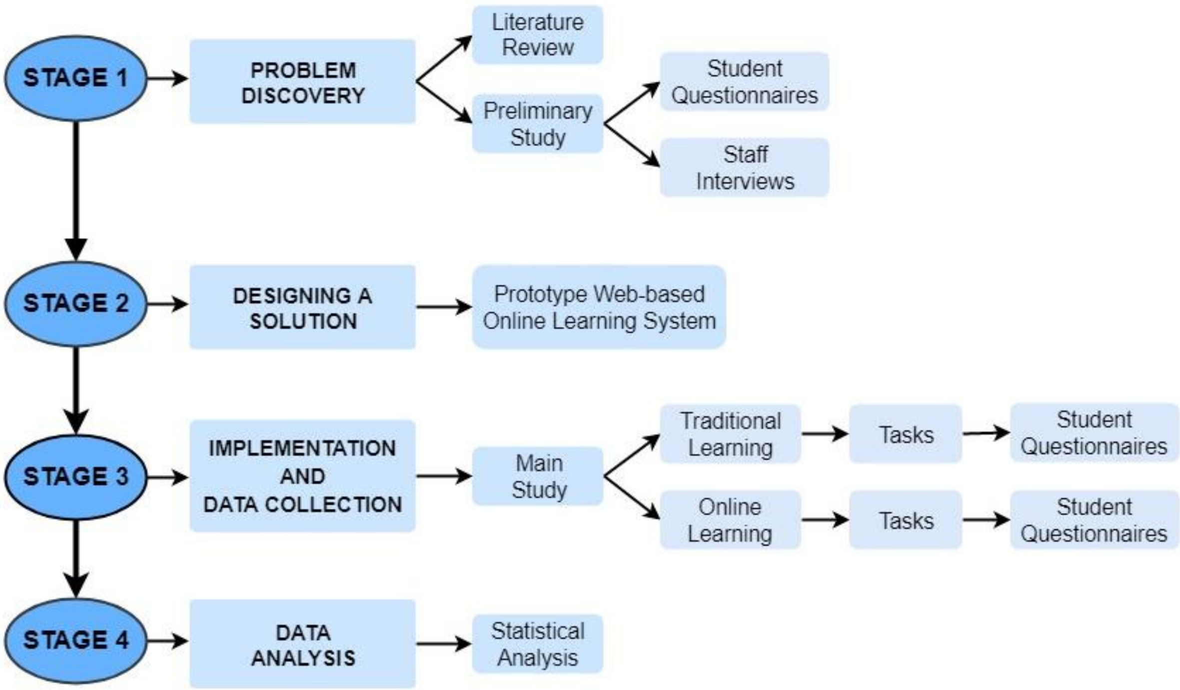


Figure 3.1: Research stages.

Stage 1 is the identification of research gaps and research problems involving: review of relevant literatures and a preliminary study. The literature reviews involved a comprehensive study of journals, theses, reports, books, and websites that highlight significant subjects in online learning in the field of mechanical engineering education. A preliminary study was carried out to explore the experiences and perspectives of students and teachers in the learning and teaching the Mechanical Engineering Design module. The study was conducted at the Universiti Teknologi Brunei (UTB) using two data collection techniques.

A total of 95 questionnaires were distributed to the undergraduates and diploma students of the mechanical engineering programme, and informal interviews were carried out with ten members of mechanical engineering staff. The data obtained from questionnaires and interviews were coded and placed in themes. The analysis has been conducted to achieve findings which can address the research problems that contributed to the design of a prototype system. The details of the preliminary study are further explained in Chapter 4.

Stage 2 involves the process of designing and developing a prototype system as a solution tool to solve the research problems. Consequently, the online web-based learning prototype system for learning the Mechanical Engineering Design module was designed. The prototype aimed to provide the participants with realistic feelings and experiences through interaction with the system and to enable them to gain a better understanding of the system (Mall, 2004). Details of the design process of this prototype system are presented in Chapter 5.

Stage 3 is the main study conducted at the Universiti Teknologi Brunei (UTB). The choice of this university is made as access available because it is the researchers' workplace. Two types of learning styles have been used during the investigation including traditional learning and online learning. Questionnaires were distributed to the mechanical engineering students to investigate their views, satisfaction, performance and confidence when attending or using the two learning styles. These students are also required to perform two assigned tasks (simple and complex tasks) using the learning materials provided in the learning sessions. They were asked to complete the hardcopy answer sheets for the two assigned tasks and continue with answering the questionnaires.

Finally, stage 4 is a data analysis that involves the screening, processing and testing of collected data. SPSS version 22.0 statistical software (the reason for choosing is explained in Chapter 5) is used to analyse the results obtained from the main study. This stage also involves the validation and interpretation of the results as well as the discussions on significant findings.

Specifically, the research was focusing on student feedback in attending traditional learning and online learning for mechanical design module. Therefore, with reference to the four research stages, the type of research and study design has been identified and explained in Table 3.2.

Table 3.2: The chosen type of research and study design.

	Perspectives	Chosen	Reasons for choosing
Type of research	On the basis of application of the findings of the study	Applied research	• to discover solution to solve the instant research problems
	On the basis of objectives of the study	Descriptive research	• to describe the prevalent aspects involving people and situation
	On the basis of mode of enquiry used in conduction the study	Quantitative research	• a structure approach of enquiry • statistical analysis to quantify the relationships
Study Design	Number of contacts with the population being studied	Cross-sectional studies	• a one-shot study as only one contact with the participants • to take a cross-section of the participants
	Reference period (time-frame)	Prospective	• prevalence of a problem in the future • to establish the outcome of an event that likely to happen
	Nature of the investigation	Experimental	• cause-and effect relationships • to introduce the intervention to be the cause of change

3.3 Research Methodology

Generally, researchers design their research to answer questions or address problems about a particular phenomenon. It is therefore important to identify appropriate research methodologies in order to achieve the objectives of the research. A research methodology is defined as a systematic way of solving the research problems (Kothari, 2004). According to Saunders et al. (2009), a research methodology involves the theoretical frameworks and the learning of several techniques used in conducting the research, testing, experiments, surveys and critical studies.

Figure 3.2 shows a research onion introduced by Saunders et al. (2009) for illustrating the overall research methodology that includes a series of decisions for research design and data collection techniques. Each layer of the onion is easy to understand and helps the research to progress effectively in identifying appropriate research methodologies. The peeling of these layers is to start from the outermost layer to the innermost layer of the research onion. Each layer illustrates different elements that include: identifying research philosophy, research approach, research strategy, time horizons, and identifying technique and procedure for data collection and analysis.

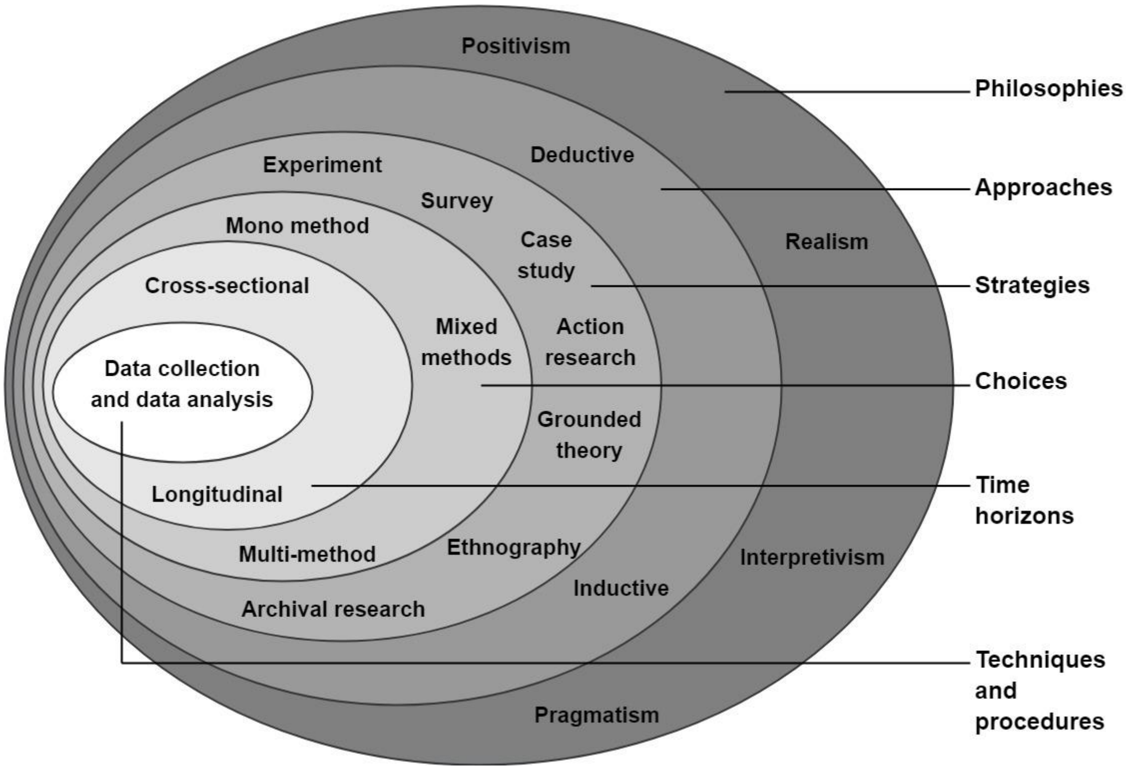


Figure 3.2: Research onion by Saunders et al. (2009).

3.4 Research Onion Framework

A research onion diagram shown in Figure 3.3 was adopted and modified from a research onion by Saunders et al. (2009) to provide a direction for this research. For a better summary of the research methodology applied in this study, an element indicating research type is added as the outermost layer of research onion.

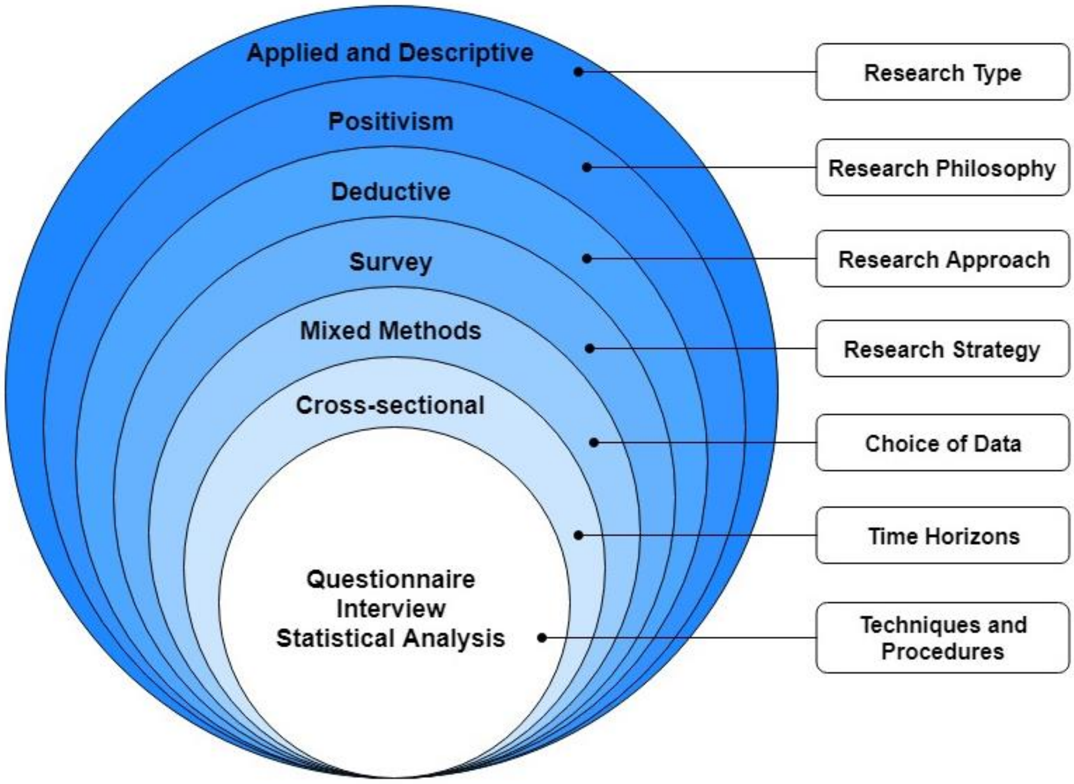


Figure 3.3: Research onion diagram (adopted and modified from Saunders et al. (2009)).

3.4.1 Research philosophy

Research philosophy depends on the way that the researcher thinks about the development of knowledge (Saunders et al., 2009). A research process onion presented in Figure 3.2 was introduced by Saunders et al. (2009) where research philosophy is the first element to be identified in a research study. Creswell (2003) identified the four types of philosophy, including post-positivism, constructivism, participatory and pragmatism. The description of each philosophy and its main elements are presented in Table 3.3. However, Allison et al. (1996) identifies the two types of philosophy: positivism and phenomenalism, that depend on the forms of research used to determine the ways of the world and human behaviour to be viewed and understood. Positivism is based on positive evidence and observable phenomena, where the descriptive laws are created from the consistencies or patterns in behaviour or properties. The forms of research may also depend on certain assumptions or postulates of the consistency of human behaviours as in Table 3.4.

Usually, a measurable evidence obtained in a positivistic research is referred as quantitative data. Sometimes, positivistic may be referred as quantitative, objectivist, experimentalist, scientific or traditionalist (Neville, 2007). In the philosophy of positivism, a role of the researcher is as an objective analyst to analyse the collected data and produce appropriate results to achieve a research aim and objectives (Saunders et al., 2009).

Table 3.3: Four types of philosophy (adapted from Creswell (2003)).

Types	Descriptions	Main Elements
Post-positivism	The study of causes that affect the outcomes; where it initiates with a theory, data collection and then the essential reviews before another test to be carried out.	Determination, reductionistic, empirical observation and measurement, and theory verification.
Constructivism	A process of interaction with humans and interpretation of the specific situations for developing a theory.	Understanding, interaction, social and historical construction and theory formation.
Participatory	Involves the integration between the theory and philosophical views to enable the generation of issues or the people that being studied. The voice of the participants included and acknowledged.	Political agenda, collaboration, issue-oriented and change-oriented.
Pragmatism	The paradigm appears from the behaviours, situations or outcomes. The study can involve the mixed methods using variety procedures of data collection and evaluation.	Significances of actions, problem-centered, and real practice.

Table 3.4: The postulates of positivistic research based on Allison et al. (1996).

Postulate of natural kinds	to assumes that all instances in categories of phenomena exhibit the same properties.
Postulate of constancy	to assumes that phenomena stays the same or change very little or slowly over time.
Postulate of determinism	to assumes that there are an orderliness and regularity of nature. Therefore there is a consistency, in the cause and effect.

Phenomenalism is one that involved the explanation and classification of phenomena (Allison et al., 1996). It does not need the three postulates above as it depends on the perception of every phenomenon that is unique and also the importance of its unique quality. In phenomenological research, the researcher as an observer-oriented to achieve a clear selection of what is being observed and a narrative description obtained from the observation is referred as qualitative. Neville (2007) identifies phenomenalism as qualitative, subjectivist, interpretative or humanistic.

Hence, this research adopted positivism as the researcher desires to maintain minimal interaction with the participants and, aims to explain and predict from the research. In addition, with positivism, the research is only focused on obtaining quantitative results and analyzing these statistically.

3.4.2 Research approach

The research approach refers to the overall orientation of the research, the type of data to be used and the type of methods used for the study. Hence, the research approach, research design and research questions are connected to each other. According to Saunders et al. (2009), two approaches may be utilized for representing the research design more explicitly:

1. *Deductive approach*; is referred to as testing a theory that involves significant characteristics: controls to allow the testing of a hypothesis, operationalise concepts, reductionism to the simplest, and generalization statistically.

2. *Inductive approach*; is referred to as building a theory that involves a better understanding of the nature of the problem, to construct a rigid methodology, concerned with a particular context and only uses a small sample of subjects.

This research implemented the deductive approach as to identify answers to the research questions from the beginning of the research.

3.4.3 Research strategy

It is important to select an appropriate research strategy to lead to answers to particular research questions and the achievement of the research objectives (Saunders et al., 2009). By familiarization with different kinds of strategies, a researcher will be able to identify the types of research questions that are implicit and also to formulate the specific research questions (Allison et al., 1996). Typical strategies used in research studies are presented in Figure 3.4.

A survey method has been preferred in this study and used to collect the required data in the main study. According to Allison et al. (1996), a survey is used to collect the data on the incidence of events in varying situations and environments. It also offers a quantitative description of trends, attitudes, or opinions of populations by studying a sample of that population (Creswell, 2003). The format of a survey includes survey design, population and sample, instrumentation, variable of the study and data analysis.

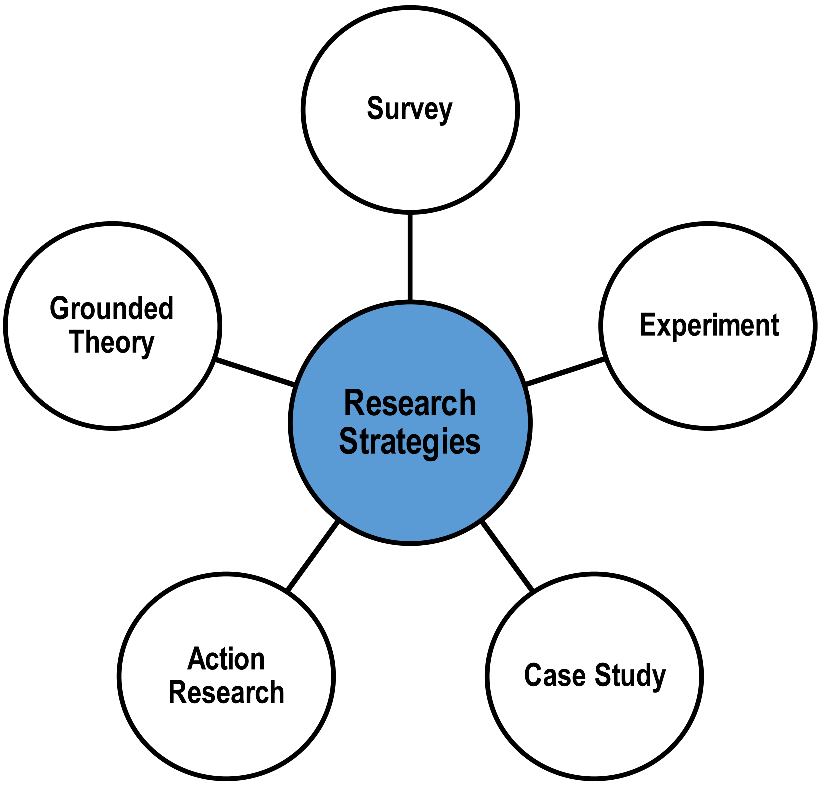


Figure 3.4: Different research strategies have been used in many research studies which include survey, experiment, case study, action research and grounded theory.

3.4.4 Choice of data

Creswell (2003) stated that the three approaches that might contribute in providing a precise direction for the data collection method in research design:

1. *Quantitative approach*; primarily uses a post-positivist or positivist paradigm where the strategies of inquiry use surveys and experiments. The approach involves collecting data using predetermined approaches, closed-ended questions, numeric data, performance data and statistical analysis.

2. *Qualitative approach*; primarily employs a constructivist paradigm, and the strategies of inquiry are narratives, phenomenologies, grounded theory studies, or case studies. The approach involves collecting data using open-ended questions, emerging methods, text and image analysis, and interview data.

3. *Mixed method approach*; uses a pragmatism paradigm and practices the strategies of inquiry by collecting data either sequentially or concurrently to achieve a better understanding of the research problem. It involves collecting data by gathering both predetermined and emerging approaches, open-ended and closed-ended questions, and both quantitative and qualitative data.

In addition, the approaches are combined and applied in research as for instance the combination of both qualitative and quantitative approaches (Neville, 2007). One advantage of performing a mixed-method approach is to draw from the strengths and reduce the weaknesses of both approaches in single research studies as well as across studies (Johnson and Onwuegbuzie, 2004). In fact, a mixed-method approach offers the researchers who desire to overview the methodologists to describe and develop the techniques that are commonly used in practice by them. Therefore, a mixed-method approach was selected as researcher used both quantitative and qualitative information. However, the analysis of the final results was measured quantitatively.

3.4.5 Time horizon

According to Saunders et al. (2009), the two types of time horizons are the cross-sectional and the longitudinal. The cross-sectional time horizon is when collecting the data at a specific time. In comparison, the longitudinal time horizon is when collecting the data repeatedly over a period of time and it is useful for study change and development. This research was considered as a cross-sectional time horizon as it aimed to do studies on some groups of students at one point of time.

3.4.6 Techniques and procedures

The selection of techniques and procedures to obtain quantitative data from the main study involve the data collection method, question type, development of the questionnaire, and data analysis.

3.4.6.1 Data collection

According to Kumar (1999) the information being investigated in research such as the information concerning a situation, issue, phenomenon or group of people, can be gathered using two different approaches: Secondary sources refer to second-hand data, and Primary sources refer to first-hand data. The questionnaire is one type of primary sources that is widely used, as it is less expensive and provides greater anonymity to respondents. Questionnaires are more beneficial than conducting an interview as interviewing is quite a costly and time-consuming method, and the quality of data may depend on the quality of the interviewer and the interaction, and the results may be biased when the interviewer is the researcher (Kumar, 1999 and Blaxter et al., 2001).

The type of questionnaire used in this study was a paper-based questionnaire to increase the chances of a high response rate and the quantitative data was collected. The questionnaires were distributed face to face and collected as soon as participants finished answering. The advantages of having a face to face session are that it offers the participants some time to ask if there are any queries. The difficulty was to set a schedule with the participants as it was quite time-consuming to contact them using the phone. Some of the participants were successfully contacted, but yet they did not show up on their preferred scheduled day.

3.4.6.2 Question type

There are several types of questions that are appropriate for different purposes and types of data. It is crucial to understand the available types of questions as the selection of question type may determine the information that is produced (Brace, 2008). Hence, both closed-ended and open-ended questions were used in the questionnaires for this study. Closed-ended questions offer a quick and easy way for respondents to answer and easier for the researcher to compare and analyse. On the other hand, open-ended questions can obtain unlimited answers, creativity, and self-expression from respondents. However, some disadvantages of open-ended questions are the different degree of answers that might not be relevant and may be difficult to compare and code when performing the statistical analysis and time-consuming.

Moreover, single and multiple indicators are the best operationalization of a variable depending on the number of questions being asked (Friesen, 2010). Usually, multiple indicators are used when a question is too complex and requires more accurate measurements as each indicator will allow the researchers to produce a relevant assessment. Likert scale is one type of the multiple indicators that often consists of a list of opinions which usually spread between 1-strongly disagree, 2-disagree, 3-neutral, 4-agree and 5-strongly agree. The 5-point Likert scale is the most commonly used in many types of research because it is more reliable and valid than other scales that use fewer points (Dawes, 2008). Thus, the 5-point Likert scale questions were also used in the questionnaires for this study.

3.4.6.3 Development of questionnaire

There are two parts in the questionnaire; a consent cover letter and the main body of the questionnaire. In a consent cover letter, the researcher clarifies all the aims and importance of doing the survey and also to assure that the respondent's involvement will be kept confidential and used for research purposes only. Respondents are provided with a full name and e-mail address for any queries or issues in the questionnaire.

For the main body of the questionnaire, there were four separate parts:

1. Participant's general background,
2. Participant's views about attending the learning sessions,
3. Participant's views about solving the assigned tasks, and
4. Participant's satisfaction, performance, and self-confidence.

3.4.6.4 Data analysis

After the survey was completed, the data entry process was performed where they were input and arranged in Microsoft Excel. By using Microsoft Excel, it is more flexible and easier when creating new variables from the existing ones. Once the data were organized according to the necessary categories, they were transferred to a statistical software (SPSS version 22.0). A survey framework used for this study is shown in Figure 3.5. Referring to this framework, the data were tested and analysed according to the testing sequences shown in
Table 3.5 and Table 3.6 respectively.

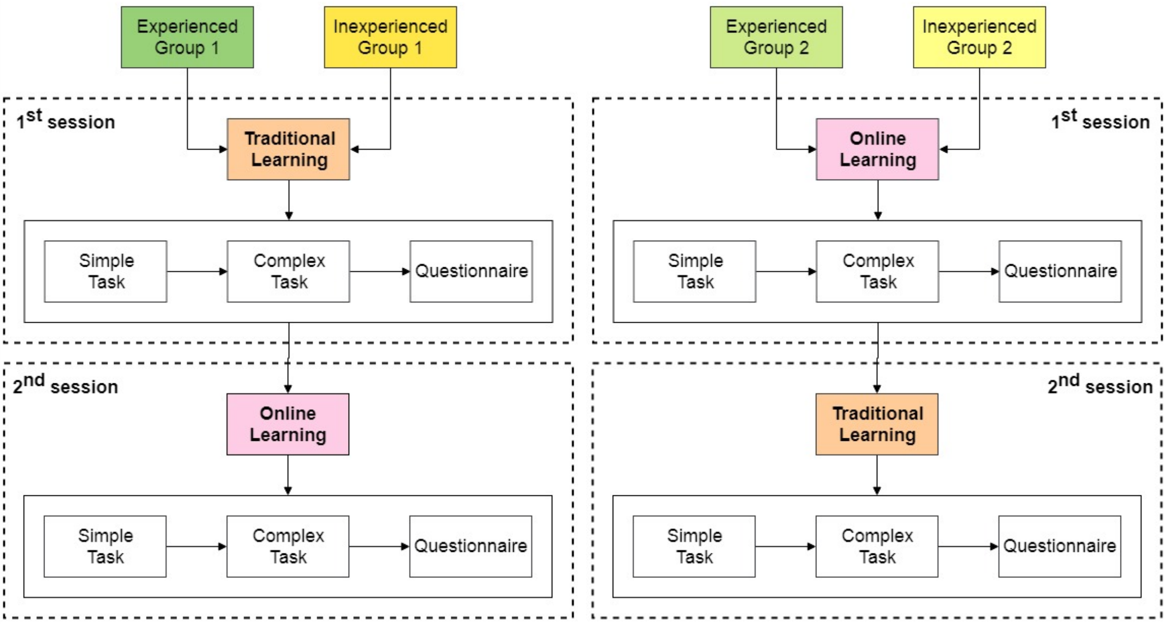


Figure 3.5: The survey framework (see 6.2.1 for explanation of simple and complex tasks).

Table 3.5: The testing sequences for experienced and inexperienced groups.

Experienced		Group 1		Group 2	
		Traditional Learning (1st Session)	Online Learning (2nd Session)	Online Learning (1st Session)	Traditional Learning (2nd Session)
Group 1	Traditional Learning (1st Session)		E1	E5	E3
	Online Learning (2nd Session)	E1		E4	E6
Group 2	Online Learning (1st Session)	E5	E4		E2
	Traditional Learning (2nd Session)	E3	E6	E2	
Inexperienced		**Group 1**		**Group 2**	
		Traditional Learning (1st Session)	Online Learning (2nd Session)	Online Learning (1st Session)	Traditional Learning (2nd Session)
Group 1	Traditional Learning (1st Session)		I1	I5	I3
	Online Learning (2nd Session)	I1		I4	I6
Group 2	Online Learning (1st Session)	I5	I4		I2
	Traditional Learning (2nd Session)	I3	I6	I2	

Note: E = Experienced group, and I = Inexperienced group.

Table 3.6: Testing sequences for traditional learning and online learning (Experienced group against inexperienced group).

<table>
<tr><th colspan="2" rowspan="2">Traditional Learning</th><th colspan="2">1st Session</th><th colspan="2">2nd Session</th></tr>
<tr><th>Experienced Group 1</th><th>Inexperienced Group 1</th><th>Experienced Group 2</th><th>Inexperienced Group 2</th></tr>
<tr><td rowspan="2">1st Session</td><td>Experienced Group 1</td><td></td><td>T1</td><td></td><td>T2</td></tr>
<tr><td>Inexperienced Group 1</td><td>T1</td><td></td><td>T3</td><td></td></tr>
<tr><td rowspan="2">2nd Session</td><td>Experienced Group 2</td><td></td><td>T3</td><td></td><td>T4</td></tr>
<tr><td>Inexperienced Group 2</td><td>T2</td><td></td><td>T4</td><td></td></tr>
<tr><th colspan="2" rowspan="2">Online Learning</th><th colspan="2">2nd Session</th><th colspan="2">1st Session</th></tr>
<tr><th>Experienced Group 1</th><th>Inexperienced Group 1</th><th>Experienced Group 2</th><th>Inexperienced Group 2</th></tr>
<tr><td rowspan="2">2nd Session</td><td>Experienced Group 1</td><td></td><td>O1</td><td></td><td>O2</td></tr>
<tr><td>Inexperienced Group 1</td><td>O1</td><td></td><td>O3</td><td></td></tr>
<tr><td rowspan="2">1st Session</td><td>Experienced Group 2</td><td></td><td>O3</td><td></td><td>O4</td></tr>
<tr><td>Inexperienced Group 2</td><td>O2</td><td></td><td>O4</td><td></td></tr>
</table>

Note: T = Traditional Learning, and O = Online Learning.

Some of the outputs were then arranged and presented using a descriptive data analysis method, so the data were easier to understand, interpret and report meaningfully. The selection of statistical data analysis was made with several discussions with statistical staffs from the Mathematics Learning Support Centre (MLSC) at Loughborough University. Thus, three types of data analysis were conducted to analyse the results as shown in Table 3.7 and Table 3.8. A Mann-Whitney U test is a non-parametric test for ordinal data having a set of opinions or categories with an ordered sequence (5-Likert points). This test was developed by Henry B. Mann and D. R. Whitney in 1947, and two assumptions that need to be followed when using the test are that the samples are independent, and the level data is ordinal (Black, 2012). In a Mann-Whitney U test, the difference between the two groups is specified using a p-value. If the p-value is less than 0.05, then it indicates that there is a significant difference between the two groups being compared.

The second statistical test was a Chi-Square test. This test studies the differences between the categorical variables. A Chi-Square test is usually used when comparing the frequency of cases that are found in one variable in two or more unrelated samples of another variable (Bryman and Cramer, 2001). When using a Chi-Square test, it is important to check; the degrees of freedom (df), the test statistic (x^2), the expected counts (must >5.0), and p-value (must <0.05). The null hypothesis will be rejected, and a relationship should be assumed to exist if the p-value is less than 0.05. In this study, a Chi-Square test of 2x2 grids was used, and the Pearson Chi-Square results were checked and presented as the data were analysed using SPSS version 22.0.

Finally, a statistical analysis of Paired Sample T-test was conducted. A Paired Sample T-test is used to compare the means of the same participants in two conditions at a time (Bryman and Cramer, 2001). Additionally, a Paired Sample T-test is most significant when comparing two samples that are correlated and is commonly used in 'before-after' studies. Therefore, this test was used to determine the differences in task completion times between experienced and inexperienced participants. A further detail of each statistical test, including data type, level of measurement and interpretation of output, is provided in Table 3.8. Additionally, Table 3.9 lists the mapping of research questions against the type of statistical analyses used in this study.

Table 3.7: The application of statistical data analysis.

Survey	Dependent Variables	Question types	Analyse Test
Questionnaire	Part B: Participant's views about attending the learning sessions	Likert Scale (5-1)	Mann-Whitney U test
	Part C: Participant's views about solving the assigned tasks	Yes or No (categorical)	Chi-Square test
	Part D: Participant's satisfaction, performance and self-confidence	Likert Scale (5-1)	Mann-Whitney U test
Answer Sheet (for solving the assigned tasks)	Time taken to solve the assigned tasks	Time Taken (interval)	Paired Sample T-test
	Self-confidence to obtain the correct solutions for the assigned tasks	Yes or No (categorical)	Chi-Square test
	Marks performance from solving the assigned tasks	Marks (5-1)	Mann-Whitney U test

Table 3.8: A further detail of the statistical analysis.

Survey	Dependent Variables	Question Types	Data Type	Level of Measurement	Statistical Test	Interpretation of Output
Questionnaire	Part B: Participant's views about attending the learning sessions	Likert Scale (5-1)	Continuous	Ordinal	Mann-Whitney U Test	Asymp. Sig (2-tailed) (< 0.05, to reject null hypothesis as there is a significant difference) Mean Rank difference (larger/smaller difference)
	Part C: Participant's views about solving the assigned tasks	Yes or No (categorical)	Binary	Nominal	Chi-Square Test	Pearson Chi-Square (< 0.05, to reject null hypothesis as there is a significant difference)
	Part D: Participant's satisfaction, performance and self-confidence	Likert Scale (5-1)	Continuous	Ordinal	Mann-Whitney U Test	Asymp. Sig (2-tailed) (< 0.05, to reject null hypothesis, there is a significant difference) Mean Rank difference (larger/smaller difference)
Answer Sheet (for solving the assigned tasks)	Time taken to solve the assigned tasks	Time Taken (difference)	Continuous	Scale	Paired Sample T Test	Compare Mean Score: positive/negative: Significantly higher or significantly lower. Effect size: Cohen's d value from *t* and N values. (< 0.05, to reject null hypothesis as there is a significant difference)
	Self-confidence to obtain the correct solutions for the assigned tasks	Yes or No (categorical)	Binary	Nominal	Chi-Square Test	Pearson Chi-Square (< 0.05, to reject null hypothesis as there is a significant difference)
	Marks performance from solving the assigned tasks	Marks (5-1)	Continuous	Ordinal	Mann-Whitney U Test	Asymp. Sig (2-tailed) (< 0.05, to reject null hypothesis as there is a significant difference) Mean Rank difference (larger/smaller difference)

Table 3.9: Mapping of the research questions against the statistical analysis.

Questionnaire: Participant's views about attending the learning sessions		
Research Questions		Statistical Analysis
RQ1a	Will attending traditional learning session by experienced students improve learning satisfaction?	Percentage
RQ1b	Will attending traditional learning session by inexperienced students improve learning satisfaction?	Percentage
RQ1c	Is there any difference between experienced and inexperienced students in learning satisfaction after attending traditional learning session?	Mann-Whitney U test
RQ1d	Will using online learning session by experienced students improve learning satisfaction?	Percentage
RQ1e	Will using online learning session by inexperienced students improve learning satisfaction?	Percentage
RQ1f	Is there any difference between experienced and inexperienced students in learning satisfaction after using online learning?	Mann-Whitney U test
Questionnaire: Participant's views about solving the assigned tasks		
Research Questions		Statistical Analysis
RQ2a	Will solving the assigned tasks using traditional learning by experienced students improve learning satisfaction?	Percentage
RQ2b	Will solving the assigned tasks using traditional learning by inexperienced students improve learning satisfaction?	Percentage
RQ2c	Is there any difference between experienced and inexperienced students in learning satisfaction after solving the assigned tasks using traditional learning?	Chi-Square test
RQ2d	Will solving the assigned tasks using online learning by experienced students improve learning satisfaction?	Percentage
RQ2e	Will solving the assigned tasks using online learning by inexperienced students improve learning satisfaction?	Percentage
RQ2f	Is there any difference between experienced and inexperienced students in learning satisfaction after solving the assigned tasks using online learning?	Chi-Square test
Answer sheet: Time taken to solve the assigned tasks		
Research Questions		Statistical Analysis

RQ3a	Will using traditional learning by experienced students improve speed in solving the assigned tasks?	Means
RQ3b	Will using traditional learning by inexperienced students improve speed in solving the assigned tasks?	Means
RQ3c	Is there any difference between experienced and inexperienced students in speed in solving the assigned tasks using traditional learning?	Paired Sample T-test
RQ3d	Will using online learning by experienced students improve speed in solving the assigned tasks?	Means
RQ3e	Will using online learning by inexperienced students improve speed in solving the assigned tasks?	Means
RQ3f	Is there any difference between experienced and inexperienced students in speed in solving the assigned tasks using online learning?	Paired Sample T-test
Answer sheet: Self-confidence to obtain the correct solutions for the assigned tasks		
Research Questions		Statistical Analysis
RQ4a	Will doing the assigned tasks using traditional learning by experienced students improve self-confidence?	Percentage
RQ4b	Will doing the assigned tasks using traditional learning by inexperienced students improve self-confidence?	Percentage
RQ4c	Is there any difference between experienced and inexperienced students in self-confidence after solving the assigned tasks using traditional learning?	Chi-Square test
RQ4d	Will doing the assigned tasks using online learning by experienced students improve self-confidence?	Percentage
RQ4e	Will doing the assigned tasks using online learning by inexperienced students improve self-confidence?	Percentage
RQ4f	Is there any difference between experienced and inexperienced students in self-confidence after solving the assigned tasks using online learning?	Chi-Square test
Answer sheet: Marks performance from solving the assigned tasks		
Research Questions		Statistical Analysis
RQ5a	Will doing the assigned tasks using traditional learning by experienced students improve marks performance?	Percentage
RQ5b	Will doing the assigned tasks using traditional learning by inexperienced students improve marks performance?	Percentage

RQ5c	Is there any difference between experienced and inexperienced students in marks performance after solving the assigned tasks using traditional learning?	Mann-Whitney U test
RQ5d	Will doing the assigned tasks using online learning by experienced students improve marks performance?	Percentage
RQ5e	Will doing the assigned tasks using online learning by inexperienced students improve marks performance?	Percentage
RQ5f	Is there any difference between experienced and inexperienced students in marks performance after solving the assigned tasks using online learning?	Mann-Whitney U test
Questionnaire: Participant's satisfaction, performance and self-confidence		
Research Questions		Statistical Analysis
RQ6a	Will attending traditional learning as the preferred learning approach by experienced students improve satisfaction, performance and self-confidence?	Percentage
RQ6b	Will attending the traditional learning as the preferred learning approach by inexperienced students improve satisfaction, performance and self-confidence?	Percentage
RQ6c	Is there any difference between experienced and inexperienced students in satisfaction, performance and self-confidence with traditional learning as the preferred learning approach?	Mann-Whitney U test
RQ6d	Will using online learning as the preferred learning approach by experienced students improve satisfaction, performance and self-confidence?	Percentage
RQ6e	Will using online learning as the preferred learning approach by inexperienced students improve satisfaction, performance and self-confidence?	Percentage
RQ6f	Is there any difference between experienced and inexperienced students in satisfaction, performance and self-confidence with online learning as the preferred learning approach?	Mann-Whitney U test

3.5 Target population

For the main study, the targeted participants were experienced and inexperienced students on the mechanical engineering course at different levels of study; diploma and undergraduate respectively. Participants involved are university students where the researcher works. 320 questionnaires and answer sheets were distributed, and a response rate of 100% was achieved. The questionnaires concentrated on investigating and measuring student perception of satisfaction, confidence and performance factors in experiencing different learning techniques. The questionnaire was also investigating the assigned tasks if they can be completed more easily and faster using different learning techniques. Two colleagues of the researcher were involved in distributing the questionnaires and monitoring the students.

3.6 Research Ethics

Ethics are the standards of professional behaviour that guide researchers in acting with integrity towards the participants involved in their research (Guthrie, 2010). Ethics may also be defined as a method or perspective to decide the action and to analyse problems or issues that are complicated (Resnik, 2011). Saunders et al. (2009) stressed that researchers must think prudently to obtain access in conducting their research and have concern for the ethical matters that could appear within their research. There are several kinds of ethical issues that may arise in research when humans are involved. In general, a code of ethics is well-known for research in medicine, law, business, psychology and other social sciences. Researchers need to be familiar with the codes relevant to their study and ensure that the codes are followed thoroughly (Robson, 2011). Several of the ethics codes and guidelines are quite vague and allow researchers to interpret them and make ethical decisions that are applicable to the specific issues that arise in their study. Kumar (1999) has identified the following three primary stakeholders that are concerned with ethical issues:

1. *Participants*; refers to those who contribute the required information for research.
2. *Researcher*; refers to those who collect the information and need to obey the code of conduct.

3. *Funding body*; relates to those who invest in the research and ensure that the information obtained in the study is not used to harm or affect any party.

Some of the ethical aspects that need to be considered when dealing with these three stakeholders is listed in Table 3.10. Furthermore, Creswell (2003) clarified that researchers should anticipate ethical issues that arise in their research such as the following:

- identifying the research problem,
- developing the research purpose,
- collecting the required data,
- analysing and interpreting the collected data, and
- writing-up the research report.

Table 3.10: Ethical issues for three different stakeholders (adapted from Kumar (1999)).

Participants	Researchers	Funding Body
Collecting relevant information	To avoid bias	Controls and restrictions
Seeking informed consent	Provision or withdrawal of an intervention or a treatment	The usage of collected information
Giving incentives	To apply appropriate research methodology	
Sensitive questions	Factual and precise report	
Harm or discomfort involvement	The use of information that being collected	
Confidentiality or hidden background		

In addition, researchers should also be concerned about how to provide ethically valid informed consent. Adams and Callahan (2014) highlighted six main features that are required in informed consent:

1. *Disclosure*: Documents must clearly inform participants about research objectives, confidentiality and anonymity, and compensation or medical treatment for any injury.

2. *Understanding*: Documents must be written in lay language (multinational where necessary) for the participant's understanding.

3. *Voluntariness*: Participants should participate voluntarily in the study with no authority or restriction over the participants so that they are free to give their opinion.

4. *Competence*: Participants need to be competent for them to participate.

5. *Consent*: Such agreement with a signature on the consent document as to indicate the participant's willingness to participate.

6. *Exculpatory language*: Exculpatory language should not be included in informed consent. It is prohibited to use any language that is waiving or appears to waive any legal right.

For this research, permission to conduct the surveys among students and lecturers was requested and approved by programmer leader responsible for the respective courses. All participants were informed verbally about the research and its purpose. They were also informed that by completing the survey questionnaire or interviews, they were agreeing to participate in the study and publication of the findings. The participants were also advised that all involvement was voluntary and kept anonymous.

3.7 Solving Assigned Tasks

The participants were being informed regarding the two assigned tasks that they need to solve before completing the survey questionnaire in both learning sessions. They were asked to record the time as they start solving the tasks and the time when they finish solving the tasks in the given answer sheets (see Appendix F). During the online learning session, the students were also requested to solve the tasks using the prototype system (explained in Chapter 5), however they still need to submit their working using the given answer sheets.

3.8 Summary

This chapter discussed an overview of the research methodologies used to ensure the data were collected and analysed properly to provide sufficient and meaningful results. The four stages in research process were problem discovery, designing a solution, implementation and data collection, and data analysis. A research onion framework was also presented in this chapter. In conclusion, the research ethics were also discussed. A careful attention was taken to confirm the participants have been selected appropriately and the guidelines of ethical issues were followed. The following chapter presents the preliminary study. It describes the preferred approach used and how the study is carried out. It also discusses the outcomes and feedback that were obtained from the study.

Chapter 4. Preliminary Study

4.1 Introduction

This chapter presents an overview of the activities involved in conducting a preliminary study for this research, including data collection using questionnaires and interviews. It begins with an overview of the purposes in conducting the study. It also describes the selected methods which include the selection of participants, the setting of tools and constructs that have been made before the results were analysed. Finally, this chapter also discusses the results obtained from both survey methods.

4.2 Overview of Preliminary Study

Preliminary studies are an important part of a good design for a study as they can be used to identify potential problems in the research (Teijlingen and Hundley, 2001). A preliminary study is also significant in the development or refinement of new interventions and other study procedures. Conducting a preliminary study allows researchers to find sufficient background information and help in focusing on specific information to be studied.

The intention of this preliminary study was to collect and analyse the data that is expected to support the problems and issues raised in the research. The study was performed through the distribution of questionnaires and interviews. The questionnaires aimed to explore the student's experience and their confidence in learning the module of Mechanical Engineering Design, which is also known as Machine Design. The focus then moves to the difficulties that are experienced by the students during their projects, particularly in the field of mechanical design. Also, the study was concerned with the significance of mechanical design calculations during student projects. Meanwhile, the interviews were performed to gather the perspectives of the lecturers based on their experiences from supervising the student projects. As a whole, the outcomes from the questionnaires and the interviews were also planned to evaluate any suggestions or improvements that might be applied.

4.3 Methods of Data Collections

4.3.1 Target participants

The participants involved were students and lecturers, particularly from the Mechanical Engineering programme at one of the higher institutions in Brunei Darussalam. 95 mechanical engineering students participated, and they comprised the three different levels of study of Higher National Diploma (HND), Foundation Degree (FD) and Bachelor of Engineering Degree (BEng). There were also ten staff comprised of lecturers and senior lecturers who had taught three levels of study and volunteered to participate in the study. Participants from the mechanical engineering programme were selected because of their teaching experiences in the field of mechanical engineering, which is related to the research (see section 4.5.1).

4.3.2 Tools

The two tools used for collecting the data were survey questionnaires and interviews. Questionnaires were distributed to the students in a face to face setting and comprised a mixture of open and closed-ended questions. Meanwhile, each of the interviews was conducted with the participation of voluntary lecturers in a structured and face to face environment. The interviews were performed with a set of similar open-ended questions to enable the participants to express their opinions and become more responsive. However, the researcher controlled the time of each interview to obtain the straightforward feedback on the questions asked. Both questionnaires and structured informal interviews were anonymous to allow an honest response. Copies of the questionnaire and the questions for the interview are presented in Appendix A and Appendix B respectively.

4.3.3 Question design

Initially, all the responses obtained from the questionnaires and the interviews were studied qualitatively before starting to analyse the data. Responses to the open-ended questions were grouped together according to similar meaning. The responses were then further evaluated quantitatively using the same coding for easy interpretation. Both set of questions for the questionnaire and the interviews were checked by some colleagues with expertise in the area of mechanical engineering design. The questionnaire comprised of open-ended and closed-ended questions, including:

- gender,
- course of study,
- four questions requiring yes or no responses,
- six questions regarding confidence (based on experience) using a 5-point Likert scale with a range from 1 (lack of confidence) to 5 (extremely confident), and
- five open-ended questions for obtaining the student opinion and feedback.

The overall results of the questionnaires were tabulated in frequency tables using Microsoft Excel to facilitate the analysis work and are presented in Appendix C. Meanwhile, some of the responses obtained from the interviews were grouped accordingly to their similarity, and some remain as they were, especially for the responses not in accordance with the other responses.

4.4 Results and Discussion - Questionnaire

4.4.1 Gender and level of study

The demographics for the 95 students, all of mechanical engineering programme students who completed the questionnaire are shown in Figure 4.1. There were more male students participating rather than female students. The questionnaires were distributed to the students from three different levels of study. As illustrated in Table 4.1, most of the responses obtained were from Foundation Degree (FD) students.

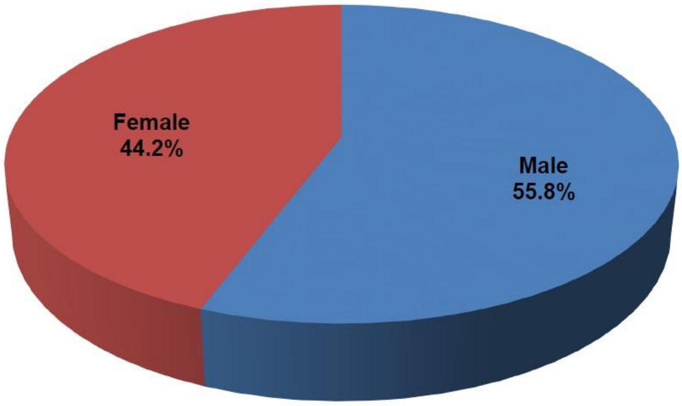


Figure 4.1: Gender distribution.

Table 4.1: Participants based on the level of study.

Gender	Level of study			
	Higher National Diploma (HND)	Foundation Degree (FD)	Undergraduate (BEng)	Percentage (100%)
Male	11	32	10	55.8
Female	8	20	14	44.2
Total Participants	19	52	24	100

4.4.2 Confidence gained from learning the module

The focus of this preliminary study was to collect student experiences in the learning of Mechanical Engineering Design or the Machine Design module. The responses confirmed that all the students had attended this module. The study, then explored the level of confidence among the students in practicing what they had learned in real practice such as in student projects. Figure 4.2 indicates that 64% of the students were neutral in terms of confidence, and only 3% considered themselves to be extremely confident.

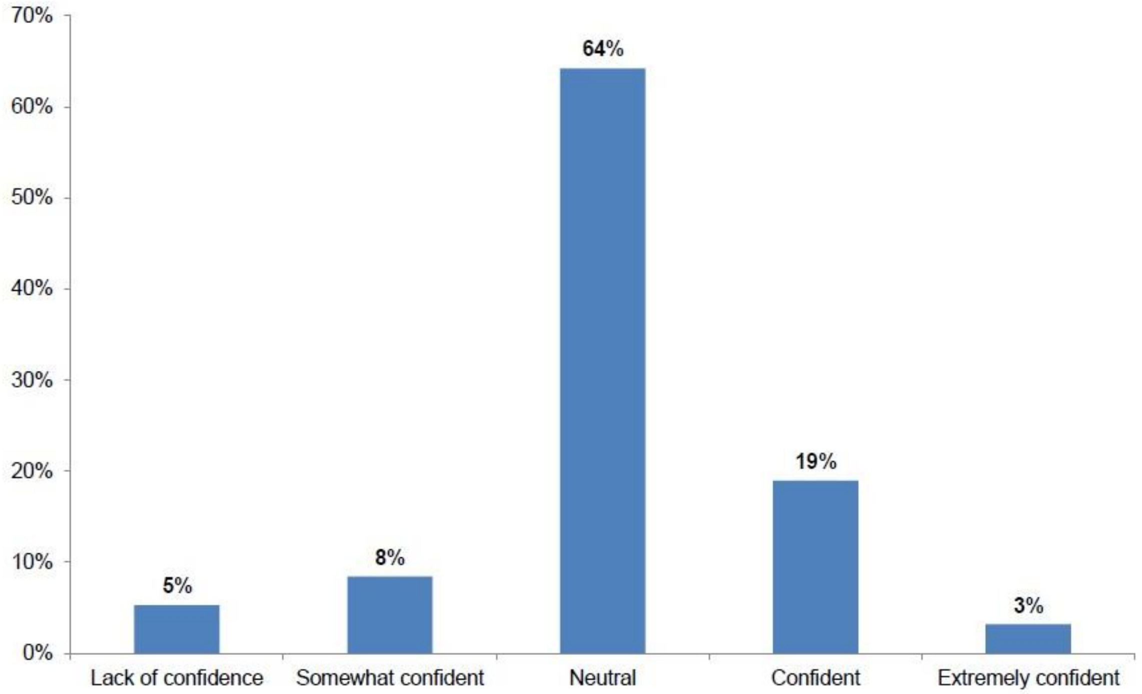


Figure 4.2: Student confidence levels in what has been learned.

4.4.3 Experiences during student projects

The study indicated that 65% (see Appendix C) of students had projects involving mechanical design, specifically including design calculations. These students were further questioned about the most difficult stage that occurred during the mechanical design process in their projects. There were four difficult stages identified by the students as shown in Figure 4.3. It is interesting to discover that 63% of the students mentioned the design calculation stage as the most difficult. 11% of students chose design planning as the second most difficult. However, 21% of the 65% students did not answer the question.

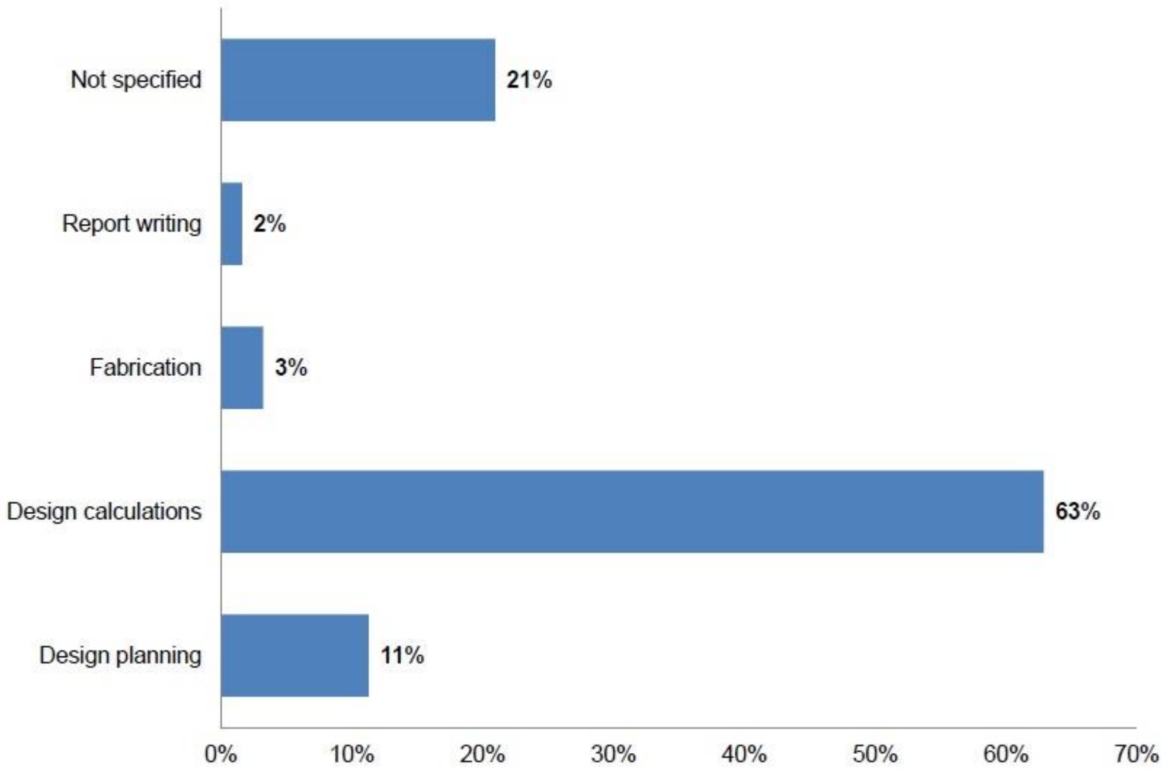


Figure 4.3: The most difficult stages in student projects.

Additional questions were asked regarding the confidence of the students in the following phases during student projects:

- Creating new ideas or designs,
- Design calculations (dimensions and sizes),
- Checking the strength, stability, lifetime considerations,
- Preparing geometric drawings (2D & 3D models), and
- Checking cost estimation.

Table 4.2 indicates that most students were neutral in confidence to these phases. It also shows that 47% of students were confident in preparing geometric drawings or modelling of the design components. Meanwhile, the lowest confidence level of 8% was specified particularly in performing design calculations.

Table 4.2: The confidence levels in some important phases during student projects.

Phases	Lack of confidence	Somewhat confidence	Neutral	Confident	Extremely Confident
Creating new ideas or designs	3%	11%	63%	19%	3%
Design calculations (dimensions & sizes)	6%	27%	55%	**8%**	3%
Checking the strength, stability, and life time considerations	6%	24%	52%	16%	2%
Preparing geometric drawings (2D & 3D models)	3%	8%	39%	**47%**	3%
Checking cost estimation	5%	19%	45%	24%	6%

Subsequently, 85% of the students who mentioned design calculations agreed that managing the design calculations had taken most of their time (as can be seen in Appendix C). The results of the student responses are presented in Figure 4.4. They are explored, averaged and formed into four separate factors including knowledge, formulae, accurate design and importance. The majority of students (36%) responded to the formulae factor; and mentioned the following:

- the necessity to ensure that the right formulae is used,
- the difficulty in choosing the right formulae as many parameters need to be considered and included, and
- a process involving many lengthy formulae and rechecking for each can be time-consuming.

The second highest reason that design calculations took a long time is in achieving the right design. Many students emphasised that the design must be accurate and should be precisely created from the beginning until the end of the design process to eliminate any initial errors and avoid future failure. Hence, with this approach, trial and error was reduced; and the final product could be completed rapidly once a precise design had been obtained.

Some of the students also stated that their time had been affected due to the accumulation of compulsory knowledge and concepts, where they required more theoretical background and related references. Additionally, more time was needed in creating a new design beyond the scope of their knowledge. Some students also revealed uncertainty in beginning design calculations due to lack of knowledge and experience as well as the lack of resources. However, 11% of the students clarified that it was important to spend more time managing the design calculations as it might influence the outcome of final results considering that if the design calculations are handled correctly and promptly, then final outcomes can be achieved efficiently and on-time.

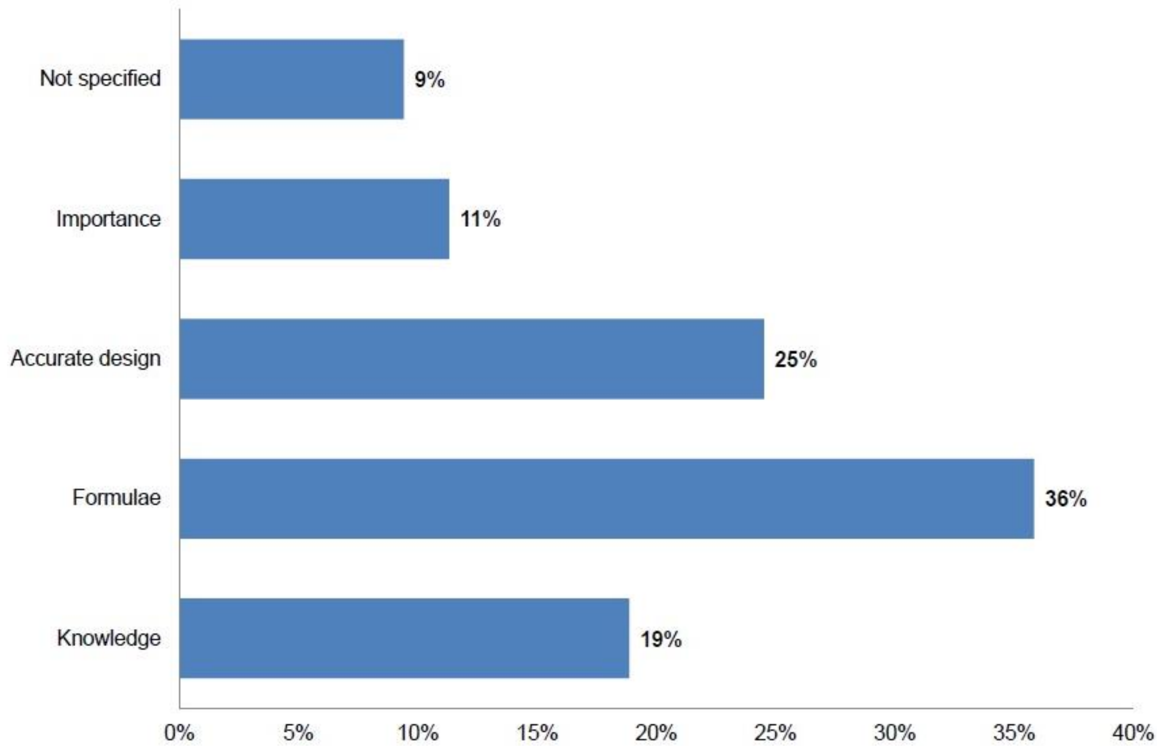


Figure 4.4: The reasons for design calculations taking a long time.

4.4.4 Opinions for improvement

Finally, the study concluded that many positive responses and feedback opinions were given to improve the design process, especially in managing the design calculations. These opinions were examined and grouped together according to their similarities. Accordingly, they were grouped to form five different aspects including IT tools, exposure, time management, understanding, and guidance (see Figure 4.5).

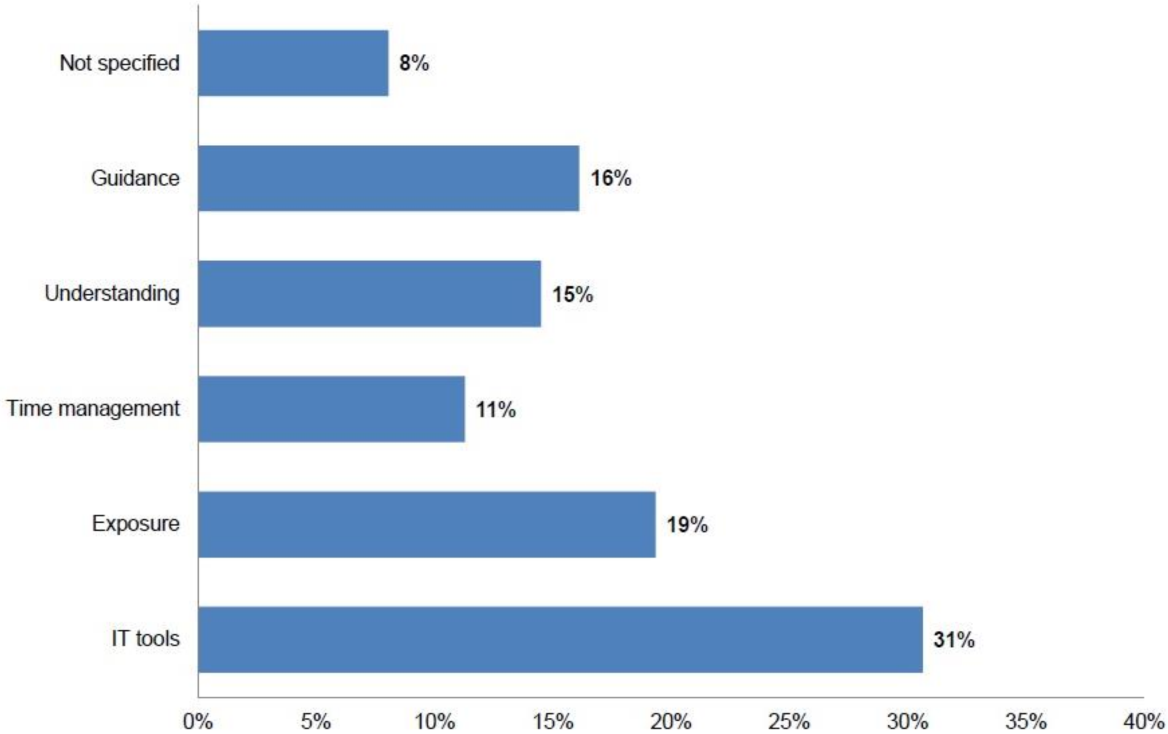


Figure 4.5: Student opinions on the improvement of design process, particularly in managing design calculations.

31% of the students felt that IT tools would able to assist them making precise design calculations, reducing errors, and organizing the lengthy formulae and necessary tables. Many students also mentioned that the IT tools could provide systematic ways to guide them on how to start the design calculations so the time to complete the design calculations can be reduce. Meanwhile, 19% of the students argued that they need to get more exposure to previous design projects as well as real practical works involving more design calculations. They also emphasized that the presence of many related theories and examples during the tutorials can assist them to manage and understand the calculations more efficiently.

Besides, some of the students also mentioned that proper guidance from their lecturers or supervisors can lead and assist them to perform better design calculations. In addition, these students stated that they should spend more time with their supervisors especially during the stages of brainstorming, planning and designing when doing their projects. Similarly, some students also thought that they should have a clear understanding of what they will do or work with before they start designing. Nevertheless, 11% of the students argued that managing their time in a systematic and efficient way can help in enhancing the design process effectively. These students also agreed that they should able to differentiate and prioritise the issues that need to be handled first.

4.5 Results and Discussion - Informal Interviews

4.5.1 Participants

Ten lecturers volunteered to participate in this study. All of them had experience in teaching the mechanical engineering course and were specialised in the following specific areas:

- Engineering Design
- Engineering Mathematics
- Engineering Materials
- Engineering Computational
- Thermofluids
- Manufacturing
- Agricultural Mechanization

4.5.2 Difficulties during design stage

Based on the experiences of supervising and examining student projects, the lecturers expressed some of the difficulties faced by their students during the design phase. Some lecturers stated that students are not able to perform the design calculation by themselves even though they have been taught. The difficulty in the design calculations involves the selection of sizes, dimensions, and materials for each component. Additionally, the most frequent difficulty is when acquiring a design specification for a new product where the students hardly tackled this complicated problem. Besides that, one of the complicated processes faced by the students was the translation of the product design specification to the next modelling stage using computer-aided drawing (CAD) and to link it further to the manufacturing stage. Therefore, major errors and failures of the final outcomes are often the case. The students also had difficulties in presenting a clear and accurate design calculation, as well as providing proper justifications in their reports. In addition, the lecturers also found that some students still need guidance in conceptualizing their designs based on the relevant fundamentals.

4.5.3 Difficulties in other tasks

The lecturers also stated that their students also had problems in performing other tasks besides the design stage, these included:

- Planning
- Brainstorming
- Cost estimation
- Product performance
- Report writing
- Time management
- Teamwork
- Limitation of resources
- Lack of knowledge
- Limited real-life practice

When doing projects, most students experienced a lack of ideas due to limited exploration of previous studies and lack of working experience. During the stage of brainstorming, most of the ideas were created by the supervisors and only few students were able to create their own ideas. However, some of the student ideas were too realistic and this required proper guidance and more advanced knowledge. In addition, students often did not apply important test procedures such as failure mode and effect analysis (FMEA), product performance evaluation and optimisation, cost estimation and a proper way of detailing the design specification. Moreover, students who completed projects in groups seemed to lose their spirit of teamwork and became less involved with the group members. Other difficulties encountered by the students were problems due to lack of knowledge; lack of practice in real-life applications; and limited resources such as the materials to be used, the availability of equipment or laboratory as well as the technician. Time management and writing reports were some important skills that must be managed by students efficiently to achieve their projects successfully.

4.5.4 Confidence in solving design calculations

Surprisingly, most lecturers revealed that most of their students were not confident enough to perform design calculations, especially in dimensioning, sizing and strength analysis. Depending on the nature of the design, some students were often confused and did not know where to start the design calculations. Some students also tried to neglect the iteration process in the calculations that needs to be done at the earliest stage of design. Indeed, some lecturers also mentioned that students with excellent results in the design module were more confident in their calculations. Otherwise, some guidance and approval was still required from the supervisor for complicated projects. Some lecturers also pointed out that the students will be confident when supervisors provide regular guidance and references. In some cases, students were also more confident when working in groups.

4.5.5 Time spent solving design calculations

The lecturers revealed that most students spent more time during the design specification in obtaining the design calculations. The necessity to perform iterative calculations in parallel with other activities in the project often made students spend less time in managing their time. Nevertheless, some lecturers also clarified that the students may spend less or more time on design calculation, depending on the nature of the project. The limitation of resources also became one of the causes that led the students to spend more time in getting the technical specifications of specific materials. Hence, the students with a lack of knowledge and practice will be less interested and lose focus on doing their calculations properly.

4.5.6 Important criteria required for student projects

During the interview, lecturers highlighted the important criteria needed for a student project to be a success, these are:

- Functional requirements
- Design specification; design calculations, testing, and evaluation
- Overall objectives
- Theoretical evaluation
- Cost estimation
- User satisfaction
- Originality and logic concept
- Proper documentation (report writing)
- Material selection
- Understanding and discussion

The lecturers also emphasized that the product design specification should be as precise as possible but not constrict the students too much so that there is no room for improvements. The specifications must include the design calculation, design evaluation, testing and, the comparison and justification of the results. Besides, the functionality requirements such as safety, cost estimation and user satisfaction must be included in a project.

The students should also indicate their understanding through the discussion, and the objectives of the project should also be achieve accordingly. It is also important to present proper documentation from design to manufacture to explain the overall flow of the project. Moreover, successful projects should have a logical concept and be original. The selection of materials is also to be considered accordingly such as concerning the safety, environmental impact, and sustainability.

4.5.7 Opinions to improve student's ability or self-confidence

Finally, by conducting the interview, some potential opinions were collected in developing the student's ability or self-confidence to perform design calculations. Lecturers suggested that the students should get more exposure to the related information, exploring previous projects or talking to their seniors on what and how has been done previously. With these methods, the students may have a better approach and understanding of how to progress well and achieve their goals. In mastering and performing well in design calculations, it is advisable for the students to study and comprehend the fundamental principles of the following:

- Engineering Mechanics (both Statics and Dynamics),
- Mechanics of Materials (Strength of Materials),
- Properties of engineering materials,
- Design for different types of loadings namely statics, fatigue, and creep, and
- Design concepts using the principles of strength of materials and fracture mechanics.

Besides, the exposure to the design module from the early stages until the end of the study will enhance the student's knowledge and understanding. Additional practical problems should also be introduced into the curriculum by a real designer from the industry. One of the lecturers suggested a design workshop for the students to attend that could help and guide the students appropriately to what is required to complete their design tasks and hence a successful project. Some lecturers also identified that some students are more comfortable working in a group as other members act as a sounding board for their work.

Moreover, some students felt more confident to perform design calculations using software tools as it can provides easy ways for them to detect the errors, and the calculations will be properly organized. Therefore, software tools such as computer programs should be designed, developed and introduced so the students could manage and check their design calculation more efficiently. Consequently, the students would become more confident and able to obtain a successful product at the end of their project hence resources used and time could be reduced and saved.

Several conclusions are apparent from the results obtained in the preliminary study. First, a significant difficulty that most students encountered was in performing the design calculations for the design specification. Secondly, some important factors that created difficulties have been highlighted, which included limitations of knowledge and exposure, inadequate guidance and real-life practice, time management in the iterative process of calculation. These factors were also mentioned by the lecturers during the interviews. Some of the potential opinions raised during the study were to provide the students with design workshops as well as the use of computer programs to guide and assist learning. These opinions correspond with the main objectives of this research. Finally, the results of this study indicated that the potential issues in this research are the on-going problem faced by the students currently and still require a solution to overcome the issue.

4.6 Summary

To summarize, an overview of the preliminary study has been presented and discussed in this chapter. The explanation of the method included target populations, tools used and question design. The results and discussion of the feedback from both questionnaire and interview were analysed, described and illustrated using the appropriate charts where necessary.

The design of a prototype system will be explained in the following Chapter 5.

Chapter 5. Design of a Prototype System

5.1 Introduction

This chapter provides an overview of the process of designing a prototype online web-based learning system for this study. The System Development Life Cycle model (SDLC) has been selected and described. It consists of four phases: Concept, Design, Coding, and Testing. All of these phases are presented and explained in this chapter with appropriate justification.

5.2 Prototype System

In general, a real system is more complex to build as a real data specification is required which is costly and time-consuming. Hence, a prototype system or model is produced and tested earlier before proceeding to a real system. Doke (1990) reported the four types of prototyping that are usually in use, and they are:

1. Illustrative: it generates mock-ups of reports and screens.
2. Simulated: it simulates some system functions without having real data or database.
3. Functional: it executes some actual system functions and has real data and/or a database, but the model not implemented.
4. Evolutionary: it produces a model that becomes a part of the real final system.

In this study, a prototype online web-based learning system was designed and developed as a functional prototype to be tested by the students during Stage 3. It offers self-development for the students through real educational experiences at their own pace. According to Rosenberg (2006) and, Ozdemir and Abrevaya (2007), a web-based learning offers huge opportunities and benefits which include: convenient access, a flexible and just-in-time learning process, real-time updating of learning content and interaction with other people regardless of being in different organizations or time zones.

5.3 System Development Life Cycle (SDLC)

A System Development Life Cycle (SDLC) is a basic planning process that is logical, sequential, and structured, and can be applied to many development programs in an effective and timely manner (Bronzite, 2000). Some various types of SDLC methodologies have been developed. A waterfall model is quite popular in SDLC where the development process is linear and sequential. This approach was defined by Winston W. Royce in 1970 (Buede and Miller, 2016) and is presented in Figure 5.1. It has different goals for each phase of development, and there is no turning back once a phase is complete.

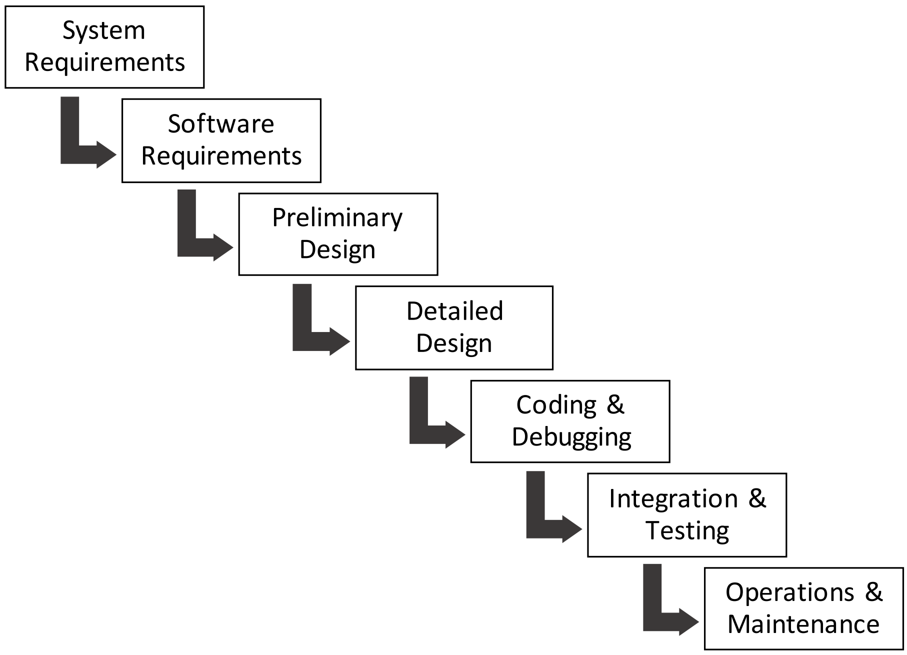


Figure 5.1: Waterfall model (each phase needs to be completed before the next phase starts).

An iterative model is a repetitive process where a new version of the program is repeatedly created with each phase until the complete program is ready. As in Figure 5.2, an iterative model made up of mini waterfalls is less costly to implement changes, but resources can be quickly consumed because of the repetition process (Half, 2014).

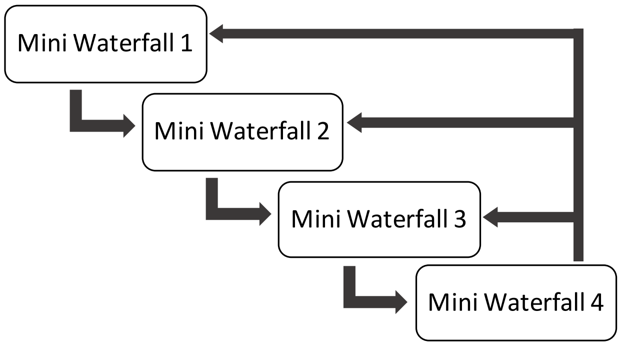


Figure 5.2: An iterative model is simple to understand and use where errors can be detected earlier.

Another SDLC model is a spiral model which was introduced by Barry Boehm in 1988. It is a combination of the iterative and waterfall models. In a spiral model, the risks can be reduced as it allows incremental refinement through each iteration around the spiral as in Figure 5.3 (Boehm, 1988). A spiral model is especially appropriate for large, expensive and very complicated projects.

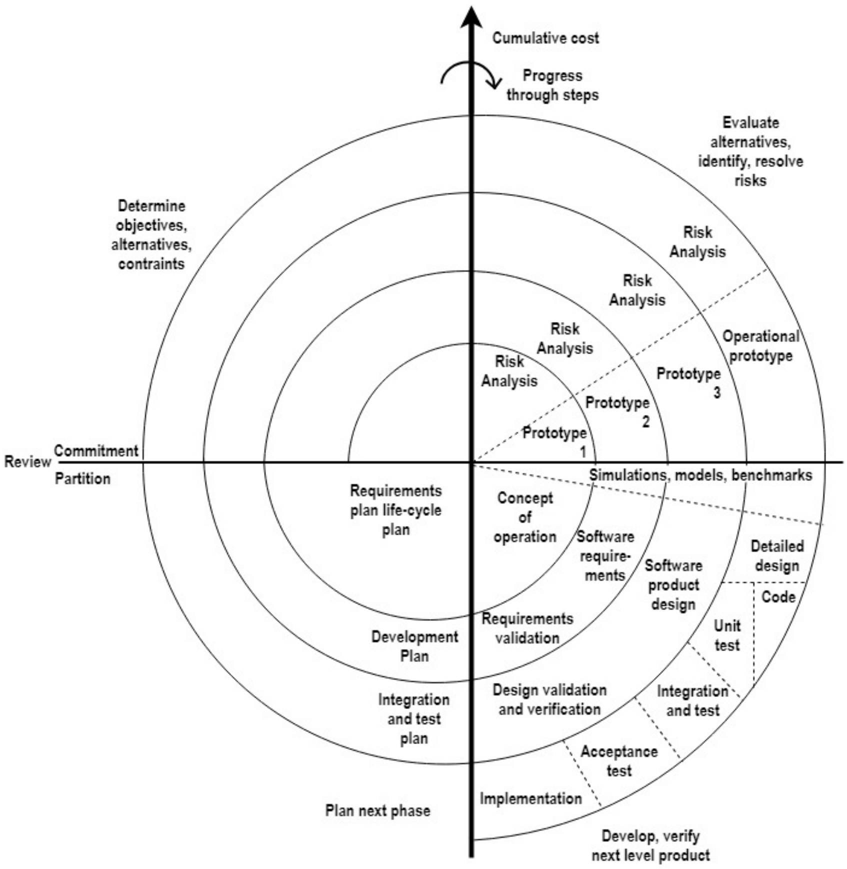


Figure 5.3: Spiral model focuses on addressing risks that needs to be done incrementally according to priority (Boehm, 1988).

Figure 5.4 shows the iterative cyclical SDLC process used in this study. Four phases were implemented including concept, design, coding and testing. It offers a straightforward approach for easy monitoring and better understanding. Hence, all of the system development phases were executed, and there will be no phase is ever omitted from the iteration. However, there was no time constraint for each iteration phase as it just depends on how difficult or easy the issues or problems were that occurred in each phase.

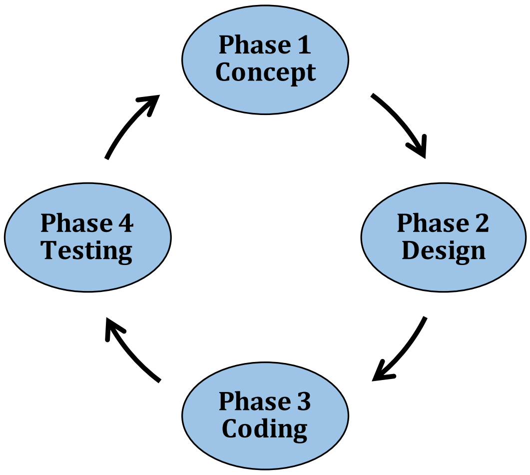


Figure 5.4: Iterative cyclical process that have been used in designing and developing a prototype online learning system.

5.4 Concept Phase

As a first step in developing the prototype, all the required information has to be gathered to define the concepts for the web-based system. The main concepts involved are:

1. Strategy:

   The prototype web system aims to create convenient learning environments for Mechanical Engineering Design and time efficient techniques for users to solve design problems.

2. Target Audience:

   The primary audiences are Mechanical Engineering students from a higher level of education including undergraduate and diploma levels.

3. Content:

   The web contents were from the lecture and tutorial notes of the Mechanical Engineering Design module used by Mechanical Engineering students in UTB. Two topics of Mechanical Engineering Design that were included are: Introduction to machine design, and Design of keys. Safety factors. Some of the sub-topics such as the unit conversion are also included in the Introduction topic. A list of examples and tutorial questions for each topic are also provided.

5.5 Design Phase

5.5.1 User Requirement Specifications

User requirements refer to the features or aspects of a designed website or application should have or how it should be performed from the user perception (Courage and Baxter, 2005). Table 5.1 shows a summary list of user requirements that related to literature review and preliminary study.

Table 5.1: User requirement specifications.

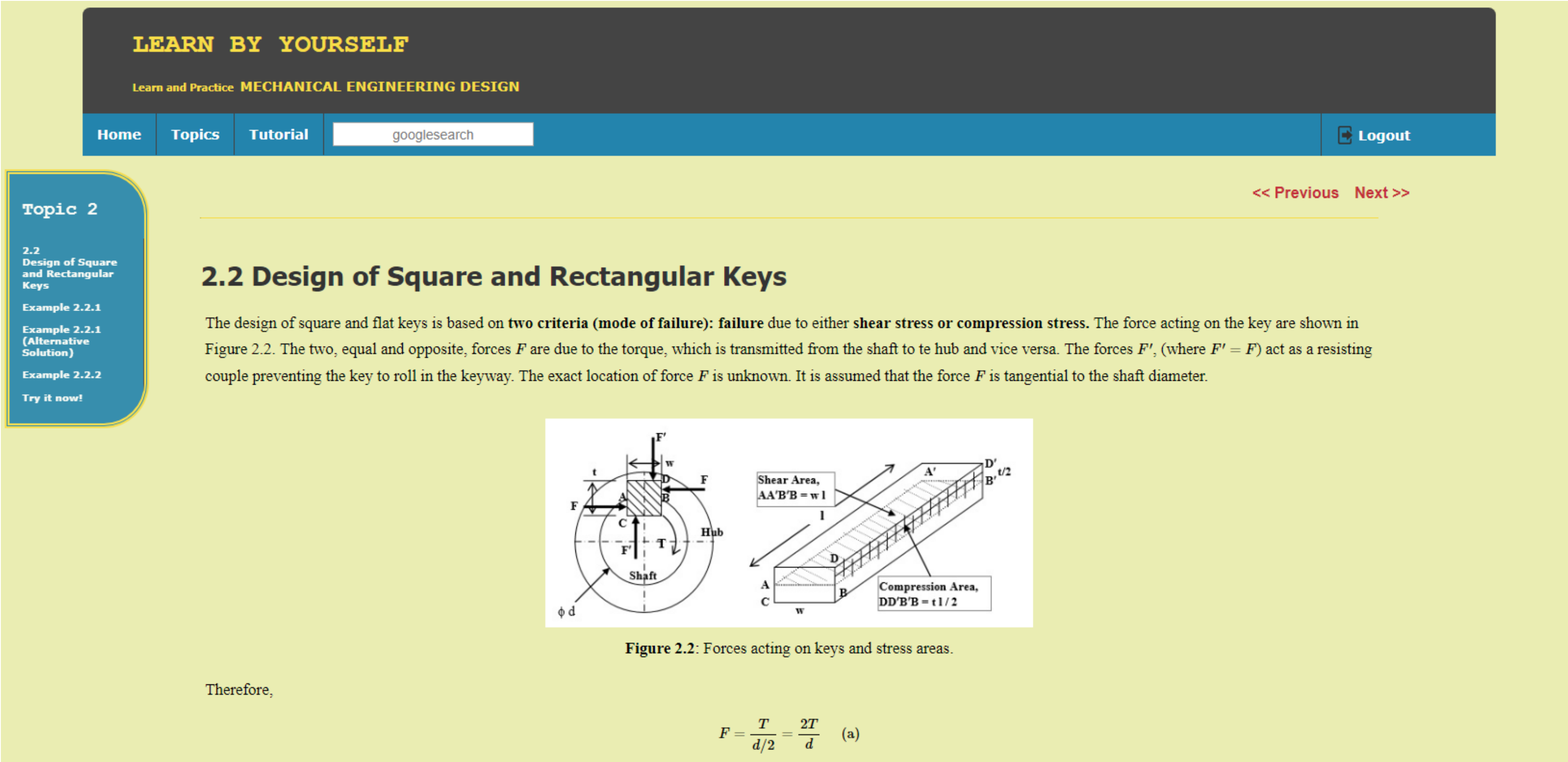
Security	The website shall have login access and password requirements.
Performance	The website needs to be reliable. The website shall accept the user input and response to it. The website shall be up and running in the respective environment. The website shall be deploys in the respective environment. The website shall be indicating the pop-up messages for error as well as for fixing the issues faced if the user encounters errors. The website shall be processing the calculation in the Try it Now! Templates and provide the correct answers to the user (depending on the data being input by the user).
Appearance	The website shall be easy to use by the user. The website shall be available in English language. The website shall be having the similar lecture and tutorial materials as in the traditional learning. The website shall be using appropriate fonts, figures and tables for easy reading and viewing. The website shall be providing a search box for the user (default to google search engine).

5.5.2 *Interface design*

The two main elements involved in designing are interface design and information design. Firstly, there will be no domain or official address for the website on the World Wide Web since this system used only for research purposes. However, a web browser was needed as software was used to load and read web pages on the World Wide Web (Muir, 2008).

Nowadays, there is a variety of web browsers available including Internet Explorer, Apple's Safari, Google Chrome, Opera, and Mozilla Firefox. For this study it was only possible to access the prototype web-based learning using Google Chrome web browser because it includes MathJax in the coding. Some details of MathJax can be found in section 5.6. Other interfaces include simple previous and next buttons, easy-to-use horizontal and vertical navigation bars with a list of links and the input type of search which is directed to a Google web search engine. Some of the layouts of the prototype online web-based learning are presented in Figure 5.5. As this research focuses on improving the ability of students in solving the design problems, hence there is no interface design of virtual learning environments i.e. blackboard, moodle, email and so on.

The most interesting component in this prototype system is a "Try it Now!" template where the design calculations will be calculated automatically once the users have inputted the relevant parameters. Figure 5.6 and Figure 5.7 show the two templates of "Try it Now!" that are available from the prototype system.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Topic 2

2.2 Design of Square and Rectangular Keys

Example 2.2.1

Example 2.2.1 (Alternative Solution)

Example 2.2.2

Try it now!

<< Previous Next >>

2.2 Design of Square and Rectangular Keys

The design of square and flat keys is based on **two criteria (mode of failure): failure** due to either **shear stress or compression stress.** The force acting on the key are shown in Figure 2.2. The two, equal and opposite, forces F are due to the torque, which is transmitted from the shaft to te hub and vice versa. The forces F', (where $F' = F$) act as a resisting couple preventing the key to roll in the keyway. The exact location of force F is unknown. It is assumed that the force F is tangential to the shaft diameter.

Figure 2.2: Forces acting on keys and stress areas.

Therefore,

$$F = \frac{T}{d/2} = \frac{2T}{d} \quad \text{(a)}$$

Figure 5.5: Example of the web page (A full set of the web pages can be found in Appendix D).

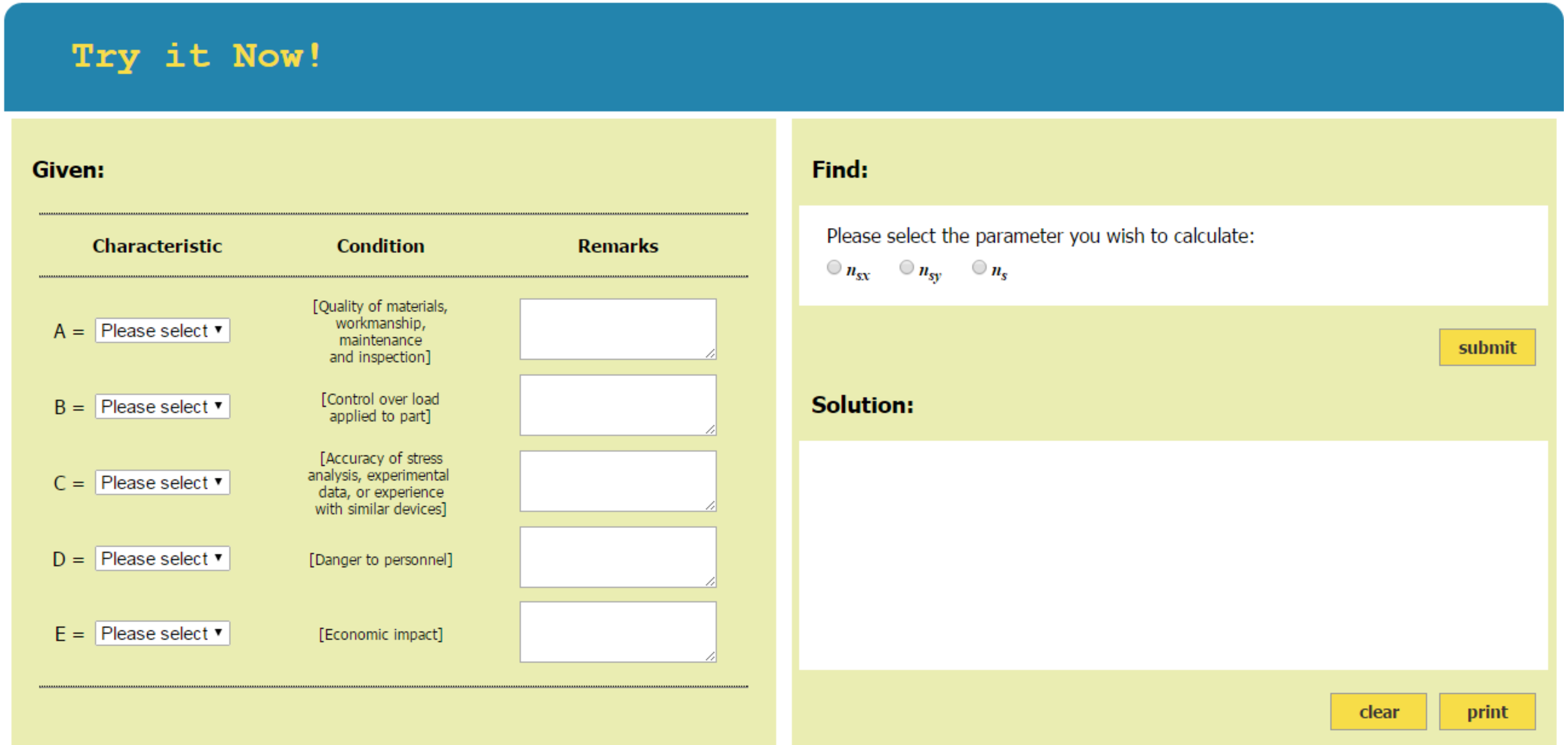


Figure 5.6: "Try it Now!" for Safety Factor (Design calculations will be calculated automatically once the users have inputted the relevant parameters).

Figure 5.7: "Try it Now!" for Design of square and rectangular keys (Design calculations will be calculated automatically once the users have inputted the relevant parameters).

5.5.3 Flowchart

For visualising how information flows, a flowchart or workflow diagram is commonly used. Hence, a flowchart is a useful graphical, or symbolic representation of a process that contains the sequences of steps and decisions that are required in performing a process. Figure 5.8 shows a flowchart designed for this study.

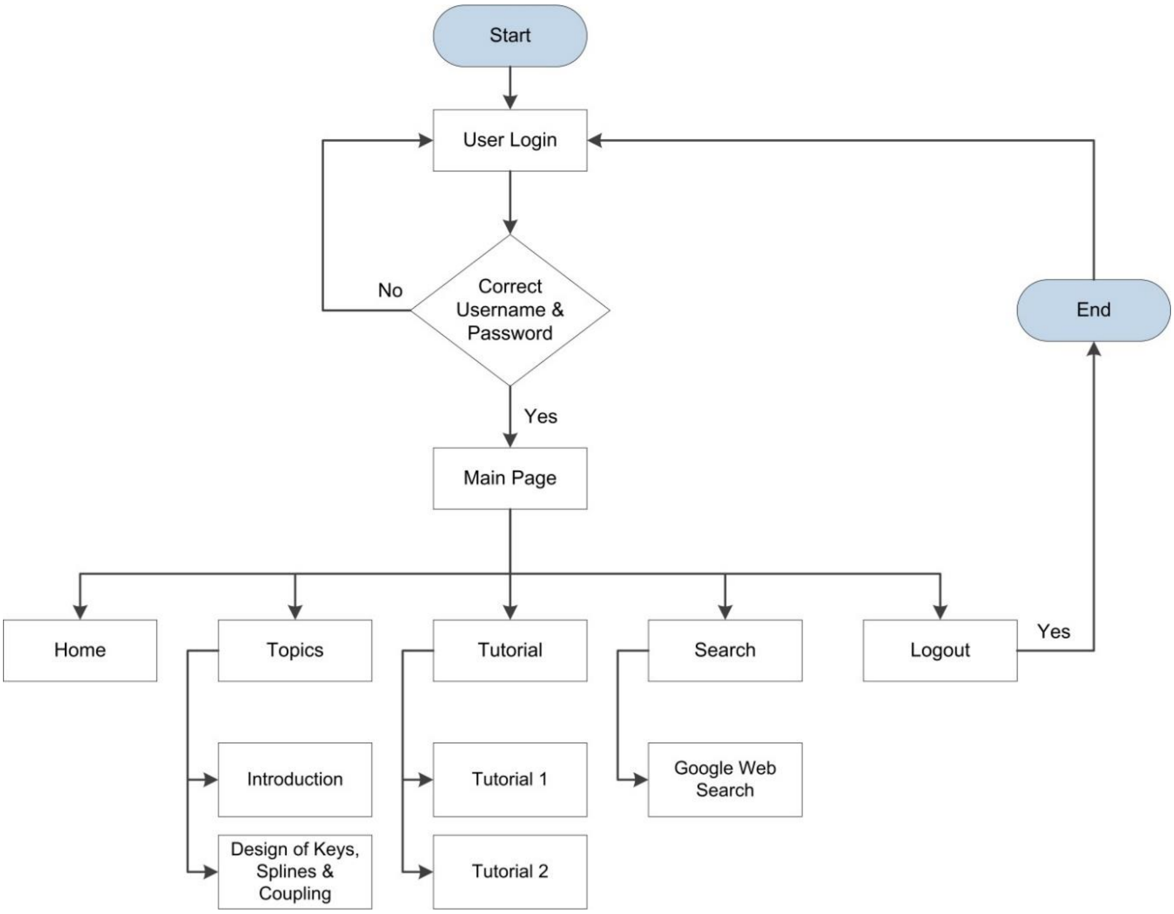


Figure 5.8: A flowchart for a prototype online learning.

5.5.4 Functional requirements

A functional requirement is essential to provide the specification documents of the operations and activities for a system to work. The main functional requirements for the prototype in this study are listed below:

1. User Login
   Description: Provides the facility to login into the system.
   Input: Enter username and password.
   Output: Main homepage.
   Processing: The system will check the user input. If the input is valid, then login is done, otherwise the system will ask the user to re-enter the username and password.

2. Selecting the event
   Description: The user can select an event from the horizontal and vertical navigation bars and buttons.
   Input: Main event and Sub-event.
   Output: Event selected successfully, the previous event page will be dismissed.
   Processing: The system will go to the selected event (page).

3. Inputting the field
   Description: The user can input a field with the required data. The input field may vary depending on the type of attribute (text or number).
   Input: Enter the data and one submit button.
   Output: If successful, the system will produce a list of results on the same screen.
   Processing: The system will check the input data. If the input is valid, then it proceeds to perform the calculation. Otherwise, the system will ask for the correct data to be re-entered.

4. Logout
   Description: The system offers the facility to log out from the site.
   Input: Select logout option.
   Output: The user will be logged out from the system.

Processing: User will log out.

5.6 Coding Phase

The coding phase is considered a programming phase as it involves writing step-by-step program code in a suitable programming language (Niederst, 2001). In this study, three types of client-side coding were used: Hyper Text Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript. HTML is an easy to learn coding language that can be used to write webpages. It can also speed up the development process and minimize errors. CSS is applied to control the layout of text and pages, and CSS files are used to store the external style sheets. Subsequently, JavaScript is used to make the web page lively. It is known as a scripting language where special instructions are inserted in web pages to add functionality. An open-source JavaScript display engine called MathJax has also been used to display the text-based mathematics equations. LaTex, MathML, and AsciiMath notation can be used to write the formulas in MathJax. With MathJax, the web pages become more interactive, dynamic and with high-quality equation typesetting. A page of this prototype displaying equations using MathJax is shown in Figure 5.9.

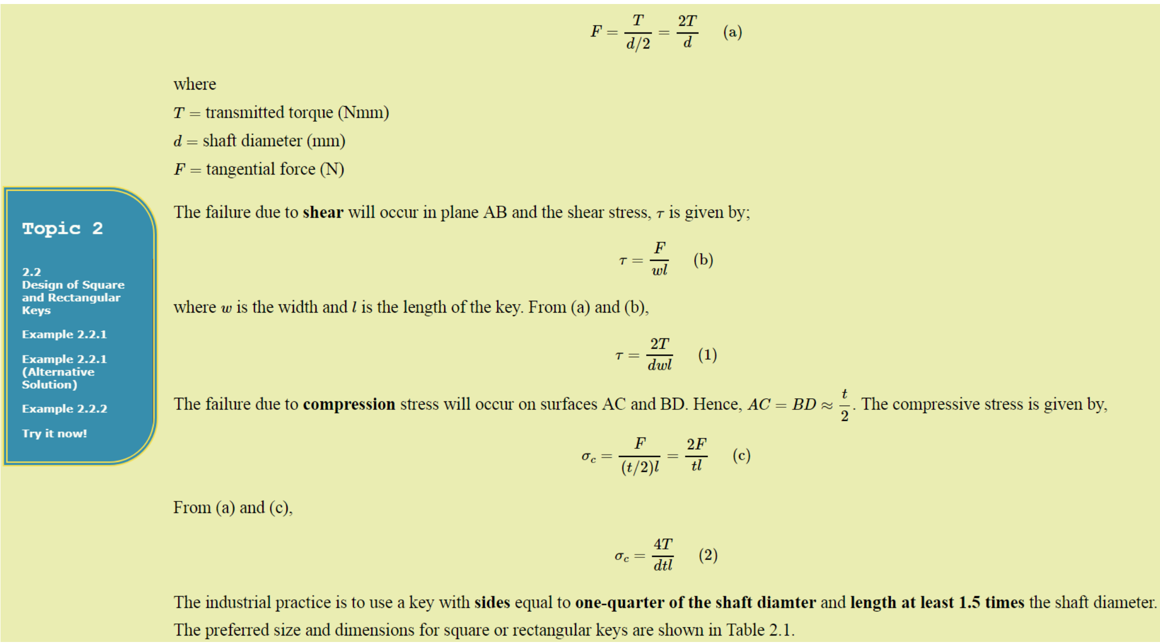


Figure 5.9: Display of mathematic equations using MathJax.

Moreover, many text editing software is available nowadays, and most are free to download. Sublime Text 3.0 is a sophisticated text editor for coding which has an efficient user interface and extraordinary features. The advantages of using this text editor are: it works with any operating system, it offers flexibility to customize anything, and it can split editing using the multiple splits in each window. Figure 5.10, Figure 5.11 and Figure 5.12 show HTML, CSS, and JavaScript coding and scripting for this prototype system using Sublime Text 3.0 respectively.

Significantly, the coding guidelines in web programming consist of rules and standards that have been applied specifically to code logic, folder structure, and names, file names, statements, classes, and functions, formatting and indentation. Also, web frameworks comprise program libraries that are used to insert all the functions, classes or subroutines for easy access during editing or adding. Program actions and logic are separated to be able to edit the interface and make design changes.

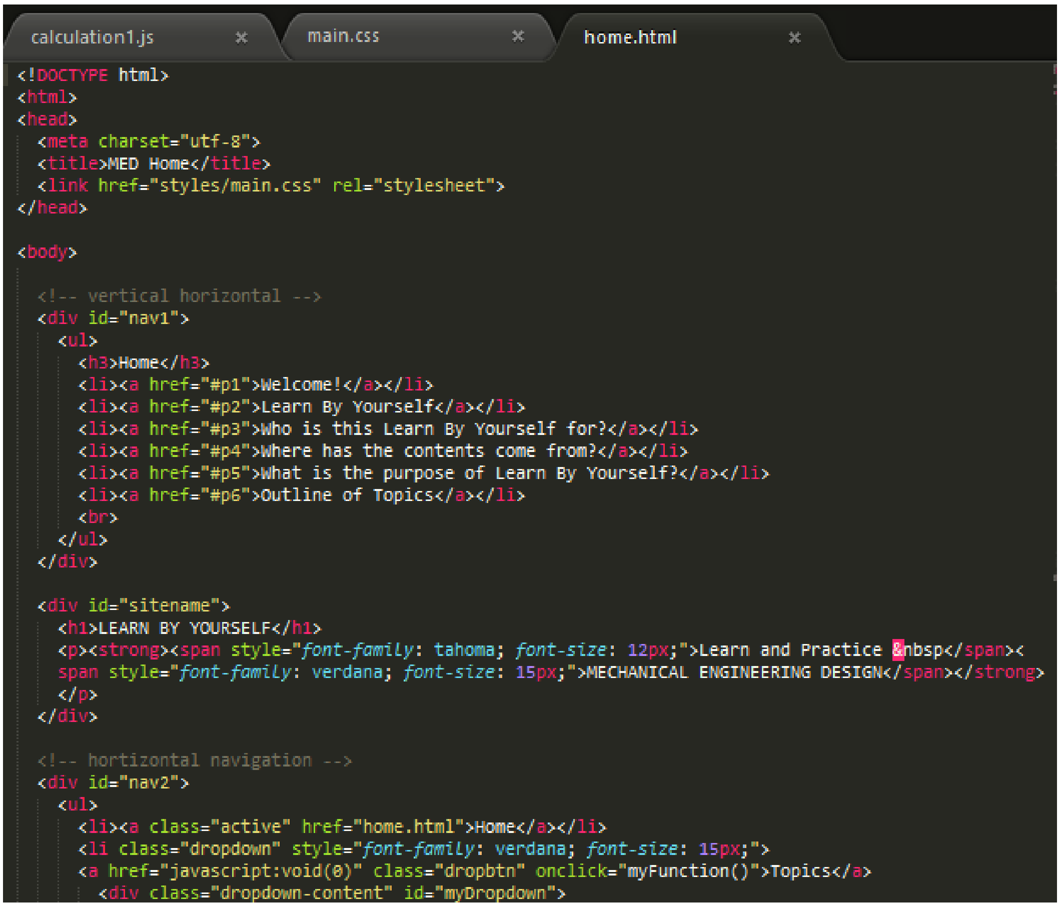


Figure 5.10: Example of HTML coding using Sublime Text 3.0.

```
calculation1.js   main.css
body {
    background-color: #EAEDB2;
    font-family: "courier new";
    font-size: 15px;
    color: #F7DD48;
}
#sitename {
    background-color: #444;
    margin-right: 5%;
    margin-left: 5%;
    padding: 5px;
    width: auto;
    text-align: left;
    text-indent: 50px;
    border-top-left-radius: 8px;
    border-top-right-radius: 8px;
}
hr {
    border-color: #F7DD48;
    border-style: 0.1px solid;
    border-top: white;
}
/*vertical navigation*/
#nav1 ul {
    background-color: #2384AD;
    list-style-type: none;
    padding: 0;
    width: 150px;
    position: fixed;
    margin-top: 180px;
    height: auto;
    overflow: auto;
```

Figure 5.11: Example of CSS coding using Sublime Text 3.0.

```
calculation1.js
/* When the user clicks on the button,
toggle between hiding and showing the dropdown content */
function myFunction() {
    document.getElementById("myDropdown").classList.toggle("show");
}

// Close the dropdown if the user clicks outside of it
window.onclick = function(e) {
  if (!e.target.matches('.dropbtn')) {

    var dropdowns = document.getElementsByClassName("dropdown-content");
    for (var d = 0; d < dropdowns.length; d++) {
      var openDropdown = dropdowns[d];
      if (openDropdown.classList.contains('show')) {
        openDropdown.classList.remove('show');
      }
    }
  }
}

/*Calculation*/
function myFunction1()
{

  var nsx_checked = document.getElementById("n_sx").checked;
  var nsy_checked = document.getElementById("n_sy").checked;
  var ns_checked = document.getElementById("n_s").checked;

  var a = document.getElementById("mySelect1").value;
  var b = document.getElementById("mySelect2").value;
  var c = document.getElementById("mySelect3").value;
```

Figure 5.12: JavaScript scripting using Sublime Text 3.0.

5.7 Testing Phase

A testing phase is carried out to ensure a system works correctly and properly. Usually, a system test concentrates on two main areas: internal efficiency and external effectiveness (Green and DiCaterino, 1998). The test for internal efficiency is to ensure the computer codes are well-organized and standardized. External effectiveness testing is to validate the software functioning according to the system design. Moreover, the testing phase should continuously run and verified to make sure the whole system was built correctly and satisfactorily (Owolabi, 2004). The researcher carried out the testing using the textbook questions and checked the answer obtained from the system.

In this study, the designed prototype has been tested frequently, and the test included were as follows:

1. Code checks for errors, bugs, and interoperability of links
2. Checks for the response for all kinds of inputs
3. Browser compatibility to ensure the performance of the web pages so they work appropriately
4. Computer compatibility to ensure the appearance of the web pages is consistent

One of the most crucial testing that was quite time-consuming was during the checking of JavaScript scripting for a “Try it Now!” template. The scripting required the user to input the necessary data and/or to select the option provided before the user could select the submit button for the system to produce the results. Two templates of “Try it Now!” were created; one for calculating the safety factor, and another to solve the design of square or rectangular keys.

Respectively, Figure 5.13, Figure 5.14 and Figure 5.15 show a template page for the safety factor: (1) before the user inputting or selecting, (2) the user input required data and selecting the option, and (3) the output results. In this template, each characteristic on the “Given” part was coded so it will be generated automatically in the calculation to produce the output results. This part required a long time to arrange and code in JavaScript, and to check that all the characteristic values were correct and similar to those given in Table 5.2.

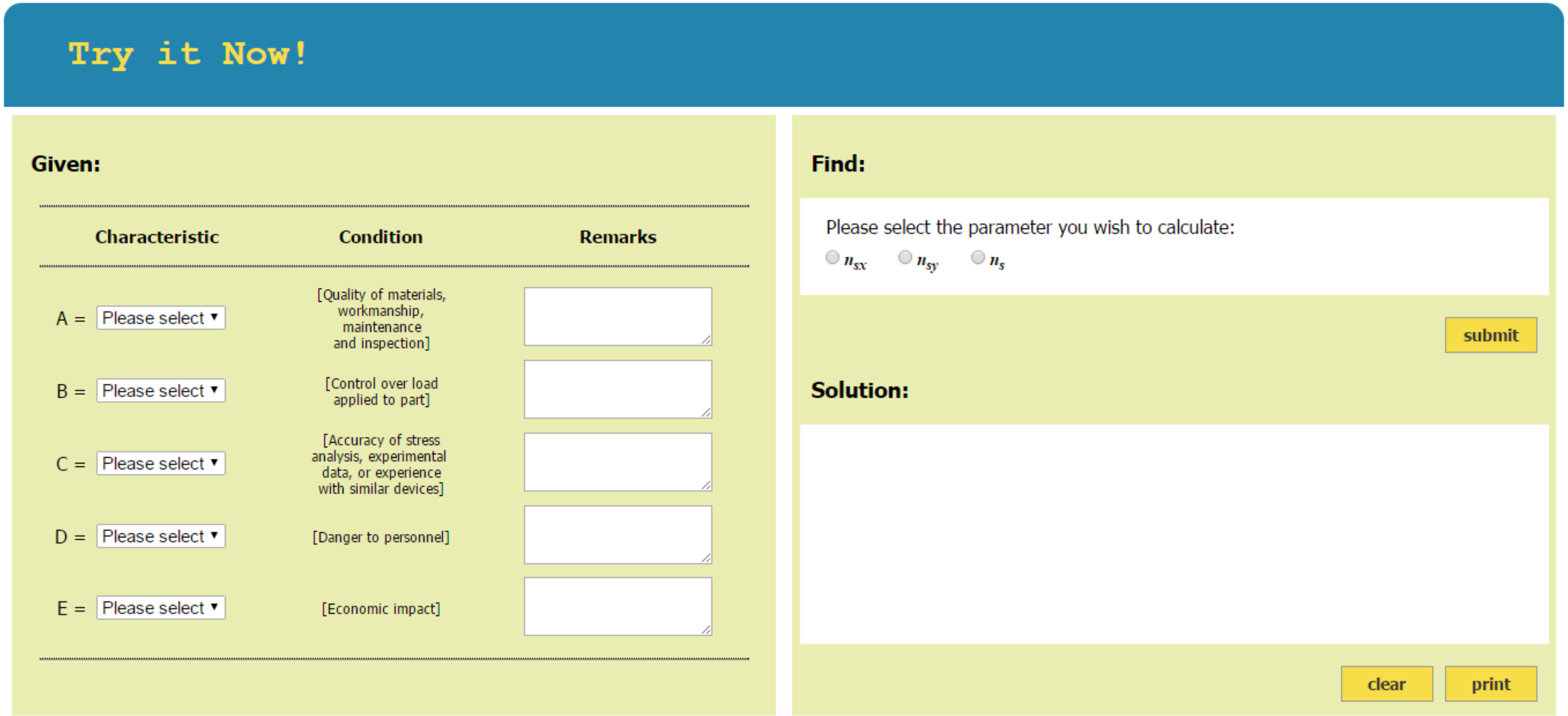


Figure 5.13: A calculation template for the factor of safety (before the user inputting or selecting).

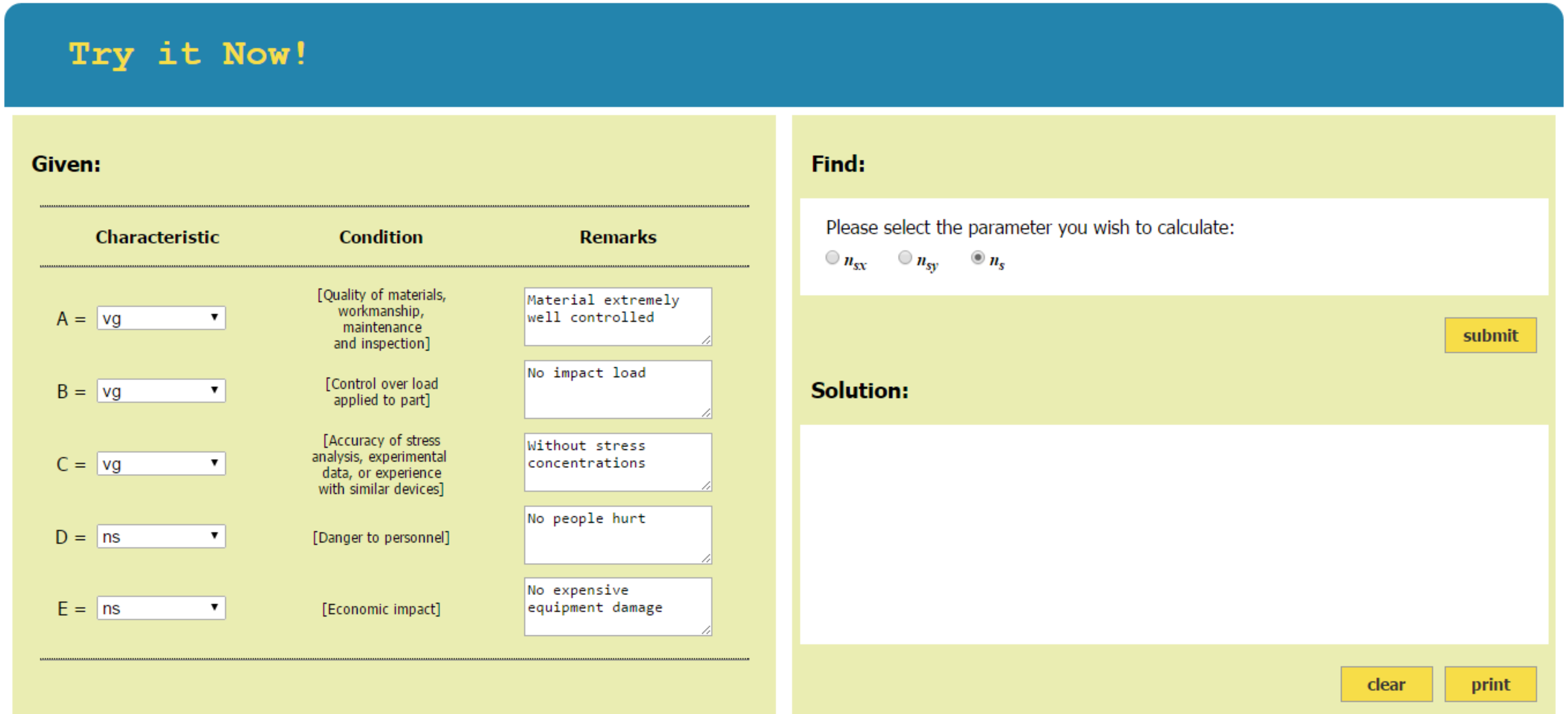


Figure 5.14: A calculation template for the factor of safety (the user input required data and selecting the option).

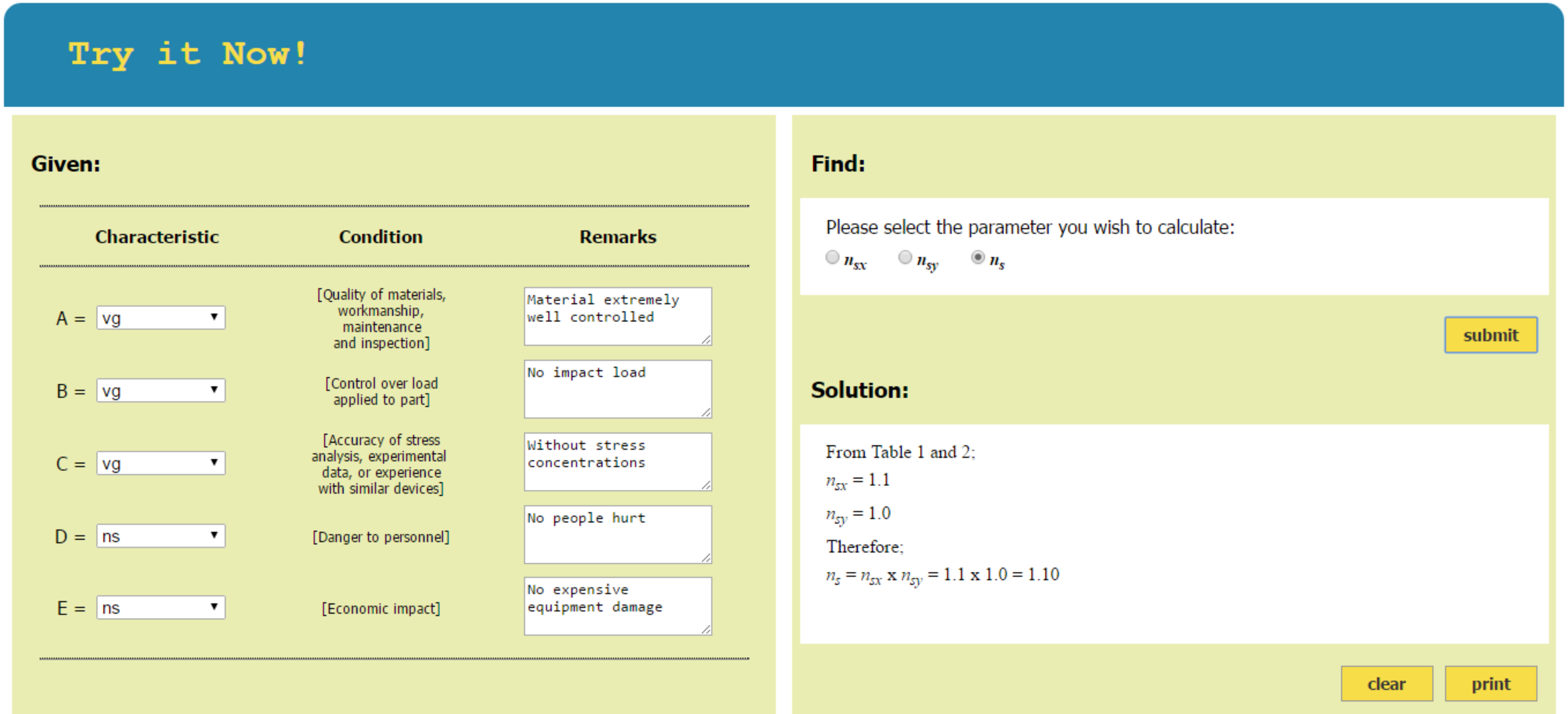


Figure 5.15: A calculation template for the factor of safety (the output results).

Table 5.2: Important characteristics used in calculating the factor of safety (according to the Pugsley method).

1: Safety factor characteristics A, B, and C						
1.1 Characteristic [a]			B =			
			vg	g	f	p
A = vg	C =	vg	1.1	1.3	1.5	1.7
		g	1.2	1.45	1.7	1.95
		f	1.3	1.6	1.9	2.2
		p	1.4	1.75	2.1	2.45
A = g	C =	vg	1.3	1.55	1.8	2.05
		g	1.45	1.75	2.05	2.35
		f	1.6	1.95	2.3	2.65
		p	1.75	2.15	2.55	2.95
A = f	C =	vg	1.5	1.8	2.1	2.4
		g	1.7	2.05	2.4	2.75
		f	1.9	2.3	2.7	3.1
		p	2.1	2.55	3.0	3.45
A = p	C =	vg	1.7	2.15	2.4	2.75
		g	1.95	2.35	2.75	3.15
		f	2.2	2.65	3.1	3.55
		p	2.45	2.95	3.45	3.95

2: Safety factor characteristics D and E				
1.2 Characteristic [b]		D =		
		ns	s	vs
E =	ns	1.0	1.2	1.4
	s	1.1	1.3	1.5
	vs	1.2	1.4	1.6

'a' – vg = very good, g = good, f = fair, p = poor.
'b' – ns = not serious, s = serious, vs = very serious.

A = quality of materials, workmanship, maintenance, and inspection.
B = control overload applied to the part.
C = accuracy of stress analysis, test data, or experience with similar parts.
D = danger to personal.
E = economic impact.

Figure 5.16, Figure 5.17, and Figure 5.18 indicate a template page for the design of square and rectangular keys: (1) before the user inputting or selecting, (2) the user input required data and selecting the option, and (3) the output results and the list of the formula used. This template required more testing such that on each selection option, inputted data as well as the selection of unit. The whole calculations and output results from both "Try it Now!" were tested to ensure that they produced the correct answers and the answers were compared with the answers determined using manual calculation. Finally, once the testing phase was completed and satisfied, this prototype online learning was then used in user-testing with the students during the main study stage in this research.

Figure 5.16: A calculation template for the design of square and rectangular keys (before the user inputting or selecting).

Figure 5.17: A calculation template for the design of square and rectangular keys (the user input required data and selecting the option).

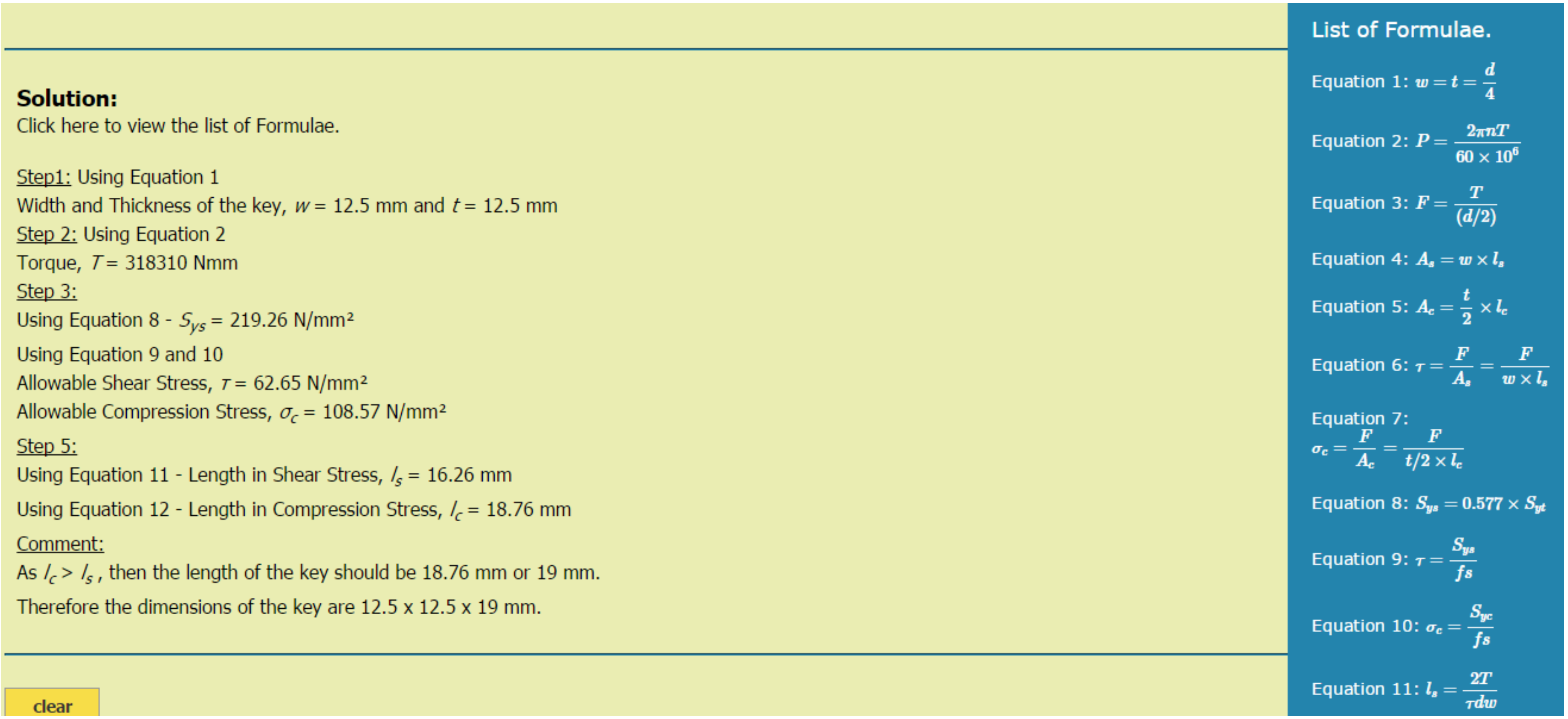


Figure 5.18: A calculation template for the design of square and rectangular keys (the output results and the list of the formula used).

5.8 Summary

In this chapter, a prototype online web-based learning system was designed, created and tested. All the four phases of SDLC have been explained and presented using appropriate figures. The flowchart and functional requirements of the prototype have also been demonstrated and validated in this chapter. The coding and testing phases are two important phases that required considerable time and full consideration to ensure the prototype online learning system works properly and efficiently.

The following Chapter 6 provides an overview of the chosen approach and the activities required for the main study stage in this research.

Chapter 6. Main Study

6.1 Introduction

An overview of a main study conducted in this research will be discussed in this chapter. The statistical data analysis was selected and used appropriately and effectively to analyse the data collected. The chapter also presents and discusses the output results obtained from the statistical analysis.

6.2 Design of Main Study

After the design of a prototype online learning system was completed, this research determined to continue with a main study as the final stage to collect the necessary data to answer the research questions. The aim of the study was to identify the learning satisfaction, performance and self-confidence of experienced and inexperienced students completing simple and complex tasks from the Mechanical Engineering Design module using either a traditional learning technique or an online learning system. The study involved the participation of undergraduate and diploma students from the department of Mechanical Engineering, Universiti Teknologi Brunei. A total of 84 undergraduate and 76 diploma students participated in the study. The students were divided into two groups: experienced and inexperienced participants. The experienced group were the undergraduate and diploma students who were in their final year and had learned the machine design module. The inexperienced group were the undergraduate and diploma students who were in their first or second year of their studies and had little or no experience in the mechanical engineering design module. Both the experienced and inexperienced groups were then divided equally into two groups: group 1 (40 participants) and group 2 (40 participants).

Each group attended two learning sessions. Group 1 attended traditional learning as their first session (1st session) and followed with online learning as their second session (2nd session). On the other hand, Group 2 attended online learning as their 1st session and then continued with their traditional learning as their 2nd session. A survey framework can be seen in Figure 3.5 (Chapter 3).

6.2.1 Assigned tasks

In both sessions, the students were provided with an instruction sheet to solve the two assigned tasks, which were simple and complex tasks. In traditional learning, the students were also provided with the relevant lecture notes for reference and an answer sheet for each assigned task. In the online learning, the students were required to use the "Try it Now!" template in the system to solve the design problem and then transferred the answers to the answer sheets. Each of the answer sheets contained a set of questions for the simple or complex tasks. The answer sheet requested the students to state their level of study and provided:

1. an empty space for working,
2. two empty boxes to record the start time and finish time, and
3. a "Yes" or "No" question: Are you confident that your solution above is correct?

The simple task was a short design problem regarding the safety factor. The task was considered to be simple because it only required selection of the characteristics and one formula to solve the design problem. The estimated time to complete this task is within 5-10 minutes. The questions and solutions used as a simple task in both traditional and online learning are presented in Table 6.1 and Table 6.2 respectively. Figure 6.1 shows the students doing the assigned tasks in a traditional learning session.

For a complex task, the question was taken from the design problem of designing square and rectangular keys. The task was considered to be complex as there are many parameters given and many formulae required in solving the problem. This task could completed within 15-20 minutes. Table 6.3 and Table 6.4 show the complex tasks that were studied in traditional and online learning respectively. Figure 6.2 shows students performing the assigned task using the online learning system. The copies of the instruction sheets and the answer sheets of assigned tasks are provided in Appendix E and Appendix F respectively. Having completed the two tasks, the participants were asked to complete a questionnaire.

Table 6.1: Simple tasks and solutions for traditional learning (see the survey framework in Figure 3.5).

Traditional Learning	
Question: A crane has a loading hook that is hanging on a steel wire. The allowable normal tensile stress in the wire gives an allowable force of 100 000 N. Find the **safety factor** that should be used. If the wire material is not controlled, the load can cause impact, and fastening the hook in the wire causes stress concentrations. (If the wire breaks, people can be seriously hurt and expensive equipment can be destroyed.)	Solution: A = p (material not controlled) B = p (load caused the impact) C = p (stress concentration) D = vs (seriously hurt) E = vs (expensive equipment lost) From table of characteristics: As A = vg, B = vg, C = vg, $n_{sx} = 3.95$ As D = ns, E = ns, $n_{sy} = 1.6$ Then safety factor is $\therefore n_s = n_{sx} \times n_{sy} = 3.95 \times 1.6 = \underline{6.32}$

Table 6.2: Simple tasks and solutions for online learning (see the survey framework in Figure 3.5).

Online Learning	
Question: A crane has a loading hook that is hanging on a steel wire. The allowable normal tensile stress in the wire gives an allowable force of 100 000 N. Find the **safety factor** that should be used. If the wire material is extremely well controlled, no impact loads are applied, and the hook is fastened in the wire without stress concentrations. (If the wire breaks, no people or expensive equipment can be damaged.)	Solution: A = vg (material extremely well controlled) B = vg (no impact load) C = vg (without stress concentration) D = ns (no people hurt) E = ns (no expensive equipment lost) From table of characteristics: As A = vg, B = vg, C = vg, $n_{sx} = 1.1$ As D = ns, E = ns, $n_{sy} = 1.0$ Then safety factor is $\therefore n_s = n_{sx} \times n_{sy} = 1.1 \times 1.0 = \underline{1.1}$

Table 6.3: Complex tasks and solutions for traditional learning (see the survey framework in Figure 3.5).

Traditional Learning
Question: It is required to design a square key for fixing a pulley on a shaft which is 60 mm in diameter. 20 kW of power at 300 rpm is transmitted from the pulley to the shaft. The key is made of steel 45C8 ($S_{yc} = S_{yt}$ = 380 N/mm^2) and the factor of safety is 3. Determine the dimensions of the key.
Solution: Given: Square Key ($w = t$), d = 60 mm, P = 20 kW, n = 300 rpm, S_{yt} = 380 N/mm^2, fs = 3 $\therefore w = t = \frac{d}{4} = \frac{60}{4} = 15\ mm$ Power: $P = \frac{2\pi nT}{60}$ $\therefore T = \frac{60 \times 10^6 P}{2\pi n} = \frac{60 \times 10^6 \times (20)}{2\pi(300)}$ $T = 636{,}620\ Nmm$ $S_{yt} = S_{yc} = 380\ N/mm^2$ $\therefore$ Allowable (Design) Compression Stress, $\sigma_c = \frac{S_{yc}}{fs} = \frac{380}{3} = 126.7\ N/mm^2$ From Eq. (1), $l_c = \frac{4T}{\sigma_c dt} = \frac{4(636{,}620)}{(126.7)(60)(15)} = 22.3\ mm$ By the distortion-energy theory, $S_{ys} = 0.577 S_{yt} = 0.577(380) = 219.3\ N/mm^2$ $\therefore$ Allowable (Design) Shear Stress, $\tau = \frac{S_{ys}}{fs} = \frac{219.3}{3} = 73.1\ N/mm^2$ From Eq. (2), $l_s = \frac{2T}{\tau dw} = \frac{2(636{,}620)}{(73.1)(60)(15)} = 19.4\ mm$ Equation 2 is the criterion for deciding the length in this case as $l_c > l_s$. The length of the key should be 22.3 or 23 mm, and its dimensions are 15 x 15 x 23 mm.

Table 6.4: Complex tasks and solutions for online learning (see the survey framework in Figure 3.5).

Online Learning
Question: It is required to design a square key for fixing a pulley on a shaft which is 50 mm in diameter. 10 kW of power at 300 rpm is transmitted from the pulley to the shaft. The key is made of steel 45C8 (S_{yc} = S_{yt} = 380 N/mm^2) and the factor of safety is 3.5. Determine the dimensions of the key.
Solution: Given: Square Key ($w = t$), d = 50 mm, P = 10 kW, n = 300 rpm, S_{yt} = 380 N/mm^2, fs = 3.5 $\therefore w = t = \frac{d}{4} = \frac{50}{4} = 12.5\, mm$ Power: $P = \frac{2\pi n T}{60}$ $\therefore T = \frac{60 \times 10^6 P}{2\pi n} = \frac{60 \times 10^6 \times (10)}{2\pi(300)}$ $T = 318{,}310\, Nmm$ $S_{yt} = S_{yc} = 380\, N/mm^2$ $\therefore$ Allowable (Design) Compression Stress, $\sigma_c = \frac{S_{yc}}{fs} = \frac{380}{3.5} = 108.6\, N/mm^2$ From Eq. (1), $l_c = \frac{4T}{\sigma_c d t} = \frac{4(318{,}310)}{(108.6)(50)(12.5)} = 18.8\, mm$ By the distortion-energy theory, $S_{ys} = 0.577 S_{yt} = 0.577(380) = 219.3\, N/mm^2$ $\therefore$ Allowable (Design) Shear Stress, $\tau = \frac{S_{ys}}{fs} = \frac{219.3}{3.5} = 62.7\, N/mm^2$ From Eq. (2), $l_s = \frac{2T}{\tau d w} = \frac{2(318{,}310)}{(62.7)(50)(12.5)} = 16.2\, mm$ Equation 2 is the criterion for deciding the length in this case as $l_c > l_s$. The length of the key should be 18.8 or 19 mm, and its dimensions are 12.5 x 12.5 x 19 mm.

(a)

(b)

Figure 6.1: Two photographs of students doing the assigned tasks using the traditional learning method.

(a)

(b)

Figure 6.2: Two photographs of students doing the assigned tasks using online learning.

6.2.2 Questionnaires

In this main study, the questionnaire was divided into four parts. Part A was about the participants' general background consisting of; gender, academic qualification, level of study and previous experience in attending Mechanical Engineering Design or Machine Design module. The descriptive statistics of the participants is shown in Table 6.5.

Table 6.5: Descriptive statistics of the participants (N = 160).

Description		Experienced	Inexperienced	Percentage (%)
Gender	Male	44	51	59.4
	Female	36	29	40.6
Academic qualification	A Level	50	68	72.8
	Higher National Diploma	6	10	10.0
	National Diploma	24	2	16.3
Level of study	Undergraduate	29	55	52.5
	Diploma	51	25	47.5
Total of Participants		80	80	100

After completing Part A, the participants were required to complete the following questions according to the learning session that they attended. If they attended a traditional learning session, they had to complete: Part B1, C1 and D1. On the other hand, the questions in Part B2, C2 and D2 were to be completed by those attending the online learning. The questions in Part B and D were designed as a five-point Likert scales to specify the level of agreement or disagreement. For questions in Part C, the participants were only required to answer "Yes" or "No". A copy of the questionnaire is provided in Appendix G.

For traditional learning, the questionnaire consisted of:

1. Part B1: Participant's views about attending traditional learning sessions

    - Do you agree that the learning environment during normal lectures and tutorials was friendly and easy to explore?
    - Do you agree that the learning materials during normal lectures and tutorials were clearly presented?
    - Do you agree that the learning materials provided in normal lectures and tutorials increased your understanding effectively?
    - Do you agree that attending normal lectures and tutorials met your learning expectations?
    - Were you satisfied with attending normal lectures and tutorials?

2. Part C1: Participant's views about solving the assigned tasks

    - Did you manage to solve a simple task using learning materials that were taught and provided during normal lectures and tutorials?
    - Did you manage to solve a complex task using learning materials that were taught and provided during normal lectures and tutorials?
    - Were you satisfied with your solutions for both assigned tasks?

3. Part D1: Participant's satisfaction, performance and self-confidence

    - Do you agree that you felt satisfied with your learning by attending normal lectures and tutorials?
    - Do you agree that by attending normal lectures and tutorials can develop your self-confidence in performing design calculations?
    - Do you agree that using learning materials provided during normal lectures and tutorials will speed up the time taken to solve a simple task?
    - Do you agree that using learning materials provided during normal lectures and tutorials will speed up the time taken to solve a complex task?

- Do you feel more likely to use learning materials provided during normal lectures and tutorials if the task is simple?
- Do you feel more likely to use the learning materials provided during normal lectures and tutorials if the task is complex?
- Do you agree with attending normal lectures and tutorials as your preferred approach to learn Machine Design or Mechanical Engineering Design module?

For attending online learning, the questionnaire was:

1. Part B2: Participant's views about attending online learning sessions

   - Do you agree that the online learning system was friendly and easy to explore?
   - Do you agree that the learning materials in the online learning system were clearly presented?
   - Do you agree that learning materials provided in the online learning system increased your understanding effectively?
   - Do you agree that the online learning system was accessible for you to meet your learning expectations?
   - Were you satisfied with learning using the online learning system?

2. Part C2: Participant's views about solving the assigned tasks

   - Did you manage to solve a simple task using the online learning system?
   - Did you manage to solve a complex task using the online learning system?
   - Were you satisfied with your solutions for both assigned tasks?

3. Part D2: Participant's satisfaction, performance and self-confidence

   - Do you agree that you felt satisfied with your learning when using the online learning system?
   - Do you agree that using learning materials provided in the online learning system can develop your self-confidence in performing design calculations?

- Do you agree that using learning materials provided in the online learning system will speed up the time taken to solve a simple task?
- Do you agree that using learning materials provided in the online learning system will speed up the time taken to solve a complex task?
- Do you feel more likely to use learning materials provided in the online learning system if the task is simple?
- Do you feel more likely to use the learning materials provided in the online learning system if the task is complex?
- Do you agree with using the online learning system as your preferred approach in learning Machine Design or Mechanical Engineering Design module?

6.3 Data Analysis

In this study, the data analysis was completed carefully starting from data collection and preparation, screening and cleaning, and analysing the collected data using descriptive and statistical tests.

6.3.1 Collection and preparation

As discussed in the previous section, all the data were collected using the questionnaires. The preparation for the data involved setting up the structure of data file: label name, types and values of variables, missing values and level of measurement of the data. At the beginning, all the data were entered into Microsoft Excel so the data are well-arranged and grouped properly. With the arranging and grouping completed, the data were then converted to the SPSS format.

6.3.2 Screening and cleaning

The first step in screening and cleaning the data was to check for any errors and missing data within categorical and numerical variables. There are three types of missing data (Hedeker and Gibbons, 2006):

1. Missing completely at random (MCAR); missing data have no relationship to the dependent variable values that were observed or those unobserved.

2. Missing at random (MAR); missing data not a function of the dependent variable when controlled for other variable effects.

3. Missing not at random (MNAR); missing data caused by an unmeasured variable or depends on its own value.

The second part of the screening and cleaning the data is to find and correct any errors. The identification of missing data for this study was performed using SPSS version 22.0 where the percentage of missing data were determined for each variable in each part of the questionnaire. As can be seen from Table 6.6, there was no missing data (0%) in each part of the questionnaire for the experienced and inexperienced students.

Table 6.6: Checking for missing data.

Part	No. of items	Missing Data (%)	
		Experienced	Inexperienced
Part A (Participant's general background)	5	0	0
Part B (Participant's views about attending the learning sessions)	5	0	0
Part C (Participant's views about solving the assigned tasks)	3	0	0
Part D (Participant's satisfaction, performance, and self-confidence)	7	0	0

6.3.3 Descriptive analysis of demographics

In this section, a summary of the demographic information of the participants is presented according to gender, academic qualification and level of study. The previous sub-section indicates that there were no missing data from the data screening. From Table 6.7, it can be seen that there were more male students in the experienced group (44 participants, 55.0%) with less female students (36 participants, 45.0%). Likewise, the inexperienced group also had more male students (51 participants, 63.7%) and fewer females (29 participants, 36.6%).

Table 6.7: Descriptive analysis for gender.

Gender	Experienced		Inexperienced	
	No.	%	No.	%
Male	44	55.0	51	63.7
Female	36	45.0	29	36.3
Total	80	100	80	100

Table 6.8 shows that most of the inexperienced students had A level qualifications (68 participants, 85.0%) and the experienced students had more Diplomas qualifications (30 participants, 37.5%) than the inexperienced students.

Table 6.8: Academic qualification.

Academic qualification	Experienced		Inexperienced	
	No.	%	No.	%
A Level	50	62.5	68	85.0
Higher National Diploma	6	7.5	10	12.5
National Diploma	24	30.0	2	2.5
Total	80	100	80	100

Table 6.9 shows that most diploma students (51 participants, 63.7%) were in the experienced group with fewer undergraduate students (29 participants, 36.3%). This is in contrast to the inexperienced group where there were more undergraduate students (55 participants, 68.8%) participated with less diplomas students (25 participants, 31.2%).

Table 6.9: Level of study.

Level of study	Experienced		Inexperienced	
	No.	%	No.	%
Undergraduate	29	36.3	55	68.8
Diploma	51	63.7	25	31.2
Total	80	100	80	100

6.4 Statistical Analysis of Research Questions

As explained in Chapter 3, the three main statistical analysis tests: Mann-Whitney U test, Paired Sample T test, and Chi-Square test, were used to analyse the results of this study. This section reports and discusses the findings related to the research questions:

RQ1a Will attending traditional learning sessions by experienced students improve learning satisfaction?

RQ1b Will attending traditional learning sessions by inexperienced students improve learning satisfaction?

Table 6.10 indicates that the majority of experienced and inexperienced participants were agreed that attending traditional learning session improved learning satisfaction.

Table 6.10: Percentage of learning satisfaction after attending traditional learning.

Competency	Learning Technique	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
Experienced Group	Traditional Learning (1st session)	2.5%	2.5%	17.5%	47.5%	30.0%
	Traditional Learning (2nd session)	0	12.5%	32.5%	50.0%	5.0%
Inexperienced Group	Traditional Learning (1st session)	5.0%	5.0%	30.0%	50.0%	10.0%
	Traditional Learning (2nd session)	0	12.5%	32.5%	52.5%	2.5%

RQ1c Is there any difference between experienced and inexperienced students in learning satisfaction after attending traditional learning sessions?

As can be seen in Table 6.11, the p-values from the Mann-Whitney U test for the 1st and 2nd sessions were 0.536 and 0.907 respectively. These two p-values are greater than the significant value of 0.05. Therefore, no significant effects were found to occur between the experienced and inexperienced participants in attending traditional learning. The mean rank for the inexperienced participants attending traditional learning in the 1st session was 41.98, which was higher than the experienced participants with the mean rank value of 39.03. The mean ranks for experienced and inexperienced participants were 40.78 and 40.23 respectively, which indicates that there was no difference between their perception that attending traditional learning in the 2nd session improved their learning satisfaction.

Table 6.11: Mann-Whitney test for learning satisfaction between experienced and inexperienced participants after attending traditional learning.

Traditional Learning (session period)	p-value	Mean rank		Significant effect
		Experienced	Inexperienced	
1st Session	0.536	39.03	41.98	Not significant
2nd Session	0.907	40.78	40.23	Not significant

*p-value less than 0.05

RQ1d Will using online learning sessions by experienced students improve learning satisfaction?

RQ1e Will using online learning sessions by inexperienced students improve learning satisfaction?

As shown in Table 6.12, there was a slightly higher percentage of inexperienced participants (30.0%) who strongly agreed that using online learning improved their learning satisfaction. Nevertheless, the majority of the participants in both groups were agreed that using online learning improved their learning satisfaction.

Table 6.12: Percentage of learning satisfaction after using online learning.

Competency	Learning Technique	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
Experienced Group	Online Learning (1st session)	0	7.5%	17.5%	52.5%	22.5%
	Online Learning (2nd session)	2.5%	12.5%	35.0%	42.5%	7.5%
Inexperienced Group	Online Learning (1st session)	5.0%	5.0%	37.5%	37.5%	15.0%
	Online Learning (2nd session)	0	0	27.5%	42.5%	30.0%

RQ1f Is there any difference between experienced and inexperienced students in learning satisfaction after using online learning?

In Table 6.13, the p-value of the Mann-Whitney U test for online learning in the 1st session was 0.530 which is more than the significant p-value of 0.05. There is no significant difference between the experienced and inexperienced participants in their preception that using traditional learning improved their learning satisfation. The mean rank for experienced participants was slightly greater at 42.04 than the mean value of inexperienced participants which was 38.96.

However, when using online learning in the 2nd session, the p-value between the experienced and inexperienced participants was 0.003 which less than the significant p-value of 0.05. This shows that there was a significant difference in perception between the two groups of participants that using online learning improved their learning satisfaction. The mean rank for the inexperienced participants was 47.74, higher than the experienced participants with the mean rank value of 33.26.

Table 6.13: Mann-Whitney test for learning satisfaction between experienced and inexperienced participants after using online learning.

Online Learning (session period)	p-value	Mean rank		Significant effect
		Experienced	Inexperienced	
1st Session	0.530	38.96	42.04	Not significant
2nd Session	0.003*	33.26	47.74	Significant

*p-value less than 0.05

RQ2a Will solving the assigned tasks using traditional learning by experienced students improve learning satisfaction?

RQ2b Will solving the assigned tasks using traditional learning by inexperienced students improve learning satisfaction?

Table 6.14 shows that both experienced and inexperienced participants were agreed that solving the assigned tasks using traditional learning improved their learning satisfaction. The experienced participants in the 2nd session had the higher percentage (82.5%) among other participants indicating that most of them were agreed with the perception that solving the assigned tasks using traditional learning improved their learning satisfaction.

Table 6.14: Percentage of learning satisfaction in solving the assigned tasks using traditional learning.

Competency	Learning Technique	Yes	No
Experienced Group	Traditional Learning (1st session)	72.5%	27.5%
	Traditional Learning (2nd session)	82.5%	17.5%
Inexperienced Group	Traditional Learning (1st session)	67.5%	32.5%
	Traditional Learning (2nd session)	72.5%	27.5%

RQ2c Is there any difference between experienced and inexperienced students in learning satisfaction after solving the assigned tasks using traditional learning?

Table 6.15 shows the results of Chi-Square tests for experienced and inexperienced participants in solving the assigned tasks using traditional learning. The Pearson Chi-Square value, df (degree of freedom) and p-value (denoted by Asymp. Sig. (2-sided)) were used to report the significance test. Hence, the p-values between the experienced and inexperienced participants solving the assigned tasks in the 1st and 2nd sessions were larger than the significant p-value of 0.05. This means that no significant association was found between the two groups of participants about the perception that solving the assigned tasks using traditional learning improved their learning satisfaction.

Table 6.15: Pearson Chi-Square test for learning satisfaction between experienced and inexperienced participants after solving the assigned tasks using traditional learning.

Traditional Learning (session period)	Experienced vs. Inexperienced			Significant effect
	value	df	Asymp. Sig. (2-sided)	
1st Session	0.238	1	0.626	Not significant
2nd Session	1.147	1	0.284	Not significant

*p-value [denoted by Asymp. Sig. (2-sided)] less than 0.05

RQ2d Will solving the assigned tasks using online learning by experienced students improve learning satisfaction?

RQ2e Will solving the assigned tasks using online learning by inexperienced students improve learning satisfaction?

As can be seen in Table 6.16, both experienced and inexperienced participants were agreed that solving the assigned tasks using online learning improved their learning satisfaction. Both experienced and inexperienced participants in the 2nd session had the same high percentage (87.5%) indicating that they agreed with the perception that solving the assigned tasks using online learning improved their learning satisfaction.

Table 6.16: Percentage of learning satisfaction in solving the assigned tasks using online learning.

Competency	Learning Technique	Yes	No
Experienced Group	Online Learning (1st session)	67.5%	32.5%
	Online Learning (2nd session)	87.5%	12.5%
Inexperienced Group	Online Learning (1st session)	77.5%	22.5%
	Online Learning (2nd session)	87.5%	12.5%

RQ2f Is there any difference between experienced and inexperienced students in learning satisfaction after solving the assigned tasks using online learning?

From the Chi-Square tests, the p-values between the experienced and inexperienced participants who solving the assigned tasks using online learning in the 1st and 2nd sessions were greater than the significant p-value of 0.05 (Table 6.17). Therefore, no significant difference was found between the two groups of participants on the perception that solving the assigned tasks using online learning improved their learning satisfaction.

Table 6.17: Pearson Chi-Square test for learning satisfaction between experienced and inexperienced participants after solving the assigned tasks using online learning.

Online Learning (session period)	Experienced vs. Inexperienced			Significant effect
	value	df	Asymp. Sig. (2-sided)	
1st Session	1.003	1	0.317	Not significant
2nd Session	0.000	1	1.000	Not significant

*p-value [denoted by Asymp. Sig. (2-sided)] less than 0.05

RQ3a Will using traditional learning by experienced students improve speed in solving the assigned tasks?

RQ3b Will using traditional learning by inexperienced students improve speed in solving the assigned tasks?

In Table 6.18, the experienced participants had spent less time solving both simple and complex tasks using traditional learning in the 2nd session with the smallest mean time taken of 7 mins and 11 mins respectively. The inexperienced group solving both simple and complex tasks in the 1st session was the slowest with the higher mean time taken of 11 mins and 15 mins respectively.

Table 6.18: Mean time taken in solving the assigned tasks using traditional learning.

Competency	Learning Technique	Simple Task	Complex Task
Experienced Group	Traditional Learning (1st session)	9 mins	12 mins
	Traditional Learning (2nd session)	7 mins	11 mins
Inexperienced Group	Traditional Learning (1st session)	11 mins	15 mins
	Traditional Learning (2nd session)	8 mins	11 mins

RQ3c Is there any difference between experienced and inexperienced students in speed in solving the assigned tasks using traditional learning?

Table 6.19 and Table 6.20 show the results of Paired Sample T tests in terms of the mean time taken for both experienced and inexperienced participants in solving both simple and complex tasks using traditional learning. The t value, df (degree of freedom) and p-value (denoted by Sig. (2-tailed)) were used to report for the significance test.

In Table 6.19, the p-value between the experienced and inexperienced participants solving the simple task in the 1st session was 0.009, smaller than the significant p-value of 0.05. This means there is a significant difference exist between the two groups of participants in the speed of solving the simple task using traditional learning. The p-value obtained between the experienced and inexperienced participants in the 2nd session was 0.165, larger than the significant p-value of 0.05. Thus, no significant effect was found between the two groups regarding speed in solving the simple task using traditional learning.

Table 6.19: Paired Sample T test for the mean time taken between experienced and inexperienced participants when solving the simple task using traditional learning.

Traditional Learning (session period)	Experienced vs. Inexperienced			Significant effect
	t	df	Sig. (2-tailed)	
1st Session	-2.757	39	0.009*	significant
2nd Session	-1.414	39	0.165	Not significant

*p-value [denoted by Sig. (2-tailed)] less than 0.05

From Table 6.20, both p-values between the experienced and inexperienced participants solving the complex task in the 1st and 2nd sessions were 0.253 and 0.635, larger than the significant p-value of 0.05. Therefore, no significant difference exists between the two groups of participants in the speed of solving the complex task using traditional learning.

Table 6.20: Paired Sample T test for the mean time taken between experienced and inexperienced participants when solving the complex task using traditional learning.

Traditional Learning (session period)	Experienced vs. Inexperienced			Significant effect
	t	df	Sig. (2-tailed)	
1st Session	1.161	39	0.253	Not significant
2nd Session	-0.479	39	0.635	Not significant

*p-value [denoted by Sig. (2-tailed)] less than 0.05

RQ3d Will using online learning by experienced students improve speed in solving the assigned tasks?

RQ3e Will using online learning by inexperienced students improve speed in solving the assigned tasks?

As shown in Table 6.21, the mean time taken for the experienced participants to solve the simple and complex tasks using traditional learning in the 2nd session were the smallest with 6 mins and 11 mins respectively. The experienced participants solving both simple and complex tasks in the 1st session had the higher mean time taken of 11 mins and 17 mins respectively.

Table 6.21: Mean time taken in solving the assigned tasks using online learning.

Competency	Learning Technique	Simple Task	Complex Task
Experienced Group	Online Learning (1st session)	11 mins	17 mins
	Online Learning (2nd session)	6 mins	11 mins
Inexperienced Group	Online Learning (1st session)	10 mins	16 mins
	Online Learning (2nd session)	6 mins	14 mins

RQ3e Is there any difference between experienced and inexperienced students in speed in solving the assigned tasks using online learning?

From Table 6.22, the p-value between the experienced and inexperienced participants solving the simple task in the 1st session was 0.002, smaller than the significant p-value of 0.05. Therefore, a significant difference exists between the two groups of participants in the speed of solving the complex task using traditional learning. The p-value obtained between the experienced and inexperienced participants in the 2nd session was 0.853 which less than 0.05, indicating no significant difference existed between the two groups regarding speed in solving the complex task using traditional learning.

Table 6.22: Paired Sample T test for the mean time taken between experienced and inexperienced participants when solving the simple task using online learning.

Online Learning (session period)	Experienced vs. Inexperienced			Significant effect
	t	df	Sig. (2-tailed)	
1st Session	-3.408	39	0.002*	significant
2nd Session	-0.187	39	0.853	Not significant

*p-value [denoted by Sig. (2-tailed)] less than 0.05

In Table 6.23, both p-values between the experienced and inexperienced participants solving the complex task during the 1st and 2nd sessions were 0.513 and 0.085, larger than the significant p-value of 0.05. This means that no significant difference exists between the two groups of participants in the speed of solving the complex task using traditional learning.

Table 6.23: Paired Sample T test for the mean time taken between experienced and inexperienced participants when solving the complex task using online learning.

Online Learning (session period)	Experienced vs. Inexperienced			Significant effect
	t	df	Sig. (2-tailed)	
1st Session	0.661	39	0.513	Not significant
2nd Session	-1.770	39	0.085	Not significant

*p-value [denoted by Sig. (2-tailed)] less than 0.05

RQ4a Will doing the assigned tasks using traditional learning by experienced students improve self-confidence?

RQ4b Will doing the assigned tasks using traditional learning by inexperienced students improve self-confidence?

Table 6.24 shows that the experienced participants solving the simple task using traditional learning in the 2nd session had the high percentage of 67.5% in self-confidence and this was more than other groups. Similarly, the experienced participants in the 1st session had the high percentage of 92.5%, indicating that most of them agreed with the perception that solving the complex task using traditional learning improved their self-confidence.

Table 6.24: Percentage of self-confidence when solving the assigned tasks using traditional learning.

Competency	Learning Technique	Simple Task		Complex Task	
		Yes	No	Yes	No
Experienced Group	Traditional Learning (1st session)	55.0%	45.0%	92.5%	7.5%
	Traditional Learning (2nd session)	67.5%	32.5%	72.5%	27.5%
Inexperienced Group	Traditional Learning (1st session)	52.5%	47.5%	77.5%	22.5%
	Traditional Learning (2nd session)	60.0%	40.0%	85.0%	15.0%

RQ4c Is there any difference between experienced and inexperienced students in self-confidence after solving the assigned tasks using traditional learning?

Table 6.25 and Table 6.26 show the results of Chi-Square tests for both experienced and inexperienced participants in solving the assigned tasks using traditional learning.

In Table 6.25, the p-values between the experienced and inexperienced participants solving the simple task in the 1st and 2nd sessions were larger than the significant p-value of 0.05. This means that no significant association exists between the two groups of participants in the perception that solving the simple task using traditional learning improved their self-confidence.

Table 6.25: Pearson Chi-Square test for self-confidence between experienced and inexperienced participants after solving the simple task using traditional learning.

Traditional Learning (session period)	Experienced vs. Inexperienced			Significant effect
	value	df	Asymp. Sig. (2-sided)	
1st Session	0.050	1	0.823	Not significant
2nd Session	0.487	1	0.485	Not significant

*p-value [denoted by Asymp. Sig. (2-sided)] less than 0.05

Similarly in Table 6.26, the p-values between the experienced and inexperienced participants solving the complex task in the 1st and 2nd sessions were larger than the significant p-value of 0.05. Thus, no significant association exists between the two groups of participants in the perception that solving the complex task using traditional learning improved their self-confidence.

Table 6.26: Pearson Chi-Square test for self-confidence between experienced and inexperienced participants after solving the complex task using traditional learning.

Traditional Learning (session period)	Experienced vs. Inexperienced			Significant effect
	value	df	Asymp. Sig. (2-sided)	
1st Session	3.529	1	0.060	Not significant
2nd Session	1.867	1	0.172	Not significant

*p-value [denoted by Asymp. Sig. (2-sided)] less than 0.05

RQ4d Will doing the assigned tasks using online learning by experienced students improve self-confidence?

RQ4e Will doing the assigned tasks using online learning by inexperienced students improve self-confidence?

Table 6.27 shows both experienced and inexperienced participants solving simple and complex tasks using online learning in the 2nd session had the high percentages of 87.5% and 97.5% respectively indicating that they agreed with the perception that solving the assigned tasks using online learning improved their self-confidence.

Table 6.27: Percentage of self-confidence when solving the assigned tasks using online learning.

Competency	Learning Technique	Simple Task		Complex Task	
		Yes	No	Yes	No
Experienced Group	Online Learning (1st session)	60.0%	40.0%	62.5%	37.5%
	Online Learning (2nd session)	87.5%	12.5%	97.5%	2.5%
Inexperienced Group	Online Learning (1st session)	52.5%	47.5%	65.0%	35.0%
	Online Learning (2nd session)	87.5%	12.5%	97.5%	2.5%

RQ4f Is there any difference between experienced and inexperienced students in self-confidence after solving the assigned tasks using online learning?

Table 6.28 and Table 6.29 show the results of Chi-Square tests for both experienced and inexperienced participants in solving the assigned tasks using online learning. From both tables, the p-values between the experienced and inexperienced participants solving simple and complex tasks in the 1st and 2nd sessions were greater than the significant p-value of 0.05. This means that no significant association exists between these groups of participants in the perception that solving the assigned tasks using traditional learning improved their self-confidence respectively.

Table 6.28: Pearson Chi-Square test for self-confidence between experienced and inexperienced participants after solving the simple task using online learning.

Online Learning (session period)	Experienced vs. Inexperienced			Significant effect
	value	df	Asymp. Sig. (2-sided)	
1st Session	0.457	1	0.499	Not significant
2nd Session	0.000	1	1.000	Not significant

*p-value [denoted by Asymp. Sig. (2-sided)] less than 0.05

Table 6.29: Pearson Chi-Square test for self-confidence between experienced and inexperienced participants after solving the complex task using online learning.

Online Learning (session period)	Experienced vs. Inexperienced			Significant effect
	value	df	Asymp. Sig. (2-sided)	
1st Session	0.054	1	0.816	Not significant
2nd Session	0.000	1	1.000	Not significant

*p-value [denoted by Asymp. Sig. (2-sided)] less than 0.05

RQ5a Will doing the assigned tasks using traditional learning by experienced students improve marks performance?

RQ5b Will doing the assigned tasks using traditional learning by inexperienced students improve marks performance?

Table 6.30 indicates that the majority of experienced participants (85.0%) scored good marks when performing the simple task using traditional learning in the 1st session. Only 5.0% of the experienced participants completing the simple task in the 2nd session scored very poor marks.

Table 6.30: Percentage of participant performances according to the range of marks when solving the simple task using traditional learning.

Competency	Learning Technique	1 Very Poor	2 Poor	3 Ok	4 Good	5 Very Good
Experienced Group	Traditional Learning (1st session)	0	2.5%	2.5%	85.0%	10.0%
	Traditional Learning (2nd session)	5.0%	7.5%	22.5%	40.0%	25.0%
Inexperienced Group	Traditional Learning (1st session)	0	2.5%	5.0%	82.5%	10.0%
	Traditional Learning (2nd session)	0	0	15.0%	60.0%	25.0%

As can be seen in Table 6.31, 87.5% of the inexperienced participants scored very good marks when performing the complex task using traditional learning in the 1st session. However, 7.5% of the experienced participants doing the complex task in the 2nd session scored poor marks.

Table 6.31: Percentage of participant performances according to the range of marks when solving the complex task using traditional learning.

Competency	Learning Technique	1 Very Poor	2 Poor	3 Ok	4 Good	5 Very Good
Experienced Group	Traditional Learning (1st session)	0	0	0	22.5%	77.5%
	Traditional Learning (2nd session)	0	7.5%	5.0%	17.5%	70.0%
Inexperienced Group	Traditional Learning (1st session)	0	0	0	12.5%	87.5%
	Traditional Learning (2nd session)	0	2.5%	7.5%	7.5%	82.5%

RQ5c Is there any difference between experienced and inexperienced students in marks performance after solving the assigned tasks using traditional learning?

From Table 6.32 and Table 6.33, the p-values from the Mann-Whitney U tests for both experienced and inexperienced participants in the 1st and 2nd sessions were greater than the significant value of 0.05. Thus, there was no significant difference likely to occur in the students' marks performance between the experienced and inexperienced participants perfoming simple and complex tasks using traditional learning in both sessions.

Table 6.32: Mann-Whitney test for marks performance between experienced and inexperienced participants after solving the simple task using traditional learning.

Traditional Learning (session period)	p-value	Mean rank		Significant effect
		Experienced	Inexperienced	
1st Session	0.793	40.94	40.06	Not significant
2nd Session	0.160	37.13	43.88	Not significant

*p-value less than 0.05

Table 6.33: Mann-Whitney test for marks performance between experienced and inexperienced participants after solving the complex task using traditional learning.

Traditional Learning (session period)	p-value	Mean rank		Significant effect
		Experienced	Inexperienced	
1st Session	0.242	38.50	42.50	Not significant
2nd Session	0.210	38.08	42.93	Not significant

*p-value less than 0.05

RQ5d Will doing the assigned tasks using online learning by experienced students improve marks performance?

RQ5e Will doing the assigned tasks using online learning by inexperienced students improve marks performance?

From Table 6.34, the majority of inexperienced participants (52.5%) scored good marks when performing the simple task using traditional learning in the 1st session. Only 5.0% of the experienced participants doing the simple task in the 1st session scored very poor marks. Table 6.35 shows that 87.5% of the inexperienced participants scored very good marks when performing the complex task using online learning in the 1st session. Only 7.5% of the experienced participants doing the complex task in the 2nd session scored very poor marks.

Table 6.34: Percentage of participant performances according to the range of marks when solving the simple task using online learning.

Competency	Learning Technique	1 Very Poor	2 Poor	3 Ok	4 Good	5 Very Good
Experienced Group	Online Learning (1st session)	5.0%	12.5%	22.5%	30.0%	30.0%
	Online Learning (2nd session)	0	12.5%	40.0%	32.5%	15.0%
Inexperienced Group	Online Learning (1st session)	0	5%	12.5%	52.5%	30.0%
	Online Learning (2nd session)	0	12.5%	30.0%	30.0%	27.5%

Table 6.35: Percentage of participant performances according to the range of marks when solving the complex task using online learning.

Competency	Learning Technique	1 Very Poor	2 Poor	3 Ok	4 Good	5 Very Good
Experienced Group	Online Learning (1st session)	7.5%	5.0%	20.0%	32.5%	35.0%
	Online Learning (2nd session)	0	0	15.0%	55.0%	30.0%
Inexperienced Group	Online Learning (1st session)	0	0	2.5%	10.0%	87.5%
	Online Learning (2nd session)	0	0	2.5%	42.5%	55.0%

RQ5f Is there any difference between experienced and inexperienced students in marks performance after solving the assigned tasks using online learning?

From Table 6.36, the p-values from the Mann-Whitney U tests for both experienced and inexperienced participants in the 1st and 2nd sessions were greater than the significant value of 0.05. Therefore, no significant difference was likely to occur in the students' marks performance between the experienced and inexperienced participants when doing the simple task using online learning in both sessions.

Table 6.36: Mann-Whitney test for marks performance between experienced and inexperienced participants after solving the simple task using online learning.

Online Learning (session period)	p-value	Mean rank		Significant effect
		Experienced	Inexperienced	
1st Session	0.165	37.09	43.91	Not significant
2nd Session	0.289	37.86	43.14	Not significant

*p-value less than 0.05

Conversely, Table 6.37 shows that the p-values from the Mann-Whitney U tests for both experienced and inexperienced participants in the 1st and 2nd sessions were 0.001 and 0.010 respectively, which are smaller than the significant value of 0.05. Thus, significant differences were found in the students' marks performance between the experienced and inexperienced participants when doing the complex task using online learning in the 1st session and 2nd sessions.

Table 6.37: Mann-Whitney test for marks performance between experienced and inexperienced participants after solving the complex task using online learning.

Online Learning (session period)	p-value	Mean rank		Significant effect
		Experienced	Inexperienced	
1st Session	0.001*	29.45	51.55	Significant
2nd Session	0.010*	34.50	46.50	Significant

*p-value less than 0.05

RQ6a Will attending traditional learning as the preferred learning approach by experienced students improve satisfaction, performance and self-confidence?

RQ6b Will attending traditional learning as the preferred learning approach by inexperienced students improve satisfaction, performance and self-confidence?

Table 6.38 indicates 35.0% of experienced participants strongly agreed that attending traditional learning as the preferred learning approach improved their satisfaction, performance and self-confidence, and they had the highest percentage among other groups. Nevertheless, the majority of the participants agreed with the perception that attending traditional learning as the preferred learning approach improved their satisfaction, performance and self-confidence.

Table 6.38: Percentage of satisfaction, performance and self-confidence when attending traditional learning as the preferred learning approach.

Competency	Learning Technique	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
Experienced Group	Traditional Learning (1st session)	0	7.5%	15.0%	42.5%	35.0%
	Traditional Learning (2nd session)	2.5%	7.5%	32.5%	50.0%	7.5%
Inexperienced Group	Traditional Learning (1st session)	2.5%	5.0%	27.5%	50.0%	15.0%
	Traditional Learning (2nd session)	2.5%	5.0%	25.0%	52.5%	15.0%

RQ6c Is there any difference between experienced and inexperienced students in satisfaction, performance and self-confidence with traditional learning as the preferred learning approach?

Table 6.39 indicates the p-values from the Mann-Whitney U tests for the 1st and 2nd sessions were 0.060 and 0.255 respectively. These p-values are greater than the significant value of 0.05. There are no significant differences between the experienced and inexperienced participants in the perception about attending traditional learning as the preferred learning approach improved their satisfaction, performance and self-confidence. In the 1st session, the mean rank for the experienced participants was 45.08, which was higher than the inexperienced participants with the mean rank value of 35.93. In the 2nd session, the mean rank for the inexperienced participants was 43.21, which was higher than the experienced participants with the mean rank value of 37.79.

Table 6.39: Mann-Whitney test for satisfaction, performance and self-confidence when attending traditional learning as the preferred learning approach.

Traditional Learning (session period)	p-value	Mean rank		Significant effect
		Experienced	Inexperienced	
1st Session	0.060	45.08	35.93	Not significant
2nd Session	0.255	37.79	43.21	Not significant

*p-value less than 0.05

RQ6d Will using online learning as the preferred learning approach by experienced students improve satisfaction, performance and self-confidence?

RQ6e Will using online learning as the preferred learning approach by inexperienced students improve satisfaction, performance and self-confidence?

Table 6.40 shows that a higher percentage of 52.5% of experienced participants were neutral that using online learning as the preferred learning approach improved their satisfaction, performance and self-confidence. The majority of the experienced participants in the 1st session and the inexperienced participants in the 2nd session agreed with 40.0% and 45.0% respectively regarding the perception that using online learning as the preferred learning approach improved their satisfaction, performance and self-confidence.

Table 6.40: Percentage of satisfaction, performance and self-confidence when using online learning as the preferred learning approach.

Competency	Learning Technique	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
Experienced Group	Online Learning (1st session)	2.5%	12.5%	30.0%	40.0%	15.0%
	Online Learning (2nd session)	0	7.5%	42.5%	37.5%	12.5%
Inexperienced Group	Online Learning (1st session)	2.5%	10.0%	52.5%	25.0%	10.0%
	Online Learning (2nd session)	0	2.5%	37.5%	45.0%	15.0%

RQ6f Is there any difference between experienced and inexperienced students in satisfaction, performance and self-confidence with online learning as the preferred learning approach?

As shown in Table 6.41, the p-values from the Mann-Whitney U tests for the 1st and 2nd sessions were 0.201 and 0.330 respectively. These p-values are greater than the significant value of 0.05, which means that no significant effects exist between the experienced and inexperienced participants in the perception that using online learning as the preferred learning approach improved their satisfaction, performance and self-confidence. In the 1st session, the mean rank for the experienced participants was 43.64, which was higher than the inexperienced participants with the mean rank value of 37.36.

Meanwhile, the mean rank for the inexperienced participants in the 2nd session was 42.85, which was higher than the experienced participants in the 2nd session with the mean rank value of 38.15.

Table 6.41: Mann-Whitney test for satisfaction, performance and self-confidence when using online learning as the preferred learning approach.

Online Learning (session period)	p-value	Mean rank		Significant effect
		Experienced	Inexperienced	
1st Session	0.201	43.64	37.36	Not significant
2nd Session	0.330	38.15	42.85	Not significant

*p-value less than 0.05

6.5 Summary

This chapter has outlined the approaches and activities involved in the main study conducted among experienced and inexperienced mechanical engineering students. Data analysis has been carried out which includes the preparation of data collection, data screening, descriptive testing and statistical testing using the Mann-Whitney U test, Paired Sample T test and Chi-Square test. The overall results obtained from the statistical analysis have been presented and interpreted in this chapter as summarised in Table 6.42 and Table 6.43.

Chapter 7 will further discuss the results obtained from the analysis earlier, hence to identify the significant findings from the main study being conducted.

Table 6.42: The overall output results obtained from statistical analysis (RQ1, RQ2 and RQ3).

Research Question	1st Session	2nd Session
RQ1a	77.5% (Agree)	55% (Agree)
RQ1b	60% (Agree)	55% (Agree)
RQ1c	Not significant	Not significant
RQ1d	75% (Agree)	**50% (Agree)**
RQ1e	52.5% (Agree)	**72.5% (Agree)**
RQ1f	Not significant	**Significant**

Research Question	1st Session	2nd Session
RQ2a	72.5% (Yes)	82.5% (Yes)
RQ2b	67.5% (Yes)	72.5% (Yes)
RQ2c	Not significant	Not significant
RQ2d	67.5% (Yes)	87.5% (Yes)
RQ2e	77.5% (Yes)	87.5% (Yes)
RQ2f	Not significant	Not significant

Research Question	1st Session	2nd Session
RQ3a	Simple Task	
	9 mins	7 mins
	Complex Task	
	11 mins	11 mins
RQ3b	Simple Task	
	11 mins	8 mins
	Complex Task	
	15 mins	11 mins
RQ3c	Simple Task	
	Significant	Not significant
	Complex Task	
	Not significant	Not significant
RQ3d	Simple Task	
	11 mins	6 mins
	Complex Task	
	17 mins	11 mins
RQ3e	Simple Task	
	10 mins	6 mins
	Complex Task	
	16 mins	14 mins
RQ3f	Simple Task	
	Significant	Not significant
	Complex Task	
	Not significant	Not significant

Table 6.43: The overall output results obtained from statistical analysis (RQ4, RQ5 and RQ6).

Research Question	1st Session	2nd Session
RQ4a	Simple Task	
	55% (Yes)	67.5% (Yes)
	Complex Task	
	92.5% (Yes)	72.5% (Yes)
RQ4b	Simple Task	
	52.5% (Yes)	60% (Yes)
	Complex Task	
	77.5% (Yes)	85% (Yes)
RQ4c	Simple Task	
	Not significant	Not significant
	Complex Task	
	Not significant	Not significant
RQ4d	Simple Task	
	60% (Yes)	87.5% (Yes)
	Complex Task	
	62.5% (Yes)	97.5% (Yes)
RQ4e	Simple Task	
	52.5% (Yes)	87.5% (Yes)
	Complex Task	
	65% (Yes)	97.5% (Yes)
RQ4f	Simple Task	
	Not significant	Not significant
	Complex Task	
	Not significant	Not significant

Research Question	1st Session	2nd Session
RQ5a	Simple Task	
	85% (Good)	40% (Good)
	Complex Task	
	77.5% (V. Good)	70% (V. Good)
RQ5b	Simple Task	
	82.5% (Good)	60% (Good)
	Complex Task	
	87.5% (V. Good)	82.5% (V. Good)
RQ5c	Simple Task	
	Not significant	Not significant
	Complex Task	
	Not significant	Not significant
RQ5d	Simple Task	
	30% (V. Good)	40% (Ok)
	Complex Task	
	35% (V. Good)	**55% (Good)**
RQ5e	Simple Task	
	52.5% (Good)	30% (Good)
	Complex Task	
	87.5% (V. Good)	**55% (V. Good)**
RQ5f	Simple Task	
	Not significant	Not significant
	Complex Task	
	Significant	**Significant**

Research Question	1st Session	2nd Session
RQ6a	77.5% (Agree)	57.5% (Agree)
RQ6b	65% (Agree)	67.5% (Agree)
RQ6c	Not significant	Not significant
RQ6d	55% (Agree)	50% (Agree)
RQ6e	35% (Agree)	60% (Agree)
RQ6f	Not significant	Not significant

Chapter 7. Discussion on Main Study

7.1 Introduction

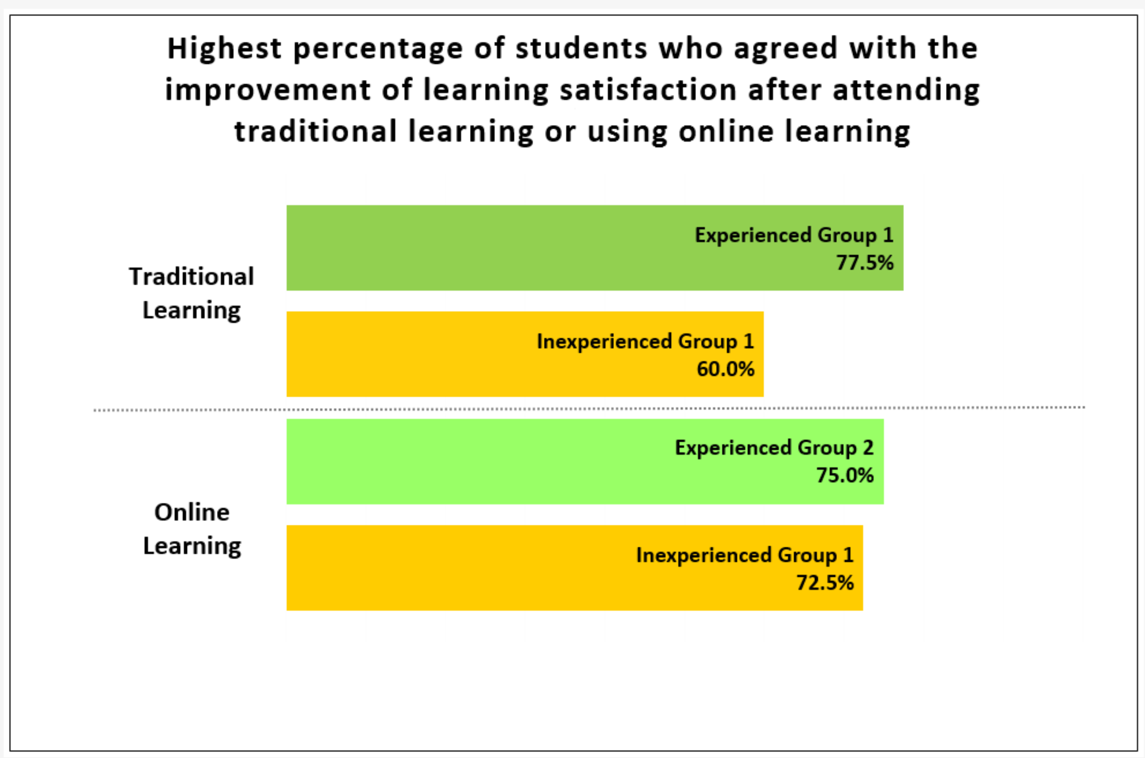
This chapter discusses the findings of the data that have been analysed in the previous chapter. Descriptive and statistical analyses have been used previously to test the data obtained from the main study. The discussion focuses on the statistical results achieved to answer the research questions that related to the participant's views of the learning methods and assigned tasks. Moreover, this chapter also discusses the findings on the participant's satisfaction, performance and self-confidence. Justification of each discussion and a summary of the final outcomes are also presented in this chapter.

7.2 Analysis Results of Demographic

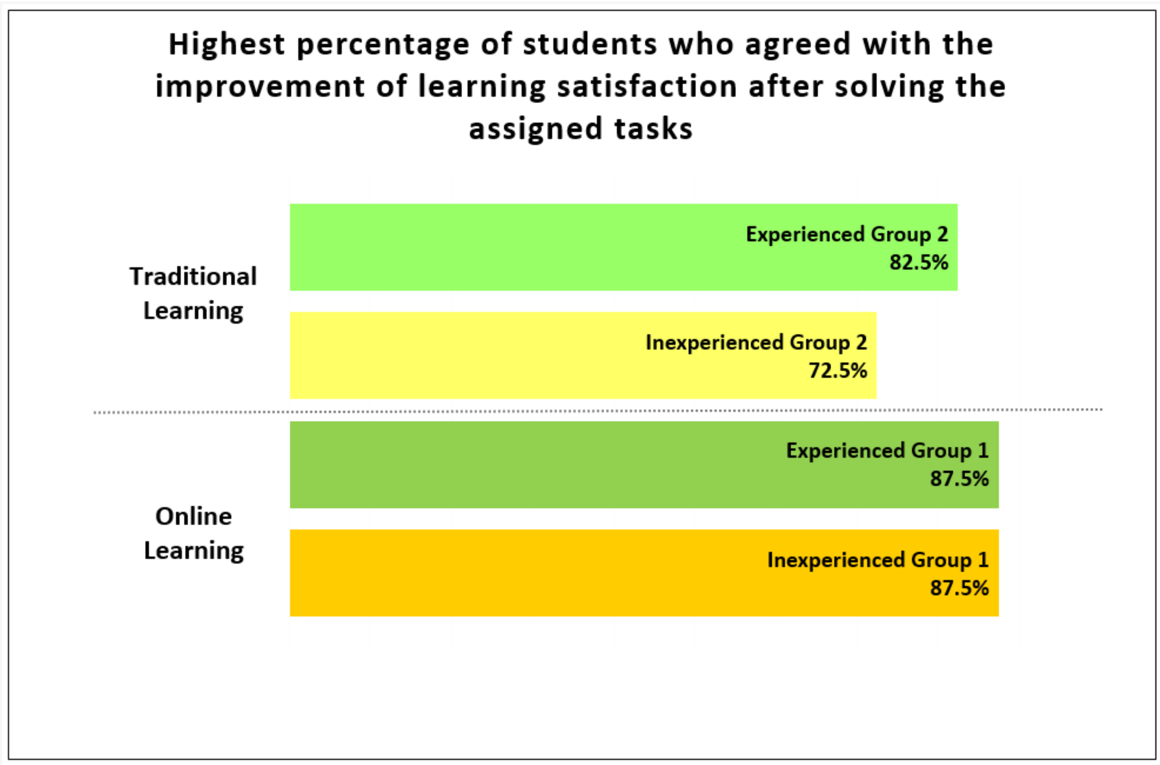
As stated in the previous chapter, no data is missing from data screening. Based from demographic analysis, 95 of the participants were male and 65 were female. Most of the participants were those having A-level backgrounds. Other participants were diploma holders. Moreover, the majority of participants in the experienced group were attending diploma programme. Whereas the inexperienced participants were mostly those attending the degree programmes.

7.3 Analysis Results of Research Questions

The overall results presented in Chapter 6 are summarised using the bar charts as shown in Figure 7.1 until Figure 7.5. These charts present the comparisons between the groups with highest percentages when using traditional and online learning methods. The following discussion will refer to these charts and some justification will be explained.

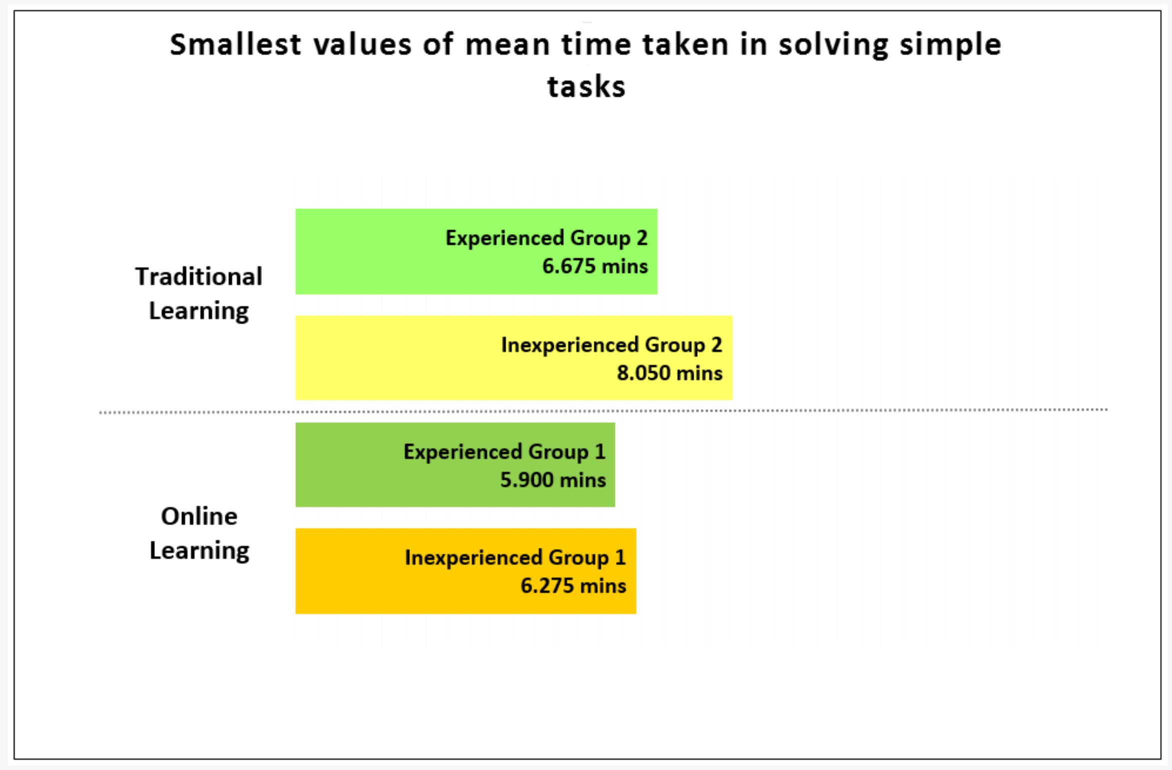


[RQ1]

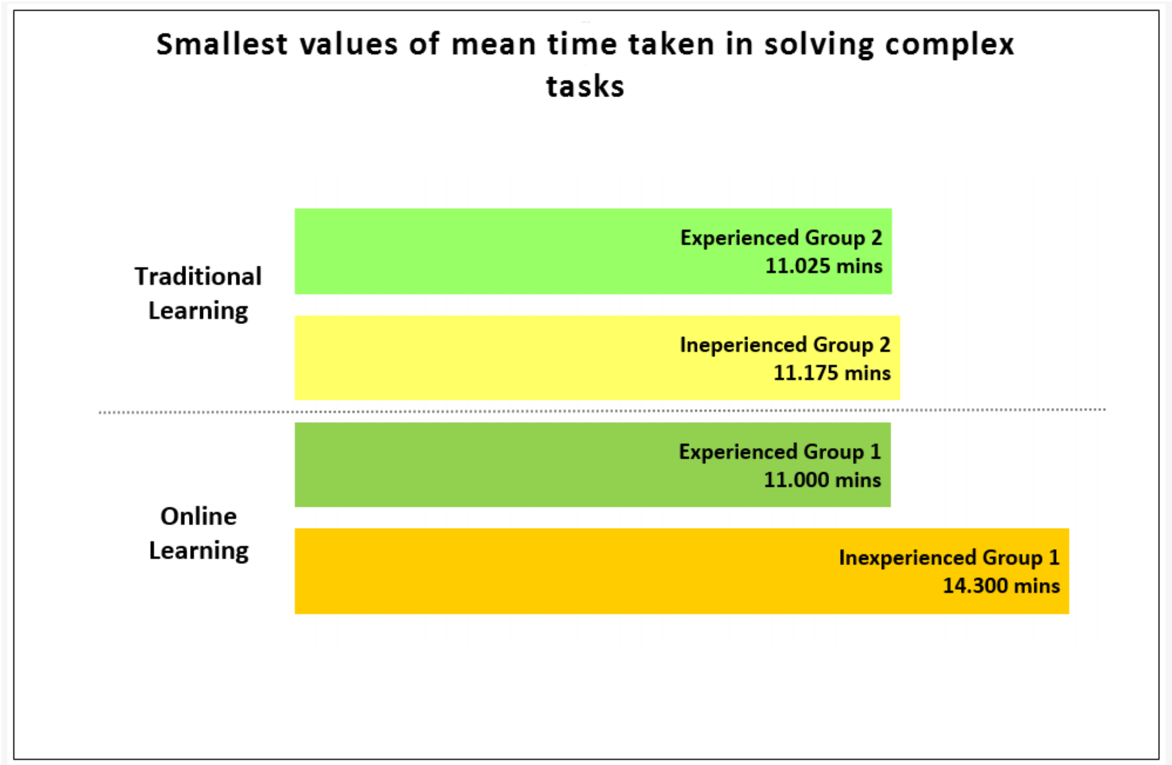


[RQ2]

Figure 7.1: Summary results of research questions - RQ1 and RQ2.

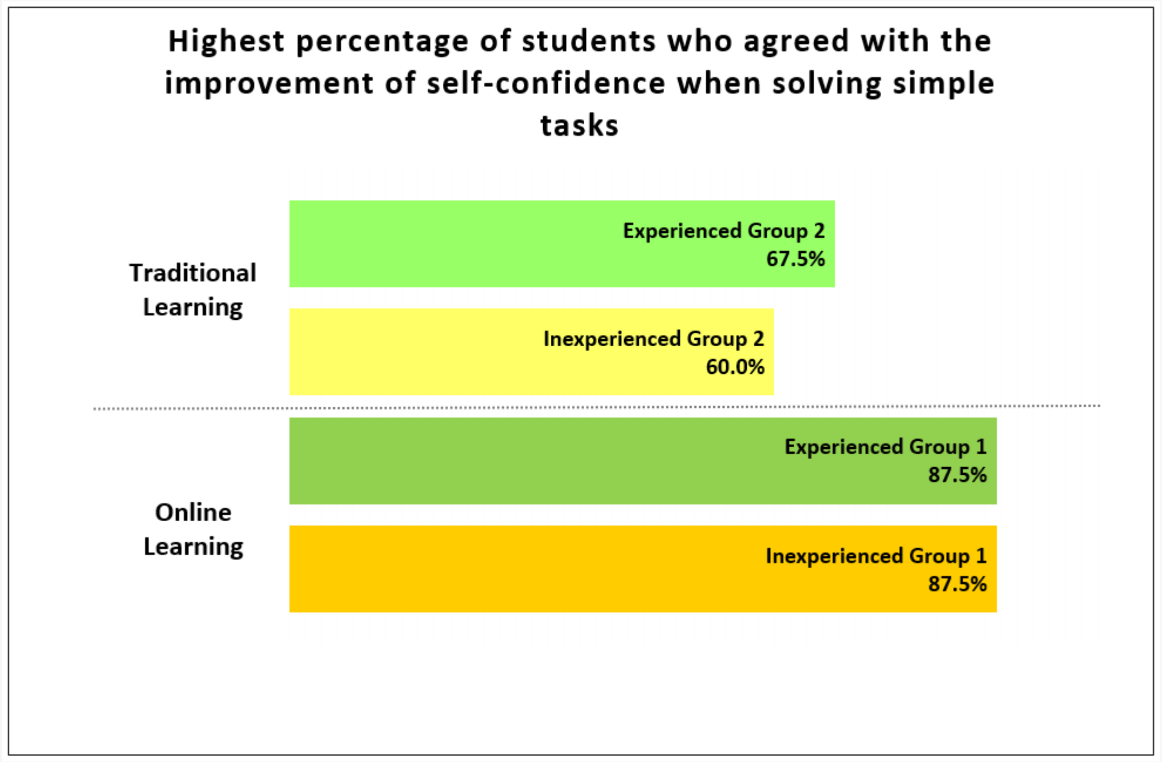


[RQ3(a)]

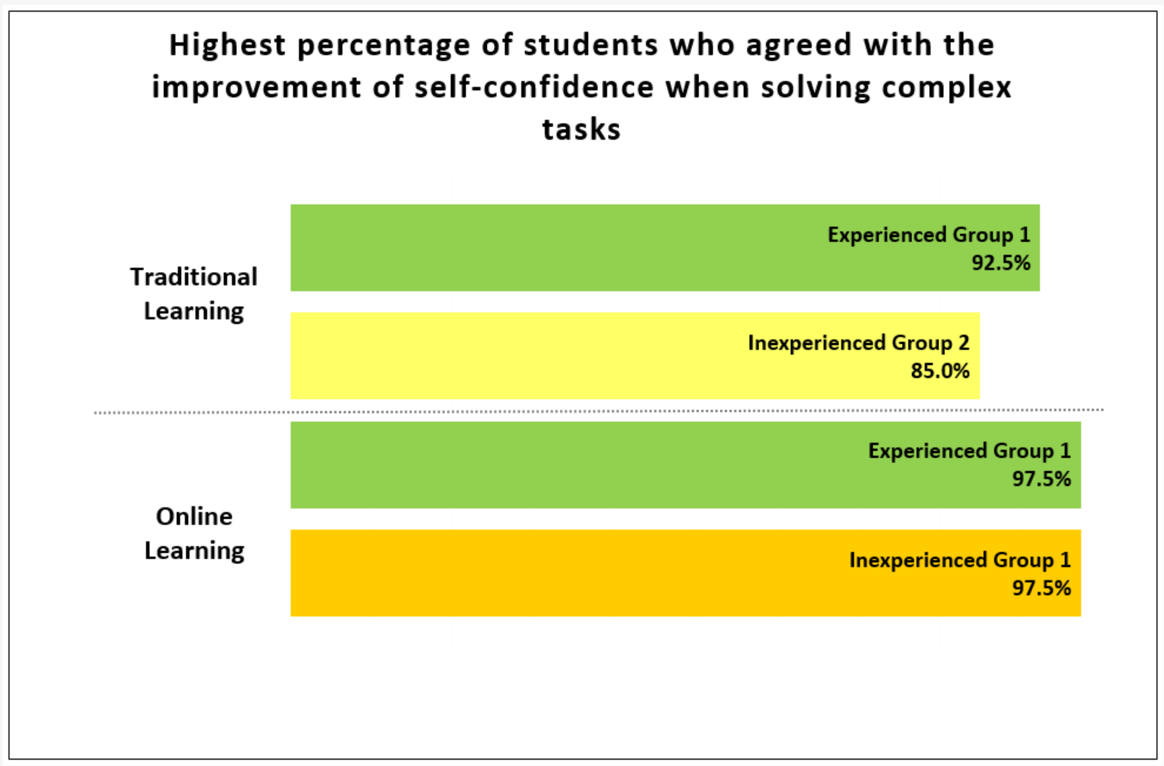


[RQ3(b)]

Figure 7.2: Summary results of research questions - RQ3.

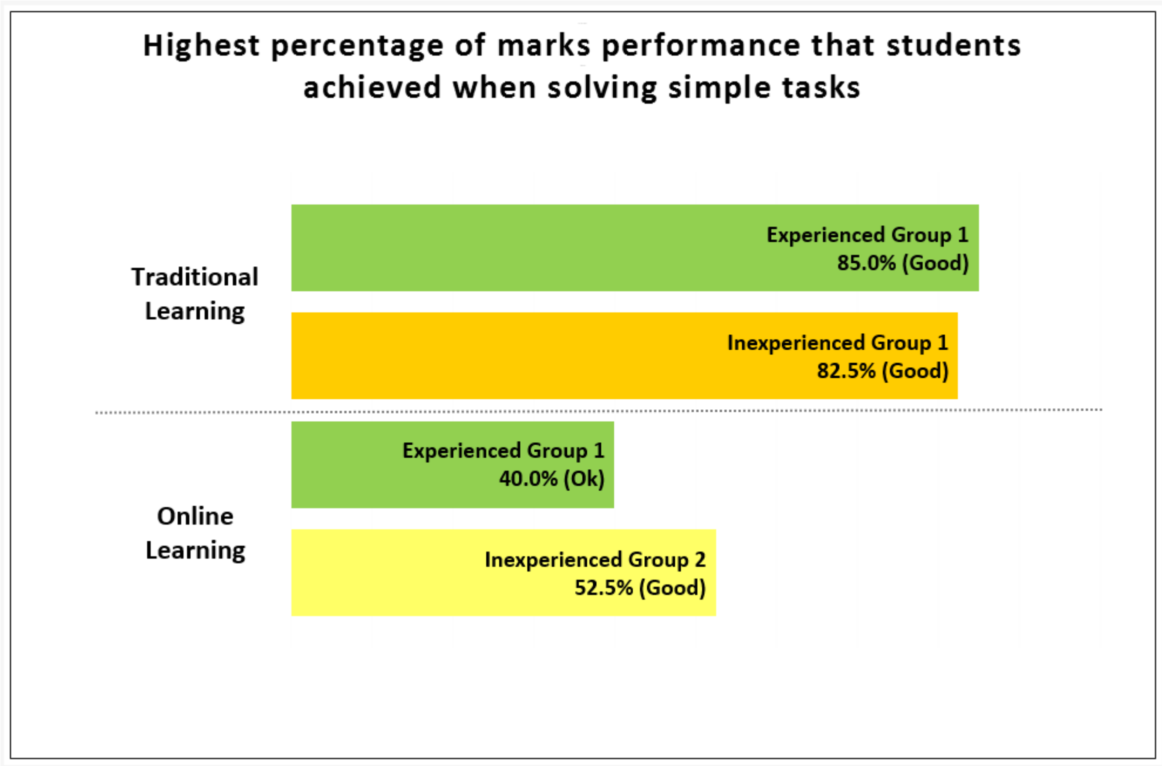


[RQ4(a)]

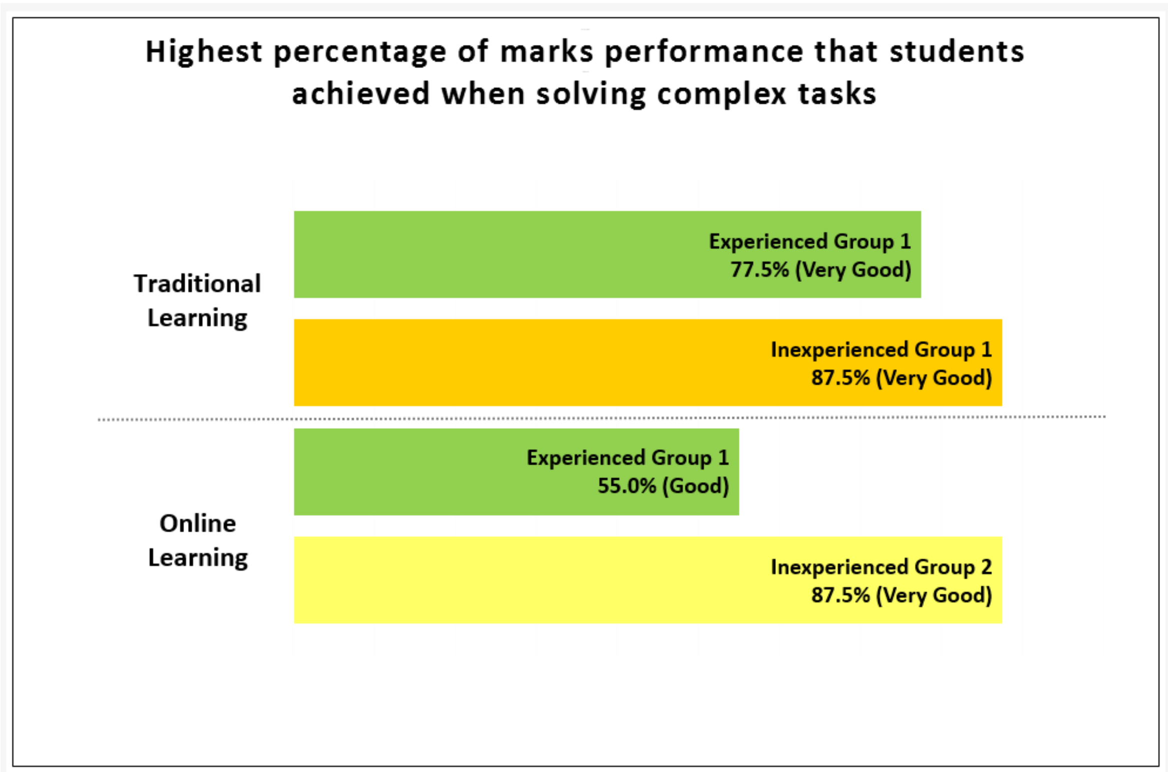


[RQ4(b)]

Figure 7.3: Summary results of research questions - RQ4.

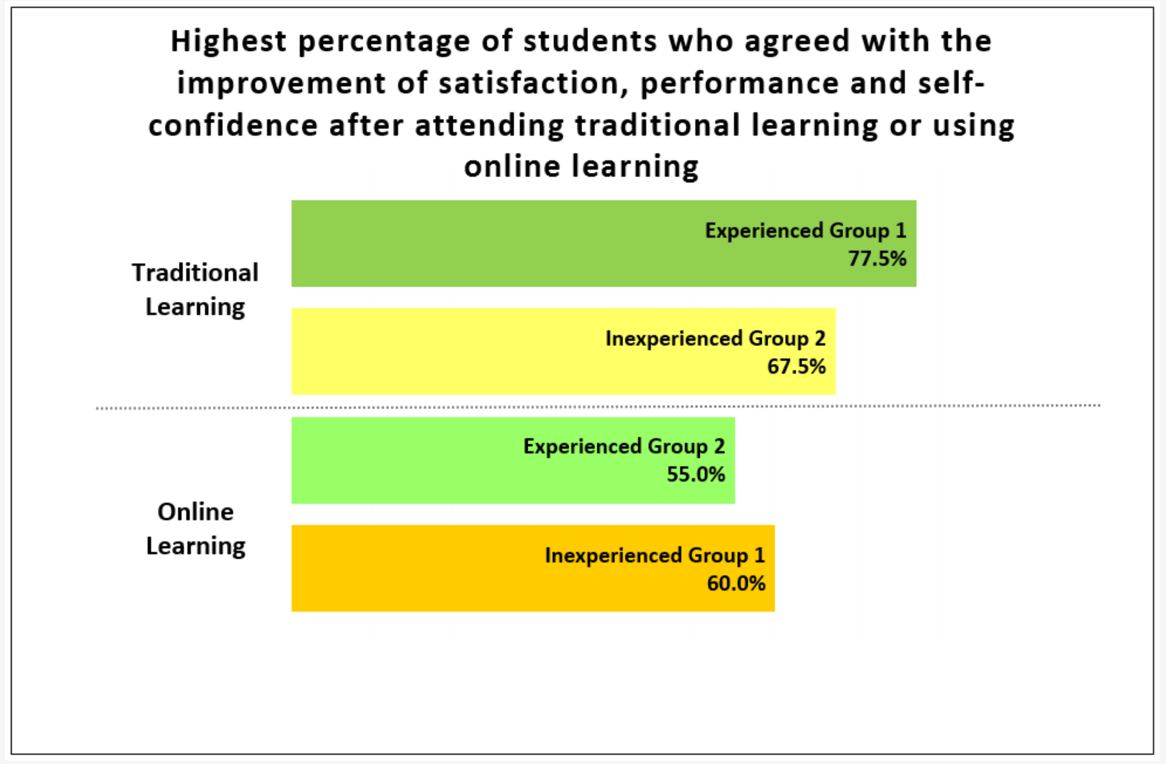


[RQ5(a)]



[RQ5(b)]

Figure 7.4: Summary results of research questions - RQ5.



[RQ6]

Figure 7.5: Summary results of research questions - RQ6.

7.3.1 Research Questions: RQ1

As can be seen in Figure 7.1 [RQ1], the experienced and inexperienced students from group 2 and group 1 respectively were agreed that using online learning improved their learning satisfaction. These students were preferred to use online learning because of its flexibility, easy to access the learning materials, customized learning and prompt feedback. They also felt that the traditional face to face learning was less preferred as teacher and learning was only accessible in a classroom setup. However, majority of experienced students in group 1 were still preferred to learn using traditional learning method. These students felt that online learning could motivate them to become isolated, confused and lost. According to Davies and Graff (2005), online learning can enhances student-centred learning, encourage more student participation, and create interaction less intimidating between students and lecturer. For online learning to succeed, students need to establish more online connections with each other to prevent isolation and academic stress.

From the Mann-Whitney U tests, no significant difference exists between experienced and inexperienced students in terms of learning satisfaction after attending traditional learning. On the contrary, there was significant difference with p-value of 0.03 exists between experienced and inexperienced students in terms of learning satisfaction after using online learning.

7.3.2 Research Questions: RQ2

Figure 7.1 [RQ2] shows the high percentages of experienced and inexperienced students in group 1 have agreed their learning satisfaction improved after solving the assigned tasks using online learning in the 2^{nd} session. It is apparent that the repetition of doing assigned tasks using any methods could enhance the student learning satisfaction. From the Pearson Chi-Square tests, there was no significant difference exists between experienced and inexperienced students in terms of their learning satisfaction when solving the assigned tasks using either traditional or online learning.

7.3.3 Research Questions: RQ3

There was a clear contrast between the online and traditional learning environments. The main study observed a relationship between two different approaches in learning and the known characteristics of learning environment. The online learning has over time changed the learning environments. Students found that online learning was effective in eliminating time and physical location barriers as well as efficient in enhancing learning performance as can be seen in Figure 7.2 [RQ3(a)] and [RQ3(b)]. The experienced students in group 1 have improved their speed in solving the assigned tasks when using online learning methods in the 2^{nd} session. This indicates that these students were able to complete the tasks quickly if they have done the same tasks previously. The inexperienced students required more time to solve the complex tasks than solving the simple tasks using online learning as they who have not yet learned the module. Hence, it can be assumed the online instructions provided to solve the simple task are easy to follow and understandable.

Statistically using Paired Sample T tests, there was significant difference with p-value of 0.009 exists between experienced group 1 and inexperienced group 1 when using traditional learning to solve simple tasks. Another significant difference of p-value 0.002 was found between experienced group 2 and inexperienced group 2 when solving simple tasks using online learning.

7.3.4 Research Questions: RQ4

It can be seen from Figure 7.3 [RQ4(a)] and [RQ4(b)], both experienced group 1 and inexperienced group 1 were felt confident when solving the assigned tasks using online learning in the 2nd session. Similarly with time taken, these students were showing their self-confidence to solve the tasks again using online learning as they have solved the tasks using traditional learning previously. From the Pearson Chi-Square tests, there was no significant difference found between the experienced and inexperienced students in self-confidence when solving the assigned tasks using both learning methods.

7.3.5 Research Questions: RQ5

According to Allen and Seaman (2007), there were significant differences found in performance between traditional and online learning. The study was focused on the student performance entails of grades, added knowledge and skill building. As a result, online education was considered more effective in terms of course completion and achievement of learning. Figure 7.4 [RQ5(a)] and [RQ5(b)] show the summary of the analysis results on the highest percentage of students achieving very good and good performance of marks when solving the assigned tasks. The majority of inexperienced students in group 2 showed their best performance with very good marks compared to the experienced students in group 1 when solving assigned tasks using online learning. This result indicates that inexperienced students who expose to online learning as their first learning method can boost their performance. Nevertheless, experienced and inexperienced in group 1 were also having high percentage of marks performance when solving the assigned tasks using traditional learning in the 1st session.

From Mann-Whitney U tests, no significant difference in marks performance when solving the assigned tasks using traditional learning and also when solving the simple task using online learning in both sessions. Nevertheless, there were significant differences in the performance of marks between experienced and inexperienced groups that have solved the complex tasks using online learning in both sessions

7.3.6 Research Questions: RQ6

Referring to Figure 7.5, it can be seen that high percentage of experienced students in group 1 were agreed on attending traditional learning as preferred learning approach to enhance their satisfaction, performance and self-confidence. These students were preferred traditional learning method in studying the Mechanical Engineering Design module due to its efficiency in the completion of the tasks. Moreover, the traditional learning provides rooms for direct discussion and one-on-one enquiries, and this was desirable for most students. However, the students with positive attitudes in using computers can enhance their own confidence to learn from computers (Garland and Noyes, 2005).

Hence, the inexperienced students in group 1 were agreed on using online learning as preferred learning approach to enhance their satisfaction, performance and self-confidence. Even though these students have attended traditional learning earlier, but they still felt that online learning method was having more advantages due to its efficiency and accessibility. Mann-Whitney U tests were used to analyse the satisfaction, performance and self-confidence when using both learning methods as preferred learning approaches. As a result, there were no significant differences found between the experienced and inexperienced groups in terms of these three aspects when attending both sessions.

7.4 Discussion of Main Findings

The challenge of changing people's attitude from the traditional face to face learning to the online mode of learning among lecturers is critical since a teacher's attitude is transferred directly to the student (Ni, 2013). When students leave universities or institutions of higher learning with negative attitudes towards online learning, it will be difficult to change their perception. A deeper understanding of the need to migrate from traditional face to face methods of learning to online learning is crucial, not just for the lecturers, but also for the students involved (Zhang et al., 2004).

Therefore, the purpose of this research was to explore the impact of online learning among mechanical students at one of the universities in Brunei Darussalam. The main study has acknowledged three important aspects. Firstly, the effectiveness of learning encompasses the performance in completing the tasks (Allen and Seaman, 2007). Even though there has been no significance difference in terms of self-confidence in solving tasks using the two learning techniques, but online learning can overtakes traditional learning technique through student learning satisfaction and marks performance. Secondly, the concern regarding low student attendance rates to attend online tutorial classes and the fact that online teaching is difficult for particular courses requiring practical sessions. Thus, online program designers need to consider the requirements of different courses to customize their needs.

Thirdly, traditional learning techniques can exploit virtual internet space to expand participation and connect online learning with classroom learning environment. According to Carr (2000), the integration of online teaching and classroom learning can enhance the quality of participation. In brief, due to the challenges in each method of learning, integrating both methods would have a positive multiplier effect. Both learning techniques could join together to form the most effective way of learning and improve self-confidence in learning. Despite no significant difference in the self-confidence when completing the given tasks, both experienced and inexperienced students were improving in terms of time taken and marks performance when solving the assigned tasks repeatedly using either online or traditional techniques.

Another essential point, the main study has also compared the efficiency of online learning and traditional classroom method of studying. It made a firm attempt to go beyond class marks performance to the self-confidence, efficiency and student persistence (Allen and Seaman, 2007). As a result, it is clear that certain courses may be more difficult for students to learn using virtual online study as opposed to traditional learning. Besides, performance measurement was quite challenging in online learning as it only relying on the given instructions and guidelines. Therefore, the main study has identified several shortcomings in online learning including the difficulties in controlling causal-effect variables, the difficulties in measuring success variables and the difficulties in accessing to the internet. These findings have different effects on learning activities, course development and content development.

Nevertheless, the bright side of online learning is unlimited. Students get to learn under a very comfortable and convenient learning atmosphere (Ni, 2013). Unlike students who have to physically access their learning environment, online students are saved the stress of choosing between work and school and have more time with family and friends. Additionally, online classes are flexible and one can choose their convenient time, unlike traditional learning where classes are scheduled.

Online learning is also preferable compared to classroom learning as far as costs are concerned (Bernard et al., 2004). Not all online courses are expensive as compared to classroom courses, the attached costs of classroom courses make them eventually expensive (Ni, 2013). Textbooks, commuting and time costs are eliminated in online classes, and not to mention the time spent in traveling. Today, some education programs provide the provision of free online classes, making it even cheaper to acquire education online. Up to this point, it is indisputable that online classes are better than classroom classes. Students should appreciate online classes for the ability to transfer the learning from traditional classroom environment. In times such as summer when one cannot physically access their colleges, online classes enable students to study from wherever they are without having to enroll in another college (Ni, 2013). In this way, students can still enjoy their summer holidays or even work without having to lose learning time.

Furthermore, the interaction between traditional learning and online learning has taken the dynamic directions (Allen et al., 2002). Traditional learning has an advantage as the social and communicative interaction between the students and the teacher, as well as among students themselves. Traditional learning prides in the availability of students to ask questions, discuss with each other, share opinions in class and disagree with other's point of views. Also, the debates among students, discussions, points clarified and assumptions challenged were held through the classroom interaction. Therefore, online learning requires communication and adjustments between the lecturer and the students for effective learning to occur (Davies and Graff, 2005). In addition, online learning could also complement classroom learning with facilities such as electronic bulletin boards, emails and discussion boards.

To conclude, online learning could be a successful experience if teachers and program designers came up with inclusive ideas on how to make the process efficient and effective. Traditional learning could be far more efficient if integrated with online virtual learning as the students can learn new concepts based on what they have already know. From the conducted study, it can be presumed that the efficiency in student performance, satisfaction and self-confidence might progress if the integration online learning is to be included in the curriculum. Table 7.1 shows a summary of the final results that has been analysed for the comparison between experienced and inexperienced students, according to the research questions.

Table 7.1: A summary of the analysed results of the comparison between experienced and inexperienced students, according to the research questions.

Research Question (RQ)	Results
RQ1c: Is there any difference between experienced and inexperienced students in learning satisfaction after attending traditional learning sessions?	No Significant Difference
RQ1f: Is there any difference between experienced and inexperienced students in learning satisfaction after using online learning?	Significant Difference
RQ2c: Is there any difference between experienced and inexperienced students in learning satisfaction after solving the assigned tasks using traditional learning?	No Significant Difference
RQ2f: Is there any difference between experienced and inexperienced students in learning satisfaction after solving the assigned tasks using online learning?	No Significant Difference
RQ3c: Is there any difference between experienced and inexperienced students in speed in solving the assigned tasks using traditional learning?	Significant Difference (Simple task)
RQ3f: Is there any difference between experienced and inexperienced students in speed in solving the assigned tasks using online learning?	Significant Difference (Simple task)
RQ4c: Is there any difference between experienced and inexperienced students in self-confidence after solving the assigned tasks using traditional learning?	No Significant Difference
RQ4f: Is there any difference between experienced and inexperienced students in self-confidence after solving the assigned tasks using online learning?	No Significant Difference
RQ5c: Is there any difference between experienced and inexperienced students in marks performance after solving the assigned tasks using traditional learning?	No Significant Difference
RQ5f: Is there any difference between experienced and inexperienced students in marks performance after solving the assigned tasks using online learning?	Significant Difference (Simple & Complex tasks)
RQ6c: Is there any difference between experienced and inexperienced students in satisfaction, performance and self-confidence with traditional learning as the preferred learning approach?	No Significant Difference
RQ6f: Is there any difference between experienced and inexperienced students in satisfaction, performance and self-confidence with online learning as the preferred learning approach?	No Significant Difference

7.5 Summary

This chapter has discussed the analysed results of a main study conducted among the experienced and inexperienced mechanical engineering students from Universiti Teknologi Brunei. A total of 160 students from three different level of education have participated in the main study. This chapter began by describing the demographic of the students which involves the identification of no missing data. The analysed results of research questions were summarised and presented using bar charts. In conclusion, this chapter discussed by summarising some most significant findings. From the study, majority of experienced students had strongly agreed their learning satisfaction improved when attending traditional learning or using online learning. In addition, both experienced and inexperienced students had also agreed with the improvement of the learning satisfaction, speed, self-confidence and marks performance when solving the assigned tasks repeatedly using either traditional or online learning methods.

Chapter 8 outlines and discusses the conclusions of the research work and research findings as well as provides the recommendations for future research.

Chapter 8. Discussion, Conclusion and Future Work

8.1 Introduction

This chapter discusses the review on the work conducted in this research by summarising the main findings with respect to answer the research questions and the achievement of research objectives. Research contributions to the progress of online learning in the field of mechanical engineering education are also summarized. Finally, recommendations for improving this research and future works are presented.

8.2 Research Review

8.2.1 Main findings

Table 8.1 outlines the research questions and a summary of the findings obtained according to the research questions. Briefly, it can be concluded by conducting the statistical analysis that the main quantitative findings are:

- A significant difference with p-value of 0.03 was existed between experienced and inexperienced groups in terms of learning satisfaction after using online learning.
- Significant differences were found between experienced and inexperienced groups in terms of time taken when solving the simple task using either traditional method or online method (p-values of 0.009 and 0.002 respectively).
- Significant differences were found between experienced and inexperienced groups in terms of marks performance when solving the complex tasks using online learning in both sessions (p-values of 0.001 and 0.010 respectively).
- Majority of experienced students were achieving many highest percentages in the results compared to other groups.
- Inexperienced students were performing better than other groups when solving the tasks using online learning technique.

Table 8.1: Summary of the main findings.

Research Question (RQ)	Learning Technique	Group	Results
RQ1 Improving learning satisfaction (by attending/using)	Traditional Learning	Experienced Group 1	77.5% (Agree)
RQ2 Improving learning satisfaction (by solving the assigned tasks)	Online Learning	Experienced Group 1	87.5% (Agree)
		Inexperienced Group 1	87.5% (Agree)
RQ3 Improving speed in solving simple tasks (mean time taken in minutes)	Online Learning	Experienced Group 1	5.900
RQ3 Improving speed in solving complex tasks (mean time taken in minutes)	Online Learning	Experienced Group 1	11.000
RQ4 Improving self-confidence when solving simple tasks	Online Learning	Experienced Group 1	87.5% (Yes)
		Inexperienced Group 1	87.5% (Yes)
RQ4 Improving self-confidence when solving complex tasks	Online Learning	Experienced Group 1	97.5% (Yes)
		Inexperienced Group 1	97.5% (Yes)
RQ5 Improving marks performance when solving simple tasks	Traditional Learning	Experienced Group 1	85.0% (Good)
RQ5 Improving marks performance when solving complex tasks	Traditional Learning	Inexperienced Group 1	87.5% (Very Good)
	Online Learning	Inexperienced Group 2	87.5% (Very Good)
RQ6 Improving satisfaction, performance and self-confidence (by attending/using)	Traditional Learning	Experienced Group 1	77.5% (Agree)

8.2.2 Achievement of research objectives

Table 8.2 presents the four objectives to achieve the research aim and these objectives have been achieved in this research.

Table 8.2: Achievement of research objectives.

Research Objective (RO)	Achievement of research objectives
RO1 To explore the online learning techniques and related current issues within the context of engineering education, mainly in the area of mechanical engineering.	This objective was fulfilled after execution of a comprehensive literature review in the areas of online learning in the perspective of mechanical engineering education.
RO2 To investigate the experience of students and teacher perceptions on the existing learning technique for the mechanical design process, particularly in the module of Mechanical Engineering Design.	This objective was fulfilled through the approach of preliminary study. A survey questionnaire was distributed to students and informal interviews was carried out among teachers. The collected data were analysed using Microsoft Excel (charts and graphs).
RO3 To design and create a prototype web-based online learning system.	This objective was met by designing and creating a web-based online learning prototype system. A System Development Life Cycle model (SDLC) has been used and implemented in four phases including the concept, design, coding and testing.
RO4 To investigate the student experiences using the prototype web-based online learning system, and compare them with the traditional face to face learning method.	This objective was fulfilled through the main study. The approach used was a survey questionnaire and participants were also asked to perform two tasks using a prototype system designed. This study was conducted to answer the research questions set for this research.

8.3 Research Contributions

The main contribution of this research is the recognition of factors, including satisfaction, performance and self-confidence that influence the learning experiences and learning outcome in the mechanical engineering education. This is seen as beneficial for the students as well as the lecturers in improving the students learning in the field of Mechanical Engineering by using the online learning method especially for developing small countries like Brunei Darussalam. This study concludes that the online learning methods are significant and able to enhance the mechanical students to become more student-centred and versatile learners in whatever learning techniques they use.

The main findings produced in this study, particularly the factors that influence the learning experiences and learning outcomes in learning the Mechanical Engineering Design using online learning technique are a significant and novel contribution to the development of new knowledge of using different learning styles for the improvement of students' satisfaction, performance and self-confidence.

The key contributions of this study are summarised as follows:

- Knowledge and understanding of the theory of influencing online learning factors, including satisfaction, performance and self-confidence for the use of universities or educational institutions, particularly in developing small countries like Brunei Darussalam.

- Awareness for educators and students on the effectiveness of online learning environment besides traditional learning that can provide more satisfying, interesting and comprehensive learning, strengthen the confidence of students and improve the ability of students to solve the design calculations in the Mechanical Engineering Design module.

- A recognition of the need to use online learning as an additional learning tool in mechanical engineering education.

- A prototype online web-based learning system has been designed, created and used in this study to enhance the learning understanding and develop a student-centred environment.

8.4 Research Limitation

Having gain feedback on the impact of online learning, it should be taken into account the limitations of this study that can be addressed in the future research, as follows:

- The data collected in this study were limited to groups of students from one university only. The difficulties were to get access to the students from other universities and institutions in Brunei Darussalam, as most of them require formal documents and longer process of approval.

- The prototype system was designed and created to provide students with experiences and exposure on online learning method that comprises learning materials and templates to solve the assigned tasks. What is missing was the inclusion of a proper way of online interaction between students and teachers or among the students, and the particular issues arise on how the teachers will provide real guidance and obtain students feedback regularly.

- Assumptions were made regarding the positive students' attitudes towards experiencing new learning styles from what they used to learn and encouraging them to participate actively in learning. However, the main findings have shown that the experienced students still prefer to learn in traditional classroom way. Without presenting the learning materials more creative and interesting than those learning materials in traditional learning, most students felt bored and less motivate that can affect the students' capacity to learn.

- The setting of time in the main study should not be controlled, especially when using the online learning. Students should have given more time to explore as they are relatively new to that learning method.

- The method used in collecting data is a survey questionnaire which also has limitations. This method alone cannot really provide a clear picture of the impact of online learning in terms of the satisfaction, performance and self-confidence. In addition, this method cannot capture the real feelings of the respondents and lack of reliable responses. The qualitative interview techniques are suggested as to address these issues and to obtain more accurate responses.

8.5 Recommendations for Future Work

This research study can be considered as the first study to discuss the satisfaction, performance and self-confidence of experienced and inexperienced students in using online learning methods for a module in Mechanical Engineering at one of the universities in Brunei Darussalam. Due to the limitations as discussed in the previous section, some potential works that could be done in the near future are as the following:

- Online discussion boards need to be implemented for the virtual discussion. It is significant to design the discussion boards more creatively and thoughtfully in terms of the formats, structure and contents. For instance, emails, synchronous chat, forum boards, electronic bulletin boards and so forth are quite useful for providing active interaction and promoting more student participation.

- Future studies need to review the analysis on the students' learning styles to obtain valuable knowledge of the teaching styles that are suitable when conducting the lectures to students of various backgrounds. The assessment of the online students using the combination of formative and summative assessments should perform to gather useful and significant information on how to motivate the students' interest and to improve the students' satisfaction.

- It is recommended that future studies should be conducted as a long-term study for in-depth study and analysis. Suggestions such as the setting up of an appropriate structure for effective testing by incorporating the most significant and relevant factors for acquiring reliable data.

- This study has only focused on investigating the impact of online learning on mechanical students from one university in Brunei Darussalam. Hence, it is recommended that future studies need to expand the size of the sample by incorporating other engineering students from the same university or from other universities and higher institutions. In addition, it also suggested that similar study should be performed using different modules in Mechanical Engineering course such as Thermodynamics, Fluid Power and so forth. The participation can also include the relevant teachers and technicians to obtain valuable feedback.

- For the data collection, other methods such as comprehensive interviews of students as well as teachers are highly recommended to obtain better and real responses.

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Appendix A - Survey Questionnaire - Preliminary Study

A set of questions for the questionnaire that was distributed to the students during the preliminary study. The questionnaire was aimed to explore the student's experience and their confidence in learning the module of Mechanical Engineering Design (refer to Chapter 4).

Appendix A - Survey Questionnaire - Preliminary Study

Questionnaire

Your information will be kept confidential and used only for the research purposes. Your response is highly appreciated. Thank you.

1. Gender

- ◯ Male
- ◯ Female

2. Course of Study

- ◯ BEng in Mechanical Engineering
- ◯ HND in Mechanical Engineering

Other (please specify)

3. Have you previously attended a Machine Design module or Mechanical Engineering Design module? If yes, please continue to the next question. If no, please go to Q5.

- ◯ Yes
- ◯ No

4. As a result of attending the above course, how confident were you to put your learning into practice, eg. In your student's project?
(1 - Lack of confidence, 5 - extremely confident)

1	2	3	4	5
◯	◯	◯	◯	◯

5. Have you produced any project that includes mechanical design? If yes, please continue to the next question. If no, please go to Q10.

- ◯ Yes
- ◯ No

6. During your project, in which stage of the mechanical design process that you have discovered the most difficult? Please specify.

7. Please state your level of confidence in obtaining the following for your project:
(1 - Lack of confidence, 5 - extremely confident)

	1	2	3	4	5
Creating new ideas or designs	◯	◯	◯	◯	◯
Design calculation (dimensions, sizes, etc)	◯	◯	◯	◯	◯
Checking the strength, stability, life time considerations	◯	◯	◯	◯	◯
Preparing geometric drawing (2D & 3D models)	◯	◯	◯	◯	◯
Checking cost estimation	◯	◯	◯	◯	◯

8. Do you agree that managing the design calculation takes most of your time during your project?

◯ Yes

◯ No

Please specify your reason for both yes or no answer:

9. Please specify your recommendations or opinions on improving the design process in an effective way, especially in managing the design calculation.

10. Have you encountered any other difficulties during your project?

◯ Yes

◯ No

Please specify your reason for both yes or no answer:

11. Please specify your recommendations or opinions on how to manage your project effectively.

Appendix B - Informal Interview Questions - Preliminary Study

A set of questions for informal interview during the preliminary study. The interview was aimed to gather the perspectives of the lecturers based on their experiences from supervising the student projects (refer to Chapter 4).

Appendix B - Informal Interview Questions - Preliminary Study

Informal Interview Questions

The research is aimed to understand how students learn in Mechanical Engineering Design aspect. The questions will only take 5-10 minutes of time. The information of the participant will be kept confidential and used only for the research purposes. All the responses are highly appreciated. Thank you.

1. What are your specialities in Mechanical Engineering Programme?

2. Based on your experience being a supervisor or examiner on the student's project, what are the difficulties that they have during the design stage?

3. Other than the tasks done at the design stage such as the concept design, design calculations, drawing and 3D modelling, do your students have any other difficulties with their project?

4. Are your students able and confident in performing their design calculations that include dimensioning, sizing and analysing the strength?

5. How much the time have taken by your students in performing their design calculations?

6. Do you feel confident and consistency in marking the student's project that includes design calculation?

7. While marking the student's project particularly that includes designing, what are the important criteria that you normally/must look at or you will consider for the student's project to be a success one?

8. Do you have any recommendations or opinions to improve or enhance the student's ability or self-confidence in performing their design calculations?

Appendix C - Questionnaire Results - Preliminary Study

The results obtained from the survey questionnaire during the preliminary study. This study was aimed to collect and analyse the data for supporting the problems and issues raised in the research (refer to Chapter 4).

Appendix C - Questionnaire Results - Preliminary Study

Questionnaire: Fequency Table

Q1 Gender

Code	Response Item	Frequency	Percent
M	Male	53	55.8%
F	Female	42	44.2%
	Total	95	100%

M = Male
F = Female

Q2 Course of Study

Code	Response Item	Frequency	Percent
L1	BENG	24	25%
L2	FD	52	55%
L3	HND	19	20%
	Total	95	100%

L1 = BENG
L2 = FD
L3 = HND

Response Item	Male	Female
BENG	10	14
FD	32	20
HND	11	8
Total	53	42

Q3 Have you previously attended a Machine Design Module or Mechanical Engineering Design Module? If yes, please continue to the next question. If no, please go to Q5.

Code	Response Item	Frequency	Percent
1	Yes	95	100%
2	No	0	0%
	Total	95	100%

1 = Yes
2 = No

Q4 As a result of attending the above course, how confident were you to put your learning into practice, eg. In you student's project? (1-Lack of confidence, 5-Extremely confident)

Code	Response Item	Frequency	Percent
1	Lack of confidence	5	5%
2	Somewhat confident	8	8%
3	Neutral	61	64%
4	Confident	18	19%
5	Extremely confident	3	3%
	Total	95	100%

1 = Lack of confidence
2 = Somewhat confident
3 = Neutral
4 = Confident
5 = Extremely confident

Q5 Have you produced any project that includes mechanical design? If yes, please continue to the next question. If no, please go to Q10.

Code	Response Item	Frequency	Percent
1	Yes	62	65%
2	No	33	35%
	Total	95	100%

1 = Yes
2 = No

Q6 During your project, in which stage of the mechanical design process that you have discovered the most difficult? Please specify.

Code	Response Item	Frequency	Percent
1	Design planning	7	11%
2	Design calculations	39	63%
3	Fabrication	2	3%
4	Report writing	1	2%
5	Not specified	13	21%
	Total	62	100%

1 = Design planning
2 = Design calculations
3 = Fabrication
4 = Report writing
5 = Not specified

Q7 Please state your level of confidence in obtaining the following for your project: (1-Lack of confidence, 5-Extremely confident)

Q7-1 Creating new ideas or designs

Code	Response Item	Frequency	Percent
1	Lack of confidence	2	3%
2	Somewhat confident	7	11%
3	Neutral	39	63%
4	Confident	12	19%
5	Extremely confident	2	3%
	Total	62	100%

1 = Lack of confidence
2 = Somewhat confident
3 = Neutral
4 = Confident
5 = Extremely confident

Q7-2 Design calculation (dimensions, sizes, etc)

Code	Response Item	Frequency	Percent
1	Lack of confidence	4	6%
2	Somewhat confident	17	27%
3	Neutral	34	55%
4	Confident	5	8%
5	Extremely confident	2	3%
	Total	62	100%

1 = Lack of confidence
2 = Somewhat confident
3 = Neutral
4 = Confident
5 = Extremely confident

Q7-3 Checking the strength, stability, life time considerations

Code	Response Item	Frequency	Percent
1	Lack of confidence	4	6%
2	Somewhat confident	15	24%
3	Neutral	32	52%
4	Confident	10	16%
5	Extremely confident	1	2%
	Total	62	100%

1 = Lack of confidence
2 = Somewhat confident
3 = Neutral
4 = Confident
5 = Extremely confident

Q7-4 Preparing geometric drawing (2D & 3D models)

Code	Response Item	Frequency	Percent
1	Lack of confidence	2	3%
2	Somewhat confident	5	8%
3	Neutral	24	39%
4	Confident	29	47%
5	Extremely confident	2	3%
	Total	62	100%

1 = Lack of confidence
2 = Somewhat confident
3 = Neutral
4 = Confident
5 = Extremely confident

Q7-5 Checking cost estimation

Code	Response Item	Frequency	Percent
1	Lack of confidence	3	5%
2	Somewhat confident	12	19%
3	Neutral	28	45%
4	Confident	15	24%
5	Extremely confident	4	6%
	Total	62	100%

1 = Lack of confidence
2 = Somewhat confident
3 = Neutral
4 = Confident
5 = Extremely confident

Q8 Do you agree that managing the design calculation takes most of your time during your project?

Code	Response Item	Frequency	Percent
1	Yes	53	85%
2	No	9	15%
	Total	62	100%

1 = Yes
2 = No

Yes, Reasons

Code	Response Item	Frequency	Percent
1	Knowledge	10	19%
2	Formulae	19	36%
3	Accurate design	13	25%
4	Importance	6	11%
5	Not specified	5	9%
	Total	53	100%

1 = Knowledge
2 = Formulae
3 = Accurate design
4 = Importance
5 = Not specified

No, Reasons

Code	Response Item	Frequency	Percent
1a	Less calculations	3	33%
2a	Fabrication	1	11%
3a	Not specified	5	56%
	Total	9	100%

1a = Less calculations
2a = Fabrication
3a = Not specified

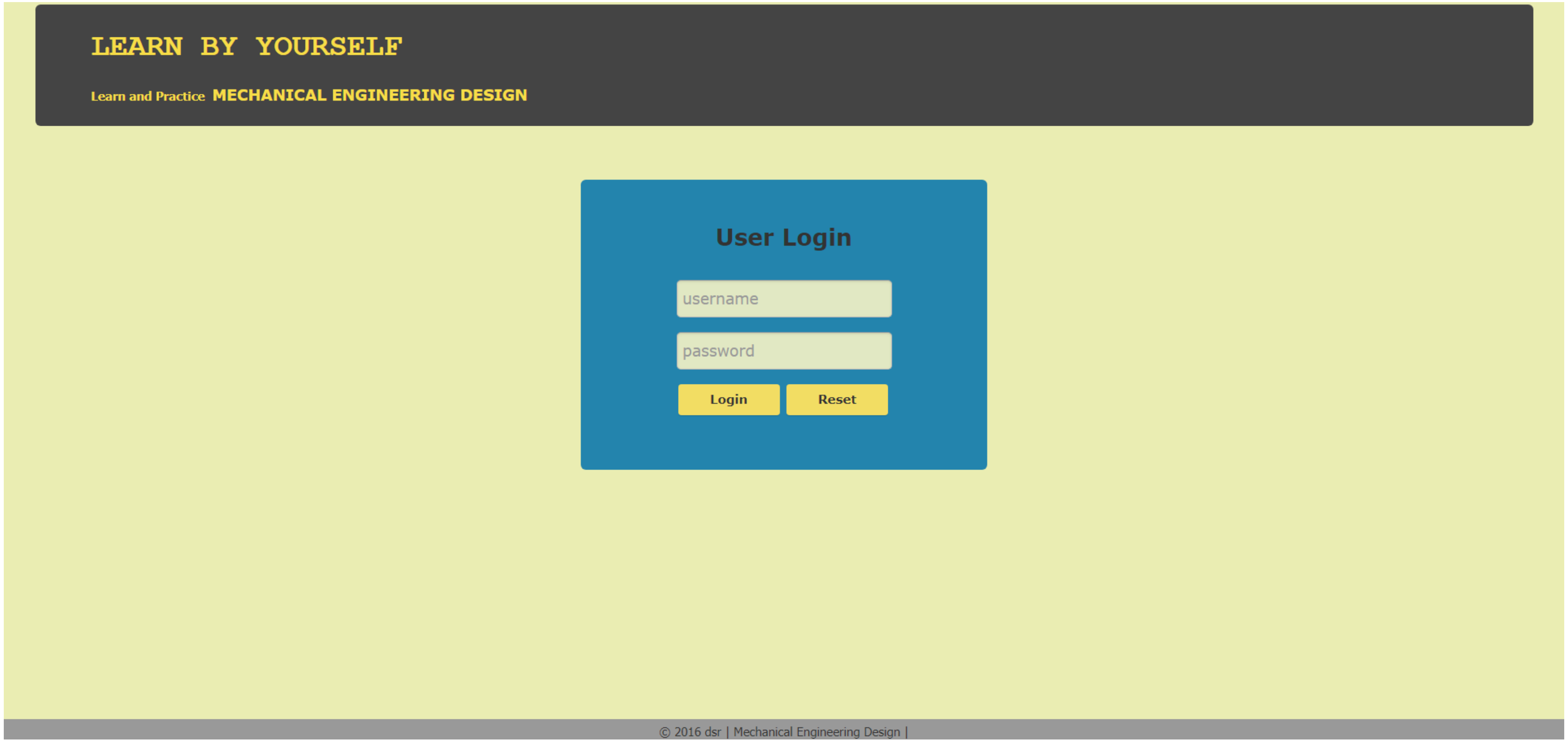
Q9 Please specify your recommendations or opinions on improving the design process in an effective way, especially in managing the design calculation.

Code	Response Item	Frequency	Percent
1	IT tools	19	31%
2	Exposure	12	19%
3	Time management	7	11%
4	Understanding	9	15%
5	Guidance	10	16%
6	Not specified	5	8%
	Total	62	92%

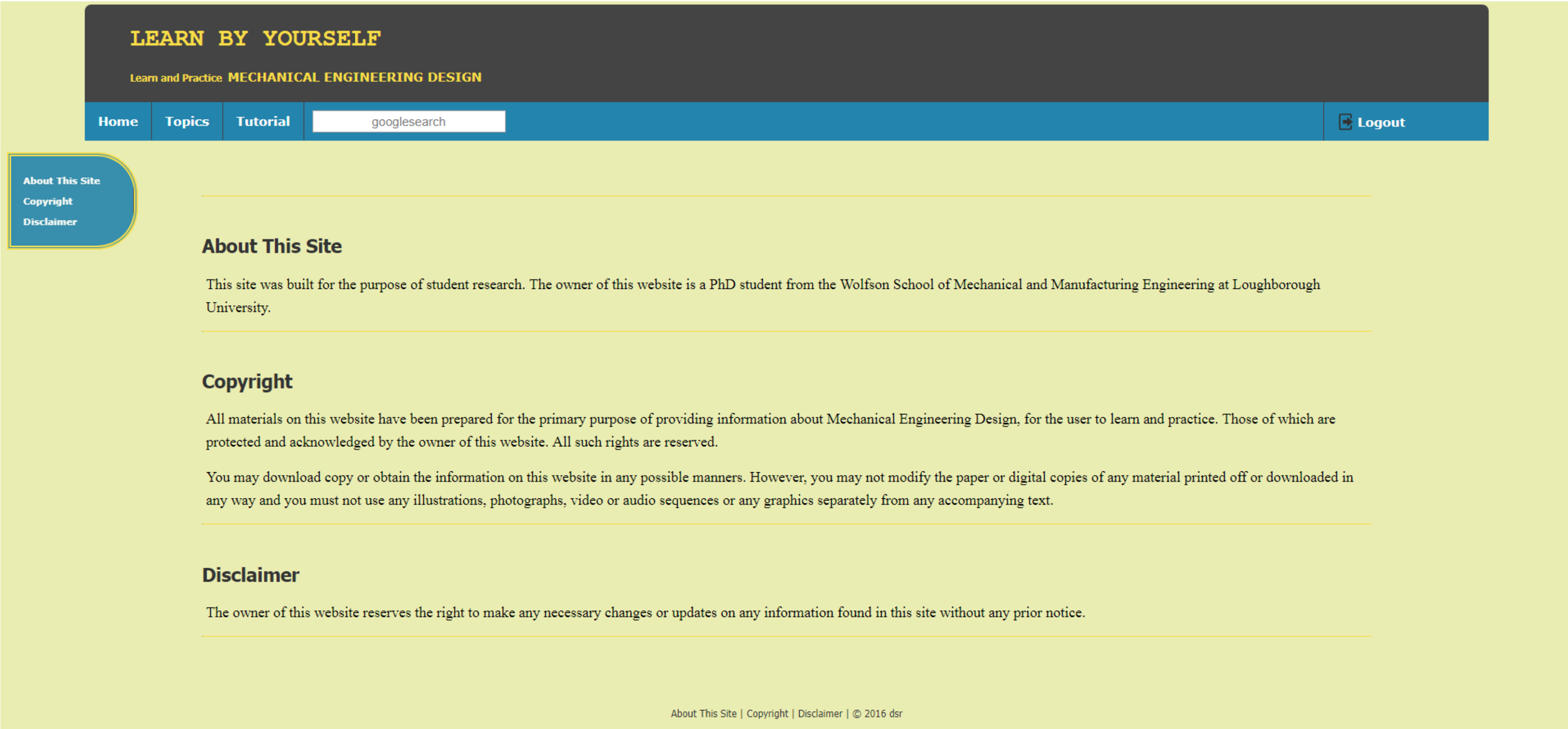
1 = IT tools
2 = Exposure
3 = Time management
4 = Understanding
5 = Guidance
6 = Not specified

Appendix D - A prototype online web-based learning system

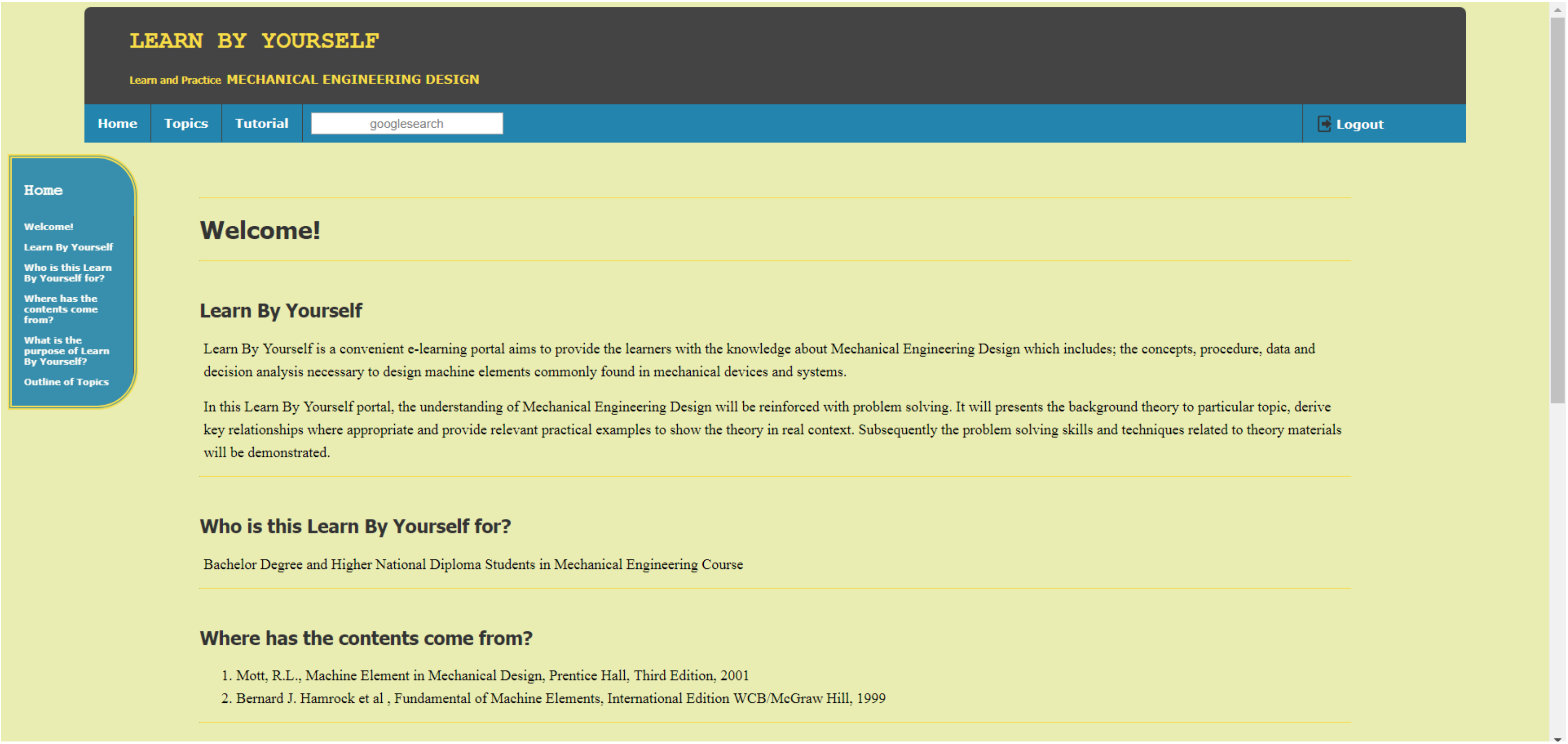
A full set of web pages of a prototype online web-based learning system. This system is designed and developed as a functional prototype to be tested by the student during the main study. A flowchart of this prototype system can be found in section 5.5.3.



A prototype online web-based learning system – User Login Page



A prototype online web-based learning system – About Page



A prototype online web-based learning system – Home Page [1]

Home

Welcome!

Learn By Yourself

Who is this Learn By Yourself for?

Where has the contents come from?

What is the purpose of Learn By Yourself?

Outline of Topics

What is the purpose of Learn By Yourself?

By the end of the session, the user will be able to:

- establish a set of criteria for evaluating proposed design and work with appropriate units in mechanical design calculations
- complete the design of keys and the corresponding keyways and keyseats giving complete geometry
- compute the forces exerted on the shaft by machine elements and specify appropriate design stresses for shafts
- identify Load-life relationship and compute Design life of rolling contact bearing, bearing selection, practical consideration in the application of bearings and life prediction under varying loads
- calculate tension ratio for flat and V-belt drive and apply guidelines for the design of V-belt and chain drives
- describe rivets, welding, brazing and adhesives and contrast them with bolts and screws for fastening applications, compute various joints conditions and analyse compression, tension and shear stress on the fasters at the joints
- design and analyse helical compression and extension springs to confirm the design requirements

Outline of Topics

1. Introduction to Mechanical Engineering Design
2. Design of Keys, Splines, Pins, Set Screws and Couplings
3. Design of Power Transmission Shafts
4. Design of Flexible Machine Elements (Flat, V and Synchronous Belts and Roller Chains)
5. Design of Welded and Bonded Joints
6. Design of Fasteners and Threaded Joints
7. Design of Helical Springs (Compression, Tension and Torsional Springs)

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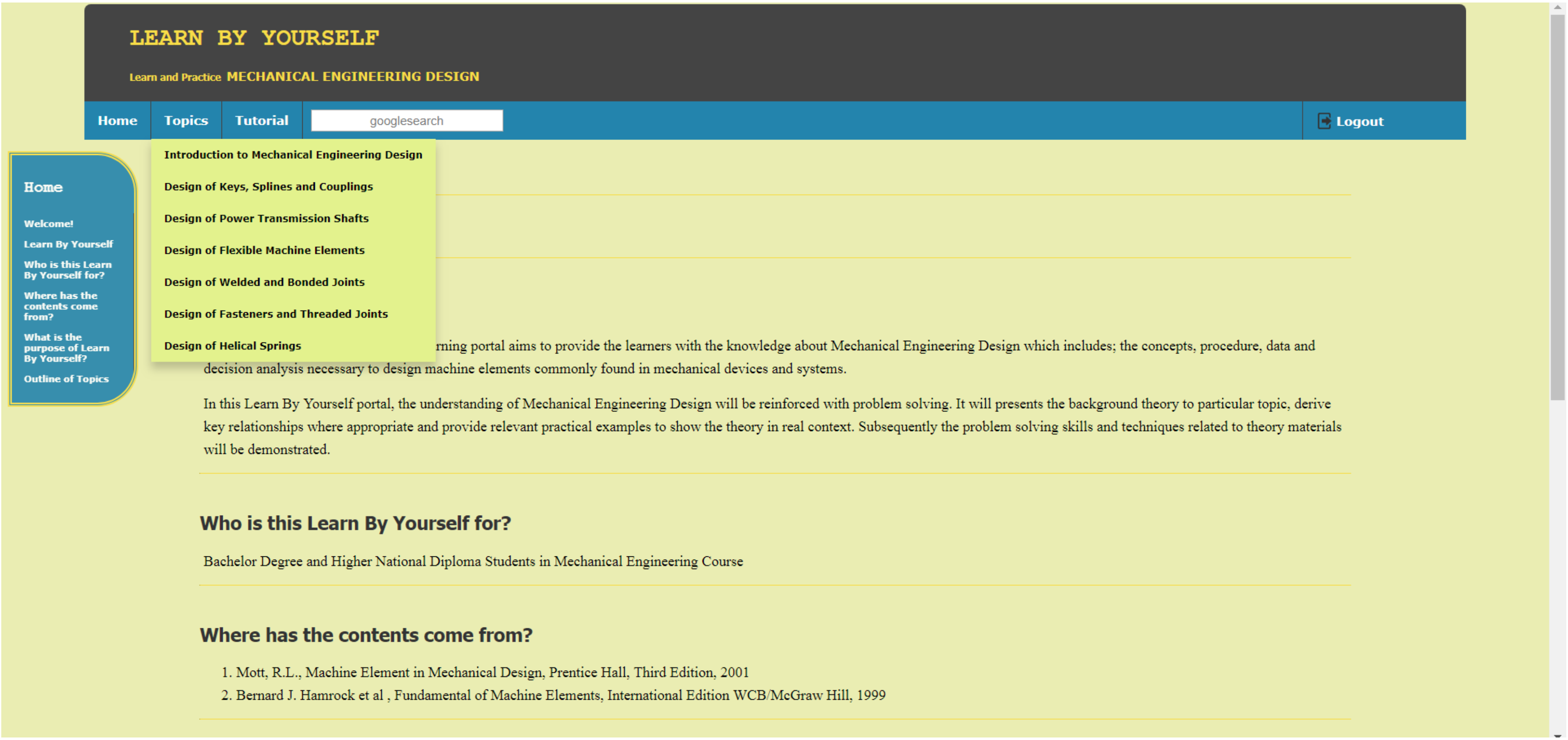
A prototype online web-based learning system – Home Page [2]



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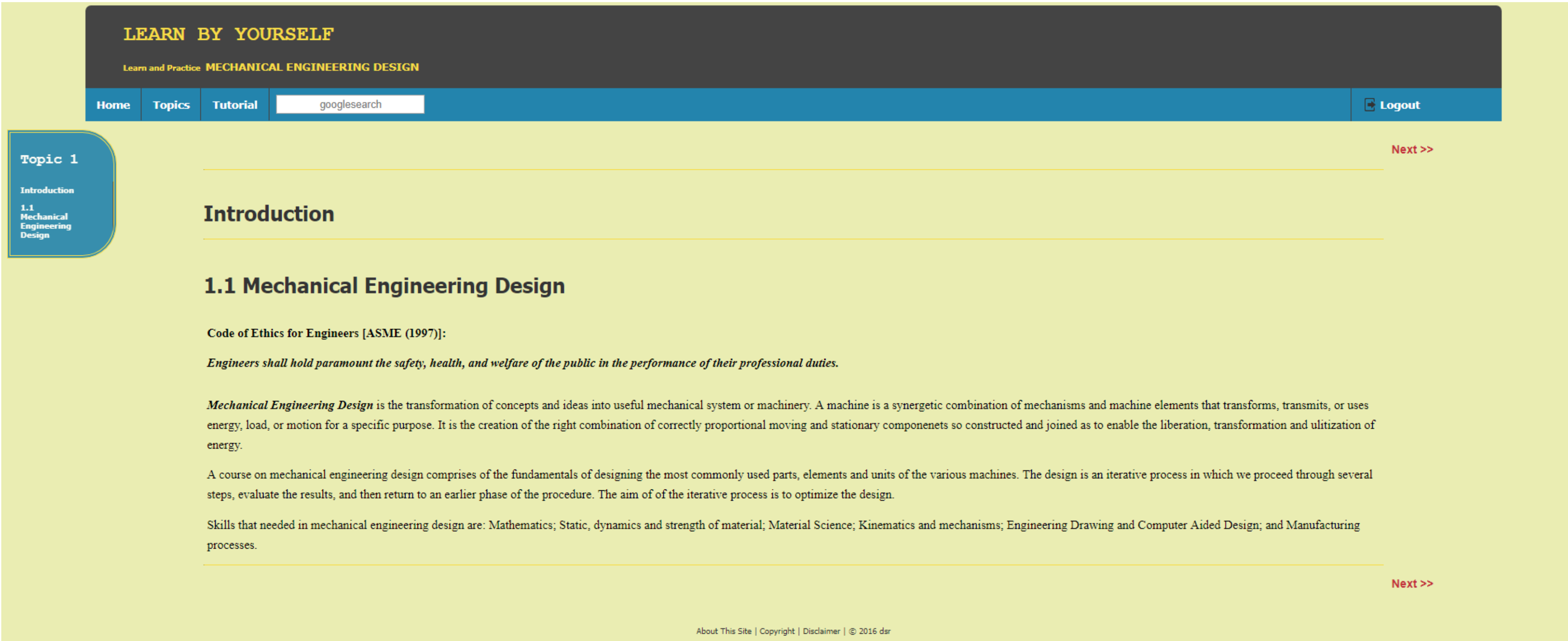

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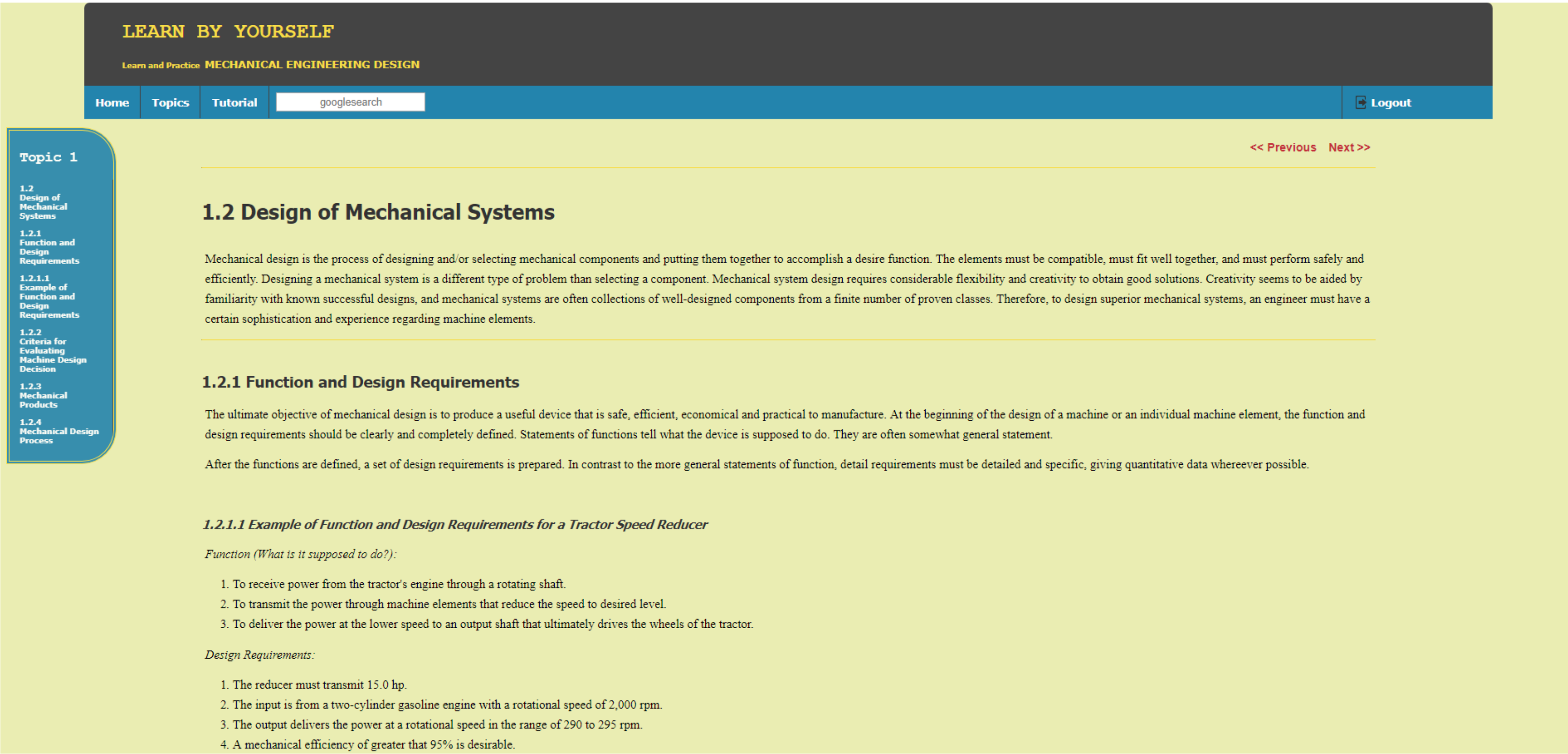

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Topic 1

- 1.2 Design of Mechanical Systems
- 1.2.1 Function and Design Requirements
- 1.2.1.1 Example of Function and Design Requirements
- 1.2.2 Criteria for Evaluating Machine Design Decision
- 1.2.3 Mechanical Products
- 1.2.4 Mechanical Design Process

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1.2 Design of Mechanical Systems

Mechanical design is the process of designing and/or selecting mechanical components and putting them together to accomplish a desire function. The elements must be compatible, must fit well together, and must perform safely and efficiently. Designing a mechanical system is a different type of problem than selecting a component. Mechanical system design requires considerable flexibility and creativity to obtain good solutions. Creativity seems to be aided by familiarity with known successful designs, and mechanical systems are often collections of well-designed components from a finite number of proven classes. Therefore, to design superior mechanical systems, an engineer must have a certain sophistication and experience regarding machine elements.

1.2.1 Function and Design Requirements

The ultimate objective of mechanical design is to produce a useful device that is safe, efficient, economical and practical to manufacture. At the beginning of the design of a machine or an individual machine element, the function and design requirements should be clearly and completely defined. Statements of functions tell what the device is supposed to do. They are often somewhat general statement.

After the functions are defined, a set of design requirements is prepared. In contrast to the more general statements of function, detail requirements must be detailed and specific, giving quantitative data whereever possible.

1.2.1.1 Example of Function and Design Requirements for a Tractor Speed Reducer

Function (What is it supposed to do?):

1. To receive power from the tractor's engine through a rotating shaft.
2. To transmit the power through machine elements that reduce the speed to desired level.
3. To deliver the power at the lower speed to an output shaft that ultimately drives the wheels of the tractor.

Design Requirements:

1. The reducer must transmit 15.0 hp.
2. The input is from a two-cylinder gasoline engine with a rotational speed of 2,000 rpm.
3. The output delivers the power at a rotational speed in the range of 290 to 295 rpm.
4. A mechanical efficiency of greater that 95% is desirable.

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Design Requirements:

1. The reducer must transmit 15.0 hp.
2. The input is from a two-cylinder gasoline engine with a rotational speed of 2,000 rpm.
3. The output delivers the power at a rotational speed in the range of 290 to 295 rpm.
4. A mechanical efficiency of greater that 95% is desirable.
5. The minimum output torque capacity of the reducer should be 3,050 Ib-in.
6. The reducer output is connected to the drive shaft for the wheels of a farm tractor. Moderate shock will be encountered.
7. The input and output shafts must be in-line.
8. THe reducer is to fastened to a rigid steel frame of the tractor.
9. Small size is desirable. The reducer must fit in a space no larger than 20 in by 20 in, with a maximum height of 24 in.
10. The tractor is expected to operated 8 hours per day, 5 days per week, with a design life od 10 years.
11. The reducer must be protected from the weather and must be capable of operating anywhere in the United States at temperatures ranging from 0 to 130°F.
12. Flexible couplings will be used on the input and output shafts to prohibit axial and bending loads from being transmitted to the reducer.
13. The production quantity is 10,000 units per year.
14. A moderate cost is critical to successful marketing.

Careful preparation of function statements and design requirements will ensure that the design effort is focused on the desired results. Much time and money can be wasted on designs that, although technically sound, do not meet design requirements. Design requirements should include everything that is needed, but at the same time they should offer ample opportunity for innovation.

1.2.2 Criteria for Evaluating Machine Design Decision

Some of important criteria for evaluating Machine Design Decision are:

1. Safety
2. Performance (≥ design objective or function)
3. Reliability (≥ design life)
4. Ease of manufacturing or assembly
5. Ease of service or replacement of components
6. Ease of operation
7. Use of easily available material and purchased items
8. Low initial cost
9. Low operating and maintenance costs
10. Small size and low weight
11. Low noise and vibration; smooth operation
12. Compliance with standards
13. Attractive appearance or aesthetic
14. Prudent use of both uniquely designed parts and commercially available parts

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Topic 1

1.2 Design of Mechanical Systems
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1.2.4 Mechanical Design Process

1.2.3 Mechanical Products

Mechanical products are often designed and produced in the following field:

- Consumer Products: Household appliances (can openers, food processors, mixers, toasters, vacuum cleaners, clothes washers), lawn mowers, chain saws, power tools, garage door openers, air conditioning systems and many others.
- Manufacturing systems: Material handling devices, conveyors, cranes, transfer devices, industrial robots, machine tools, automated assembly systems, special-purpose processing systems, forklift trucks and packaging systems.
- Construction Equipment: Tractors with front-end loaders or backhoes, mobile cranes, power shovels, earthmovers, graders, dump trucks, road pavers, concrete mixers, powered nailers and staplers, compressors and many others.
- Agricultural equipment: Tractors, harvesters (for corn, wheat, tomatoes, cotton, fruit and many other crops), rakes, hay balers, plows, disc harrows, cultivators and conveyors.
- Transportation equipment: Automobiles, trucks and buses which include hundreds of mechanical devices such as suspension components (springs, shock absorbers, and struts); door and window operators; steering systems; hook and trunk latches and hinges; clutch and braking systems; transmissions; driveshafts; seat adjusters; and numerous parts of the engine systems. Aircraft seat reclining mechanisms, dozens of latches, structural components and door operators.
- Ships: Winches to haul up the anchor, cargo-handling cranes, rotating radar antennas, rudder steering gear, drive gearing and drive shafts, and the numerous sensors and controls for operating on-board systems.
- Space system: Satelite systems, the space shuttle, and launch systems which contain numerous mechanical systems such as devices to deploy antennas, hatches, docking systems, robotic arms, devices to secure cargo, positioning devices for instruments and propulsion systems.

1.2.4 Mechanical Design Process

Product Realization Process (PRP) is one of the mechanical design process where the concepts, ideas and customer requirements are brought to the market as products. Some of PRP activities are:

- **Marketing** function to access customer requirements
- **Research** the available technology that can reasonably be used in the product
- Availability of **materials** and **components** that can be incorporated into the product
- Product **design and development**
- Performance **testing**
- **Documentation** of the design
- **Vendor** relationships and **purchasing** functions
- Consideration of **global sourcing** of materials and global marketing
- **Work-force** skills
- Physical **plant** and facilities available
- Capability of **manufacturing systems**
- **Production planning** and control of production systems
- **Production support** systems and personnel
- **Quality** systems requirements
- **Operation and maintenace** of the physical plant
- **Distribution systems** to get products to the customer

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Topic 1

1.2 Design of Mechanical Systems
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- Capability of **manufacturing systems**
- **Production planning** and control of production systems
- **Production support** systems and personnel
- **Quality** systems requirements
- **Operation and maintenace** of the physical plant
- **Distribution systems** to get products to the customer
- **Sales** operations and time schedules
- **Cost targets** and other competitive issues
- **Customer service** requirements
- **Environmental** concerns
- **Legal** requirements
- Availability of **financial** capital

Can you add to this list?

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Topic 1

1.3 Design of Machine Elements

1.3.1 Failure

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1.3 Design of Machine Elements

A design synthesis process is normally begin with suggesting a mechanical system. The particular machine element classes are then chosen, possibly leading to further design iterations. The following steps are usually included in designing a proper machine element:

1. Selecting a suitable type of machine element from consideration of its function
2. Estimating the size of the machine element that is likely to be satisfactory
3. Evaluating the machine element's performance against the requirements
4. Modifying the design and the dimensions until the performance is near to whichever optimum is considered most important

The first two steps needs some creative decisions and being the most difficult part of design. While the last two steps are fairly easily to be handled by those who is trained in analytical methods and understands the fundamental principles of subject.

1.3.1 Failure

After a suitable type of machine element has been selected for the required function, the specific machine element is designed by analyzing kinematics, load, and stress. These analyses, coupled with proper material selection, will enable a stress-strain-strength evaluation in terms of a safety factor. A primary question in designing any machine element is whether it will fail in service. Most people, ncluding engineers are commonly associate failure with the actual breaking of a machine element. Although breaking is one type of failure, a design engineer must have a broader understanding of what really determines whether a part has failed.

A machine element is considered to have failed:

1. When it becomes completely inoperable
2. When it is still operable but is unable to perform its intended function satisfactorily
3. When serious deterioration has made it unreliable or unsafe for continued use, necessitating its immediate removal from service for repair or replacement

The role of the design engineer is to predict the circumstances uner which failure is likely to occur. These circumstances are stress-strain-strength relationships involving the bulk of the solid members and such surface phenomena as friction, wear, lubrication, and environment deterioration.

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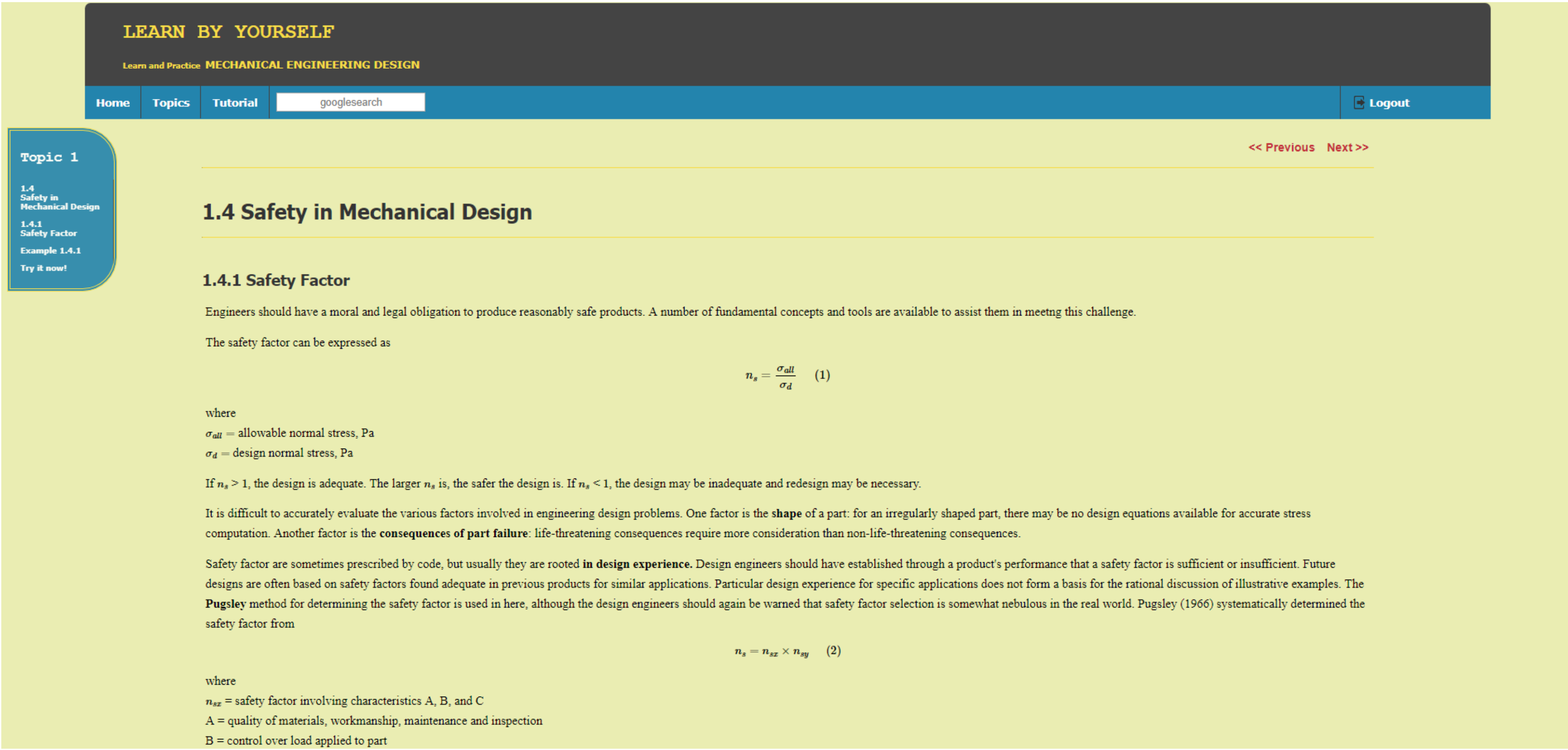

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Topic 1

1.4 Safety in Mechanical Design

1.4.1 Safety Factor

Example 1.4.1

Try it now!

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1.4 Safety in Mechanical Design

1.4.1 Safety Factor

Engineers should have a moral and legal obligation to produce reasonably safe products. A number of fundamental concepts and tools are available to assist them in meetng this challenge.

The safety factor can be expressed as

$$n_s = \frac{\sigma_{all}}{\sigma_d} \quad (1)$$

where
σ_{all} = allowable normal stress, Pa
σ_d = design normal stress, Pa

If $n_s > 1$, the design is adequate. The larger n_s is, the safer the design is. If $n_s < 1$, the design may be inadequate and redesign may be necessary.

It is difficult to accurately evaluate the various factors involved in engineering design problems. One factor is the **shape** of a part: for an irregularly shaped part, there may be no design equations available for accurate stress computation. Another factor is the **consequences of part failure**: life-threatening consequences require more consideration than non-life-threatening consequences.

Safety factor are sometimes prescribed by code, but usually they are rooted **in design experience.** Design engineers should have established through a product's performance that a safety factor is sufficient or insufficient. Future designs are often based on safety factors found adequate in previous products for similar applications. Particular design experience for specific applications does not form a basis for the rational discussion of illustrative examples. The **Pugsley** method for determining the safety factor is used in here, although the design engineers should again be warned that safety factor selection is somewhat nebulous in the real world. Pugsley (1966) systematically determined the safety factor from

$$n_s = n_{sx} \times n_{sy} \quad (2)$$

where
n_{sx} = safety factor involving characteristics A, B, and C
A = quality of materials, workmanship, maintenance and inspection
B = control over load applied to part

A prototype online web-based learning system – Topic 1: Introduction Page [7] (Safety factor)

$$n_s = n_{sx} \times n_{sy} \quad (2)$$

where

n_{sx} = safety factor involving characteristics A, B, and C

A = quality of materials, workmanship, maintenance and inspection

B = control over load applied to part

C = accuracy of stress analysis, experimental data, or experience with similar devices

n_{sy} = safety factor involving characteristics D and E

D = danger to personnel

E = economics impact

Topic 1

1.4 Safety in Mechanical Design

1.4.1 Safety Factor

Example 1.4.1

Try it now!

Table 1.1: Safety factor characteristics A, B and C

Table 1.1 Characteristic [a]			B =			
			vg	g	f	p
A = vg	C =	vg	1.1	1.3	1.5	1.7
		g	1.2	1.45	1.7	1.95
		f	1.3	1.6	1.9	2.2
		p	1.4	1.75	2.1	2.45
A = g	C =	vg	1.3	1.55	1.8	2.05
		g	1.45	1.75	2.05	2.35
		f	1.6	1.95	2.3	2.65
		p	1.75	2.15	2.55	2.95
A = f	C =	vg	1.5	1.8	2.1	2.4
		g	1.7	2.05	2.4	2.75
		f	1.9	2.3	2.7	3.1
		p	2.1	2.55	3.0	3.45
A = p	C =	vg	1.7	2.15	2.4	2.75
		g	1.95	2.35	2.75	3.15
		f	2.2	2.65	3.1	3.55
		p	2.45	2.95	3.45	3.95

Table 1.2: Safety factor characteristics D and E

Table 1.2 Characteristic [b]		D =		
		ns	s	vs
E =	ns	1.0	1.2	1.4
	s	1.1	1.3	1.5
	vs	1.2	1.4	1.6

'a' – vg = very good, g = good, f = fair, p = poor.

'b' – ns = not serious, s = serious, vs = very serious.

A = quality of materials, workmanship, maintenance, and inspection.
B = control over load applied to part.
C = accuracy of stress analysis, test data, or experience with similar parts.

D = danger to personal.
E = economic impact.

Table 1.1 gives n_{sx} = values for various **A, B,** and **C** conditions. To use this table, estimate characteristics for a particular application as being **very good (vg), good (g), fair (f), or poor (p).** Table 1.2 gives n_{sy} = values for various **D** and **E** conditions. To use this table, estimate each characteristics for a paricular application as being either **very serious (vs), serious (s),** or **not serious (ns).** Putting the values of n_{sx} and n_{sy} into equation (2) yields the factor.

The Pugsley method is merely a guideline and is no especially conservative; most engineering safety factor are much higher than those resulting from equation (2), as illustrated in example below.

Example 1.4.1

A prototype online web-based learning system – Topic 1: Introduction Page [8] (Safety factor)

		vg	[illegible]	[illegible]	[illegible]	[illegible]
A = f	**C =**	**g**	1.7	2.05	2.4	2.75
		f	1.9	2.3	2.7	3.1
		p	2.1	2.55	3.0	3.45
A = p	**C =**	**vg**	1.7	2.15	2.4	2.75
		g	1.95	2.35	2.75	3.15
		f	2.2	2.65	3.1	3.55
		p	2.45	2.95	3.45	3.95

A = quality of materials, workmanship, maintenance, and inspection.
B = control over load applied to part.
C = accuracy of stress analysis, test data, or experience with similar parts.

D = danger to personal.
E = economic impact.

Topic 1

1.4 Safety in Mechanical Design

1.4.1 Safety Factor

Example 1.4.1

Try it now!

Table 1.1 gives n_{sx} = values for various **A, B,** and **C** conditions. To use this table, estimate characteristics for a particular application as being **very good (vg), good (g), fair (f), or poor (p).** Table 1.2 gives n_{sy} = values for various **D** and **E** conditions. To use this table, estimate each characteristics for a paricular application as being either **very serious (vs), serious (s),** or **not serious (ns).** Putting the values of n_{sx} and n_{sy} into equation (2) yields the factor.

The Pugsley method is merely a guideline and is no especially conservative; most engineering safety factor are much higher than those resulting from equation (2), as illustrated in example below.

Example 1.4.1

Question:
A wire rope is used on an elevator transporting people to the 20th floor of a building. The design of the elevator can be 50% overloaded before the safety switch shuts off the motor. What is the safety factor?

Solution:
A = vg, because life-threatening
B = f, since large overloads are possible
C = vg, due to being highly regulated
From Table 1.1, $n_{sx} = 1.5$
D = vs, people could die if the elevator fell from the 20th floor
E = s, possible lawsuits
From Table 1.2, $n_{sy} = 1.5$

Therefore from Tables 1.1 and 1.2, equation (2) gives the safety factor:

$$n_s = n_{sx} \times n_{sy} = 1.5 \times 1.5 = 2.25$$

By improving factors over which there is come control n_{sx} can be reduced to 1.6 to 1.0 according to the Pugsley method, thus reducing the safety factor to 1.5. The Pugsley method could possibly suggest that a passenger elevator wire rope be designed with a safety factor of 1.5. In reality, the safety factor is precribed by an industry standard and connot be lower than 7.6 and may be a higher as 11.9 [ANSI (1995)].

Try it Now!

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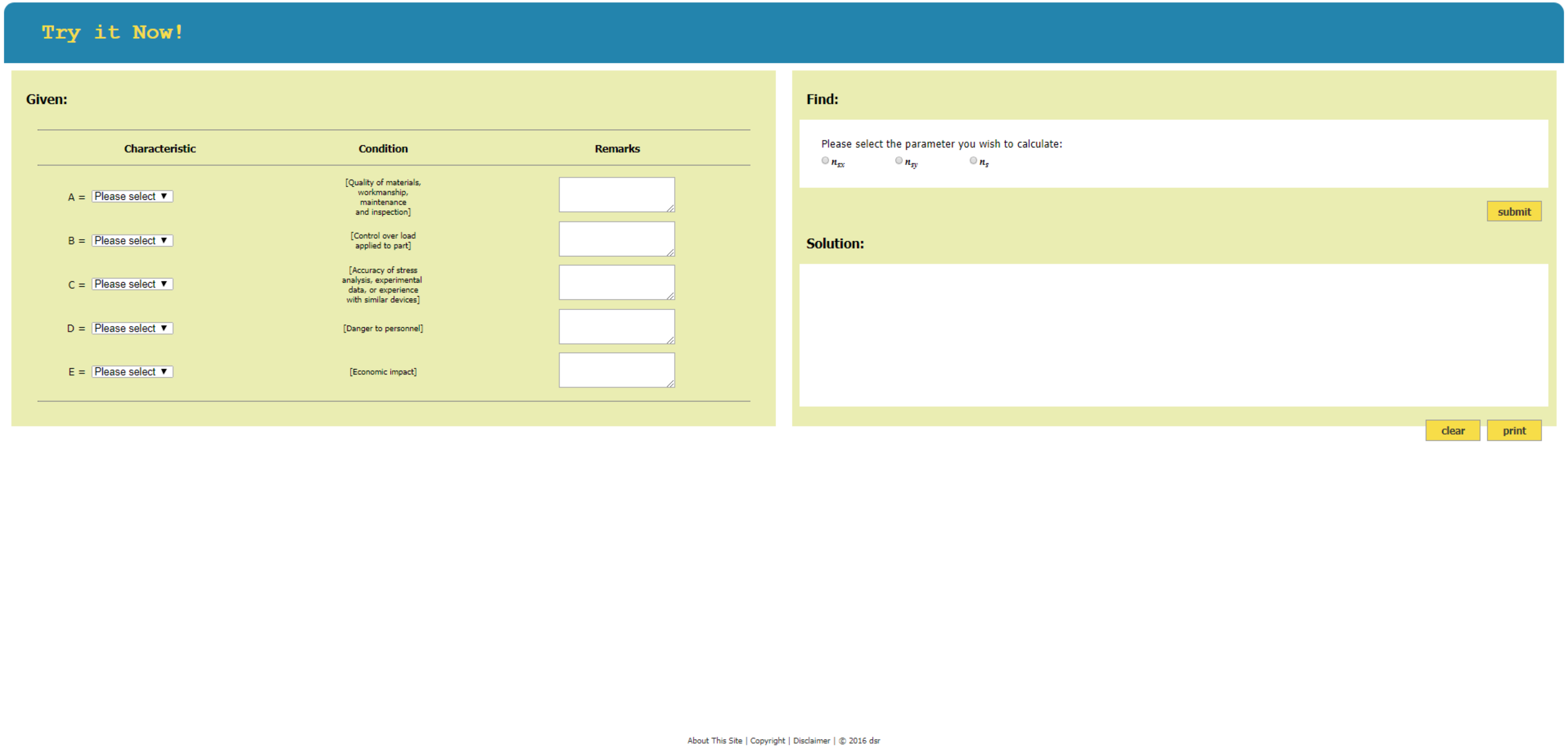

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(Safety factor - Try it Now!)

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Design of Keys, Splines and Couplings

Topic 2

Design of Keys, Splines and Couplings

2.1 Keys

2.1 Keys

The **function** of a **key** is to prevent the relative motion between the transmission **shaft** and the **hub** of a rotating element like gear, pulley, clutch or sprocket. The key transmits the **torque** from the shaft to the hub and vice versa. Varieties of keys commonly used in practice are shown in Figure 2.1.

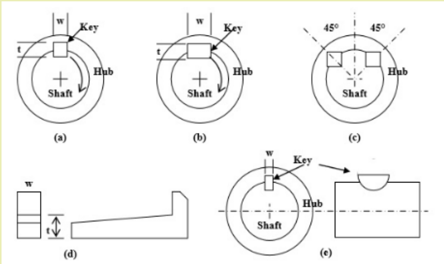

Figure 2.1: Types of Keys: (a) Square key, (b) Rectangular key, (c) Kennedy key, (d) Gib-head key, and (e) Woodruff key.

Rectangular and **square** parallel keys are most commonly used in general industrial machinery. The rectangular key has more stability as compared with the square key and the former one is recommended for larger shaft sizes. The **key-seats** in the shaft and the **key-ways** in the hub are designed so that one-half of the height of the key is bearing on the side of shaft key-seat and the other half on the side of the hub key-way.

The **Kennedy** key, consisting of the two square keys, is preferred for heavy-duty applications. In this case, the hub is bored off the center and the two keys force the hub and shaft to a concentric position.

The **Gib-head** key has a uniform width or breath (w or b) but the height or thickness (h or t) is given a taper of 1 in 100. It is easy to remove the key due to the head, however the projection of the head is hazardous for rotating elements.

Woodruff key, owing to its peculiar geometric shape, can align itself in the seat. The standard dimensions of these keys can be obtained from the repective standards.

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A prototype online web-based learning system – Topic 2: Design of keys, splines and couplings Page [1]

Topic 2

2.2 Design of Square and Rectangular Keys

The design of square and flat keys is based on **two criteria (mode of failure): failure** due to either **shear stress or compression stress.** The force acting on the key are shown in Figure 2.2. The two, equal and opposite, forces F are due to the torque, which is transmitted from the shaft to te hub and vice versa. The forces F', (where $F' = F$) act as a resisting couple preventing the key to roll in the keyway. The exact location of force F is unknown. It is assumed that the force F is tangential to the shaft diameter.

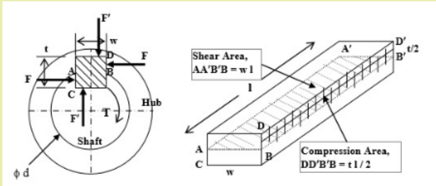


Figure 2.2: Forces acting on keys and stress areas.

Therefore,

$$F = \frac{T}{d/2} = \frac{2T}{d} \quad \text{(a)}$$

where
T = transmitted torque (Nmm)
d = shaft diameter (mm)
F = tangential force (N)

The failure due to **shear** will occur in plane AB and the shear stress, τ is given by;

$$\tau = \frac{F}{wl} \quad \text{(b)}$$

where w is the width and l is the length of the key. From (a) and (b),

$$\tau = \frac{2T}{dwl} \quad (1)$$

The failure due to **compression** stress will occur on surfaces AC and BD. Hence, $AC = BD \approx \frac{t}{2}$. The compressive stress is given by,

$$\sigma_c = \frac{F}{(t/2)l} = \frac{2F}{tl} \quad \text{(c)}$$

A prototype online web-based learning system – Topic 2: Design of keys, splines and couplings Page [2] (Design of square and rectangular keys)

Topic 2

2.2
Design of Square and Rectangular Keys

Example 2.2.1

Example 2.2.1 (Alternative Solution)

Example 2.2.2

Try it now!

where w is the width and l is the length of the key. From (a) and (b),

$$\tau = \frac{2T}{dwl} \quad (1)$$

The failure due to **compression** stress will occur on surfaces AC and BD. Hence, $AC = BD \approx \frac{t}{2}$. The compressive stress is given by,

$$\sigma_c = \frac{F}{(t/2)l} = \frac{2F}{tl} \quad (c)$$

From (a) and (c),

$$\sigma_c = \frac{4T}{dtl} \quad (2)$$

The industrial practice is to use a key with **sides** equal to **one-quarter of the shaft diamter** and **length at least 1.5 times** the shaft diameter. The preferred size and dimensions for square or rectangular keys are shown in Table 2.1.

Table 2.1: Preferred Size and Dimensions for Square or Rectangular Keys (mm)

Shaft Diameter		Key X-Section		Length of Key	
Above	**Up to**	w	t	l **(min)**	l **(max)**
6	8	2	2	6	20
8	**10**	**3**	**3**	**6**	**36**
10	12	4	4	8	45
12	**17**	**5**	**5**	**10**	**56**
17	22	6	6	14	71
22	**30**	**8**	**7**	**18**	**90**
30	38	10	8	22	110
38	**44**	**12**	**8**	**28**	**140**
44	50	14	9	36	160
50	**58**	**16**	**10**	**45**	**180**
58	65	18	11	50	200
65	**75**	**20**	**12**	**56**	**220**
75	85	22	14	63	250
85	**95**	**25**	**14**	**71**	**280**
95	110	28	16	80	320
110	**130**	**32**	**18**	**90**	**360**
130	150	36	20	100	400
150	**170**	**40**	**22**	**110**	**400**
170	200	45	25	125	400
200	**230**	**50**	**28**	**140**	**400**
230	260	56	32	160	400
260	**290**	**63**	**34**	**180**	**400**
290	330	70	36	200	400
330	**380**	**80**	**40**	**220**	**400**
380	440	90	45	250	400
440	**500**	**100**	**50**	**280**	**400**

Example 2.2.1

A prototype online web-based learning system – Topic 2: Design of keys, splines and couplings Page [3] (Design of square and rectangular keys)

Topic 2

2.2
Design of Square and Rectangular Keys

Example 2.2.1

Example 2.2.1 (Alternative Solution)

Example 2.2.2

Try it now!

Example 2.2.1

Question:

It is required to design a square key for fixing a gear on a shaft, of 40 mm shaft to the gear. A 25 kW power at 720 rpm is transmitted from the shaft to the gear. The key is made of steel 1020 CD ($S_{yt} = 352\,\mathrm{N/mm^2}$) and the factor of safety is 3. The yield strength in compression can be assumed to be equal to the yield strength in tension. Determine the dimensions of the key.

Given:

Square key ($w = t$), $d = 40\,\mathrm{mm}$, $P = 25\,\mathrm{kW}$, $n = 720\,\mathrm{rpm}$, $S_{yt} = 352\,\mathrm{N/mm^2}$, $fs = 3$

Find:

$w \times t \times l$

Solution:

Step 1

As $d = 40\,\mathrm{mm}$, then $w = t = \frac{d}{4} = \frac{40}{4} = 10\,\mathrm{mm}$

Step 2

Power (Watt), $P = \frac{2\pi nT}{60}$ where n in rpm and T in Nm

$$\therefore T = \frac{60 \times 10^6 P}{2\pi n} = \frac{60 \times 10^6 \times 25}{2\pi \times 720} = 331,572.8\,\mathrm{Nmm}$$

Step 3

As $S_{yt} = S_{yc} = 352\,\mathrm{N/mm^2}$

Then, Allowable (Design) Compression Stress: $\sigma_c = \frac{S_{yc}}{fs} = \frac{352}{3} = 117.33\,\mathrm{N/mm^2}$

By the distortion-energy theory, $S_{ys} = 0.577 S_{yt} = 0.577(352) = 203.10\,\mathrm{N/mm^2}$

Then, Allowable (Design) Shear Stress: $\tau = \frac{S_{ys}}{fs} = \frac{203.10}{3} = 67.70\,\mathrm{N/mm^2}$

Step 4

Therefore,

From Equation (1): $l_s = \frac{2T}{\tau dw} \frac{2(331,572.8)}{(67.70)(40)(10)} = 24.49\,\mathrm{mm}$

From Equation (2): $l_c = \frac{4T}{\sigma_c dt} \frac{4(331,572.8)}{(117.33)(40)(10)} = 28.26\,\mathrm{mm}$

Comment

Equation (2) is the criterion for deciding the length in this case as $l_c > l_s$. The length of the key should be 28.3 or 28 or 29 mm, and its dimensions are $10 \times 10 \times 28\,\mathrm{mm}$.

A prototype online web-based learning system – Topic 2: Design of keys, splines and couplings Page [4]

(Design of square and rectangular keys)

Topic 2

2.2
Design of Square and Rectangular Keys

Example 2.2.1

Example 2.2.1 (Alternative Solution)

Example 2.2.2

Try it now!

Example 2.2.1 (Alternative Solution)

Question:

It is required to design a square key for fixing a gear on a shaft, of $40\,\mathrm{mm}$ shaft to the gear. A $25\,\mathrm{kW}$ power at $720\,\mathrm{rpm}$ is transmitted from the shaft to the gear. The key is made of steel 1020 CD ($S_{yt} = 352\,\mathrm{N/mm^2}$) and the factor of safety is 3. The yield strength in compression can be assumed to be equal to the yield strength in tension. Determine the dimensions of the key.

Given:

Square key $(w = t)$, $d = 40\,\mathrm{mm}$, $P = 25\,\mathrm{kW}$, $n = 720\,\mathrm{rpm}$, $S_{yt} = 352\,\mathrm{N/mm^2}$, $fs = 3$

Find:

$w \times t \times l$

Solution:

Step 1

As $d = 40\,\mathrm{mm}$, then $w = t = \frac{d}{4} = \frac{40}{4} = 10\,\mathrm{mm}$

Step 2

Shear Area on key: $A_s = w \times l_s = 10(l_s)$

Compression Area on key: $A_c = \frac{t}{2} \times l_c = 5(l_c)$

Step 3

Load on the key: $F = \frac{T}{d/2} = \frac{331,572.8}{40/2} = 16,578.6\,\mathrm{N}$

Step 4

As $S_{yt} = S_{yc} = 352\,\mathrm{N/mm^2}$

Then, Allowable (Design) Compression Stress: $\sigma_c = \frac{S_{yc}}{fs} = \frac{352}{3} = 117.33\,\mathrm{N/mm^2}$

By the distortion-energy theory, $S_{ys} = 0.577 S_{yt} = 0.577(460) = 203.10\,\mathrm{N/mm^2}$

Then, Allowable (Design) Shear Stress: $\tau = \frac{S_{ys}}{fs} = \frac{203.10}{3} = 67.70\,\mathrm{N/mm^2}$

Step 5

Therefore,

Allowable Shear Stress: $\tau = \frac{F}{A_s} \to l_s = \frac{F}{(\tau \times w)} = \frac{16,578.6}{(67.70 \times 10)} = 24.5\,\mathrm{mm}$

Allowable Compression Stress: $\sigma_c = \frac{F}{A_c} \to l_c = \frac{F}{\sigma_c \times (t/2)} = \frac{16,578.6}{117.33 \times (10/2)} = 28.3\,\mathrm{mm}$

Comment

As $l_c > l_s$, then the length of the key should be 28.3 or 28 or $29\,\mathrm{mm}$. Therefore, the dimensions of the key are $10 \times 10 \times 28\,\mathrm{mm}$.

A prototype online web-based learning system – Topic 2: Design of keys, splines and couplings Page [5] (Design of square and rectangular keys)

Topic 2

2.2 Design of Square and Rectangular Keys

Example 2.2.1

Example 2.2.1 (Alternative Solution)

Example 2.2.2

Try it now!

Example 2.2.2

Question:

The standard cross-section for a flat key, which is fitted on a $50\,\mathrm{mm}$ diameter shaft, is $16 \times 10\,\mathrm{mm}$. The key is transmitting ($475\,\mathrm{Nm}$) torque from the shaft to the hub and is made of commercial steel ($S_{yt} = S_{yc} = 230\,\mathrm{N/mm^2}$). Determine the length of the key, if the factor of safety is 3.

Given:

Rectangular key ($w \times t = 16 \times 10\,\mathrm{mm}$), $d = 50\,\mathrm{mm}$, $T = 475\,\mathrm{Nm}$, $S_{yt} = S_{yc} = 230\,\mathrm{N/mm^2}$, $fs = 3$

Find:

length, $l = ?$

Solution:

Step 1

As $S_{yt} = S_{yc} = 230\,\mathrm{N/mm^2}$

Then, Allowable (Design) Compression Stress: $\sigma_c = \frac{S_{yc}}{fs} = \frac{230}{3} = 76.67\,\mathrm{N/mm^2}$

By the distortion-energy theory, $S_{ys} = 0.577 S_{yt} = 0.577(230) = 132.71\,\mathrm{N/mm^2}$

Then, Allowable (Design) Shear Stress: $\tau = \frac{S_{ys}}{fs} = \frac{132.71}{3} = 44.24\,\mathrm{N/mm^2}$

Step 2

$T = 475\,\mathrm{Nm} = 475 \times 1000\,\mathrm{Nmm} = 475,000\,\mathrm{Nmm}$

From Equation (1): $l_s = \frac{2T}{\tau d w} \frac{2(475,000)}{(44.24)(50)(16)} = 26.84\,\mathrm{mm}$

From Equation (2): $l_c = \frac{4T}{\sigma_c d t} \frac{4(475,000)}{(76.67)(50)(16)} = 49.56\,\mathrm{mm}$

Comment

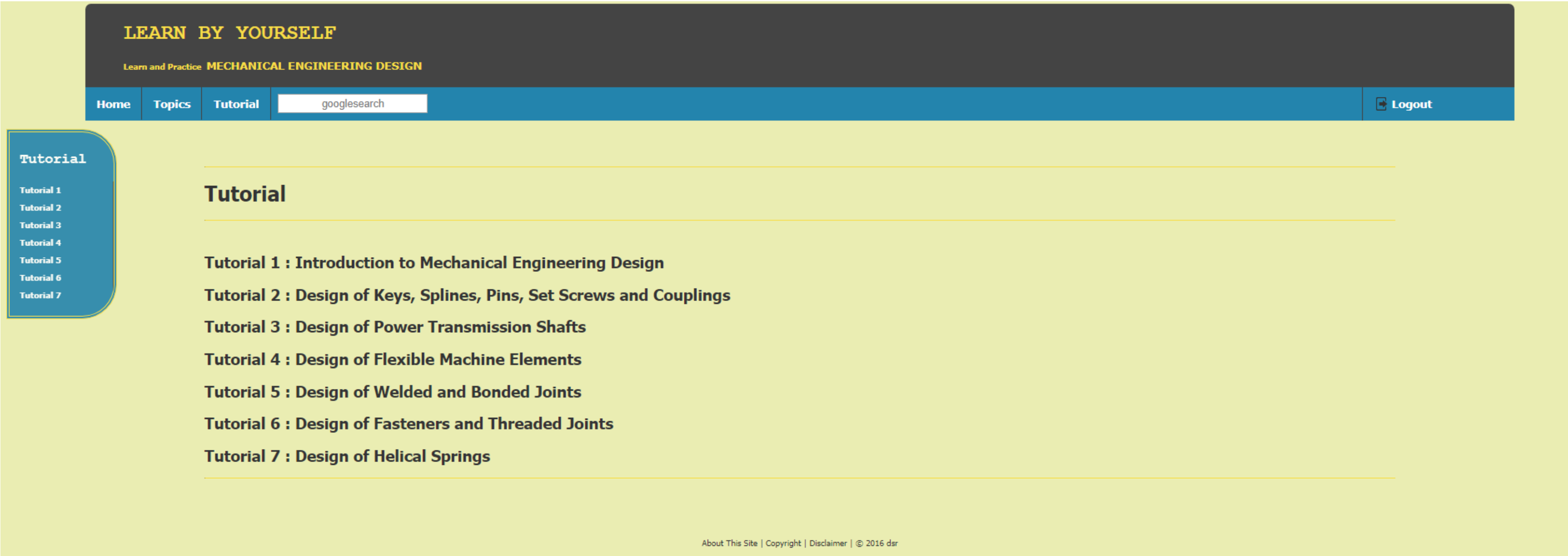
The length of the key should be $50\,\mathrm{mm}$ as $l_c > l_s$, and its dimensions are $16 \times 10 \times 50\,\mathrm{mm}$.

Try it Now!

<< Previous Next >>

A prototype online web-based learning system – Topic 2: Design of keys, splines and couplings Page [6] (Design of square and rectangular keys)

A prototype online web-based learning system – Topic 2: Design of keys, splines and couplings Page [7] (Design of square and rectangular keys – Try it Now!)



A prototype online web-based learning system – Tutorial List Page

Appendix E - Instructions to perform the assigned tasks - Main Study

The instruction sheets on how to perform the assigned for both learning sessions were given to the students during the main study (refer to section 6.2.1).

Appendix E - Instructions to perform the assigned tasks - Main Study

Instructions for Traditional Learning:

1. Please read through the provided lecture notes and use them to solve the assigned tasks.
2. Please show your working solutions in the given space of the answer sheets.
3. Please note down Start Time (indicating h:m) and Finish Time (indicating h:m) when solving the assigned tasks.
4. Please complete the questionnaire as your feedback and comments are important to the research.

Thank you for your time and support.

Instructions for Online Learning:

1. Please explore the web-based learning system for about 5-10 minutes.
2. Then read through the notes and examples in 1.4.1 for Topic 1: Safety Factor and then press "Try it Now!" button to solve the simple task. Please show your working solutions in the given space of the answer sheet.
3. Then read through the notes and examples in 2.2 for Topic 2: Design of Square and Rectangular Keys and then press "Try it Now!" button to solve the complex task. Please show your working solutions in the given space of the answer sheet. (Note that: factor of safety, $fs = fs_s = fs_c$).
4. Please note down Start Time (indicating h:m) and Finish Time (indicating h:m) when solving the assigned tasks.
5. Please complete the questionnaire as your feedback and comments are important to the research.

Thank you for your time and support.

Appendix F - Answer sheets for the assigned tasks - Main Study

The answer sheets for solving the assigned tasks in both learning sessions that were provided for the students during the main study. There were two different tasks given which include simple and complex tasks (refer to section 6.2.1).

Appendix F - Answer sheets for the assigned tasks - Main Study

Traditional Learning

Task:	**Simple**	Level of study:	□ **BEng** □ **FD** □ **HND**	Intake:	

Topic:	**Safety Factor**	Start Time:	___ : ___
Question			
A crane has a loading hook that is hanging on a steel wire. The allowable normal tensile stress in the wire gives an allowable force of 100 000 N. Find the **safety factor** that should be used. If the wire material is not controlled, the load can cause impact, and fastening the hook in the wire causes stress concentrations. (If the wire breaks, people can be seriously hurt and expensive equipment can be destroyed.)			
Solution			
Are you confident that your solution above is correct?	□ **Yes** □ **No**	Finish Time:	___ : ___

1 of 1

Online Learning

Task:	**Simple**	Level of study:	☐ **BEng** ☐ **FD** ☐ **HND**	Intake:	

Topic:	**Safety Factor**	Start Time:	___ : ___

Question

A crane has a loading hook that is hanging on a steel wire. The allowable normal tensile stress in the wire gives an allowable force of 100 000 N. Find the **safety factor** that should be used.

If the wire material is extremely well controlled, no impact loads are applied, and the hook is fastened in the wire without stress concentrations. (If the wire breaks, no people or expensive equipment can be damaged.)

Solution

Are you confident that your solution above is correct?	☐ **Yes** ☐ **No**	Finish Time:	___ : ___

Traditional Learning

Task:	**Complex**	Level of study:	□ **BEng** □ **FD** □ **HND**	Intake:	

Topic:	**Design of Square and Rectangular Keys**	Start Time:	___ : ___

Question

It is required to design a **square key** for fixing a pulley on a shaft which is 60 mm in diameter. 20 kW of power at 300 rpm is transmitted from the pulley to the shaft. The key is made of steel 45C8 ($S_{yc} = S_{yt} = 380$ N/mm^2) and the factor of safety is 3. Determine the dimensions of the key.

Solution

Are you confident that your solution above is correct?	□ **Yes** □ **No**	Finish Time:	___ : ___

1 of 1

Online Learning

Task:	**Complex**	Level of study:	□ **BEng** □ **FD** □ **HND**	Intake:	

Topic:	**Design of Square and Rectangular Keys**	Start Time:	___ : ___

Question

It is required to design a **square key** for fixing a pulley on a shaft which is 50 mm in diameter. 10 kW of power at 300 rpm is transmitted from the pulley to the shaft. The key is made of steel 45C8 ($S_{yc} = S_{yt} = 380$ N/mm^2) and the factor of safety is 3.5. Determine the dimensions of the key.

Solution

Are you confident that your solution above is correct?	□ **Yes** □ **No**	Finish Time:	___ : ___

Appendix G - Survey Questionnaire - Main Study

A survey questionnaire that was distributed to the students during the main study. It was aimed to identify the learning satisfaction, performance and self-confidence of experienced and inexperienced students completing simple and complex tasks using either a traditional learning method or an online learning (refer to Chapter 6).

Appendix G - Survey Questionnaire - Main Study

Questionnaire

Wolfson School of Mechanical and Manufacturing Engineering
Loughborough University, United Kingdom

This study is part of PhD research and aimed to identify the difference of learning experiences between attending a traditional learning technique (normal lecture and tutorial in a classroom) and using the online learning system. Furthermore, the study is proposed to investigate the participant's satisfaction, performance and self-confidence in learning, particularly in a module of Machine Design or Mechanical Engineering Design. This questionnaire consists of four parts. Firstly, part A is regarding the general background of participants. Part B and part C are related to the participant's view toward the two learning techniques and the assigned tasks respectively. Finally, part D is about the participant's satisfaction, performance and self-confidence.

Please complete each question by either ticking or circling the appropriate response and putting your answer in the space provided. All your information and responses will be kept confidential and will only be used for the purpose of this research. Your response is highly appreciated. Thank you for your time and participation.

Dk Seri Rahayu Pg Ya'akub
D.S.R.Pg-YaAkub@lboro.ac.uk

****

Part A: Participant's general background							
1.	Gender:	☐ Male ☐ Female					
2.	Academic qualification:	☐ O-Level or A-Level ☐ Certificate or National Diploma ☐ Others: ____________					
3.	Level of study:	☐ Bachelor of Degree (BEng) ☐ Foundation of Degree (FD) ☐ Higher National Diploma (HND)					
4.	Have you previously attended a module of Machine Design or Mechanical Engineering Design? If no, please continue to answer Part B.					☐ Yes	☐ No
	1-Strongly disagree **2**-Disagree **3**-Neither agree nor disagree **4**-Agree **5**-Strongly agree						
5.	As a result of attending the module, do you agree that you have self-confidence to apply what you have learned in practice?	1	2	3	4	5	

If you are attending for ***Traditional Learning Test***, please answer **B1**, **C1** and **D1**.

If you are attending for ***Online Learning Test***, please answer **B2**, **C2** and **D2**.

Traditional Learning Test

Part B1: Participant's views about attending traditional learning sessions for Machine Design or Mechanical Engineering Design module						
1-Strongly disagree **2**-Disagree **3**-Neither agree nor disagree **4**-Agree **5**-Strongly agree						
6.	Do you agree that the learning environment during normal lectures and tutorials was friendly and easy to explore?	1	2	3	4	5
7.	Do you agree that the learning materials during normal lectures and tutorials were clearly presented?	1	2	3	4	5
8.	Do you agree that the learning materials provided in normal lectures and tutorials increased your understanding effectively?	1	2	3	4	5
9.	Do you agree that attending normal lectures and tutorials met your learning expectations?	1	2	3	4	5
10.	Were you satisfied with attending normal lectures and tutorials?	1	2	3	4	5
11.	Please leave further comments on your opinion about attending normal lectures and tutorials. __________ __________ __________					

Part C1: Participant's views about solving the assigned tasks			
12.	Did you manage to solve a simple task using learning materials that were taught and provided during normal lectures and tutorials? If No, please state your reason below. __________ __________	☐ Yes	☐ No
13.	Did you manage to solve a complex task using learning materials that were taught and provided during normal lectures and tutorials? If No, please state your reason below. __________ __________	☐ Yes	☐ No
14.	Were you satisfied with your solutions for both assigned tasks? If No, please state your reason below. __________ __________	☐ Yes	☐ No
15.	Please leave further comments on your own opinion about the assigned tasks. __________ __________		

Page 2

Part D1: Participant's satisfaction, performance and self-confidence						
1-Strongly disagree **2**-Disagree **3**-Neither agree nor disagree **4**-Agree **5**-Strongly agree						
16.	Do you agree that you felt satisfied with your learning by attending normal lectures and tutorials?	1	2	3	4	5
17.	Do you agree that by attending normal lectures and tutorials can develop your self-confidence in performing design calculations?	1	2	3	4	5
18.	Do you agree that using learning materials provided during normal lectures and tutorials will speed up the time taken to solve a simple task?	1	2	3	4	5
19.	Do you agree that using learning materials provided during normal lectures and tutorials will speed up the time taken to solve a complex task?	1	2	3	4	5
20.	Do you feel more likely to use learning materials provided during normal lectures and tutorials if the task is simple?	1	2	3	4	5
21.	Do you feel more likely to use the learning materials provided during normal lectures and tutorials if the task is complex?	1	2	3	4	5
22.	Please leave further comments about your satisfaction, performance and self-confidence after attending normal lecture and tutorial. ____________________ ____________________ ____________________					
23.	Do you agree with attending normal lectures and tutorials as your main approach to learn Machine Design or Mechanical Engineering Design module? Please leave further comments to support your answer. ____________________ ____________________	1	2	3	4	5
24.	In your own words, please state the things that you would like to improve in the normal lecture and tutorial, in order to improve your learning and self-confidence in design calculations? ____________________ ____________________ ____________________					

Part B2: Participant's views about attending online learning sessions for Machine Design or Mechanical Engineering Design module						
1-Strongly disagree **2**-Disagree **3**-Neither agree nor disagree **4**-Agree **5**-Strongly agree						
6.	Do you agree that the online learning system was friendly and easy to explore?	1	2	3	4	5
7.	Do you agree that the learning materials in the online learning system were clearly presented?	1	2	3	4	5
8.	Do you agree that learning materials provided in the online learning system increased your understanding effectively?	1	2	3	4	5
9.	Do you agree that the online learning system was accessible for you to meet your learning expectations?	1	2	3	4	5
10.	Were you satisfied with learning using the online learning system?	1	2	3	4	5
11.	Please leave further comments on your own opinion about the online learning system. __________ __________ __________					

Part C2: Participant's views about solving the assigned tasks			
12.	Did you manage to solve a simple task using the online learning system? If No, please state your reason below. __________ __________	☐ Yes	☐ No
13.	Did you manage to solve a complex task using the online learning system? If No, please state your reason below. __________ __________	☐ Yes	☐ No
14.	Were you satisfied with your solutions for both assigned tasks? If No, please state your reason below. __________ __________	☐ Yes	☐ No
15.	Please leave further comments on your own opinion about the assigned tasks. __________ __________ __________		

Part D2: Participant's satisfaction, performance and self-confidence						
1-Strongly disagree 2-Disagree 3-Neither agree nor disagree 4-Agree 5-Strongly agree						
16.	Do you agree that you felt satisfied with your learning when using the online learning system?	1	2	3	4	5
17.	Do you agree that using learning materials provided in the online learning system can develop your self-confidence in performing design calculations?	1	2	3	4	5
18.	Do you agree that using learning materials provided in the online learning system will speed up the time taken to solve a simple task?	1	2	3	4	5
19.	Do you agree that using learning materials provided in the online learning system will speed up the time taken to solve a complex task?	1	2	3	4	5
20.	Do you feel more likely to use learning materials provided in the online learning system if the task is simple?	1	2	3	4	5
21.	Do you feel more likely to use the learning materials provided in the online learning system if the task is complex?	1	2	3	4	5
22.	Please leave further comments about your satisfaction, performance and self-confidence after using the online learning system. ____________________ ____________________ ____________________					
23.	Do you agree with using the online learning system as your main approach in learning Machine Design or Mechanical Engineering Design module? Please leave further comments to support your answer. ____________________ ____________________	1	2	3	4	5
24.	In your own words, please state the things that you would like to improve in the online learning system, in order to improve your learning and self-confidence in design calculations? ____________________ ____________________ ____________________					

** END **