EVALUATING THE USABILITY AND PATTERNS OF INTERACTIONS FOR ENHANCED TECHNOLOGY ASSISTED PROBLEM SOLVING (TAPS) PACKAGE

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EVALUATING THE USABILITY AND PATTERNS OF INTERACTIONS FOR ENHANCED TECHNOLOGY ASSISTED PROBLEM SOLVING (TAPS) PACKAGE

By

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A Thesis Submitted to the College of Graduate Studies, Universiti Tenaga Nasional, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Information & Communication Technology

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DECLARATION

I hereby declare that this thesis, submitted to Universiti Tenaga Nasional as fulfillment of the requirements for the degree of Doctor of Philosophy in Information & Communication Technology has not been submitted as an exercise for a similar degree at any other university. I also certify that the work described here is entirely my own except for excerpts and summaries whose sources have been appropriately cited in the references.

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30th MARCH 2018 Lee Chen Kang

ABSTRACT

Engineering Mechanics Dynamics course is known as one of the challenging course for the mechanical engineering students. This course is built upon the strong fundamental knowledge in physics and mathematics. This course requires the students to have a strong abstract thinking, reasoning and problem solving skills. In response to the new paradigm shift in engineering education that emphasizes on the use of Information and Communication Technologies (ICT) to facilitate the teaching and learning for tertiary education, there have been numerous studies that proposed the solutions utilizing the Computer Aided Learning (CAL) platform. The usability of the CAL software to facilitate the learning of the students need further investigation empirically. In this research, a technology assisted problem solving (TAPS) package which is a branch of CAL was enhanced with twenty five patterns of interactions and tested on the mechanical engineering students from Universiti Tenaga Nasional (UNITEN). This research study identified the students learning preferences using the Honey and Munford's Learning Styles Questionnaire and the Ogden's Personality and Learning Styles Questionnaire. The research study further investigated the usability of enhanced multimedia TAPS package embedded with 25 proposed patterns of interactions. Through the usability testing, two of the usability evaluation instruments, System Usability Scale (SUS) and Post-Study System Usability Questionnaire (PSSUQ) were employed. The usability testing results indicated consistent feedbacks on the good usability achievement level for the enhanced multimedia TAPS package. The proposed 25 patterns of interactions embedded in the enhanced multimedia TAPS package was grouped statistically through the exploratory factor analysis method into five main categories. Multiple linear regression (MLR) analysis was performed to evaluate the five categories of interaction patterns. The empirical result revealed that four out of five categories of the interaction patterns are positively associated with engineering problem solving tasks. This study supports the use of enhanced multimedia TAPS package embedded with patterns of interactions to facilitate the engineering students especially to enhance the problem solving skills in the context of mechanics dynamics that build up a strong foundation further in mechanical design and its application in daily life.

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LIST OF ABBREVIATIONS

CAL	Computer Aided Learning
CPU	Central Processing Unit
DVR	Desktop Virtual Reality
EFA	Exploratory Factor Analysis
HCI	Human Computer Interactions
ICT	Information and Communication Technology
ILS	Index of Learning Styles
ISO	International Organization for Standardization
LSI	Learning Style Inventory
LSQ	Learning Styles Questionnaire
MBTI	Myers-Briggs Type Indicator
MLR	Multiple Linear Regression
PSSUQ	Post-Study System Usability Questionnaire
RAM	Random-Access Memory
SUS	System Usability Scale
TAPS	Technology Assisted Problem Solving

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Manjit Sidhu, S., & Lee, C. K. (2010). Emerging Trends and Technologies for Enhancing Engineering Education: An Overview. *International Journal of Information and Communication Technology Education (IJICTE)*, *6*(4), 38–48. (****SCOPUS-Cited Publication****)

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Lee, C. K., & Manjit Singh, S. (2013). *The Potential of Computer Aided Learning Tool to Enhance the Learning of Engineering Students* (2(1)).

Research Awards

1) UNITEN Research Exposition 2014 (UNIREX 2014) – "**Most Innovative Award**"

2) Malaysia Technology Expo (MTE) 2015 – Special Award "**The Best Award**"

3) Malaysia Technology Expo (MTE) 2015 – **Gold Medal**

4) Postgraduate Research Exposition (REXPO 2016) – **First Place Winner**

5) 27th International Invention, Innovation and Technology Exhibition 2016 (ITEX 2016) – **Silver Medal**

6) Pertandingan Rekacipta dan Inovasi Institusi Pengajian Tinggi Swasta (PERINTIS 2016) – **Gold Medal**

7) International Competition and Exhibition on Computing Innovation 2016 (ICE-CINNO 2016) – **Gold Medal**

CHAPTER 1

INTRODUCTION

1.1 Overview

This Chapter discusses the background study, problem statement and research objectives. This Chapter also discusses the significance and scope of the research. The last part of this Chapter discusses the thesis outline for this research study.

1.2 Background of the Study

In the era of knowledge driven society, changes occur rapidly throughout the industries and the marketplace. Two main factors that drive the rapid change in the market environment and the society are the globalization and the revolution of Information and Communication Technologies (ICT). Knowledge has played an important role as a sustainable competitive factor for survival in the dynamic marketplace (Bhatti et al., 2016; Hana, 2013; Li & Liu, 2014; Lin, 2011). As mentioned by the well-known management Guru, Peter Drucker (1993), the main challenge in the knowledge-based economy is how to make the information and knowledge productive enough to compete in this constantly changing environment. The globe is moving towards the era of post-industrial knowledge society where the future will be essentially determined by the ability to utilize knowledge for unique ideas, products and services that emphasize on innovation efforts for competitive advantage. In fact, the shift from material and labor intensive products and processes to knowledge intensive products and services are the unavoidable major trends in the knowledge driven economy (Ferriera et al., 2017; Sala et al., 2016).

The paradigm shift in engineering education in response to the revolution of the knowledge society has created new opportunities for education practitioners. The utilization of Information and Communication Technologies (ICT) to facilitate the teaching and learning in engineering has increasingly raised the interest of the education practitioners throughout the world. As can be identified from the literature, students evolving from the classrooms that are integrated with the multimedia environment are more motivated and enthusiastic in learning activities and therefore more committed to their relationship to knowledge (Bai et al., 2016; Doong & Ho, 2012; Koh et al., 2015; Wang et al., 2014). There are many computer-based learning packages in the domain of engineering (e.g. the animation and simulation software, virtual laboratories, experimental video, virtual reality application, simulation based virtual laboratories and etc.) which have been developed for higher learning institutions and also used commercially in western countries (Cheng, 2014; Fang & Guo, 2016; Kojmane et al., 2016; Morsi et al., 2015; Pocsova et al., 2016; Re & Giubergia, 2013; Salam, 2011).

In the context of Malaysia, the development of TAPS (Technology Assisted Problem Solving) packages founded by Professor Manjit has made one of the pioneering efforts to facilitate the engineering problem solving in the domain of mechanical engineering (Fang & Guo, 2016). The TAPS packages "*aimed at coaching students, particularly who need additional support in applying principles presented in lectures to problems, on the best approach to solve a particular engineering problem in a step-by-step or logical approach*" (Manjit, 2006). This research would further build on top of the previously developed TAPS packages to study, propose and develop effective patterns of interactions that aim to provide better interactions to aid in the engineering problem solving tasks.

1.3 Motivation for the Research

In the perspective of mechanical engineering (mechanics dynamics domain) the following issues have motivated this study:

A primary motivation for this research is to further extend the capabilities of previously developed TAPS packages by Manjit, (2006) in which 25 patterns of interactions were proposed, developed and tested with new interface design. The proposed patterns of interactions were further explored and categorized according to different categories based on its role and function. In addition, the categorized patterns of interactions were tested to determine its relationship as associated with the problem solving tasks in engineering. The proposed patterns of interactions for the TAPS package were designed to facilitate the engineering problem solving tasks by which the students may strengthen their problem solving skills for the mechanics dynamics course.

Although some academicians have taken the initiative to develop computer aided learning (CAL) software in the context of mechanics dynamics, the perceived usability of the respective software is yet to be further investigated through empirical study. This research adopted the usability evaluation instruments System Usability Scale (SUS) and Post-Study System Usability Questionnaire (PSSUQ) in order to evaluate the perceived usability of the enhanced multimedia TAPS package. This helped to ensure better user experience through the interaction with the enhanced multimedia TAPS package to facilitate the process of engineering problem solving tasks.

Before the development of the enhanced multimedia TAPS package, the students (learners) learning styles preferences were evaluated. The incorporation of learning styles preferences in the design and development of the enhanced multimedia TAPS package is important to ensure the interaction design of the TAPS package match closely to the learning styles of the students for effective learning and better engineering problem solving tasks. Thus, the Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles Questionnaire were employed to measure the engineering students learning styles preferences. Two sets of instruments were adopted in order to ensure consistency for the students learning styles preferences obtained.

This thesis is concerned with the research study on the design, development and evaluation of enhanced multimedia TAPS package embedded with 25 proposed patterns of interactions that facilitate the students in engineering problem solving tasks in the mechanics dynamics course. The following discussions throughout the thesis focused solely on the context of mechanics dynamics problems for mechanical engineering students with the case in Universiti Tenaga Nasional (UNITEN).

1.4 Problem Statement

Research has found that computer aided learning (CAL) applications or software can enhance students understanding, support visualization and learning performance in the context of engineering education (Ayad & Rigas, 2010; Aziz, 2011; Behzadan et al., 2015; Benito et al., 2014; Fang & Guo, 2016; Figueiredo et al., 2014; Gao, 2011; Haque et al., 2016; Martín-Gutiérrez et al., 2011; Mehendale & Irwin, 2015; Saleh, 2010; Yueh et al., 2014). Through the use of CAL software, the students interact with the learning materials / contents through the respective interfaces of the learning software. Interaction is an essential ingredient of any learning environment (face-to-face classroom-based, synchronous/asynchronous online education, or blended models) (Mayer, 2011). Interaction in learning is "*a necessary and fundamental process for knowledge acquisition and the development of both cognitive and physical skills*" (Barker, 1994). Thus, increasing interaction and enhancing its quality have been important research goals for mediated instructional settings as computer-assisted instruction (CAI), computer-assisted learning (CAL), Internet-based learning, and Web-based learning (WBI) (Chen & Catrambone, 2014; Violante & Vezzetti, 2015).

Unfortunately, it was acknowledged that the field of interactivity design is still in its infancy state and there was insufficient finding regarding the usability design and its relationship associated with the engineering problem solving tasks to enhance the learning performance (Blasco-Arcas et al., 2013; Savin et al., 2010; Zaharis & Mehlenbacher, 2012). This issue is in line with the statements raised previously by Cairncross (2002) that "*It was found that learners did not always make full use of interactive features provided. The issue of how best to design learning activities that engage the user needs to be further addressed.*"

Similarly, previous research conducted by Manjit (2006) indicates that TAPS packages have great potential in aiding the learning of engineering and to enhance students' visualization in solving engineering mechanics problems. However, the study for the patterns of interactions for TAPS packages is still in its initial stage. Further research and study are necessary for the interface design of TAPS packages for better interactivity and navigation which could provide great potential to engage students in learning. This research focused on the design and development to enhance the interface design of the current TAPS packages embedded with series of patterns of interactions to facilitate the learning and problem solving tasks in engineering.

1.5 Research Questions

The specific research questions and research hypotheses are listed as followings:

Research Question 1 (RQ1): Are the students facing difficulties in learning Mechanics Dynamics subject? If yes, what are the difficulties faced by students?

Based on RQ1, the following hypotheses were derived:

H_1: Students faced difficulties in learning Mechanics Dynamics subject (students perspective)

H_2: Students faced difficulties in learning Mechanics Dynamics subject (instructors perspective)

Research Question 2 (RQ2): What are the learning styles preferences for engineering students? Since this is an exploratory study, no hypothesis was derived.

Research Question 3 (RQ3): Are the learning styles instruments showing consistent results on the students learning styles preference?

Based on RQ3, the following hypothesis was derived:

H_3: The engineering students learning styles preferences evaluated through Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles instrument are consistent.

Research Question 4 (RQ4): Is the enhanced multimedia TAPS package highly usable?

Based on RQ4, the following hypothesis was derived:

H_4: The usability evaluation for the enhanced multimedia TAPS package is better than the standard norm value.

Research Question 5 (RQ5): Does the usability results show consistency through various usability instruments?

Based on RQ5, the following hypothesis was derived:

H_5: The evaluation study of the usability design for enhanced multimedia TAPS package indicated consistent findings (using different usability evaluation instruments).

Research Question 6 (RQ6): What are the proposed interaction patterns for the enhanced multimedia TAPS package that may aid in the students problem solving tasks? Since this is an exploratory study, no hypothesis was derived.

Research Question 7 (RQ7): Can the interactions patterns be grouped into few categories?

Based on RQ7, the following hypothesis was derived:

H_6: The proposed 25-items of interactions patterns can be grouped into few categories.

Research Question 8 (RQ8): Does each of these categories (patterns of interactions) significantly associate with engineering problem solving tasks?

Based on RQ8, the following hypotheses were derived:

H_7: The "visualization" interaction patterns significantly associate with engineering problem solving.

H_8: The "attention grabber" interaction patterns significantly associate with engineering problem solving.

H_9: The "knowledge retention" interaction patterns significantly associate with engineering problem solving.

H_{10}: The "supportive patterns I" interaction patterns significantly associate with engineering problem solving.

H_{11}: The "supportive patterns II" interaction patterns significantly associate with engineering problem solving tasks.

1.6 Research Objectives

The objective of the work reported in this thesis was to enhance the understanding and problem solving skills of the engineering students taking the mechanics dynamics course at UNITEN through careful study of the students learning difficulties, students learning styles preferences, the development and evaluation of the enhanced multimedia TAPS package embedded with 25 proposed patterns of interactions and its perceived usability. More specifically, the research objectives of this study can be summarized as follows in response to the research questions stated in section 1.5:

1) To identify the learning difficulties faced by the students in learning mechanics dynamics.

2) To examine the preferred learning styles for engineering students through the use of Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles Questionnaire.

3) To measure students' perception towards the usability of the enhanced multimedia TAPS package.

4) To propose a series of patterns of interactions for the enhanced multimedia TAPS package.

5) To explore the categorization of the proposed patterns of interactions for the enhanced multimedia TAPS package.

6) To investigate the relationships between the groups of interaction patterns as associated with the engineering problem solving tasks for the enhanced multimedia TAPS package.

The linkage among the research questions, research objectives and research hypotheses can be found in Table 1.1.

Table 1.1 Linkages between the research questions, research objectives and hypotheses

Research Objectives		**Research Questions**		**Hypotheses**
To identify the learning difficulties faced by the students in learning mechanics dynamics.	**RQ1**	Are the students facing difficulties in learning Mechanics Dynamics course? If yes, what are the difficulties faced by students?	**H1**	Students faced difficulties in learning Mechanics Dynamics course (students perspective)
			H2	Students faced difficulties in learning Mechanics Dynamics course (instructors perspective)
To examine the preferred learning styles for engineering students through the use of Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles Questionnaire.	**RQ2**	What are the learning styles preferences for engineering students?		-
	RQ3	Are the learning styles instruments showing consistent results on the students learning styles preference?	**H3**	The engineering students learning styles preferences evaluated through Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles instrument are consistent.
To measure students' perception towards the usability of the enhanced multimedia TAPS package.	**RQ4**	Is the enhanced multimedia TAPS package highly usable?	**H4**	The usability evaluation for the enhanced multimedia TAPS software is better than the standard norm value.
	RQ5	Does the usability results show consistency through various usability instruments?	**H5**	The evaluation study of the usability design for enhanced multimedia TAPS package indicated consistent findings (using different usability evaluation instruments).
To propose series of patterns of interactions for the enhanced multimedia TAPS package.	**RQ6**	What are the proposed interaction patterns for the enhanced multimedia TAPS package that may aid in the students problem solving?		-

To explore the categorization of the proposed patterns of interactions for the enhanced multimedia TAPS package.	**RQ7**	Can the interactions patterns be grouped into few categories?	**H6**	The proposed 25-items of interactions patterns can be grouped into few categories.
To investigate the relationships between the groups of interaction patterns as associated with the engineering problem solving tasks for the enhanced multimedia TAPS package.	**RQ8**	Does each of these categories (patterns of interactions) significantly associate with engineering problem solving tasks?	**H7**	The "visualization" interaction patterns significantly associate with engineering problem solving.
			H8	The "attention grabber" interaction patterns significantly associate with engineering problem solving.
			H9	The "knowledge retention" interaction patterns significantly associate with engineering problem solving.
			H10	The "supportive patterns I" interaction patterns significantly associate with engineering problem solving.
			H11	The "supportive patterns II" interaction patterns significantly associate with engineering problem solving.

1.7 Significance of the Research

The contributions of the research are listed as follows:

1) The primary contribution of this research lies in the novel area of computer aided learning (CAL) domain for engineering education. The enhanced multimedia TAPS package with 25 proposed patterns of interactions associated significantly with engineering problem solving tasks (in the context of mechanics dynamics).

2) The second contribution of this research was the consistent findings of the learning styles preferences for engineering students through the use of Honey and Mumford's Learning Styles Questionnaire and the Ogden's Personality and Learning Styles Questionnaire that significantly contribute to the body of knowledge in engineering education domain on students learning styles preferences.

3) The third contribution of this research was the consistent findings on the usability evaluation using the SUS and PSSUQ instruments for the enhanced multimedia TAPS package.

1.8 Scope of the Research

Based on this research study, the scope of the research focused on:

1) Limits its scope to specific topic (Planar Kinematics of a Rigid Body) in the selected engineering mechanics dynamics problem.

2) Limits its study on the derivation of the relationship among the group of interaction patterns associated with engineering problem solving tasks in the context of mechanics dynamics.

3) To further enhance the multimedia TAPS package with new interface design and features within the boundary of previous TAPS packages framework.

4) The design and development of the enhanced multimedia TAPS package was customized in order to adapt with the learning styles preferences of engineering students in UNITEN.

1.9 Outline of the Thesis

The introduction and outline of this study, including the problem statements and objectives have been discussed in Chapter 1.

Chapter 2 provides the overview regarding the trends and paradigm shift in engineering education. Through the literature, the problems in mechanical engineering specifically for the learning of mechanics dynamics are identified. The importance of Information and Communication Technologies (ICT) and the application of computer aided learning (CAL) in engineering education are further discussed. In the last section of this Chapter, the theory of learning styles associated with engineering education and its importance are discussed.

Chapter 3 of this research study reviewed the issues on user interface design. The importance of user interface design and interaction methods are discussed. In addition, the guidelines for user interface design associated with learning environment were reviewed. In the last section of this Chapter, the usability evaluation methods and its importance are discussed.

The subsequence Chapter discusses on the research framework, including the methodologies employed on each phase to perform the research studies for user requirements gathering, learning styles evaluations and usability testing procedure for the enhanced multimedia TAPS package. In addition, the procedures for exploratory factor analysis to categorize the patterns of interactions and the procedures for multiple linear regression analysis to investigate the relationships among the dependent variable (engineering problem solving tasks) and the independent variables (group of interaction patterns) are discussed.

Chapter 5 of this research study discusses the study and findings of the students' learning difficulties both from the students and instructors perspective to understand the students' requirements for the enhanced multimedia TAPS package development. This Chapter also evaluates the students learning styles preferences using Honey and Mumford Learning Styles instrument (LSQ) and Ogden's Personality and Learning Styles instrument. Students learning styles preference was identified and comparison study was performed to show the consistency results gained through different learning styles instruments.

Chapter 6 of this research study discusses the teaching and learning of mechanics dynamics in UNITEN by which the learning problems were identified. This Chapter also discusses the development process (pre-authoring, authoring and post-authoring process) for the enhanced multimedia TAPS package embedded with twenty five patterns of interactions to facilitate the learning process of students in engineering problem solving tasks in the context of mechanics dynamics. The last section of this Chapter discussed the knowledge acquisition procedure using the enhanced multimedia TAPS package.

Chapter 7 discusses the findings of the perceived usability for the enhanced multimedia TAPS package through the questionnaires adapted from the System Usability Scale (SUS) instrument and the Post-Study System Usability Questionnaire (PSSUQ) version 3. This Chapter also evaluates the categorization for the proposed patterns of interactions through the use of exploratory factor analysis (EFA). Multiple linear regression analysis was performed to identify the relationship between the dependent variable (problem solving tasks) and the independent variables (different groups of interaction patterns).

Chapter 8 discusses the overall findings of this research. The limitations and future works of the research are reported accordingly in the last section of this Chapter.

In summary, this research study is focused on the design, development and evaluation of the enhanced multimedia TAPS package embedded with proposed patterns of interactions to facilitate the engineering problem solving tasks in the context of mechanics dynamics. This research aimed to enhance the previous TAPS packages to provide a better user experience in learning and problem solving process that adapt to the learning preferences of the students through the aid of tested interactions patterns to supplement the current teaching and learning of the mechanics dynamics course.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This Chapter reviewed the literature on the trends and paradigm shifts in engineering education. Through the literature, the problems in mechanical engineering specifically for the learning of mechanics dynamics were identified. The importance of Information and Communication Technologies (ICT) and the application of computer aided learning (CAL) in engineering education was discussed. In the last section of this Chapter, the theory of learning styles associated with engineering education was studied.

2.2 Engineering Education

2.2.1 Overview

Engineering education is regarded as one of the important educational domains in the tertiary education. As defined by Cheshier (1998);

> "*Engineering education for the professional focuses primarily on the conceptual and theoretical aspects of science and engineering aimed at preparing graduates for the practice of engineering closest to the research, development, and conceptual design functions*" (p. 36).

In the earlier days, when the engineering education was introduced, it followed the apprenticeship form with an emphasis on hands-on practical education (ASEE, 1987; Michko, 2007). Later, engineering education was formalized into the academic studies and followed a general pattern of teaching and learning. In general, engineering education involves two distinct learning environments which are the classroom teaching on theoretical knowledge for conceptual understanding and the laboratory sessions to obtain the practical knowledge (Balamuralithara & Woods, 2009).

Recently, the paradigm shift in engineering education raised the attention of the engineering communities and is actively discussed in numerous reports (Auguestine, 2005; Froyd et al., 2012; National Science Board, 2007; Prados, 1998; Wince-Smith, 2005). As discussed by Duderstadt (2008), one of the characteristics for new paradigms of engineering education is the change of pedagogical style that shifted from classroom based pedagogy to active learning approaches that engaged problem-solving skills and team building, by which it is more focused on discovery oriented, interactive and collaborative learning experiences. Table 2.1 summarizes the characteristics for old and new paradigms of engineering education as discussed in details by Duderstadt (2008).

Table 2.1 Comparisons on the Characteristics for Old and New Paradigms of Engineering Education

Engineering Education (characteristics)	**Old Paradigms**	**New Paradigms**
The Curriculum	▪ Focused on scientific and technical courses as the core of an engineering education.	▪ Not only focused on scientific and technical courses but include new curriculum that must reflect a broad range of concerns on economic, political, social, and environmental context of engineering practice.
The Ability and Skills	▪ Technical knowledge and skills	▪ Technical knowledge and skills ▪ Communication skills ▪ Teamwork / Teambuilding

		▪ Ability to adapt to an increasingly diverse world ▪ Ability not only to adapt to change but to actually drive change ▪ Social and environmental consciousness
Depth vs. Breadth	▪ Follow the reductionism approach - focused on teaching and scholarship on increasingly narrow and specialized topics.	▪ Focused more on comprehensive curriculum and broader educational experience in which topics are better connected and integrated. ▪ Holistic approach to address social needs
Pedagogical Style	▪ Classroom based pedagogy – lecture-dominated system (large lecture courses, rigidly defined problem assignments, highly structured laboratory courses).	▪ Active learning approaches that engage problem-solving skills and team building. ▪ Focused on discovery-oriented, interactive, and collaborative learning experiences.
Lifelong Learning	▪ Less awareness on lifelong learning – concerns more on the acquiring of knowledge for future jobs.	▪ Aware on the importance of lifelong learning and concerns more on the knowledge of how to learn and continue to learn throughout the life time.
New Technologies	▪ From microscopic level of info-bio-nano.	▪ To the macroscopic level of global systems.
A Broader Concern	▪ Focus primarily on educating students for the engineering profession.	▪ Educating not simply professional engineers but a new breed of graduates with an engineering-based, liberal education.

Froyd et al. (2012) identified the five major shifts which have reshaped (the first and second shifts) or currently reshaping (the third, fourth and fifth shifts) the engineering education for the past 100 years. The details are summarized in Table 2.2.

Table 2.2 Five major shifts in engineering education (Adopted from Froyd et al., 2012)

	Engineering Education Major Shifts	**Descriptions**
1	A shift from hands-on and practical emphasis to engineering science and analytical emphasis	- Engineering curricula moved from hands-on, practice-based curricula to ones that emphasized mathematical modeling and theory-based approaches.
2	A shift to outcomes-based education and accreditation	- Based largely on the actions of the Accreditation Board for Engineering and Technology (ABET), engineering education and accreditation became outcomes based. - Through ABET and its predecessors, accreditation has provided quality control for engineering education, seeking to assure that graduates of accredited programs are prepared for professional practice.
3	A shift to emphasizing engineering design	- This major shift emphasis on professional practice that enabling students to move from being passive viewers of engineering action to taking their place as active participants or creators within the field of engineering.
4	A shift to applying education, learning, and social-behavioral sciences research	- Use of educational objectives, and, more broadly, student learning outcomes and Bloom's Taxonomy (original or revised) is an indication that research in psychology, education, and learning science is having a noticeable influence on the engineering education community. - Student engagement or involvement in learning is the second area for which there is evidence of the influence of research in psychology, education, and learning science on the practice of engineering education. - Inquiry and inquiry-based or guided approaches focus first on the question, problem, challenge, or goal to be addressed. Then, students learn content, concepts, and processes while addressing the question, problem, challenge, or goal. - Understanding by Design (UbD) is an increasingly popular tool for educational planning focused on teaching for understanding. The emphasis of UbD is on backward design, the practice of first looking at the outcomes in order to design curriculum units, performance assessments, and classroom instruction. - Evidence of increased emphasis on a broader range of knowledge, skills, and attributes (or habits of mind and modes of thinking) for engineering graduates abounds. - Emergence of increased emphasis on a scholarly approach to engineering education is indicated.
5	A shift to integrating information, computational,	- Emphasized application of information, communication, and computational technologies (ICCT) in engineering

	and communications technology in education	education. - Some of the principal instructional technologies and their applications have been: content delivery (television, videotape, and the Internet); programmed instruction (individualized student); feedback; personal response systems; computational technologies; intelligent tutors (second phase of individualized); student feedback; simulations; games and competitions; remote laboratories; grading.

In response to the aforementioned paradigm shift in engineering education, the engineering communities from academic, research and industry have contributed invaluable efforts. One of the efforts that the engineering community focused on is the utilization of information and communication technology (ICT) to foster the teaching and learning in engineering education (Manjit, 2006; Michko, 2007; Froyd et al., 2012). Although educational technology is not an ultimate solution for the paradigm change in engineering education, but at least, educational technology supports some of the attributes in the new engineering education paradigm such as support for educational methods that stress active learning; communication, team work, group problem-solving skills; cater to different learning styles and foster more effective learning for engineering education. The issues related to ICT and its impact on education are discussed in section 2.3.

2.2.2 Mechanical Engineering and Mechanics Dynamics

Mechanical engineering is defined as the discipline that applies the principles of engineering, physics, and materials science for the design, analysis, manufacturing, and maintenance of mechanical systems (The American Heritage Dictionaries, 2011). Mechanical engineering is a diverse subject that derives its breath from the need to design and manufacture everything from small individual parts and devices (e.g., micro scale sensors and inkjet printer nozzles) to large systems (e.g., spacecraft and machine tools) (Hone, 2012). It is one of the oldest and popular engineering disciplines. According to The Accreditation Board for Engineering and Technology (ABET), "*the program must demonstrate that graduates have the ability to: apply* *principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations) to model, analyze, design, and realize physical systems, components or processes; and work professionally in both thermal and mechanical systems areas.*"(ABET, 2013).

Generally, mechanics dynamics is offered as one of the important subject to the first year or second year mechanical engineering students. In the respective course, students discover mechanisms and are often asked to solve problems related to modeling, analysis and design of system in motion (Kojmane & Aboutajeddine, 2016). In the literature, syllabi of the course of dynamics of different universities around the world describe the competencies that students are expected to acquire are summarized in Table 2.3.

Table 2.3 Competencies that students are expected to acquire

By completing the Dynamics course, students should be able to:
To understand the purpose of dynamics in relation to engineering.
To understand the basic physical concepts of dynamics.
To create a free body model of a rigid dynamical system.
To perform a kinematic and kinetic analysis of a rigid body particle or system.
To analyse fundamental rigid body dynamics problem using concepts of work, energy, impulse and momentum.
To apply Newton's Laws to particles and rigid bodies to solve problems related to dynamic behaviour.
To use properly the theory and equations and practice them in practical applications.
To know the appropriate use of modern computational tools related to mechanical dynamics.
To understand basic dynamics as used in the design process.

In traditional teaching methods, students learn within a classroom with the help of lectures, notes or by using textbooks. Educational research reveals that such type of a passive environment is not effective and results in limited knowledge retention by students (Tembe & Kamble, 2016). In the traditional (instructor-centered) engineering teaching, where the instructor introduces each topic by lecturing the general principle followed by derivation of mathematical models and illustrative applications of the models, may lead to the students difficulties in understanding the concepts and principles (Haque, Nayna, & Ahmed, 2016). In addition, many students think that dynamics is a collection of problem-specific tricks instead of a unified body of knowledge built upon a very limited number of basic equations and principles (Barroso, Morgan, & Simpson, 2008). It can be observed that many of the students would treat each course as an individual entity that has minimal connections to each other. Without seeing the relevance of the material, they tend to forget the materials instantly after the final exam. This poses a challenge for knowledge transfer to other courses later in their degree program. As such, following basic pedagogies issues have been identified as underlying the difficulties most students have (Barroso et al., 2008): 1) forgetting, misconceptions and misapplication of prior knowledge leading to difficulties with knowledge transfer between courses; 2) difficulties developing models and connecting the response of those models to real system behavior; 3) critical thinking about complex problems and systems, both in how to break down a problem and identify appropriate simplifying assumptions, as well as how to evaluate their problem solution and system behavior. According to Kojmane & Aboutajeddine (2016), the dynamics course is critical for students where they can be exposed to engineering real-world problems, and can sense the real meaning of engineering and design. The example given by Kojmane & Aboutajeddine (2016), "*for instance, in the automotive and aeronautical industry, employers become more and more requiring as regards the quality of the hired engineers, and there's an augmenting demand for engineers who master the design tools of systems in motion, and who are capable to solve problems related to the development of products.*"

Therefore, to deal with the work environment of today's engineers, it is necessary to adapt the engineering education curriculum, in order to produce engineering graduates well prepared for their role as competent engineers and well equipped with the critical in-demand job skills (Nasr, 2014). Engineering teachers are often encouraged to incorporate new instructional strategies such as active learning methods that motivate their students to be more actively engaged with the subject course materials (Tembe & Kamble, 2016). As described by Bonwell (1991), in active learning, students participate in their own learning through: a) taking responsibility in the learning process and b) involving in activities beyond just listening – such as reading, writing, discussing and solving problems. Active learning is found/believed to improve the students' overall learning in engineering education. Through the research findings by Prince (2004), active learning consists of students being engaged in learning through participating in knowledge construction process (cognitive process), resulting in a deeper knowledge. According to Prince (2004), strong evidence is available to support the use of active learning for improvement in recall of information. There are many techniques / activities that can involve the engineering students in active learning. Active learning techniques include in-class group work, concept mapping, use of multimedia in course materials, project based learning, problem-based learning, think-pair-share strategy and "clicker" questions using student response systems (Aglan & Ali, 1996). Technology can be used to promote active learning and meaningful learning and it provides interactivity between students and knowledge content (Shapiro, 1998) (Tembe & Kamble, 2016) (M. Wang, Shen, Novak, & Pan, 2009).

2.3 ICT and its Role in Education

The interest of using new technologies among the researchers to improve the teaching and learning in education is increasing rapidly (Martin et al., 2011). The Information and Communication Technology (ICT) which includes the major digital technologies (software, hardware and networking technologies) can be considered as one of the great potential tools to facilitate the educational change and enhance the learning process (Dhandabani & Sukumaran, 2014; Jonassen, 1999; Smeets, 2005;

Tinio, 2003). In fact, the impact of ICT in education can be identified through various educational levels from pre-school, primary education, secondary education to tertiary education. In tertiary education, as argued by Kirkwood (2009), ICT was usually adopted to support the formal teaching and learning process through the following ways as shown in Table 2.4.

Table 2.4 ICT and Its Functions in Support for the Formal Teaching and Learning (Adopted from Kirkwood, 2009).

Function	Descriptions
presentation	Making materials and resources (text, data, sounds, still and moving images, etc.) available for students to refer to, either at predetermined times or 'on demand'.
interaction	Enabling learners to actively engage with resources, to manipulate or interrogate information or data, and so on.
dialogue	Facilitating communication between teachers and learners or between peers for discussion, cooperation, collaboration, and so on.
generative activity	Enabling learners to record, create, assemble, store and retrieve items (text, data, images, etc.) in response to learning activities or assignments and to evidence their experiences and capabilities.

Using ICT to foster better learning environments build on the foundation of educational models to facilitate the teaching and learning process. The popular educational models used in tertiary education are summarized as shown in Table 2.5. ICT greatly facilitates the implementation of all types of educational learning theories and delivery models that support and encourage innovative teaching and learning modalities both for theoretical courses and lab courses (Dhandabani & Sukumaran, 2014). Meanwhile, there is a great potential for utilization of ICT in education as students in tertiary education today are known as 'digital natives'; those who grew up with technology all around them (cell phones, laptops, and tables) (Morsi & Mull, 2015).

Table 2.5 Educational Models used in Teaching and Learning (Adopted from Dhandabani & Sukumaran, 2014)

Educational Practices	Purpose
Curriculum development Theories and Principles (Connelly & Xu, 2012)	Utilized in creating course curriculum and syllabi.
Instructional System Design (Kelting-Gibson, 2013)	Utilized in creating the overall course learning plan that comprises of course rationale, objectives, schedule, assessments, evaluation and feedback.
ADDIE Model (Welty, 2007)	Utilized in designing teaching materials, student leaning worksheets, assessment materials, learning evaluation materials, feedback materials.
Bloom Taxonomy (Bloom, 1969)	Utilized in designing a micro plan of a session and objectives of the session.
Cone of Learning Model (Dale, 1969)	Utilized in designing self-learning activities for learning simulation.
Kirkpatrick’s Model (Kirkpatrick & Craig, 1976)	Utilized for training evaluation.
Assessment Model (Kay & Knaack, 2008)	Utilized for learning assessment.
Feedback Model (Pendleton, 1984)	Utilized for collection of online feedback.
Robert Gagne’s Model (Gagne, 1985)	Utilized for blended learning in classroom/laboratory teaching.
Epistemological Rationale (Tsai, Chai, Wong, Hong, & Tan, 2013)	Utilized to examine educational assessments
Training and Educational Psychology (Ross, Morrison, & Lowther, 2010), (Lindsay, 2007)	Utilized in providing guidance and counseling.

ICT has been used to foster better learning environments since 1970s (Deniz & Cakir, 2006; Sakamotao et al., 1979). According to Reiser (2001), there were three stages of the evolution for educational technology and can be identified between 1900 till 2000s. The stages refer to the visual instruction movement (1900 -1920s), the audiovisual movement (1920s - 1970) and the computer instruction movement (1970s onwards). Technology evolved throughout the evolution (see Figure 2.1).

Reiser provided detailed descriptions of the evolution of educational technology and further derived a conclusion from the history that the media technologies had minimal impact on instructional practices. However, he predicted positively that over the next decade, the ICT will contribute to greater changes in instructional practices than any previous media technology.

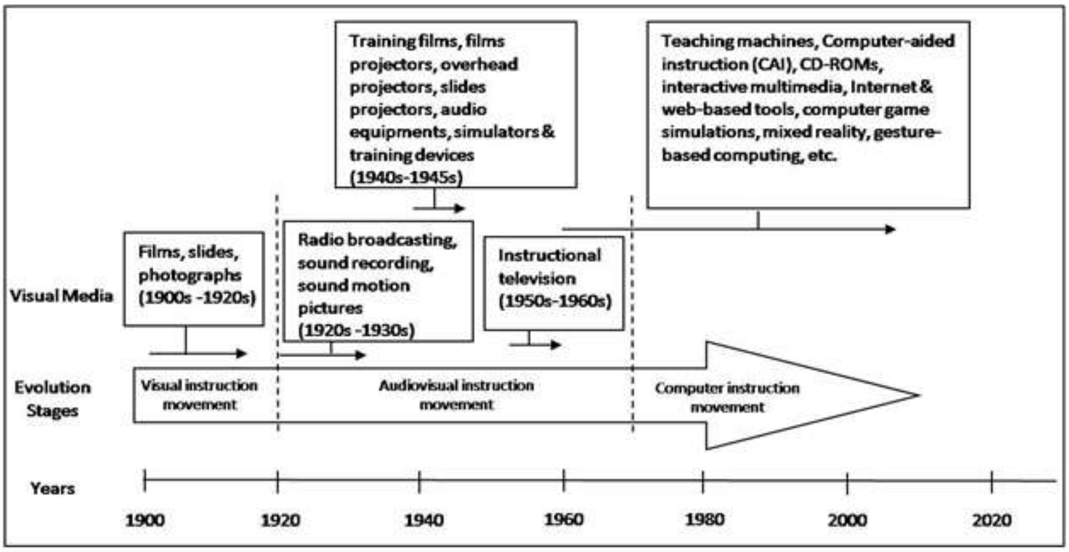

Figure 2.1. The evolution of educational technology (1900s – 2000s).

When the significant computer revolution started, the influence of the computer was best seen in its multimedia configuration which included an integration of multiple media elements such as text, graphics, animation, audio and video into a coherent learning environment; which in turn transformed student learning and problem solving approach (Entwistle et al., 1992; Janson, 1992). The benefits of utilizing the multimedia technologies to support and assist in learning can be easily identified in the literature. For example, Kulik and Kulik (1991) argued that computer assisted learning (CAL) including multimedia is an effective form of instruction because it produces high student outcomes of achievement in short periods of time. Furthermore, research studies on multimedia learning found that multimedia foster cognitive change (Mautone & Mayer, 2001); deepens perception of ideas and of concepts (Achikalin & Dur 2005); improved performance in problem solving (Zheng et al., 2006); and facilitate information processing in learning (Mayer & Moreno, 2003; Rieber & Kini, 1991). In addition, the engagement for the learners in their learning process can be improved through the aid of multimedia in learning. This is because the use of multimedia elements in an integrated way involved a wider range of stimuli, verbal and visual, thereby increasing the state of engagement (Teoh & Neo, 2006; Zheng et al., 2008).

In today's knowledge society and innovation-led economy, higher order thinking skills are important as a response to the quick and uncertain change in the market environment. Examples of higher order thinking skills are critical system thinking, decision making, and problem solving (Miri et al., 2007). In fact, the higher order thinking skills correspond to the higher scale of Bloom's taxonomy which includes the analysis, synthesis and/or evaluation stages (Kek & Huijser, 2011; Miri et al., 2007; Zohar, 2004). It is important to develop the higher order thinking skills in students especially during the tertiary education stage. As known, the ultimate goal of higher education is to promote a deep approach to learning (higher levels of learning) (Biggs, 2003). As a continuous effort in improving education, many education practitioners actively propose a variety of learning approaches that may contribute to develop higher order thinking skills. In this situation, educational technologies used for cognitive support in learning may contribute to enhance the students' higher-order thinking skills (Kirschner & ErKens, 2006; McMahon, 2009; Ringstaff & Kelley, 2002). However, the warnings of cognitive overload as discussed by Clark and Mayer (2011) and gratification needs of the learners (Blumler & Katz, 1974) should be carefully considered.

Another significant achievement for the use of ICT to enhance teaching and learning is the formation of student-centered learning environments. As described by Hannafin and Land (1997), student-centered learning environments emphasize on "*constructing personal meaning by relating new knowledge to existing conceptions and understandings; technology promotes access to resources and tools that facilitate construction*" (p.170). From a constructivist perspective learners need to be encouraged to take responsibility for their learning, with learners having a sense of ownership of learning experiences (Squires, 1999). In a student-centered learning environment, the students will have higher learner control throughout the learning process. The term learner control has been defined and used to represent choice in learning in various contexts, such as learning content, method of delivery, order and way of learning, time and pace of learning as well as the level of learning instructions or activities (Stemler, 1997). Such conditions can be implemented with the aid of multimedia technology to create a suitable learning environment that focuses on student-centered. This is fundamental because multimedia supports the characteristics by which the delivery of information (through multiple media / format), the organization in which it is delivered and the timing of that delivery can be controlled by the user (Cairnscross & Mannion, 1999; Manjit, 2006). In addition, the non-linear fashion offered by the multimedia provides flexibility in navigation (Cairnscross & Mannion, 1999; Manjit, 2006). As such, the learners may have the opportunity to choose on the learning contents that suit to their learning levels accordingly. Within the learning contents, the hypertext and hypermedia functionalities provide the flexibility for the learners to further explore the information that are connected and related to each other for further explanations and reference.

Another important attribute of multimedia is the interactivity capability. Borsook and Higginbotham-Wheat (1991), believed that the computer's interactive potential makes it unique in the history of educational/instructional technology and sets it apart from all other instructional devices. As stated by Manjit et al. (2004), interaction refers to the reciprocal action of two phenomena and has both a physical connotation (one entity operating on another) and a psychological connotation (two entities influencing each other's behaviour). By having interactivity, the learning environment generated by computer will respond instantly and accordingly based on the learners' response. The key attributes model of multimedia (Manjit et al., 2004) is shown in Figure 2.2. As such, multimedia provides the opportunity to fulfill the aforementioned conditions that it can support for flexible control and aid in facilitating the student-centered learning environments. By allowing flexibility in control, greater individualization in learning at different paces can be achieved (Teoh & Neo, 2006). This will lead to a greater opportunity for the student to learn at his or her full potential (Tway, 1995) and nurture "deep learning" (Kabouridis, 2010). Deep learning is associated with the higher scale of Bloom's taxonomy which includes the analysis, synthesis and evaluation.

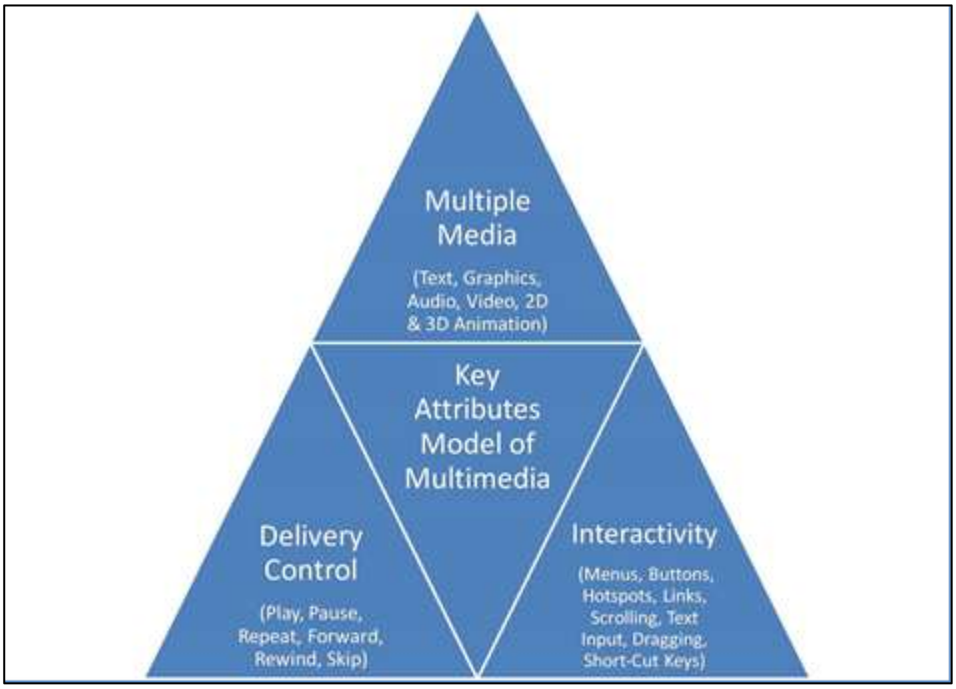

Figure 2.2 Key attributes model of multimedia (Adopted from Manjit, 2004).

2.4 Computer-Aided Learning (CAL) for Engineering Education

Computer-aided learning (CAL) is defined as the means of attaining knowledge via computer-based technologies, leading to a lasting change in behavior (Huczynski & Johnston, 2005). CAL environments increasingly are using a combination of interactive multimedia and virtual reality (VR) features in delivering the learning contents (Manjit, 2006). The research studies on CAL started a few decades ago. Although the research results vary, the tendency is towards the positive side of support for students learning (Deniz & Cakir, 2006). Within engineering education, there are many computer-based learning packages which have been developed for higher learning institutions and also used commercially in western countries (Manjit, 2006). However Manjit (2006), argued that these computer-based learning packages may not be suitable for the use of local students as the dialect used may hinder / delay students from understanding its contents, does not use a step-by-step approach in problem solving and lacks delivery control. Some detailed descriptions of the various computer-based learning packages that were developed to support engineering education can be found in the literature (Aziz, 2011; Bailey et al., 1995; Gao et al., 2011; Gupta, 2002; Hmelo et al., 1995; Hsieh et al., 2005; John & Abdollah, 1998; Lynn et al., 1997; Mackenzie et al., 2001; Marcico, 2001; Noronha et al., 2000; Norrie, 1996; Ranga & Gramoll, 1999; Scott, 1996).

In general, the computer-aided learning packages for engineering education can be broadly divided into six main categories which are simulations, intelligent tutors, remote laboratories, interactive instructional packages, mixed realities and multi-approaches packages. Each type of the computer-aided learning packages serves different learning purposes (see Table 2.6). Interestingly, it is quite common to identify the redundancy in the purposes and roles played by each type of the CAL packages as illustrated in Table 2.6.

Table 2.6 Types of CAL and Its Purposes

Types of CAL	Purposes
Simulations	To aid in the design and visualization of engineering models in 2-D/3-D dynamics form.
	Allow the students to perform active interaction to manipulate the engineering models.
Intelligent Tutors	To guide, aid and assist the students in understanding and applying of basic engineering concepts through artificial intelligent mechanism.
	To act as the drill and practice platform for engineering students in engineering problem solving.
Remote Laboratories	To partially replace live experimentation and reduce the cost of expensive equipment (Froyd et al., 2012)
Interactive Instructional Packages	Act as the supplementary individualize learning applications for the students to learn/ revise the engineering modules through the presentation of multimedia elements (text, graphics, audio, video and animation). Usually will include the lecture, tutorial, exercises and demonstration activities in a courseware.
Mixed Reality	To create a new learning environment to support engineering visualization by integrating the virtual models into the real scenes with the support of mixed-reality technologies.
Multi-Approaches	To create a virtual learning environment for engineering education by including multiple representation approaches (simulations, intelligent tutors, coach based, cooperative learning and etc.) into an integrated learning

	platform.

2.4.1 Factors influencing the success of CAL in Engineering Education

The computer aided learning that used to support engineering education will not achieve its goal if technology components are considered as the sole factor involved in the CAL development. In fact, Norman (1993) claimed that technologies are rather neutral in its role and neither is inherently good or bad. It is the learning environments created that will facilitate and support the learning process. Figure 2.3 depicts the proposed factors that contribute to the creation of CAL environments for engineering education. A suitable computer aided learning environment that may facilitate the learning process should not simply just replicate efforts of the traditional learning environment with the ICT overlaid on it. Rather, it should be a completely redesign of the whole learning environment that involves at least the consideration from the instructional design perspective and the technical design perspective (Ko & Rossen, 2005). According to Renes and Strange (2011), an effective instructional design depends on two basic requirements which include the pedagogical knowledge and the content knowledge. The importance of pedagogical factors that play a significant role in determining the successful implementation of CAL was critically discussed in the literature (Ahern et al., 2006; Albion & Gibson, 2000; Clark, 1994; Ferdig, 2006; Park & Hannafin, 1993; Tamim et al., 2011; Zheng et al., 2008). In the context of educational psychology, there are three popular categories of learning theories, namely, behaviorism, cognitivism and constructivism. Each of these categories has its own significant characteristics that may impact on the instructional design of the learning tools that should be taken into serious consideration when designing and developing the CAL packages. Descriptions of these learning theories can be found in the literature (Atkins, 1993; Bransford et al., 2006; Fosnot, 1996).

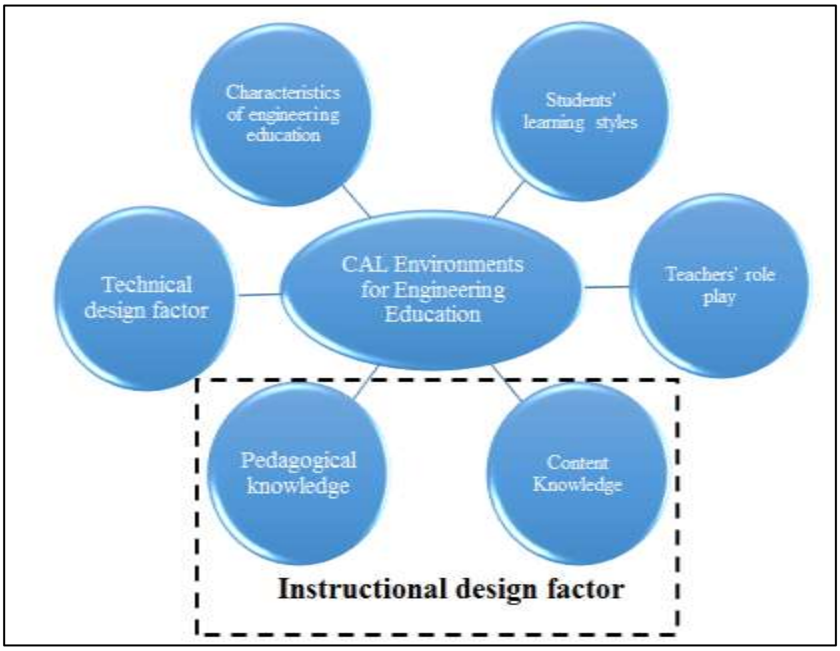

Figure 2.3 Factors contribute to the creation of CAL environments for engineering education.

From the technical design perspective, the user interface designs of the learning tools is a significant factor that should be taken into serious consideration when designing the CAL packages. User interface is defined as the part of computer system with which a user interacts in order to undertake his or her tasks and achieve his or her goal (Stone et al., 2005). This includes the study of screen layouts design and the display menu design (Renes & Strange, 2011). When the learners performed the study with the aid of ICT, the interfaces will act as the bridge between the computer systems and the learners. As emphasized by Liang and Sedig (2010), "*even though a tool might be pedagogically sound, but if it is not properly designed, it might not achieve the intended learning goals*" (p.989). As claimed by Schar et al. (2000), the current research on CAL is too focused on the issue related to learning content representation while neglect on the impact of user-interface in the process of learning. Proper design of the user interface for the CAL packages is important since the students (learners) will directly interact with the interface while performing the learning procedures through the use of CAL packages.

In order to have a proper computer aided learning environment, the students learning styles should not be neglected. As known, learning styles are defined as the characteristic cognitive, affective, and psychological behaviours that serve as relatively stable indicators of how learner perceives, interacts with, and responds to the learning environment (Keefe, 1991). In the process of teaching and learning, we should be aware that different students are comfortable with different learning styles (Felder & Brent, 2005). In the literature, there are four widely accepted learning style models in engineering education context (Manjit, 2006; Ogot & Okudan, 2006), which are the Myers-Briggs Type Indicator (MBTI), Kolb's Learning Style Model, Felder-Silverman Model and Honey and Mumford Learning Styles Evaluation. All these learning style instruments can be used to measure and identify the learners' preferences. A better understanding of the students learning styles may help the educator to design for better learning strategies in the CAL learning environments that may cater for different students' preferences in learning.

As commonly known, in the traditional learning environment, the teachers (instructors) play a central and significant role in the teaching and learning process. In fact, there is still insufficient definition regarding the role played by the teacher in the computer aided learning environments (Urhahne et al., 2010). As claimed by Lai (1993), the role of the teacher is to act as the knowledge facilitator instead of the knowledge presenter in a computer-supported learning environment. This claim seems to be consistent with the research findings by Zhu (2010) which found that teachers of facilitator/expert profile and facilitator/delegator profile are more inclined to adopt educational technology. In addition, Urhahne et al. (2010) further proposed a 5E model (envision the lesson, enable collaboration, encourage students, ensure learning, evaluate achievement) that illustrates the roles played by a teacher which cross the whole instructional process from lessons preparation till the assessment of achievement. However, Urhahne et al. claimed that this model still needs further investigation on its effectiveness to improve students' achievements. In the engineering education context, with the paradigm shift in engineering education, the emphasis will be more on active learning that involves critical thinking and problem solving approach. With the shift towards computer-supported learning environment, the emerging new roles of the engineering teachers are unavoidable and need the attention urgently from the engineering educators. Intensive empirical research is urged to ensure clearer and solid definitions on the new roles played by teachers in engineering education domain and its effectiveness in integrating with the computer-supported learning environment.

2.4.2 Implementation of CAL Applications in Engineering Education

In engineering education, numerous studies have been carried out to implement Computer-Aided Learning (CAL) packages that incorporate multimedia and associated technologies in the educational context. A list of such multimedia CAL packages reported in the literatures is presented in Table 2.7.

Table 2.7 Multimedia CAL packages developed for engineering education (Adapted from Manjit, 2006)

CAL Packages	Educational Objectives	References
Multimedia Tutorials Package (MTP)	To replace traditional lecture part of a course in engineering materials with studio exercises that could help students visualize 3-D evolving processes that cannot be presented effectively using static illustrations.	McMahon (2000)
Multimedia Based Environment (MBE)	To provide adequate MBE tutorials on engineering mechanics to motivate students in learning.	Noronha et al. (2000).
Interactive Multimedia Intelligent Tutoring System (IMITS)	To permit individual tutoring of students, i.e. allow students to solve assignments in any manner the student chooses and is able to determine the student's ability to apply and understand basic concepts of engineering.	Brain (2000)
Amoco Computer Simulation (ACS)	To innovate teaching of engineering design by developing problem solving skills.	Mackenzie et al. (2001)
Computer Graphics Simulation (CGS)	To provide multimedia dynamic solid models for visualization.	Wilson (2001)
Multimedia Mechanics of Materials Laboratory	To familiarize students with testing equipment, data acquisition, testing procedures and reporting results.	Salvatore (2001)
Interactive Virtual Tutor (IVT)	To guide and provide helpful hints to student in an intelligent and interactive manner in solving problems in engineering mechanics statics	Gupta (2002)

Intelligent Practice Environment (IPE)	To allow the user to explore complex relationships through discovery and problem solving activities in a 3-D environment.	Janet (2002)
Interactive Tutoring Components (ITC)	To help students understand the engineering mechanics dynamics subject with the development of multiple interactive tutoring components	Shang et al. (2005)
An Interactive Multimedia E-Learning System (IMELS)	To provide students with a comprehensive problem-based learning environment for the discipline of industrial engineering.	Lau et al. (2006)
Augmented Reality and Web 3D in Engineering Education	To allow students to interact with 3D web content using virtual and augmented reality. Learners of this interface can view multimedia content, to support a lecturers traditional delivery, either locally or over the Internet and in a table-top augmented reality environment.	Liarokapis et al. (2007)
Technology Assisted Problem Solving (TAPS) Packages	The TAPS packages aimed at coaching students in learning particularly slow learners (students who have difficulties in understanding the concepts in Engineering mechanics dynamics subject), on the best approach to solve a particular engineering problem in step-by-step or logical approach.	Manjit (2006)
Visualization Tool (Dynamics Learning)	Visualization tool was developed to assist the students in learning Dynamics.	(Gu & Tan, 2009)
Interactive animation software	This interactive animation software for an introductory Thermodynamics course has been developed, which is intended to be part of the WileyPLUS platform (John Wiley and Sons, Inc.). It is unique because each animation is directly linked to a homework problem and no programming is required of the user. The animations are web-based (hard-coded in Adobe® Flash Action Script), so no external computer programs are needed.	(Stanley & DiGiuseppe, 2009)
Mobile Learning Application in Augmented Reality Environment	A mobile learning application that uses modified Reciprocal Teaching method provided as a learning aid tool for assisting student in visualizing the concept.	(Salam, 2011)
Simulation software	In this work, the researchers intended to test whether computer simulation activities can help students overcome difficulties in mechanics thought the used of teaching software (Dynamic mechanics).	(Hassouny, Kaddari, Elachqar, & Alami, 2013)
Simulation based Virtual Laboratories	Two simulation based virtual laboratories were developed to look into the empirical foundation of classical dynamics for physics learning.	(Ré & Giubergia, 2013)

Interactive Dynamics Learning Course (IDLC) web based simulations	Simulations of different mechanisms studied in the IDLC will be made available to the students on the course web site to supplement the interactive dynamics course in the classroom	(Mehendale & Irwin, 2015)
Visualization tool using Sim2Bil	This research study utilized the visualization tool Sim2Bil, which combines a simulation of two cars, velocity graphs, and an input for velocity functions to facilitate mathematics education in engineering studies.	(Hogstad, Isabwe, &Vos, 2016)
Interactive Computer Simulation and Animation (CSA) module	A new interactive CSA module was developed to improve student learning of particle kinetics in an undergraduate engineering dynamics course. The unique feature of this CSA module is that it integrates computer visualization with mathematical modeling, so students can directly connect engineering dynamics phenomena to underlying mathematics.	(Fang & Guo, 2016)

2.4.3 Technology Assisted Problem Solving Packages (TAPS)

TAPS packages are specialized computer programs developed to work as stand-alone (PC Based) or with Web servers that can supplement student learning; for revision, laboratory experiments, and self-study founded by Manjit (2006). Although many computer-based learning environments have emerged in general as discussed in section 2.3, 2.4.1 and 2.4.2, the term technology assisted problem solving (TAPS) environment would be used to refer to the packages that aimed at coaching students in learning particularly slow learners (students who have difficulties in understanding the concepts in Engineering mechanics dynamics subject), on the best approach to solve a particular engineering problem in a step-by-step or logical approach (Manjit, 2008). Although a TAPS package may be considered as a form of CAL, more specifically, TAPS packages were designed to allow independent problem solving, develop logical thinking, and promote learning of the subject matter. The research study on TAPS packages found that students benefited and appreciated the most from such a TAPS package and they also found that the course becomes more interesting, enjoyable, easy and understandable when compared to the traditional method of classroom learning (Manjit, 2006). The reasons for employing TAPS packages can be summarized as follows (Manjit, 2008):

1) to use and store the knowledge of experienced instructions (human) and make the same easily accessible to the students;
2) to develop a suitable user interface for simplifying the difficult engineering concepts
3) to help slow learners acquire problem solving skills
4) to provide encouragement to students in independent learning by incorporating simple intelligent (expert system like rules) in the TAPS packages; and
5) as an attempt to improvise the limitations of the already existing computer based learning packages thereby making them more acceptable as effective learning aids in UNITEN.

As described by Manjit (2006), the TAPS packages employed a variety of multimedia elements such as text, 2-D animated and still graphics, 3-D animated and still geometric models, audio, video and animations, stereoscopic images, desktop virtual reality (DVR) and simple artificial intelligent techniques to develop individualized computer based learning environment. The extended key attributes model of multimedia and DVR can be referred to Figure 2.4.

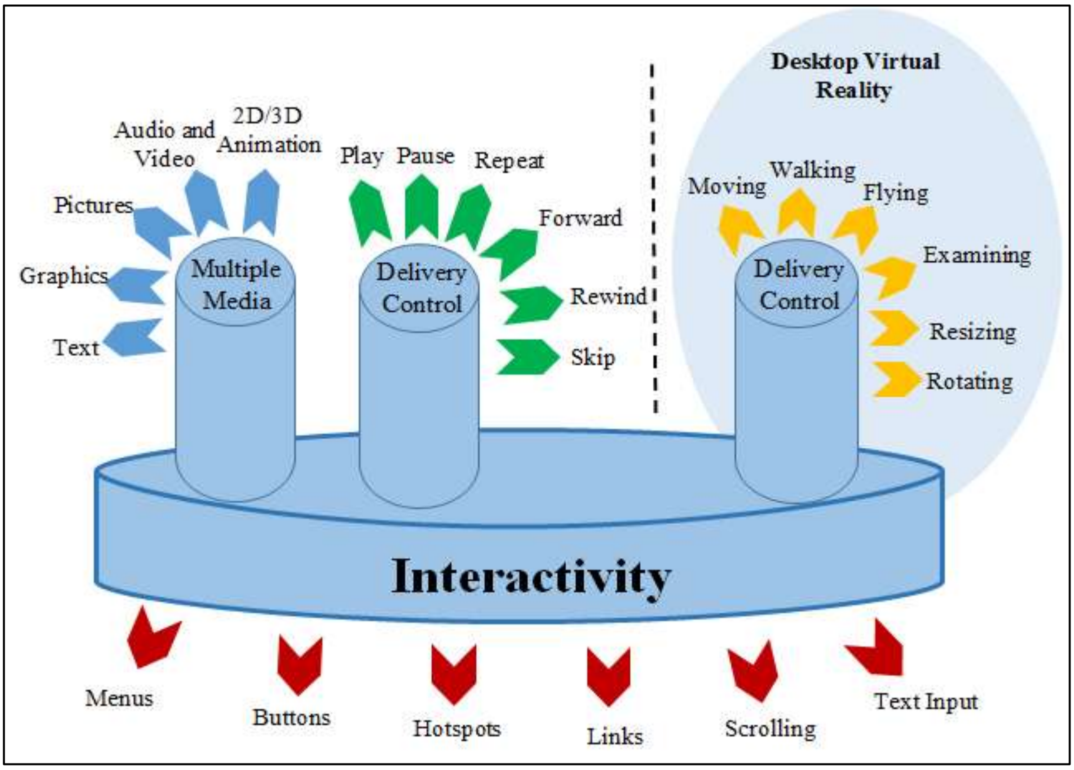

Figure 2.4 Extended key attributes model of multimedia and DVR (Adopted from Manjit, 2006).

The extended attributes as stated in the Figure 2.4 are important because without it, the package cannot be fully adaptive to the individual student's on-going learning and problem solving needs during instruction. Four design approaches were designed and tested by Manjit (2006) (see Figure 2.5) in developing the TAPS packages namely 2-D graphics and animation (design approach 1), coach-based environment (design approach 2), 3-D virtual environment (design approach 3), and desktop virtual reality (design approach 4). These TAPS packages can be classified as cognitive tools for learning, problem solving, testing, and simulation. The summary of key features and differences of each of these four TAPS package is provided in Table 2.8 (Manjit, 2006) which act as the main reference for the development of the enhanced multimedia TAPS package (see Chapter 6) specifically on the usability design and the interaction patterns proposed.

Table 2.8 Summary of key features and differences of each TAPS package (Adopted from Manjit, 2006)

Key Features	2-D TAPS Package	Coach Based TAPS Package	3-D TAPS Package	3-D Desktop Virtual Reality TAPS package
Objective	• To examine various levels of interaction for a tutorial and problem-solving topic on Structural Analysis.	• To provide an environment that could help the student solve Engineering Mechanics problems without the help of a human instructor.	• To incorporate interactivity multimedia to study curvilinear motion of cylindrical components in a 3-D virtual environment.	• To study curvilinear motion of cylindrical components where the user could interact in a desktop virtual reality (DVR) environment for greater interaction and visualization.
Design approach	• Employed 2-D graphics/ images, colors, and tweening technique to produce animations.	• Employed 2-D graphics/images, colors, sound, and tweening technique to produce animations. • Provide user with more dynamic and interactive support. • Provide user support tools such as calculator and notepad.	• Employed 2-D graphics/images, 3-D geometric model, colors, sound, and tweening technique to produce animations. • Provide user with more dynamic and interactive support in a 3-D virtual environment. • Provide user support tools such as calculator and notepad. • Allow user to plot curvilinear path of a moving object in a 3-D virtual environment.	• Employed 2-D graphics/images, 3-D geometric model, colors, sound, and tweening technique to produce animations. • Provide user with more dynamic and interactive support in a 3-D virtual environment. • Provide user support tools such as calculator and notepad. • Allow user to plot curvilinear path of a moving object in a 3-D virtual environment and real time interaction. • Provides animated and static stereoscopic images.
Learning/ Problem solving approach	• Provides learning objectives to user. • A sequence of steps and solution of the problem are presented to the student. The student moves forward	• Provides learning objectives to user. • A sequence of steps and solution of the problem are presented to the student. The student moves forward	• Provides learning objectives to user. • A sequence of steps and solution of the problem are presented to the student. The student moves forward	• Provides learning objectives to user. • A sequence of steps and solution of the problem are presented to the student. The student moves forward to the next step or back to the previous step or solution.

	to the next step or back to the previous step or solution.	to the next step or back to the previous step or solution. • Allows user to select a formula from a list provided and validates if the correct formula has been applied to solve a problem. • Allows user to make mistakes. • Employed simple expert system rules to coach user.	to the next step or back to the previous step or solution. • Allows text, numeric and special characters as input data.	• Allows text, numeric and special characters as input data. • Employed simple expert system rules to coach user.
Association	• The user needs to be able to associate the virtual environment of 2-D elements and hid/her interactions with related information such as images, textual resources, and the other data with the problem solving process performed by the user.	• The user needs to be able to associate the virtual environment of 2-D elements and hid/her interactions with related information such as images, textual resources, and the other data with the problem solving process performed by the user.	• The user needs to be able to associate the virtual environment of 3-D geometric elements and hid/her interactions with related information such as images, textual resources, and the other data with the problem solving process performed by the user.	The user needs to be able to associate the virtual environment of 3-D geometric elements and hid/her interactions with related information such as images, textual resources, and the other data with the problem solving process performed by the user.
Coaching	• Coaching is provided to enhance the user's problem solving experience while performing complex tasks in 2-D environment.	• Coaching is provided to enhance the user's problem solving experience while performing complex tasks in 2-D environment. • The built-in expert system rules manage the user's activities in the 2-D problem solving environment and provides dynamic coaching advice and feedback based on the	• Coaching is provided to enhance the user's problem solving experience while performing complex tasks in 3-D environment.	• Coaching is provided to enhance the user's problem solving experience while performing complex tasks in 3-D environment. • The built-in expert system rules manage the user's activities in the 3-D problem solving environment and provides dynamic coaching advice and feedback based on the user's activities in a 3-D coach based environment.

		user's activities in a 2-D coach based environment.		
Feedback and Assessment	• For a positive experience, the user is given feedback and assessment to understand his/her progress.	• For a positive experience, the user is given feedback and assessment to understand his/her progress • Allow text, numeric and special characters as input data. • User' progress i.e. scores is stored in database. • The problem solving environment provides timely feedback and assessment directly related to the user's interactions. The feedback helps increase the user's ability to reason and analyze the problem solving environment.	• For a positive experience, the user is given feedback and assessment to understand his/her progress	• For a positive experience, the user is given feedback and assessment to understand his/her progress • Allow text, numeric and special characters as input data. • Multiple choice questions and answers are randomized. • The problem solving environment provides timely feedback and assessment directly related to the user's interactions. The feedback helps increase the user's ability to reason and analyze the problem solving environment.
Text/Contents	• Minimum text of theory is used in order to make use of multimedia elements.	• Minimum text of theory is used in order to make use of multimedia elements.	• Minimum text of theory is used in order to make use of multimedia elements.	• Minimum text of theory is used in order to make use of multimedia elements.
Interactivity	• The student interacts and observes meaningful tasks i.e. such as movement of the support and rotation of structure.	• The student interacts and observes meaningful tasks i.e. such as movement of the support and rotation of structure. • Provides the user with more dynamic and interactive support than what has been provided in existing computer aided learning packages such as	• The student interacts and observes meaningful tasks i.e. such as curvilinear motion of cylindrical components in a 3-D virtual environment. • A simple algorithm that allows student to plot path / path in a 3-D virtual environment.	• The student interacts and observes meaningful tasks i.e. such as movement of the support and rotation of structure. • A simple algorithm that allows student to plot path in a 3-D virtual environment.

		motion, and feedback response in the event when student makes mistake. • Uses reasoning support (simple expert system rules are used) and explanations of complicated concepts while the user is trying to solve the problem presented in the package. Thus this approach can help students make decisions and complete tasks better and also provide explanation for reasoning, enabling continual performance and improvement.		
General Outcomes and Benefits	• The use of tweening technique was found to be helpful where animations were used to illustrate motions such as movement of the support and rotation of structure. • The use of 2-D animated graphics and colors helped students understand better in solving the problem presented in the TAPS package. • Benefits noted from this package include interactive multimedia provide comprehensive coverage	• The TAPS package help students to manage the sequence of steps the student should perform to solve the problem and control the 2-D animated mechanisms leading from problem statement till the solution. • It is generally accepted that this TAPS package can help students process better cognitive-perceptions which can result in fast and better understanding of the problem. • Benefits noted from this	• Helped students to understand and visualized the problem on curvilinear motion which, was otherwise difficult to explain to students. • Dynamic models present challenges to students beyond what they have learnt in the traditional way, this is in agreement as stated by Liang (2002). • Benefits noted from this package include interactive multimedia provide comprehensive coverage combining full-motion,	• Allow student to experiment simulated problem-solving problem in 3-D environment and manage a complex task in real time. • Stereoscopic images and animated video files gives a better 3-D view of the robotic arm and path as it is not the same as static image as shown in the textbooks. The stereoscopic images help students enhance depth perception that could reduce learning time as compared to the conventional. • It is generally accepted that the stereoscopic images could create great interest and enthusiasm for students in understanding the

	combining full motion, audio, video and 2-D animated graphics. • Interactive multimedia provides the student as integrated learning environment, which combines explanations with illustrative examples, this is in agreement as stated by Cairncross (2002).	package include interactive multimedia provide comprehensive coverage combining full-motion, audio, video and 2-D animated graphics.	audio, video, 2-D and 3-D animated graphics. • More emphasis is given to the visualization of 3-D objects because 3-D could enhance the process of leaning, increase the level of understanding enabling students to understand more effectively through interactivity. This environment can provide a rewarding learning experience that would be otherwise difficult to obtain (Liarokapis et al. 2007)	problem presented in the TAPS package, particularly, students experiencing difficulties in understanding the Engineering Mechanics Dynamics subject. • Multimedia and virtual reality techniques with simulation initiates a new appearance for learning applications –real time presentations of 3-D data, this is in agreement as stated by Klett (2002). • With simulations, students are able to take a more active role in learning, this is in agreement as stated by Jesica and Tara (2005). • Dynamic representations enable more efficient communication of complex concepts; this is in agreement as stated by Hennessy et al. (2007).

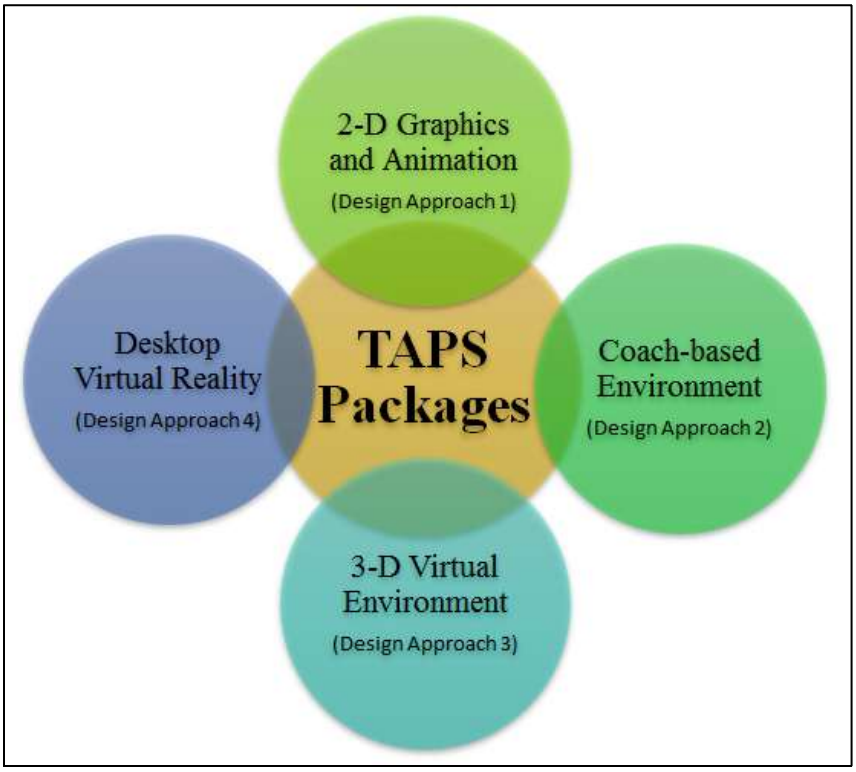

Figure 2.5 Four main design approaches used for TAPS packages

This research aimed to improve the user interface for the TAPS package (enhancement of multimedia TAPS package). Detail descriptions on the development process for the enhanced multimedia TAPS package embedded with 25 proposed patterns of interactions are discussed in details (see Chapter 6).

2.5 Learning Styles

In the era of post-capitalist knowledge society, paradigm shift in engineering education is unavoidable in response to the rapid changes in the global market environment that emphasize on the innovation efforts for competitive advantage. Many practitioners in the engineering industry look seriously into this issue and did propose for new paradigms of engineering education in response to the changes in today's increasingly knowledge driven environment. The details can be found in numerous research papers and reports (Chua, 2014; Froyd et al., 2012; Mistree et al., 2014; National Academies of Science, Engineering, and Medicine, 2007; National

Science Board, 2007; Prados, 1998; Rajala, 2012; Rosen, 2007; Wince-Smith, 2005). In order to further enhance the quality of teaching and learning in engineering education, the students' preference in learning is an important factor that should raise the attention of the education practitioners. This referred to the learning styles of the students. Learning styles are defined as "*the characteristic cognitive, affective, and psychological behaviors that serve as relatively stable indicators of how learner perceives, interacts with, and responds to the learning environment*" (Keefe, 1991, p. 4). The engineering instructors, should be aware that different students are comfortable with different learning styles (Felder & Brent, 2005). The understanding of students' preferences may contribute to the adjustment of teaching strategies and the design of learning instructions that will better accommodate for students learning needs (Cavanagh & Coffin, 1994; Chen & Chiou, 2012; Graf, 2007; Graf et al., 2007; Noguera & Wageman, 2011; Pedrosa de Jesus et al., 2004).

2.5.1 Overview of Learning Styles

The research on learning styles has been active since four decades ago (Cassidy, 2004; Pedrosa de Jesus et al., 2004). There exist various definitions for learning styles. According to Campbell et al. (2003), learning styles is defined as a certain specified pattern of behavior according to which the individual approaches learning experience. While Felder and Spurlin (2005) defined learning styles as the different ways students take in and process information. Another popular definition for learning styles refers to individuals' characteristics and preferred ways of gathering, organizing and thinking about information (Fleming, 2005). As noted by Kolb (1983), learning styles are not fixed personality traits but rather one's adaptive orientation to learning. Felder and Spurlin (2005) shared similar view with Kolb by which they stressed that "*learning style profiles suggest behavioral tendencies rather than being infallible predictors of behavior*" (p. 104). Many of the researchers did agree that individuals may tend to have a preference for one or two learning styles over others and the preferences can be affected by a student's educational experience (Felder & Spurlin, 2005; Honey & Mumford, 1992; Kolb, 1983). Therefore, learning styles are "*relatively stable but are not immutable*" (Pedrosa de Jesus et al., 2004,

p. 533). Throughout the learning process and based on different educational experience, the students may discover better way of learning and develop certain learning preferences. The learning style assessments can benefit both the instructors and students (Felder & Spurlin, 2005; Larkin-Hein & Budny, 2001). Thus, from the instructors' perspective, the identification of the students learning styles may lead to gain better understanding of learners with different learning styles. This may contribute to assist the design of teaching and learning instructions to accommodate the different learning needs of students. While from the students' perspective, better understanding of the learning styles may provide ideas on how the students might further improve on the less preferred styles and overcome the learning difficulties by developing the skills for balance approach in effective learning.

There are considerable amount of literature regarding the issue of learning styles (Cassidy, 2004; Coffield et al., 2004a; Coffield et al., 2004b; Deborah et al., 2012; Kolb et al., 2001; Riding & Rayner, 1998; Sadler-Smith, 1997; Sternberg &Grigorenko, 1997) and various instruments for learning styles measurements throughout all these years (Cornwell &Manfredo, 1994; Dunn & Dunn, 1979; Felder & Silverman, 1988; Fleming, 2005; Gregorc, 1985; Honey & Mumford, 1992; Kolb, 1983; McCaulley, 2000). As argued by Hawk and Shah (2007), although various different instruments are available for learning styles measurement, the learning styles instruments or inventories vary in length, format and complexity, and no single instrument can capture all of the richness of the phenomena of learning styles.

Recently, engineering educators have been increasingly taking the learning style theories into serious consideration for classrooms teaching and learning (for example, Cagiltay, 2008; Felder, 1996; Felder & Brent, 2005; Felder & Silverman, 1988; Holvikivi, 2007; Manjit, 2006; Miskioglu & Wood, 2013; Rosati et al., 1988). In the literature, there are four widely accepted learning style models in engineering education context, which are the Myers-Briggs Type Indicator (MBTI), Kolb's Learning Style Model, Felder-Silverman Model and Honey and Mumford Learning Styles Questionnaires (Manjit Sidhu, 2006; Ogot & Okudan, 2007). All these learning style instruments can be used to measure and identify the learners' preferences.

2.5.2 Theory of Learning Styles

2.5.2.1 Kolb's Experiential Learning Model

Kolb developed the learning style inventory (LSI) in 1976 and revised in 1985 (Tendy & Geiser, 1997). In Kolb's model, students are classified as having a preference for (a) concrete experience or abstract conceptualization (how they take information in) and (b) active experimentation or reflective observation (how they process information) (Cornwell & Manfredo, 1994; Kolb, 1983; Stice, 1987). Figure 2.6 illustrates the learning styles and learning cycle based on Kolb's model.

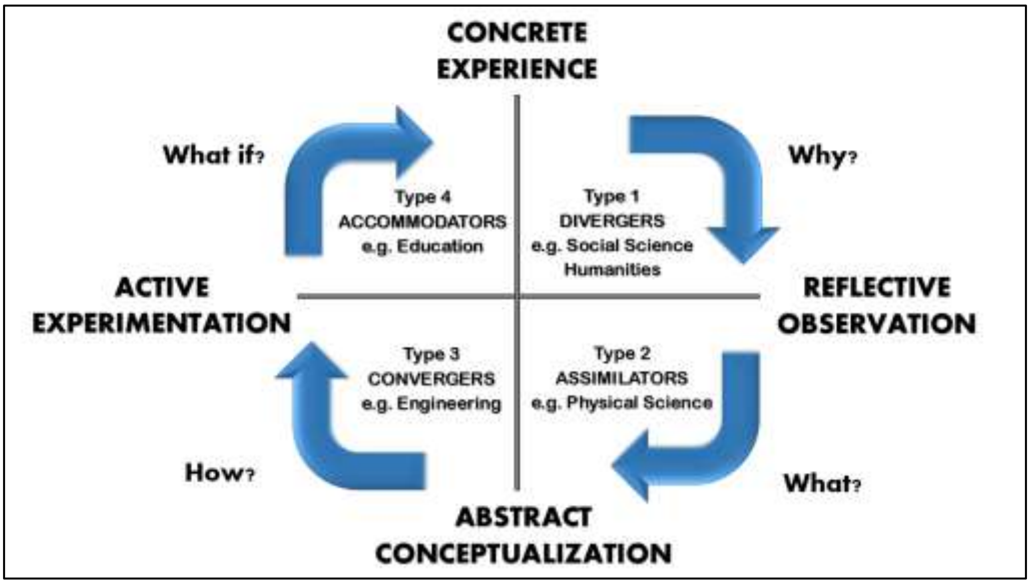

Figure 2.6 Learning styles and learning cycle based on Kolb's Model (Adopted from Montgomery & Groat, 1998)

The four types of learners in this classification (Figure 2.6) scheme are:

- Type 1 (concrete, reflective) – the **diverger**. Type 1 learners respond well to explanations of how course material relates to their experience, interests, and future careers. Their characteristic question is “Why?”
- Type 2 (abstract, reflective) – the **assimilator**. Type 2 learners respond to information presented in an organized, logical fashion and benefit if they are given time for reflection. Their characteristic question is “What?”
- Type 3 (abstract, active) – the **converger**. Type 3 learners respond to having opportunities to work actively on well-defined tasks and to learn by trial-and-error in an environment that allows them to fail safely. Their characteristic question is “How?”
- Type 4 (concrete, active) – the **accommodator**. Type 4 learners like applying course materials in new situation to solve real problems. Their characteristic question is “What if?”

2.5.2.2 Honey and Mumford’s Learning Styles Questionnaire (LSQ)

Honey and Mumford defined learning styles as “*a description of the attitudes and behaviours that determines an individual’s preferred way of learning*” (Honey & Mumford, 2000, p. 6). Honey and Mumford proposed a model similar to Kolb’s in which individuals have a mixture of four learning styles, normally with a preference for one or two of the styles. Honey and Mumford’s learning styles questionnaire (LSQ) and Kolb’s learning styles inventory (LSI) are both diagnostic tests to help individuals identify their strengths, weaknesses, and development needs. The four learning styles, based on Kolb’s theory of stages in the learning cycle, are: activist, reflector, theorist, and pragmatist as shown in Table 2.9. Through the use of the LSQ instrument, instructors can gain a better understanding of individual learners’ attitudes, behaviors and learning processes (Armstrong et al., 2005; Jackson, 2002).

Table 2.9 The Honey and Mumford's four learning styles (Honey & Mumford, 1986)

Learning styles	**Strengths**	**Weakness**
Activist (learn best when they are actively involve in new tasks)	Sociable, open-minded, welcome challenge, highly involved, prefers here-and-now	Bored by implementation details and the longer term, always seeks the limelight
Reflector (learn best through review and reflect)	Good listener, tolerant, sees different perspectives, postpones judgement, cautious	Takes a back seat in meetings, low profile, distant
Theorist (learn best when they can relate new information to concept & theory)	Integrates observations with theory, rationale, objective, analytical	Perfectionist, detached, impatient with subjective and intuitive thinking
Pragmatist (learn best when they see relevance of real life issues)	Experimenter, quick to adopt and try out new ideas, practical, down-to-earth	Impatient with theory, impatient with open-ended discussion

2.5.2.3 The Myers-Briggs Type Indicator

People (genera; public) are classified on the Myers-Briggs Type Indicator (MBTI) according to their preferences on four scales derived from Jung's Theory of Psychological Types (McCaulley, 2000; Pittenger, 2005).

- **Extraverts** (try things out, focus on the outer world of people) or Introverts (think things through, focus on the inner world of ideas).
- **Sensors** (practical, detailed-oriented, focus on facts and procedures) or Intuitors (imaginative, concept-oriented, focus on meanings and possibilities).
- **Thinkers** (skeptical, tend to make decisions based on logic and rules) or Feelers (appreciative, tend to make decisions based on personal and humanistic considerations).
- **Judgers** (set and follow agendas, seek closure even with incomplete data) or Perceivers (adapt to changing circumstances, postpone reaching closure to obtain more data).

As discussed by Felder and Brent (2005), most engineering instruction is oriented toward introverts (lecturing and individual assignments rather than active class involvement and cooperative learning), intuitors (emphasis on science and math fundamentals rather than engineering applications and operations), thinkers (emphasis on objective analysis rather than interpersonal considerations in decision-making), and judgers (emphasis on following the syllabus and meeting assignment deadlines rather than on exploration of ideas and creative problem solving).

2.5.2.4 Felder-Silverman Index of Learning Styles (ILS)

The Felder-Silverman Learning Style Model classifies students along four dimensions: sensing/intuitive, visual/verbal, active/reflective and sequential/global as shown in Table 2.10 (Felder, 1993; Felder & Silverman, 1988). Previous studies (mainly undergraduate students in engineering domain) that adopted the Felder-Silverman ILS are summarized as shown in Table 2.11. Through Table 2.11, the engineering students learning styles preferences from various studies can be identified and compared.

Table 2.10 The four dimensions of Felder and Silverman's learning styles

Learning Styles	**Descriptions**
Sensory/Intuitive	Sensors prefer facts, data, experimentation, sights and sounds, physical sensations are careful and patient with details, but may be slow. Intuitions prefer concepts, principles and theories, memories, thoughts, insights and may be quick but careless.
Visual/Verbal	Visual learners prefer pictures, diagrams, charts, movies, demonstrations and exhibitions. Verbal learners prefer words, discussions, explanations, written and spoken explanations, formulas and equations.
Active/Reflective	Active learners learn by doing and participating through engagement in physical activity or discussion. Reflective learners learn by thinking or pondering through introspection.
Sequential/Global	Sequential learners take things logically step by step and will be partially effective with understanding. Global learners must see the whole picture for any of it to make sense and are completely ineffective until they suddenly understand the entire subject.

Table 2.11 Reported learning preferences (adapted from Felder and Spurlin, 2005)

Sampled population	**A**	**S**	**Vs**	**Sq**	***N***	**Reference**
Iowa State, Materials Engr.	63%	67%	85%	58%	129	Constant (1997)
Michigan Tech, Env. Engr.	56%	63%	74%	53%	83	Paterson (1999)
Oxford Brookes Univ., Business	64%	70%	68%	64%	63	Vita (2001)
British students	85%	86%	52%	76%	21	
International students	52%	62%	76%	52%	42	
Ryerson Univ., Elec. Engr.						
Students (2000)	53%	66%	86%	72%	87	Zywno&Waalen (2001)
Students (2001)	60%	66%	89%	59%	119	Zywno (2002)
Students (2002)	63%	63%	89%	58%	132	Zywno (2003)
Faculty	38%	42%	94%	35%	48	
Tulane, Engr.						
Second-Year Students	62%	60%	88%	48%	245	Livesay et al. (2002)
First-Year Students	56%	46%	83%	56%	192	Dee et al. (2003)
Universities in Belo Horizonte (Brazil)						
Sciences	65%	81%	79%	67%	214	Lopez (2002)
Humanities	52%	62%	39%	62%	235	
Univ. of Limerick, Mfg. Engr.	70%	78%	91%	58%	167	Seery et al. (2003)
Univ. of Michigan, Chem. Engr.	67%	57%	69%	71%	143	Montgomery (1995)
Univ. of Puerto Rico-Mayaguez						
Biology (Semester 1)	65%	77%	74%	83%	39	Buxeda& Moore (1999)
Biology (Semester 2)	51%	69%	66%	85%	37	Buxeda& Moore (1999)
Biology (Semester 3)	56%	78%	77%	74%	32	Buxeda& Moore (1999)
Elect. & Comp. Engr.	47%	61%	82%	67%	?	Buxeda et al. (2001)
Univ. of Sao Paulo, Engr.	60%	74%	79%	50%	351	Kuri&Truzzi (2002)
Civil Engr.	69%	86%	76%	54%	110	
Elec. Engr.	57%	68%	80%	51%	91	
Mech. Engr.	53%	67%	84%	45%	94	
Indust. Engr.	66%	70%	73%	50%	56	
Univ. of Technology Kingston, Jamaica	55%	60%	70%	55%	?	Smith et al. (2002)
Univ. of Western Ontario, Engr.	69%	59%	80%	67%	858	Rosati (1999)
First year engr.	66%	59%	78%	69%	499	Rosati (1996)

Fourth year engr.	72%	58%	81%	63%	359	Rosati (1996)
Engr. Faculty	51%	40%	94%	53%	53	Rosati (1996)
Brunel Univ. UK, IS & Computing	64%	70%	82%	68%	148	Baldwin &Sabry (2003)
Universidad de las Americas, Puebla	67%	82%	90%	55%	290	Palou (2006)
California Polytechnic State Univ.	56%	74%	79%	71%	86	Self &Widmann (2009)
Auckland Univ., Chemical & Materials Engr. course	34%	69%	81%	72%	29	Patterson (2011)
Utah State Univ., Mechanical & Aerospace Engr. course	42%	89%	89%	69%	61	Fang & Zhao (2013)
Beijing ForestryUniv., Civil Engr.	55%	80%	76%	55%	71	Fang & Zhao (2013)
The HK Institute of Education	56%	66%	81%	59%	32	Cheng (2014)
Texas Tech University	51%	69%	82%	65%	51	Hames & Baker (2015)
Durban University of Technology (Industrial Engineering)					200	Jackson (2015)
Level 1 Engineering Students	55%	66%	61%	57%	?	
Level 2 Engineering Students	56%	65%	62%	57%	?	
Level 3 Engineering Students	57%	65%	69%	55%	?	
United Arab Emirates University	57%	71%	83%	68%	118	Chowdhury (2015)
National Institute of Technical Teachers Training & Research, Chandigarh.						PK et al. (2016)
CS & Engineering	69%	69%	91%	75%	32	
Civil Engineering	50%	70%	87%	70%	30	
Electrical Engineering	62%	57%	95%	54%	37	
Electronic & Communication Engineering	55%	65%	90%	65%	31	
Mechanical Engineering	49%	60%	96%	67%	45	

2.5.2.5 Ogden's Personality and Learning Styles Questionnaire

Personality and Learning Styles Questionnaire is a set of instrument that measures individual's learning styles. The questionnaire has been designed by Richard Ogden in UK, a professional psychologist based on reliable and valid psychometric principles (Ogden, 2007). According to Richard, it is primarily intended for those in an academic environment, although the content will be useful for anyone interested in understanding more about learning and their own, special personality preferences.

The learning style model explores three key areas, highlighting how the student may prefer to go about learning things or approaching tasks based on (i) approach to learning (Structured or Spontaneous), (ii) focus on learning (Pragmatic or Conceptual),(iii) transfer of learning (Concrete or Fluid). The detail descriptions for the three key areas of learning preferences are listed in Table 2.12.

Table 2.12 Detail descriptions of three key areas of learning preferences

Areas	Preference style	
Approach to learning (To what extent the learners need structure and organization during learning?)	Structured	Spontaneous
	Structured learners are more likely to: • Like well-organized environments and therefore might feel uncomfortable in more ambiguous situations. • Prefer their learning to be well structured and formally planned. • Are good at following step-by-step procedures. • Be more likely to maintain focus and avoid distractions. • Prefer to stick with tried-and-tested approaches and methods. • Get uncomfortable if things are left to "loose" or they do not know what is coming up.	Spontaneous learners are more likely to: • Learn through trial-and-error • Be content with lecturers to give them "loose" and brief guidelines and they will be happy to get on with their assignments • Be happy with less structured approaches to learning. • Need lots of variety in their day and may get bored with routine. • Get stuck in; can be impatient with instructions or briefings • Enjoy spontaneity and are not worried that they don't know what is coming up next.
Focus on learning (How interested are the learners in the underlying concepts and workings?)	Pragmatic	Conceptual
	Pragmatic learners are more likely to: • Focus on practical aspects e.g. how useful, and how can they apply the learnt skills to something? • Tend to be focused on concrete, more immediate benefits of	Conceptual learners are more likely to: • Enjoy understanding how things work from a theoretical perspective • They are more likely to enjoy complex, theoretical thinking about subjects such as Psychology. • Spend time thinking about concepts

	learning. • Don't necessarily see the point of being absorbed into the theory or spending time on conceptual discussions. • Believe in keeping things neat and simple. • Make their minds up quickly, think on their feet. • Prefer hands-on practical jobs, perhaps more suited to vocational education • Be more focused with the task at hand and not likely to be side-tracked by conceptual details. • Be seen as "down-to-earth," having "common sense" and good at getting things done	and taking it to a deeper level of understanding, perhaps to appreciate wider possibilities and related subjects or information. • Appreciate the logic and rationale behind proposed procedure • Be more curious about how the world around them "works," more likely to ask "why?" or "how?" in their mind. • Carefully weigh things up and therefore on occasions may find it harder to be decisive about complex matters, less likely to take a clear stances towards matters. • Get occasionally engrossed in the things that personally interest them and may be lose sight of the practical goals or tasks at hand. • Very high scorers can seem to have their "head in the clouds" at times by more pragmatic people.
Transfer of learning (Do the learners focus on a specific problem, or transfer learning across situations?)	Concrete	Fluid
	Concrete learners are more likely to: • Take their learning literally i.e., this learnt skill is used for this specific situation. • Find it more difficult to adapt what they have learnt to other similar situations. • Prefer following clear instructions and to be offered or given solutions. • Need to concentrate on one thing at a time, working through information in a step-by-step fashion. • Have less need to review and explore what they can do with what they have learnt.	Fluid learners are more likely to: • Enjoy tackling several things at the same time • Like exploring the links or connections between things • Automatically consider widening the original application after learning "what else can I do with this knowledge?" • See if it is possible to transfer and adapt learning from one situation to other very different situation. • Boost their learning by drawing on their own previous experiences, perhaps from totally different areas. • Be more able to adapt to changing situations.

As per Ogden (2007), the student learning preference can also be represented using "Hemispheric Map" Diagram (see Figure 2.9). It is a simpler way of representing where the students preferences are, and also shows the student which side of brain the student may prefer to use when processing information. The left hemisphere preference and right hemisphere preference both shown different and contrast characteristics as stated in Table 2.13.

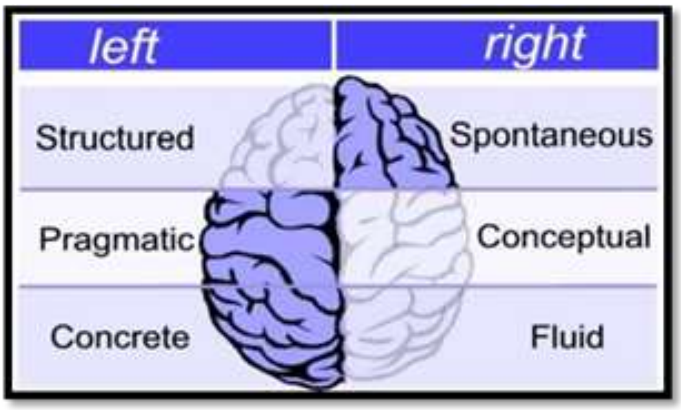

Figure 2.7 Snapshot of "Hemispheric Map" diagram indicated a particular student's learning preference and the preference side of brain when processing information

Table 2.13 Characteristics both for left hemisphere preference and right hemisphere preference

Left hemisphere preference	**Right hemisphere preference**
Likes written information, responds well to spoken instructions.	Likes to see things in action, and responds better to demonstrations (prefer demonstrations).
Solves problems in a step-by-step, logical manner.	Solves problems by using "gut feel" and hunches
Looks for differences and when things don't "fit."	Looks for patterns and links
Plans and structures.	Looks for relationships and similarities
Prefers established, more objective types of information e.g., science.	Prefers more subjective, diffuse or elusive information, e.g., art, politics.
Likes asking questions, likes things with a clear answer or predictable outcome	Happy with ambiguity, explores matters without need for a clear answer.
Less open or valuing of feelings	Responds more to feelings and open with emotions.
Splits things up - makes distinctions	Jumps in, makes things up as go along, chunks things together
Looks for cause and effect	Interested more in expression than cause and effect.

Each individual learner may be able to identify their learning preference towards using the left side or the right side of the brain based on the report generated after the questionnaire is submitted through the online form. The report would provide specific advice to help the learners to balance his/her approach in learning and to learn more effectively.

2.6 Summary

In summary this Chapter discussed the issues on engineering education and its challenges in the knowledge based society. Computer aided learning specifically in the context of engineering education and the importance of learning styles were also discussed. In this research study, the Honey and Mumford's Learning Styles Questionnaire (LSQ) and the Ogden's personality and learning styles questionnaire were identified and adopted to evaluate the engineering students learning preferences due to their good reliabilities as suggested in the literature.

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CHAPTER 3

USER INTERFACE DESIGN

3.1 Overview

In this Chapter, the user interface design and the grounded learning theories are discussed. Next, the interaction styles and the types of interactions are discussed. The usability benchmark and the usability evaluation instruments are discussed also in this Chapter.

3.2 User Interface Design

User interface is defined as the part of computer system with which a user interacts in order to undertake his or her tasks and achieve his or her goal (Stone et al., 2005). It is the bridge between the world of computer system and the world of the user. It is widely acknowledged by researchers (Norman, 2013; Shneiderman et al., 2017) that good interfaces ought to satisfy the principle of visibility: (a) users should be able to 'see' the actions that are open to them at every choice point, (b) they should receive immediate feedback about the actions they have just taken – since few things upset computer users more than not knowing what a computer is doing when it seems to be churning unexpectedly, and (c) they should get timely and insightful information about the consequences of their actions.

Unfortunately, many system developers have over emphasized on the technical functionalities of the user interface design thus neglected the usability aspects of the interface design. These efforts violate the initial purpose of the interface design that user is essential in this field (Atoum & Bong, 2015; Maguire, 2013; Manresa-Yee et al., 2010; Norman, 1999). As stated by Luostarinen et al. (2010), the user interface design is often heavily based on the technical properties of the devices thus cause the usability related issues to be forgotten or totally dismissed in the design process. This is in line with the argument by Maguire (2013) that many systems are hard to use which leads to poor user experience by causing people to abandon the system or fail to use the system effectively. Therefore, the goals for a good human-computer interaction are to decrease the errors, increase satisfaction for the user, and better performance of machine-assisted tasks (Manresa-Yee et al., 2010).

Designing a user interface with good usability is a challenging task. Fortunately, many interface design practitioners did propose the guidelines for good interface design. Shneiderman's Eight Golden Rules of Interface Design suggests the following guidelines for the practitioner as follow (Shneiderman et al., 2017):

1) Strive for consistency
2) Enable frequent users to use shortcuts
3) Offer information feedback
4) Design dialog to yield closure
5) Offer simple error handling
6) Permit easy reversal of actions
7) Support internal locus of control
8) Reduce short-term memory load

Jacob Nielsen's ten usability heuristics also serve as the basic reference for all user interface design (Nielsen, 1995) listed in Table 3.1. Nielsen stressed in his article that these ten principles are called "heuristic" because they should be treated as broad rules of thumb not specific usability guidelines. Although the Nielsen and Shneiderman's interface design guidelines can act as the generic reference for all the user interface system design, however, Gong (2009) raised the concern more specifically that additional efforts must be included to identify different types of users and their needs and skills, and to analyze different tasks and the purpose of the system while designing a user interface. This is consistent with the statement as argued by Obeidat and Salim (2010) that different users have different characteristics, such as background, education, personality, cognitive skills and preferences, thus designing a good interface would be a great challenge.

Table 3.1 Ten Usability Heuristics for Interface Design (Adopted from Nielsen, 1995)

10 Usability Heuristics for User Interface Design	
Visibility of system status	Recognition rather than recall
Match between system and the real world	Flexibility and efficiency of use
User control and freedom	Aesthetic and minimalist design
Consistency and standards	Help users recognize, diagnose, and recover from errors
Error prevention	Help and documentation

The next section will further discuss the interface design issues specifically related to the computer aided learning environments.

3.3 User Interface Design for Computer Aided Learning Environment

In the knowledge age, the requirements for effective learning have changed as compare to previous era. The five key requirements for effective learning in the knowledge age are summarized in Table 3.2.

Table 3.2 Five Key Requirements for Effective Learning (Adapted from Sawyer, 2008)

	Key Requirements	**Descriptions**
1	Support deep conceptual understanding	Expert knowledge includes facts and procedures, but acquiring these isn't enough. Facts and procedures are useful only when a person knows when and how to apply them, and how to adapt them to new contexts.
2	Focus on learning, not just teaching	Students can gain deep conceptual understanding only by actively participating in their own learning process. The learning sciences focus on students' learning processes as well as teachers' instructional techniques.
3	Create learning environments	The role of schools is to support students in becoming competent adult experts. This includes learning facts and procedures, but also gaining the deeper conceptual understanding necessary for real-world problem solving.
4	Build on learners' prior knowledge	Student learn best from experiences that build on their existing knowledge, which includes working with both accurate and flawed preconceptions.
5	Support reflection	Learners benefit from opportunities to express their developing knowledge and to analyse their current state of understanding, whether through discussion or the creation of artefacts like papers, reports or media.

Educational technologies play a major role in the learning science. As raised by Oviatt (2013), the current research focus is on how technology can be used to support the requirements as stated in Table 3.2. Similarly, the challenge on how the interface design may use to facilitate the users learning process in the computer aided learning environment is yet to empirically explore. As noted by Peters (2014):

"*Research has now proven that multimedia and interface design affects how users learn. The myth of visual design as an optional extra is in desperate need of busting. The hard fact is that how you create graphics, sequence interaction, display information, use animation, and design for social presence and emotion will impact how users learn. This is interface design. And this is where a new sub discipline is ready to step in and change the game*."

In response to the research trend that increasingly emphasized on the important role of interface design for learning, Oviatt (2013) stressed on the following key points for further exploration:

1) New educational interfaces need to be designed as cognitive tools for stimulating flexible thinking and adaptive learning rather than formatting documents and transmitting information.
2) New educational interfaces are needed that increase students' engagement in complex, multi-part, extended problems rather than supporting the simple and repetitive tasks.

Thus, the researchers did highlight the difference between the user-centered design and learner-centered design. As mentioned by Quintana et al (2006), developing new understanding is the main goal for learners. Thus, the indicator for a successful learner-centered software is that the learner's understanding will grow and change significantly while using the software. While user-centered design is often about supporting task completion by users, learner-centered design is about transforming the user (Peters, 2014).

The design and development of educational interfaces should be grounded on learning theories as the foundation. The traditional learning theories (behaviorism, cognitivism, constructivism) and the digital age learning theory (connectivism) will be further discussed in the next section.

3.4 Learning Theory for Educational Interfaces

Learning theories are conceptual frameworks describing how knowledge is absorbed, processed and retained during learning (Simandan, 2013). As stated by Ertmer & Newby (2013), learning is a complex process that has generated numerous interpretation and theories of how it is effectively accomplished. The common learning theories that are widely applicable in the context of educational technology are behaviourism, cognitivism, constructivism and connectivism. Different learning theories are grounded based on different philosophy. According to the famous quotation by Hilgard and Bower (1966), they described that:

"*While it is extremely difficult to formulate a satisfactory definition of learning so as to include all the activities and processes which we wish to include and eliminate all those which we wish to exclude the difficulty does not prove to be embarrassing because it is not a source of controversy as between theories. The controversy is over fact and interpretation, not over definition."*

Peters (2014) further add on that different perspective on learning are valuable for different reasons and within different contexts, and no single theory is ideal for every situation. This is due to the reason that learning is a complex process that normally is not performed in a linear fashion. Furthermore, each learning theory has its strengths and weaknesses, thus the selection of the theory that suits for certain learning context depends on multiple aspects of learning such as learning goals, learners and situation (Arshavskiy, 2013). The task of translating the learning theory into practical applications for the interface design is a challenging task that needs further exploration. The common learning theories would be reviewed and discussed in the next section.

3.4.1 Behaviorism

Behaviourism is a philosophy, theory and pedagogy that are underpinned by the principles of stimulus-response, without the focus on any attempt to consider internal mental processes (Peters, 2014; Winn, 1990; Woollard, 2010). Behaviorism is based on observable and measureable changes in behavior (Arshavskiy, 2013). Behaviorists claimed that only observable behavior was worth studying (to measure, predict, and manipulate patterns of behavior) empirically (Peters, 2014). The learner is characterized as being reactive to conditions in the environment as opposed to taking an active role in discovering the environment (Ertmer & Newby, 2013). The behaviorist strategies have generally been proven reliable and effective in facilitating learning that involves recalling facts, defining and illustrating concepts, applying explanations, and automatically performing a specified procedure (Ertmer & Newby, 2013). However, it is generally agreed that behavioral principles cannot adequately explain the acquisition of higher level cognitive skills such as language development, problem solving, inference generating, and critical thinking (Schunk, 2015).

In the context of computer aided learning, behaviorism has inspired many of the best known educational technologies, from early computer-assisted instruction (CAI) to present-day page-turners and drill-and-practice games (Ertmer & Newby, 2013; Peters, 2014). The specific assumptions or principles for the usage of behaviorist theory to instructional design can be referred to Table 3.3. One of the major limitation for CAI grounded on the behaviorist theory is that the learning material is often presented in small, isolated chunks of knowledge which is less to emphasize on connecting the pieces (Peters, 2014).

Table 3.3 Specific principles (behaviourism) to instructional design (Adopted from Ertmer & Newby, 2013)

Learning Theory	**Principles to instructional design (ID)**	**Possible ID applications**
Behaviourism	An emphasis on producing observable and measurable outcomes in students	behavioural objectives, task analysis, criterion-referenced assessment
	Pre-assessment of students to determine where instruction should begin	learner analysis
	Emphasis on mastering early steps before progressing to more complex levels of performance	sequencing of instructional presentation, mastery learning
	Use of reinforcement to impact performance	tangible rewards, informative feedback
	Use of cues, shaping and practice to ensure a strong stimulus-response association	simple to complex sequencing of practice, use of prompts

3.4.2 Cognitivism

Cognitivism as a learning theory can be traced back to the early twentieth century when psychologists and educators began to emphasize more on the complex cognitive processes such as thinking, problem solving, decision making, language, concept formation and information processing (Ertmer & Newby, 2013; Peters, 2014; Yilmaz, 2011). From the learning perspective, Cognitive theories focus on the conceptualization of students' learning processes and address the issues of how information is received, organized, stored, and retrieved by the mind (Arshavskiy, 2013; Ertmer & Newby, 2013). Cognitivists assert that we learn better when we can connect new information to things we already know (Peters, 2014). Thus, learning is concerned not so much with what learners do but with what they know and how they come to acquire it (Jonassen, 1991). The learner is viewed as a very active participant in the learning process that involved cognitive activities (Arshavskiy, 2013).

Cognitivism has inspired the educational technology especially for the design and development of the intelligent tutoring system (ITS). Intelligent tutoring system is defined as a computer system that aims to provide immediate and customized instruction or feedback to the learners (Almurshidi & Naser, 2017). ITS adapts to an individual student's performance automatically by drawing on the knowledge incorporated into its database instead of just the predetermined questions, answers, and predefined pathways that made up behaviorist's CAI technologies (Peters, 2014). The specific assumptions or principles for the usage of cognitivist theory to instructional design can be referred to Table 3.4.

Table 3.4 Specific principles (cognitivism) to instructional design (Adopted from Ertmer & Newby, 2013)

Learning Theory	Principles to instructional design (ID)	Possible ID applications
Cognitivism	Emphasis on the active involvement of the learner in the learning process	learner control, metacognitive training (e.g., self-planning, monitoring, and revising techniques)
	Use of hierarchical analyses to identify and illustrate prerequisite relationships	cognitive task analysis procedures
	Emphasis on structuring, organizing, and sequencing information to facilitate optimal processing	use of cognitive strategies such as outlining, summaries, synthesizers, advance organizers, etc.
	Creation of learning environments that allow and encourage students to make connections with previously learned material	recall of prerequisite skill; use of relevant examples, analogies

3.4.2.1 Cognitive Load Theory and Multimedia Learning

Cognitive load theory was proposed by John Sweller in the late 1980s (Sweller, 1988). The basic idea for cognitive load theory is that the cognitive capacity in working memory is limited and thus learning tasks should be designed in a way to avoid cognitive overload (Jong, 2010). Extensive research studies have been conducted grounded on cognitive load theory to facilitate learning process by optimizing the working memory capacity (Peters, 2014). Based on the cognitive load theory and findings from cognitive science, Mayer and his team developed the cognitive theory of multimedia learning which specifically deals with the multimedia design issues for education (Clark & Mayer, 2011). The cognitive theory of multimedia learning is based on three assumptions as follows:

1) We process visual and auditory information through separate channels (dual channel processing)
2) We are limited in the amount of information we take into either channel at once.
3) When we are engaged in active learning, we are not passively receiving information. Instead, we a) pay attention, b) organize incoming information (picking and choosing what's important), and c) integrate incoming information with other knowledge. We do all this in order to build a mental model of the key parts and relationships of the information we are presented with.

Based on the three assumptions, Mayer and his research team proposed the guideline for multimedia design principles supported by strong empirical research findings. According to Peters (2014), Mayer's research in the past fifteen years has led to the development of a number of research-based multimedia learning design principles, many of which pertain specifically to interface design. The Mayer's principles of multimedia learning can be referred to Table 3.5.

Table 3.5 Mayer's Principles of Multimedia Learning

Mayer's Principles of Multimedia Learning	
Multimedia principle	Segmenting principle
Contiguity principle	Pre-training principle
Modality principle	Signaling principle
Coherence principle	Voice principle
Personalization principle	Image principle
Redundancy principle	Individual differences principle

3.4.3 Constructivism

Constructivism is a general learning theory, by which it emphasizes that people actively construct their own understanding of the world through interactive experiences. (Oviatt, 2013; Peters, 2014). As opposed to behaviorist and cognitivist, constructivist argue that knowledge is a function of how the individual creates meaning from his or her own experiences (Ertmer & Newby, 2013). Learning is not viewed as the acquisition and accumulation of a finite set of skills and facts (Tam, 2009). As further elaborated by Peters (2014):

"*Knowledge, rather than being an objective matchup with reality, is an individual's interpretation and construction based on a unique collection of past experiences, prior knowledge, and ways of interpreting things.*"

Constructivism has multiple roots in the philosophical and psychological viewpoints of this century, specifically in the works of Piaget, Bruner, and Goodman (Perkins, 1991). Constructivism has received increased attention in a number of different disciplines, including instructional design (Bednar et al., 1991; Ertmer & Newby, 2013; Ractham et al., 2012; Schrader, 2015). In the educational technology context, constructivist technology might provide tools for group discussion and knowledge building like wikis, collaborative media-making tools, discussion forums or chat rooms. (Peters, 2014). In addition, the web based 3-D worlds that let learners engage in virtual fieldwork experiences, explore virtual environments, making hypotheses, collect various types of data, and propose solutions draw on constructivist learning theory as well. (Peters, 2014). However, Tam (2009) raised the concern that computer-supported constructivist environments should not only limit to involve the knowledge and intelligence to guide and structure the learning process, but rather should create situations and offer tools that stimulate students to maximize the use of their cognitive potential. The specific assumptions or principles for the usage of constructivist theory to instructional design can be refer to Table 3.6.

Table 3.6 Specific principles (constructivism) to instructional design (Adopted from Ertmer & Newby, 2013)

Learning Theory	Principles to instructional design (ID)	Possible ID applications
Constructivism	An emphasis on the identification of the context in which the skills will be learned and subsequently applied	anchoring learning in meaningful contexts
	An emphasis on learner control and the capability of the learner to manipulate information	actively using what is learned
	The need for information to be presented in a variety of different way	revisiting content at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives
	Supporting the use of problem solving skills that allow leaners to go "beyond the information given"	developing pattern-recognition skills, presenting alternative ways of representing problems
	Assessment focused on transfer of knowledge and skills	presenting new problems and situations that differ from the conditions of the initial instruction

3.4.4 Connectivism

Connectivism is a relatively new learning theory as compared to behaviorism, cognitivism and constructivism. It is a learning theory promoted by Stephen Downes and George Siemens in the mid of 2000s that takes into account the needs and realities of the knowledge age. (Peters, 2014). In connectivism, the starting point for learning occurs when knowledge is actuated through the process of a learner connecting to and feeding information into a learning community (Goldie, 2016; Kop & Hill, 2008). As defined by Siemens (2005), "*A community is the clustering of similar areas of interest that allows for interaction, sharing, dialoguing, and thinking together*." Siemens (2006) further argued that a new learning theory, in fact, is required, due to the exponential growth and complexity of information available on the Internet, new possibilities for people to communicate on global networks, and for the ability to aggregate different information streams. In general, connectivism's principles are shifting focus from content itself to the connections of content (AlDahdouh, 2017). Similarly, our ability to connect to new knowledge is more important than how much we actually already know (Peters, 2014).

Duke, Harper, & Johnston (2013) further summarized that connectivism could be a learning theory based on the following three reasons:

1) Connectivism is characterized as the enhancement of how a student learns with the knowledge and perception gained through the addition of a personal network. It is only through these personal networks that the learner can acquire the viewpoint and diversity of opinion to learn to make critical decisions through collaboration.
2) The sheer amount of data available makes it impossible for a learner to know all that is needed to critically examine a specific situation. Being able to tap into huge databases of knowledge in an instant empowers a learner to seek further knowledge.
3) Explaining learning by means of traditional learning theories is severely limited by the rapid change brought about by technology. Connectivism is defined as actionable knowledge, where an understanding of where to find knowledge may be more important than answering how or what that knowledge encompasses.

In contrast, some of the researchers argued on the validity of connectivism as a learning theory (Duke et al., 2013; Kerr, 2006; Weber & Vas, 2016). As described by Duke et al (2013), connectivism is a pedagogical view rather than a learning theory since the learning theories should address the issue of how to enable the learner at the instructional level not just remain at the curriculum level (focus on what is learned and why). This is consistent with the argument by Kerr (2006) that connectivism is claimed to be part of the existing learning theories, where various technologies only affect methods of instruction in numerous ways.

While the debate on connectivism theory will continue for many years, connectivism has become an important school of thought applicable to the use of technology to support for classroom learning such as the online learning with the combination of 3D interactive graphics, artificial neural networks and web technologies. (AlDahdouh, 2017; Kop & Hill, 2008; Peters, 2014).

3.5 Interaction Styles

Interaction styles are the different ways that a user can communicate with a computer system and vice versa. As defined by Stone et al, (2005), "*an interaction style is a collection of user interface controls and their associated behavior. The interaction style provides both the look (appearance) and feel (behavior) of the user interface components indicating the way a user will communicate with the system*." There are several interaction styles from which a designer may choose and the details are listed in Table 3.7.

Table 3.7 Descriptions, advantages and disadvantages of the five primary interaction styles (Adopted from Stone et al., 2005)

Interaction Style	Descriptions	Advantages	Disadvantages
Command Line	The command line interface was the first interactive dialog style to be commonly used. It provides a means of directly instructing the system, using function keys on a keyboard, single characters, abbreviations, or whole-word commands.	▪ Is versatile and flexible ▪ Appeals to expert users ▪ Supports users' initiative by allowing them to define macros and shortcuts	▪ Requires substantial training and memorization of commands
Menu Selection	A menu is a set of options from which the user must choose. Typically, the interface displays the options as menu items or icons and the user indicates a choice with a pointing device or keystroke, receiving feedback that	▪ Is easy to learn ▪ Involves fewer keystrokes than command line ▪ Structures decision making by breaking down the functionality into a set of menu items	▪ Presents the danger of creating too many menus and complex menu hierarchies ▪ May slow frequent users who would

	indicates which option he or she has chosen, and the outcome of the command being executed.	▪ Is good for learners and infrequent users	prefer to use commands or shortcuts ▪ Consumes screen space
Form-fill	Form-fill interfaces allow for easy movement around the form and for some fields to be left blank. The users work through the form, entering appropriate values.	▪ Simplifies data entry ▪ May require modest training ▪ Assists users by providing defaults	▪ Consumes screen space
Direct Manipulation	Direct manipulation (DM) interfaces allow user to interact directly with the user interface objects. In DM interfaces, the keyboard entry of commands or menu choices is replaced by manipulating a visible set of objects and actions.	▪ Presents the task concepts visually – the user can see the task objects and act on them directly ▪ Is easy to learn ▪ Is easy to remember how to use ▪ Avoids errors and allows easy recovery from errors if they occur ▪ Encourage exploration	▪ Requires graphic displays and continuous input devices ▪ Presents the danger that icons and metaphors may have different meanings for different user groups.
Anthropomorphic interfaces	Anthropomorphic interface aim to interact with users in the same way that humans interact with each other. Natural language interfaces and interfaces that recognize gestures, facial expressions, or eye movements all belong to this category.	▪ Can relieve the burden of learning the syntax for the interaction with the system.	▪ Can be unpredictable ▪ Difficult to implement

3.6 Types of Interactions

There are three types of interactions that shape the learning process (Moore 2012; More 1989): learner-content interaction, learner-instructor interaction, and learner-learner interaction.

1) **Learner-content interaction** - The first type of interaction is interaction between the learner and the content or subject of study. This is a defining characteristic of education. Without it there cannot be education, since it is the process of intellectually interacting with content that results in changes in the learner's understanding, the learner's perspective, or the cognitive structures of the learner's mind.
2) **Learner-instructor interaction** - The second type of interaction is regarded as essential by many educators, and as highly desirable by many learners is the interaction between the learner and the expert who prepared the subject material, or some other expert acting as instructor.
3) **Learner-learner interaction** - It is the third form of interaction, a new dimension of distance education that will be a challenge to our thinking and practice. This is inter-learner interaction, between one learner and other learners, alone or in group settings, with or without the real-time presence of an instructor.

The three types of interactions as proposed by Moore (1989) were further discussed by Evan and Sabry (2003) by which each of these types of interaction may make use of the computer technology and the related works are summarized in Table 3.8.

Table 3.8 Interaction Types & Technology Involved (Adopted from Evan & Sabry, 2003)

<table>
<tr><th>No.</th><th colspan="2">Interaction Types (Learning Perspective)</th><th>The computer technology involved</th></tr>
<tr><td>1</td><td colspan="2">Student-student interaction</td><td rowspan="2">Electronic discussions boards, text chat rooms, video conferencing or electronic white-boarding.</td></tr>
<tr><td>2</td><td colspan="2">Teacher-student interaction</td></tr>
<tr><td rowspan="2">3</td><td colspan="2">Student-content interaction</td><td rowspan="2">Computer-based learning packages such as multimedia CD-ROMs and the Web.</td></tr>
<tr><td>Student-initiated interaction</td><td>Computer-initiated interaction (Schar & Krueger, 2000)</td></tr>
</table>

In Table 3.8, the student-content interaction can be further categorized into student-initiated interaction and computer-initiated interaction (Schar & Krueger, 2000). From the computer-initiated interaction perspective, Evans and Sabry (2003) proposed and formulated an interaction model called “The Three-Way Model of Interactivity (3-WMI)”.

This model consists of three sequential actions (as refer to Figure 3.1):

1) Computer initiation: the computer presents a task or a series of options to the learner, in the form of a question or button (e.g., click here to begin);
2) Learner response: the learner selects an action in response to the options presented by the computer in the initiation stage;
3) Computer feedback: the computer presents the learner a new screen containing an assessment of the learner’s response.

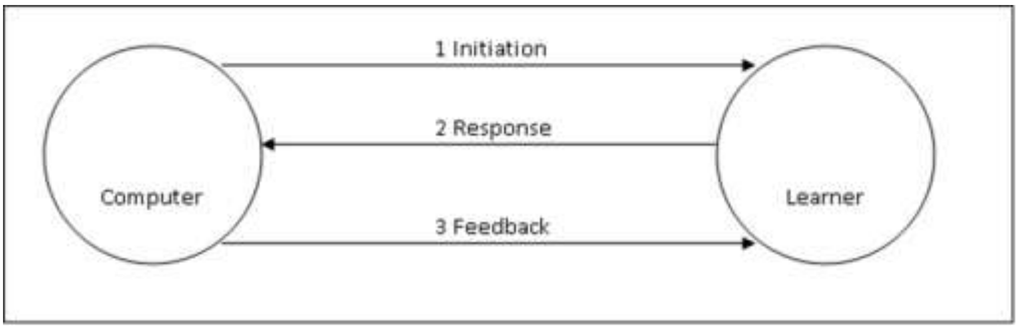

Figure 3.1: The three-way model applied to computer-initiated interactivity (Evan & Sabry, 2003).

In addition, the three actions of the three-way model may form part of an iterative interactivity cycle. In such a cycle, computer feedback simultaneously initiates another interaction as illustrated in Figure 3.2. The only requirement for computer-initiated activity cycle is that they must begin with computer initiation and ultimately terminate with computer feedback.

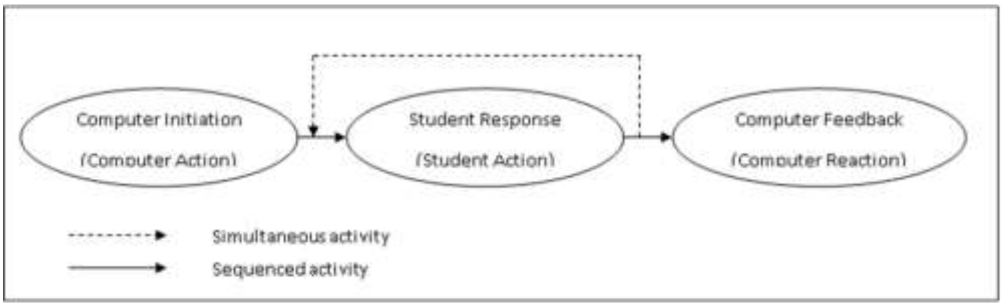

Figure 3.2 Illustration of the interactivity cycle (Evan & Sabry, 2003).

Sometimes, the variety of forms of interaction often creates confusion over the meaning of the use of the word interactivity. In order to clarify what Evans and Gibbons (2007) meant by the term interactive system, they adopted the 3-way interaction model as formulated by Evan and Sabry (2003). Hillman et al. (1994) added a fourth component on learner-interface interaction to the literature discussion. They defined learner-interface interaction as "*a process of manipulating tools to accomplish a tas*k". They stressed the importance of learner-interface interaction because the learner must interact with the technological medium in order to interact with the content, instructor, or other learners.

A good interface design that may facilitate the learning will follow certain usability benchmark as the design consideration and reference. The usability benchmark and standards proposed for interface designs will be discussed in the next section.

3.7 Usability Benchmark and Standards

Standards are impartial best practices or definitions that act at as a national, multinational or international level (Brooks, 2015). As defined in the Oxford dictionary, "*standard is a level of quality or attainment or something used as a measure, norm, or model in comparative evaluations*" (Oxford, 2017). According to Bevan (2006), Human Computer Interaction (HCI) standards have been developed over the last 20 years. International standards for HCI are developed under the auspices of the International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC). Standards related to usability can be categorized as primarily concerned with (Bevan, 2006):

1) The use of the product (effectiveness, efficiency and satisfaction in a particular context of use).
2) The user interface and interaction.
3) The process used to develop the product.
4) The capability of an organisation to apply user centred design.

The international standards related to HCI context are listed in Table 3.9.

Table 3.9 International Standards related to HCI context (adapted from Bevan, 2006)

Section	Principles and recommendations
1) Context and test methods	ISO/IEC 9126-1: Software Engineering – Product quality – Quality model
	ISO/ IEC TR 9126-4: Software Engineering – Product quality – Quality in use metrics
	ISO 9241-11: Guidance on Usability
	ISO/IEC DTR 19764 Guidelines methodology, and reference criteria for cultural and linguistic adaptability in information technology products
2) Software interface and interaction	ISO/IEC TR 9126-2: Software Engineering – Product quality – External metrics
	ISO/IEC TR 9126-3: Software Engineering – Product quality – Internal metrics
	ISO 9241: Ergonomic requirements for office work with visual display terminals. Part 10-17

	ISO 14915: Software ergonomics for multimedia user interfaces
	ISO TS 16071: Software accessibility
	ISO TR 19765 Survey of existing icons and symbols for elderly and disabled persons
	ISO TR 19766 Design requirements for icons and symbols for elderly and disabled persons
	ISO CD 23974: Software ergonomics for World Wide Web user interfaces
	IEC TR 61997: Guidelines for the user interfaces in multimedia equipment for general purpose use
3) Hardware interface	ISO 11064: Ergonomic design of control centres
	ISO/IEC TR15440 Future keyboards and other associated input devices and related entry methods
4) Development process	ISO 13407: Human-centred design processes for interactive systems
	ISO TR 16982: Usability methods supporting human centred design
5) Usability capability	ISO TR 18529: Human-centred lifecycle process descriptions
	ISO PAS 18152: A specification for the process assessment of human-system issues
6) Other related standards	ISO 9241-1: General Introduction
	ISO 9241-2: Guidance on task requirements
	ISO 10075-1: Ergonomic principles related to mental workload – General terms and definitions

3.7.1 ISO 9241-11 Standard: Guidance on Usability (1998)

ISO 9241-11 standard provides the guidance on usability design by which it refers to the extent to which a product is usable. As defined in ISO 9241-11 standard, "*usability refer to the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" (ISO, 1998). ISO documentation further provides the definitions regarding what is mean by effectiveness, efficiency and satisfaction as shown in Table 3.10.

Table 3.10 Usability Factors and its Descriptions according to ISO 9241-11 (ISO, 1998).

Usability factors	Descriptions
Effectiveness	The accuracy and completeness with which users achieve specified goals.
Efficiency	The resources expended in relation to the accuracy and completeness with which users achieve goals.
Satisfaction	The comfort and acceptability of use.

As also described by Bevan et al. (2015), effectiveness means success in achieving goals, efficiency means not wasting time and satisfaction means willingness to use the system.

3.7.2 ISO 9241-210: Human-Centred Design for Interactive Systems (2010)

The ISO 9241-210 standard provides a framework for human-centred design (HCD) activities comprising the four stages: context of use, specification of user and organizational requirements, design solutions, and evaluation of design against requirements (ISO, 2010). These activities are carried out in an iterative fashion with the cycle being repeated until the design objectives have been attained (Maguire, 2013). According to Bevan (2014), ISO 9241-210 uses the phrase “human-centred” rather than “user-centred” to acknowledge the importance of stakeholders who may not be users. As further claimed by Bevan (2014), ISO 9241-210 standard provides one of the best concise introductions to usability for designers’ reference. There are many supportive reasons for adopting the human centred design principle as shown in Table 3.11.

Table 3.11 Rationale for adopting human centered design principle (adapted from Bevan, 2014)

Rationale for adopting principle of human centred design	
1	The design is based upon an explicit understanding of users, tasks and environments
2	Users are involved throughout design and development
3	The design is driven and refined by user-centred evaluation
4	The process is iterative
5	The design addresses the whole user experience
6	The design team includes multi-disciplinary skills and perspectives

3.7.3 Justification on the Standards Reference

Throughout this research study especially on the design and development of the enhanced multimedia TAPS package, the ISO 9241-11 and ISO 9241-210 standards were adopted as reference guidelines for the usability designs. This was due to the following reasons:

1) The best practices stated in the standards can be a guideline for the usability design since the standards were contributed from the industry experts with the accumulation of vast experience (all these years). As raised by Brooke (2015), it is possible to instantly leverage the experience of industry experts and adopt the best practices if any designer is familiar with the standards.

2) By following the international standard as a guideline can provide authoritative evidence to cite regarding the user interface design decision. This is parallel with the statement that the standards have been highly successful in providing an internationally accepted basis for understanding and applying usability based on human centred design (Bevan et al., 2015; Maguire, 2013).

However, it should be noted that the ISO 9241-11 and ISO 9241-210 contents provide valuable direction as a reference rather than tell the designer on how to design (Brooke, 2015).

3.8 Usability Testing and its Instruments

Usability is one of the important quality attributes to measure how usable and effective / useful is the software system (Masood et al., 2014). According to Nielsen (2012), usability is one of the quality attribute that assesses how easy user interfaces are to use. Nielsen further add on that there are five quality components used to define usability which are learnability, efficiency, memorability, errors and satisfaction. Concept of usability has been widely applied to improve the quality of software systems, human computer interaction, software process improvement, and software process descriptions (Masood et al., 2014). In the context of software engineering, many researchers have contributed the quality models to measure and assure the software quality through various quality factors such as usability, learnability and efficiency (Kabir et al., 2016). Among all these factors, usability is the major quality factor due to its impact on software acceptance (Kabir et al., 2016). The various quality model for software with usability factors can be referred to Table 3.12.

Table 3.12 Quality Model for Software with Usability Factors (Adopted from Kabir et al., 2016)

	Published Year	Quality Model Name	Usability Factors	Source
1	1977	McCall	Operability, Training, Communicativeness	(McCall et al., 1977)
2	1978	Boehm	Reliability, Efficiency, Human Engineering	(Boehm, 1978)
3	1991	Shackel	Effectiveness, Learnability, Flexibility, Attitude	(Shackel, 1991)
4	1992	FURPS	Human Factors, Aesthetics, Consistency, Documentation, Responsiveness	(Grady, 1992)
5	1993	Nielsen	Learnability, Efficiency, Memorability, Errors, Satisfaction	(Nielsen, 1993)
6	1998	SUMI	Efficiency, Affect, Helpfulness, Control, Learnability	Kirakowski & Corbett (1993)
7	1998	ISO 9242-11	Effectiveness, Efficiency, Satisfaction	(ISO, 1998)
8	2001	ISO 9126	Understandability, Learnability, Operability, Attractiveness, Usability Compliance	(ISO, 2001)
9	2006	QUIM	Productivity, Efficiency, Effectiveness, Safety, Learnability, Accessibility Satisfaction, Truthfulness, Universality, Usefulness	(Padda, 2009)
10	2014	SEM	Understandability, Learnability, Applicability, Effectiveness / Usefulness for Future Projects, User Satisfaction.	(Masood et al., 2014)

In the next section, the standardize usability instruments will be discussed including the specific usability questionnaires that were used in this research study.

3.8.1 Standardized Usability Questionnaires

A standardized questionnaire is a questionnaire designed for repeated use, typically with a specific set of questions presented in a specified order using a specified format, with specific rules for producing metrics based on the answers of respondents (Sauro & Lewis, 2012). As part of the development of standardized questionnaires, it is customary for the developer to report measurements of its reliability, validity and sensitivity, in other words, for the questionnaire to have undergone psychometric qualification (Nunnally, 1978). The standardized usability questionnaires can be further defined as the standardized questionnaires designed to assess participants' satisfaction with the perceived usability of products or systems during or immediately after usability testing (Sauro & Lewis, 2012; Garcia, 2013). Standardized measures offer many advantages to practitioners as summarized and shown in Table 3.13.

Table 3.13 Advantages of Standardized Usability Questionnaires (adopted from Nunnally, 1978)

Advantages	Descriptions
Objectivity	A standardized measurement supports objectivity because it allows usability practitioners to independently verify the measurement statements of other practitioners.
Replicability	It is easier to replicate the studies of others, or even one's own studies, when using standardized methods.
Quantification	Standardized measurements allow practitioners to report results in finer detail than they could using only personal judgement. In addition, standardization also permits practitioners to use powerful methods of mathematics and statistics to better understand their results.
Economy	Developing standardized measures requires a substantial amount of work. However, once developed, they are very economical to reuse.
Communication	It is easier for practitioners to communicate effectively when standardized measures are available. Inadequate efficiency and fidelity of communication in any field impedes progress.
Scientific generalization	Scientific generalization is at the heart of scientific work. Standardization is essential for accessing the generalization of results.

The common and widely used standardize usability questionnaires and its source are summarized as shown in Table 3.14. Some of the standardized usability questionnaires required the licensing fees for using the instruments for usability testing such as Questionnaire for User Interaction Satisfaction (QUIS) and Software Usability Measurement Inventory (SUMI). In contrast, some of the standardized usability questionnaires are available for free such as the Post-Study System Usability Questionnaire (PSSUQ) and Software Usability Scale (SUS).

Table 3.14 Common and widely used Standardized Usability Questionnaires

	Specific Standardized Usability Questionnaire	Source
1	Questionnaire for User Interaction Satisfaction (QUIS)	(Chin et al., 1988)
2	Software Usability Measurement Inventory (SUMI)	(Kirakowski & Corbett, 1993; McSweeney, 1992)
3	Post-Study System Usability Questionnaire (PSSUQ)	(Lewis 1990a, 1992, 1995, 2002)
4	Software Usability Scale (SUS)	(Brooke, 1996)
5	After-Scenario Questionnaire (ASQ)	(Lewis, 1990b, 1991, 1995)
6	Expectation ratings (ER)	(Albert & Dixon, 2003)
7	Usability Magnitude Estimation (UME)	(McGee, 2003, 2004)
8	Single Ease Question (SEQ)	(Sauro, 2010b; Tedesco & Tullis, 2006)
9	Subjective Mental Effort Question (SMEQ)	(Sauro and Dumas, 2009)

3.8.1.1 System Usability Scale (SUS)

SUS usability evaluation instrument was developed by John Brooke in 1986 (Brooke, 1996). It is a 10 questions long survey instrument, each with five scale steps. The odd-numbered items have a positive tone while the even-numbered items have a negative tone. SUS can be used to quantify the usability of websites, applications, or any software or hardware that users interact with (Rotolo, 2017). The SUS questionnaire is highly reliable (Cronbach’s alpha value = 0.91) and free of charges, thus widely accepted as one of the popular standardized usability questionnaire in the market (Garcia, 2013). It is also widely used in the context of educational software for the usability testing. Table 3.15 compiled with the list on the usage of SUS for educational software as found in the literature.

Table 3.15 Compilation of the SUS usage for Educational Software Evaluation

Educational Software	Purpose	Source
e-learning platform evaluation	Their aim was to detect usability problems and to cultivate knowledge of web developers on their end-users and user centred design.	(Renaut, Christophe, Flory, & Heyde, 2006)
DELTA (a distributed learning resources repository)	They used SUS to evaluate the perceived usability of DELTA.	(Venturi & Bessis, 2006)
Edutainment platforms (Virtual Classroom, Game-based & Storytelling).	Their purpose was to evaluate three edutainment platforms in terms of user performance, learning effectiveness and satisfaction in order to explore usability aspect of educational entertainment in e-Learning.	(Ayad & Rigas, 2010)
UNITE (an e-learning platform)	SUS was used as one of the usability evaluation technique to evaluate UNITE, an e-learning platform for secondary schools.	(Granić & Ćukušić, 2011)
Virtual learning environment	They used SUS to evaluate the usability of the virtual learning environment adopted by the Distance Education Center of the Federal Institute of Espírito Santo – Brazil, which has the Moodle platform as a basis.	(Simões & de Moraes, 2012)
Topolor system	Their aim was to assess the usability of the first version of the Topolor system a Social Personalized Adaptive E-Learning Environment (SPAEE)	(Shi, Awan, & Cristea, 2013)
Moodle system with the Drag & Share tool	Their aim was to evaluate the user satisfaction for the Moddle system with and without the Drag & Share tool.	(Marco, Penichet, & Gallud, 2013)
Simulation-based learning system	Their aim was to assess the simulation-based learning system perceived usability.	(Luo, Liu, Kuo, & Yuan, 2014)
Moodle-based Learning Management Systems (LMSs)	SUS was used to evaluate the perceived usability of LMSs.	(Orfanou, Tselios, & Katsanos, 2015)
MyGrammerTest (myGraTe) mobile application	SUS was used to evaluate the perceived usability of the respective mobile application.	(Ganapathy, Shuib, & Azizan, 2016)

According to Brooke (1996), participants should complete the SUS questionnaire after having used the system under evaluation but before any debriefing or other discussion. The SUS scoring method requires participants to provide a response to all 10 items. Based on the descriptions by Sauro and Lewis (2012), the very first step in scoring a SUS is to determine the contribution of each item's score, which range from 0 to 4. For positively worded items (odd numbers), the score contribution is the scale position minus 1 (xi-1). For negatively worded items (even numbers), the score contribution is 5 minus the scale position (5- xi). To get the overall SUS score, the sum of the item score contributions need to be multiplied by 2.5. Thus, overall SUS scores range from 0 to 100 in 2.5-point increments.

Through the literature search, recent research on the psychometric properties of the SUS has provided some normative data for reference. The basic statistical information about the SUS from the data reported by Bagor et al. (2008) and Lewis and Sauro (2009) can be referred to Table 3.16.

Table 3.16 Basic Statistical Information for SUS

Statistic	**Bangor et al. (2008)**	**Lewis and Sauro (2009)**		
	Overall	**Overall**	**Usable**	**Learnable**
N	2,324	324	324	324
Minimum	0	7.5	0	0
Maximum	100	100	100	100
Mean	70.14	62.1	59.44	72.72
Variance	471.32	494.38	531.54	674.47
Standard deviation	21.71	22.24	23.06	25.97
Standard error of the mean	0.45	1.24	1.28	1.44
Skewness	NA	-0.43	-0.38	-0.8
Kurtosis	NA	-0.61	-0.6	-0.17
First quartile	55	45	40.63	50
Median	75	65	62.5	75
Third quartile	87.5	75	78.13	100
Interquartile range	32.5	30	37.5	50
Critical z (99.9%)	3.09	3.09	3.09	3.09
Critical d (99.9%)	1.39	3.82	3.96	4.46
99.9% confidence interval upper limit	71.53	65.92	63.4	77.18
99.9% confidence interval lower limit	68.75	58.28	55.48	68.27
Note: Add and subtract critical d (computed by multiplying the critical z and the standard error) from the mean to get the upper and lower bounds of the 99.9% confidence interval.				

Another significant contribution was by Sauro (2011). He analysed the data from 3,187 completed SUS questionnaires and derived the curved grading scale interpretation of SUS scores as shown in Table 3.17. This curved grading scale interpretation table contributes as a norm table for SUS scores.

Table 3.17 Curved Grading Scale Interpretation of SUS Scores (Sauro, 2011)

SUS Score Range	Grade	Percentile Range
84.1-100	A+	96-100
80.8-84	A	90-95
78.9-80.7	A-	85-89
77.2-78.8	B+	80-84
74.1-77.1	B	70-79
72.6-74	B-	65-69
71.1-72.5	C+	60-64
65-71	C	41-59
62.7-64.9	C-	35-40
51.7-62.6	D	15-34
0-51.7	F	0-14

3.8.1.2 Post-Study System Usability Questionnaire (PSSUQ)

The PSSUQ is a questionnaire designed to assess users' perceived satisfaction with computer systems or applications (Sauro & Lewis, 2012). PSSUQ questionnaire is highly reliable (Cronbach's alpha value = 0.94) and free of charges (Garcia, 2013). The latest third version of PSSUQ has 16-items in the questionnaire.

The PSSUQ items produce four scores – one overall and three subscales. The rules for computing them are:

- Overall: Average responses for Item 1 through 16 (all the items)
- System Quality(SysQual): Average Items 1 through 6
- Information Quality (InfoQual): Average Items 7 through 12
- Interface Quality (IntQual): Average Items 13 through 15

According to Sauro and Lewis (2012), the resulting scores for each item in PSSUQ questionnaire can take values between 1 and 7, with lower scores indicating a higher degree of satisfaction. The interpretation of the PSSUQ data is best performed through the comparison with PSSUQ Norms. The best available norms for PSSUQ version 3 (means and 99% confidence intervals) is shown in Table 3.18 (Sauro and Lewis, 2012).

In this research, the SUS and PSSUQ instruments were chosen as the usability evaluation instruments to test the usability of the enhanced multimedia TAPS package due to the following reasons:

1) Both the SUS and PSSUQ usability questionnaires are widely accepted in the market with high reliability (both Cronbach's alpha value > 0.9).
2) The procedures for data analysis is straightforward with established norms to support data interpretations.
3) Both the SUS and PSSUQ usability questionnaire are available for free without any charges.

Table 3.18 PSSUQ Version 3 Norms (Means and 99% Confidence Intervals)

Item	Item Text	Lower Limit	Mean	Upper Limit
1	Overall, I am satisfied with how easy it is to use this system.	2.6	2.85	3.09
2	It was simple to use this system.	2.45	2.69	2.93
3	I was able to complete the tasks and scenarios quickly using this system.	2.86	3.16	3.45
4	I felt comfortable using this system.	2.4	2.66	2.91
5	It was easy to learn to use this system.	2.07	2.27	2.48
6	I believe I could become productive quickly using this system.	2.54	2.86	3.17
7	The system gave error messages that clearly told me how to fix problems.	3.36	3.7	4.05
8	Whenever I made a mistake using the system, I could recover easily and quickly.	2.93	3.21	3.49
9	The information (e.g., online help, on-screen messages, and other documentation) provided with this system was clear.	2.65	2.96	3.27
10	It was easy to find the information I needed.	2.79	3.09	3.38
11	The information was effective in helping me complete the tasks and scenarios.	2.46	2.74	3.01
12	The organization of information on the system screens was clear.	2.41	2.66	2.92
13	The interface of this system was pleasant.	2.06	2.28	2.49
14	I liked using the interface of this system.	2.18	2.42	2.66
15	This system has all the functions and capabilities I expect it to have.	2.51	2.79	3.07
16	Overall, I am satisfied with this system.	2.55	2.82	3.09
Scale	Scale Scoring Rule			
SysUse	Average Items 1-6.	2.57	2.8	3.02
InfoQual	Average Items 7-12.	2.79	3.02	3.24
IntQual	Average Items 13-15.	2.28	2.49	2.71
Overall	Average Items 1-16.	2.62	2.82	3.02
Note: These data are from 21 studies and 210 participants, analysed at the participant level.				

3.9 Summary

In summary this Chapter discussed the issues on user interface design, user interface design in the computer aided learning environment and its challenge, learning theories for interface design and recommendations. Usability issues and benchmarks were also discussed, and various usability testing instruments that can be used for usability evaluation were identified.

CHAPTER 4

METHODOLOGY

4.1 Overview

The Chapter begins with a discussion of the research paradigm and sampling technique. Next, the overall research design and approaches used to conduct the study are discussed including the seven sub-phases in the research methodology. The Chapter concludes by describing the ethical guidelines adopted in this research study.

4.2 Research Paradigm

Research paradigm refers to assumptions about the nature of the knowledge upon which research is to be conducted (Collis & Hussey, 2013). This can be further explained as the philosophical views of the researchers on the nature, purpose and approaches of the research (Derek, 2017). There are two major research paradigms, mainly positivism and interpretivism (Antwi & Kasim, 2015; Cohen et. al., 2017). The positivist paradigm starts with formulating hypotheses that can be tested with quantitative methods and these quantitative methods provide objective interpretations of reality (Orlikowski & Baroudi, 1991). As summarized by Samarasinghe (2012), a study is positivist if it provides (1) stating of formal hypotheses, (2) quantifiable measures of variables (3) hypotheses testing (4) drawing of inferences about a phenomenon from the sample to a stated population.

In contrast, the interpretivist paradigm depicts the subjective understanding of social reality by researchers and research participants (Samarasinghe, 2012). As claimed by

Derek (2017), "*the researcher's main goal is to allow the participants to construct their own "meaning" of the situation, often negotiated socially, culturally and historically.*" Based on the assumption of interpretivist, meaning is embedded in the participants' experiences and that this meaning is mediated through the researcher's own perceptions (Antwi & Kasim, 2015; Merriam, 2007). Thus, interpretations of the collected data will cover more aspects without the restriction to just a few accepted and mainstream ideas and perceptions (Derek, 2017).

Although both the paradigms differ from each other by having different research philosophy, both of these two paradigms have their own value and significance in the growth and development of new knowledge (Antwi & Kasim, 2015; Cohen et. al., 2017). The aim of the present research was to make generalizable assertions for certain relationships based on the research hypotheses. Therefore, the current research was dominated by the positivist paradigm, with minor elements of interpretivist research employed to interpret the hypotheses confirmed.

4.3 Quantitative versus Qualitative

There are commonly two research approaches for the research study, namely quantitative and qualitative approaches. Quantitative research is defined as any kind of research that relies on objectives measurements (Samarasinghe, 2012). Through quantitative research, statistical methods are used in analysing the data. As noted by Alkharang (2014), quantitative studies implement empirical research with regard to the belief that there can be the reduction of all phenomena to empirical indicators, which are able to provide facts. Through quantitative approach, researchers are allowed to draw conclusion and insights about patterns in the data (Scherbaum & Shockley, 2015) and to use inferential statistics to accept or to reject certain predetermined hypotheses (Samarasinghe, 2012). Therefore, the positivist research paradigm normally is implemented by using quantitative research (Alkharang, 2014; Derek, 2017; Samarasinghe, 2012). As described by Kothari (2014), the quantitative approach can be further sub-classified into inferential, experimental and simulation approaches to research (see Table 4.1).

Table 4.1 Sub-Classification of the Quantitative Approach

Sub-Classification (Quantitative Approach)	**Purposes it Served**
Inferential approach	The purpose of inferential approach to research is to form a database from which to infer characteristics or relationships of population. This usually means survey research where a sample of population is studied (questioned or observed) to determine its characteristics, and it is then inferred that the population has the same characteristics.
Experimental approach	Experimental approach is characterised by much greater control over the research environment and in this case some variables are manipulated to observe their effect on other variables.
Simulation approach	Simulation approach involves the construction of an artificial environment within which relevant information and data can be generated. This permits an observation of the dynamic behaviour of a system (or its sub-system) under controlled conditions.

Qualitative research is defined as any kind of research that produces findings not arrived at by means of statistical procedures (Corbin & Strauss, 2015) and relies on direct interpretations of rich data by the researcher (Samarasinghe, 2012). As further described by Cooper & Schindler (2014), qualitative research includes an "*array of interpretive techniques which seek to describe, decode, translate, and otherwise come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world*." Qualitative approaches usually involve collection of data in an unstructured way, through the techniques such as in-depth interview, observations, group discussions or by visual techniques (Cohen et al., 2017; Kothari, 2014; Kumar, 2014; Walliman, 2017). Therefore, the interpretivist research paradigm normally is implemented by using qualitative research (Alkharang, 2014; Derek, 2017; Samarasinghe, 2012).

4.4 Population and Sample

The research quality not only stands or falls by the appropriateness of methodology and instrumentation but also by the suitability of the sampling strategy that has been adopted (Cohen et al., 2017). As defined by Sekaran & Bougie (2016):

> "S*ampling is the process of selecting a sufficient number of elements from the population, so that a study of the sample and an understanding of its properties or characteristics would make it possible for us to generalize such properties or characteristics to the population elements*."

Sampling is equally important for both quantitative and qualitative research designs, as both require the researchers to select the proper sample that gives appropriate data to answer the respective research questions (Ng, 2017). Table 4.2 summarized the comparison between sampling for quantitative and qualitative studies.

Table 4.2 Comparison between Sampling for Quantitative and Qualitative Studies (Adopted from Teddlie & Yu, 2007)

Dimension of Contrast	**Sampling for Quantitative Studies**	**Sampling for Qualitative Studies**
Overall purpose of sampling	Designed to generate a sample that will address research questions	Designed to generate a sample that will address research questions
Issues of generalisability	Seeks a form of generalisability (external validity)	Sometimes seeks a form of generalisability (transferability)
Rational for selecting cases / units	Representativeness – the researcher selects cases that are collectively representative of the population	To address specific purposes related to the research questions – the researcher selects cases she or he can learn the most from
Sample Size	Large enough to establish representativeness (usually at least 50 units)	Typically small (usually 30 cases or less)

Depth / breath of information per case / unit	Focus on breath of information generated by the sampling units	Focus on the depth of information generated by the cases
When the sample is selected	Before the study begins	Before the study begins, during the study or both
How selection is made	Often based on application of mathematical formulas	Utilises expert judgement
Sampling frame	Formal sampling frame typically much larger than sample	Informal sampling frame somewhat larger than sample
Form of the data generated	Focus on numeric data, narrative data can also be generated	Focus on narrative data, numeric data can also be generated

According to Scherbaum and Shockley (2015), sampling is important for two reasons from the quantitative analysis perspective. First, representativeness can lead to sample statistics that are unbiased estimates of population parameters. Second, representativeness can produce these unbiased estimates in the most efficient way (i.e. with the smallest sample possible). Both of these points ultimately relate to the generalizability of the sample statistics as estimates of the population parameters. In general, there are six steps involved in the selection of sampling unit. Steps in selecting a sample for this research are summarised as shown in Figure 4.1.

Figure 4.1 Steps in Selecting a Sample (Adopted from Ng, 2017)

4.4.1 Target Population

Population refers to the entire group of people, events, or things of interest that the researcher wishes to investigate (Sekaran & Bougie, 2016). In this research, the target population refer to the mechanical engineering students from Universiti Tenaga Nasional (UNITEN) specifically taking the mechanics dynamics course. The mechanical engineering students from UNITEN were chosen as the target population for this research study for the following reasons:

1) UNITEN is one of the established private universities in Malaysia that is well known for its high quality engineering degree courses in Malaysia. Specifically, the mechanical engineering programme in UNITEN is recognized by the professional body such as the Institute of Mechanical Engineers (IMechE).
2) The mechanical engineering department of UNITEN shown the great interest to solve the problems for students in learning mechanics dynamics course through the use of computer assisted learning software.

4.4.2 Sampling Frame

A sampling frame is a list that records all population elements. As defined by Cooper & Schindler (2014), sampling frame is the complete and correct list of population members only from which the sample is actually selected. In this research, the sampling frame is the list of mechanical engineering students who were taking the mechanics dynamics course provided by the registrar office of UNITEN. The details of the mechanical engineering students who registered for the mechanics dynamics course for every semester since semester one 2013/ 2014 till semester two 2016 / 2017 is listed as shown in Table 4.3. The average number of intake (per semester) for mechanical engineering students throughout the four years was 196 (target population size, $N = 196$).

Table 4.3 Descriptive Statistics for Registered Students (Mechanics Dynamics course)

Year	**2013/2014**		**2014/2015**		**2015/2016**		**2016/2017**	
Semester	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
Total	**244**	**178**	**216**	**164**	**226**	**172**	**217**	**151**
(Mean)	196 (per semester)							

4.4.3 Sampling Strategy

The purpose of a sampling strategy is to select sampling units. Generally, there are two groups of sampling strategies: probability sampling strategies and non-probability sampling strategies. In probability sampling methods, each element of the sampling frame has a non-zero probability of being selected into the sample and the probability is known (Scherbaum & Shockley, 2015; Sekaran & Bougie, 2016). Probability sampling methods include simple random sampling, stratified sampling, systematic sampling and cluster sampling (Scherbaum & Shockley, 2015; Sekaran & Bougie, 2016). For non-probability sampling, the probability of selecting population elements is unknown (Cooper & Schindler, 2014).

Non-probability sampling methods include quota sampling, purposive sampling, snowball sampling and convenience sampling (Scherbaum & Shockley, 2015; Sekaran & Bougie, 2016). Probability sampling techniques give the most reliable representation of the whole population, while non-probability techniques, relying on the judgement of the researcher or on accident, cannot generally be used to make generalizations about the whole population (Walliman, 2017). Further information regarding the main difference between the probability and non-probability sampling strategies can be referred to Table 4.4. Since this is a quantitative research, probability sampling strategies was considered appropriate as the strategy to select the sampling unit.

Table 4.4 Probability and Non-probability Sampling (adopted from Ng, 2017)

Probability Sampling	Non-probability Sampling
A sampling technique in which every member of the population has a known, non-zero probability of selection	The probability of any particular member of the population being chosen is unknown
Use when there is a need to answer research questions that require statistical estimation on the characteristics of the population from the sample (to generalise results to the population).	A sampling technique in which units of the sample are selected on the basis of personal subjective judgement or convenience. Result not generalizable to the population.
Often associated with quantitative studies where a questionnaire data-collection approach is used.	Often associated with qualitative studies where an in-depth-interview data-collection approach is used.
Can be used only when a sampling frame is available	Use when a sampling frame is not available.

4.4.4 Sampling Technique

For this research study, probability sampling specifically the simple random sampling technique was adopted. This technique was chosen because the target population was not large (N < 250) (Hair et al., 2007). In simple random sampling, each element of the sampling frame has an equal probability of being selected into the sample (Scherbaum & Shockley, 2015; Sekaran & Bougie, 2016).

The process of selecting elements from the sampling frame is completely random based on the students list (students who registered for mechanics dynamics course in 2015 / 2016 semesters) provided by mechanical engineering department in UNITEN. In this study, every 3rd student in the students list was selected (e.g. 3rd, 6th, 9th, 12th, 15th, 18th, etc.) till 162 students were randomly selected as the sample unit for this research study. However, out of the 162 students, only 150 students concerted to participate in the research study.

4.4.5 Sample Size

Sample size was calculated based on Krejcie and Morgan's formula (1970) which is shown below:

$$s = X^2 NP (1-P) \div d^2 (N-1) + X^2 P (1-P)$$

Where;

s = required sample size.

X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841).

N = the population size.

P = the population proportion (assumed to be .50 since this would provide the maximum sample size).

d = the degree of accuracy expressed as a proportion (.05).

Thus;

(3.841*196 *0.50*(1-0.50) / ((0.0025 (196-1)) + (3.841*0.50*(1-0.50))) = 130 = sample size.

Based on the formula proposed by Krejcie & Morgan (1970), for a 95% confidence level and a population of 196 (see Table 4.3) mechanical engineering students (who took the mechanics dynamics course), the sample size required for this study is at least 130. The result gained is parallel to the sample size selection from a given target population as shown in Table 4.5. Furthermore, this is consistent with the sample size selection as proposed by Cohen, Manion & Morrison (2017). As discussed by Cohen et al. (2017), the determination of sample size for a probability sample is in relation to the confidence level and sampling error. Table 4.6 shows the sample size selection based on the confidence levels of 95 per cent and 99 per cent and sampling errors of 5 per cent and 1 per cent respectively. For this research study, based on the population size of 196 with confidence levels of 95 per cent and sampling errors of 5 per cent, the sample size needed is at least 130. This is consistent with the findings from the formula as proposed by Krejcie & Morgan (1970). As claimed by Roscoe (1975) and Sekaran & Bougie (2016), one of the rules of thumb for determining sample size is that the sample sizes > 30 and < 500 are appropriate for most research.

Table 4.5 Table for Determining Sample Size from a Given Population (Adapted from Krejcie & Morgan, 1970)

N	***S***	***N***	***S***	***N***	***S***	***N***	***S***	***N***	***S***
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	346
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	354
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	191	1200	291	6000	361
45	40	170	118	400	196	1300	297	7000	364
50	44	180	123	420	201	1400	302	8000	367
55	48	190	127	440	205	1500	306	9000	368
60	52	**200**	**132**	460	210	1600	310	10000	370
65	56	210	136	480	214	1700	313	15000	375
70	59	220	140	500	217	1800	317	20000	377
75	63	230	144	550	226	1900	320	30000	379
80	66	240	148	600	234	2000	322	40000	380
85	70	250	152	650	242	2200	327	50000	381
90	73	260	155	700	248	2400	331	75000	382
95	76	270	159	750	254	2600	335	100000	384

Note. – *N* is population size. *S* is sample size.

Table 4.6 Sample Size Selection based on Confidence Levels (Cohen et al., 2017)

Population Size	**Confidence = 95% Margin of Error**				**Confidence = 99% Margin of Error**			
	5.0%	**3.5%**	**2.5%**	**1.0%**	**5.0%**	**3.5%**	**2.5%**	**1.0%**
10	10	10	10	10	10	10	10	10
20	19	20	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	47	48	50	47	48	49	50
75	63	69	72	74	67	71	73	75
100	80	89	94	99	87	93	96	99
150	108	126	137	148	122	135	142	149
200	**132**	160	177	196	154	174	186	198
250	152	190	215	244	182	211	229	246
300	169	217	251	291	207	246	270	295
400	146	265	318	384	250	309	348	391
500	217	306	377	475	285	365	421	485
600	234	340	432	565	315	416	490	579
700	248	370	481	653	341	462	554	672
800	260	396	526	739	363	503	615	763
1,000	278	440	606	906	399	575	727	943
1,200	291	474	674	1,067	427	636	827	1,119
1,500	306	515	759	1,297	460	712	959	1,376
2,000	322	563	869	1,655	498	808	1,141	1,785
2,500	333	597	952	1,984	524	879	1,288	2,173
3,500	346	641	1,068	2,565	558	977	1,510	2,890
5,000	357	678	1,176	3,288	586	1,066	1,734	3,842
7,500	365	710	1,275	4,211	610	1,147	1,960	5,165
10,000	370	727	1,332	4,899	622	1,193	2,098	6,239
25,000	378	760	1,448	6,939	646	1,285	2,399	9,972
50,000	381	772	1,491	8,056	655	1,318	2,520	12,455
75,000	382	776	1,506	8,514	658	1,330	2,563	13,583
100,000	383	778	1,513	8,762	659	1,336	2,585	14,227
250,000	384	782	1,527	9,248	662	1,347	2,626	15,555
500,000	384	783	1,532	9,423	663	1,350	2,640	16,055
1,000,000	384	783	1,534	9,512	663	1,352	2,647	16,317
2,500,000	384	783	1,536	9,567	663	1,353	2,651	16,478
10,000,000	384	784	1,536	9,594	663	1,354	2,653	16,560
100,000,000	384	784	1,537	9,603	663	1,354	2,654	16,584
300,000,000	384	784	1,537	9,603	663	1,354	2,654	16,586

4.4.6 Sample Unit

The sample unit is from the students who registered for the mechanics dynamics course in UNITEN.

4.5 Research Design Adopted for the Study and Overall Research Framework

This research study adopted the quantitative research approach. The overall research framework for this study can be referred to Figure 4.2. This research framework was divided into seven phases. The following sections further discuss the activities for each phase (phase 1 till phase 7) in details.

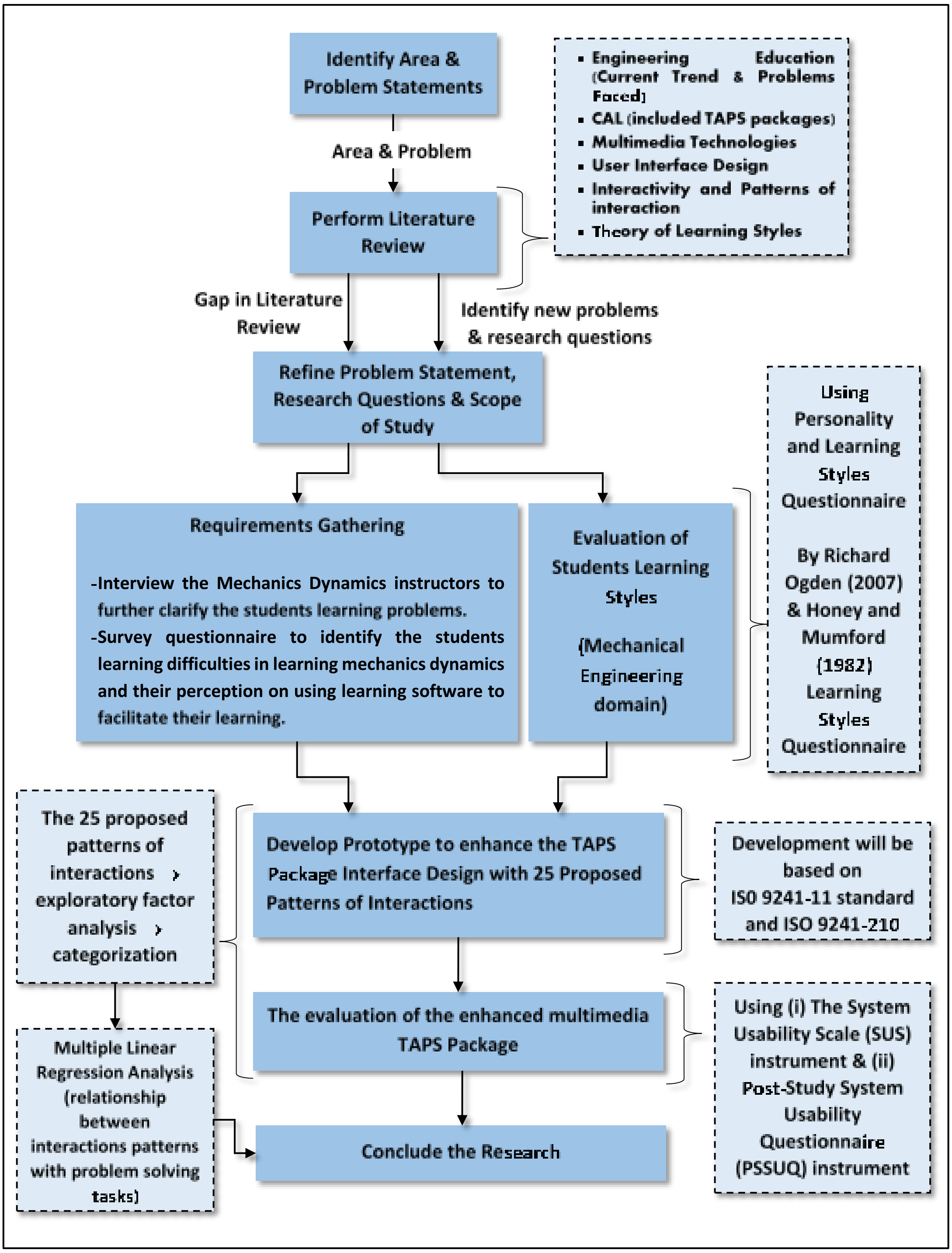

Figure 4.2 Overall research framework

4.6 Research Methodology Phase 1 (Awareness of Problem & Research Gap)

The research activities performed in Phase 1 can be referred to the diagram as shown in Figure 4.3.

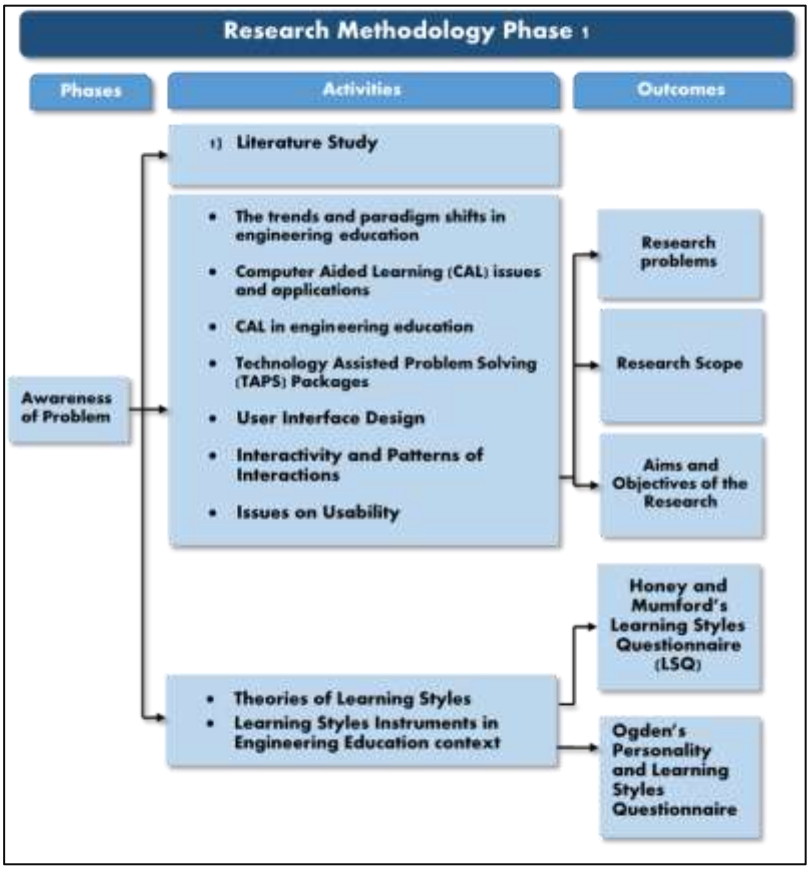

Figure 4.3 Research activities and outcomes performed in Phase 1

In Phase 1, the main research activities were to perform the literature review based on few context (as shown in Figure 4.3) in order to determine the research gap. These studies (details can be refer to Chapters 2 and 3) lead to the construction of research questions, objectives, scope and significant of research as discussed in Chapter 1. Meanwhile, the literature study on the theory of learning styles and the learning styles instruments (details can be referred to Chapter 2) contributed to the selection of specific learning styles instruments to be employed in this research. The detail flow of the research activities and its related outcome can be referred to Figure 4.3.

4.7 Research Methodology Phase 2 (Requirements Gathering & Analysis)

The research activities performed in Phase 2 can be referred to the diagram as shown in Figure 4.4.

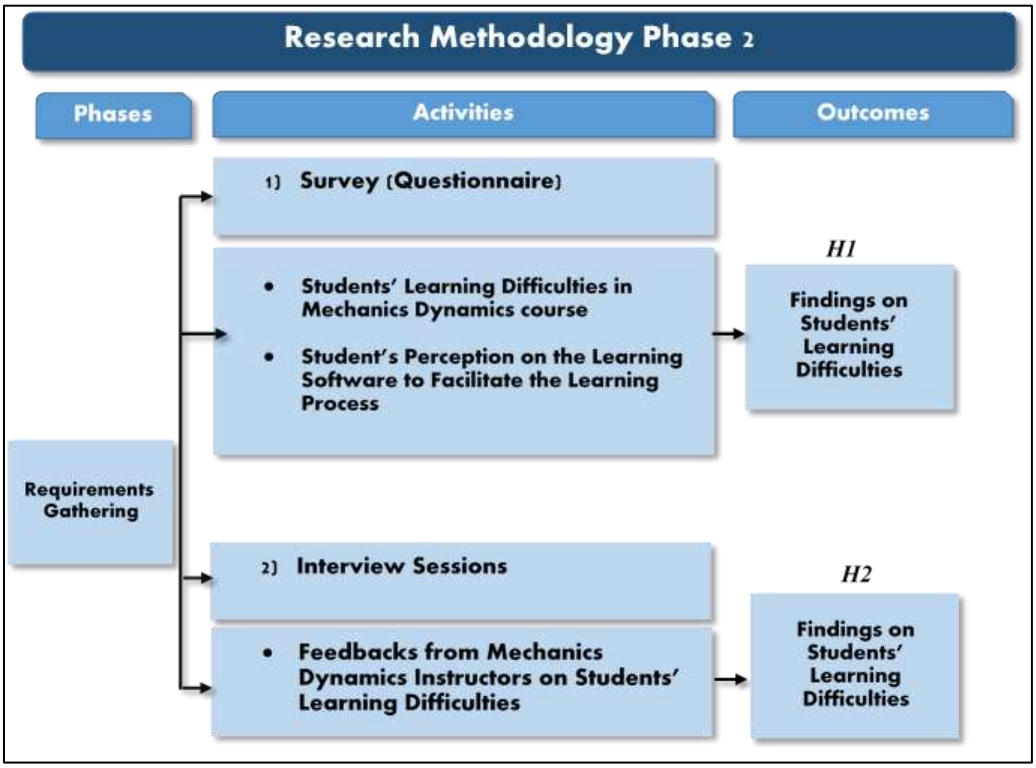

Figure 4.4 Research activities and outcomes performed in Phase 2

The data collected from this phase acted as the main reference for the design and development of the enhanced multimedia TAPS package. In order to gather the students' perception on the learning difficulties in Mechanics Dynamics course and the student's perception on the learning software to facilitate the learning process, questionnaire (see Appendix A) was used as the data collection method. A questionnaire is a pre-formulated written set of questions to which respondents record their answers, usually within rather closely defined alternatives (Hair et al., 2007; Sekaran & Bougie, 2016). Likert scale oriented questionnaire was adopted in this research study. As supported by Cohen et al. (2017), Likert scale oriented questionnaire "*build in a degree of sensitivity and differentiation of response whilst still generating numbers*."

Interviews are particularly helpful in gathering data when dealing with complex issues, and when open-ended questions are used to collect data (Hair et al., 2007). "*Through interview, an interchange of views between two or more people on a topic of mutual interest, sees the centrality of human interaction for knowledge production, and emphasizes the social situatedness of research data*" (Brinkmann & Kvale, 2014). In this research study, semi-structured interviews were used to collect the data from the mechanics dynamics course instructors regarding the feedbacks on students' learning difficulties on the course. Through semi-structured interviews, the author had the flexibility to further ask some questions to follow up with the interviewee's answers to the questions. As highlighted by Hair et al. (2007), semi-structured interviews may result in unexpected and insightful information that may enhance the findings.

Based on the gathered students' learning difficulties both from the students' perspectives and the instructors' perspective, it contributed as a guideline for the development of the proposed patterns of interactions embedded with the enhanced multimedia TAPS package. The outcome of this phase of the research was able to evaluate the hypothesis 1 (H_1) and hypothesis 2 (H_2) (see Figure 4.4) in response to the research question (RQ1) stated in Chapter 1 section 1.5. RQ1: "*Are the students facing difficulties in learning Mechanics Dynamics subject? If yes, what are the difficulties faced by students?*" The detail discussions can be found in Chapter 5 section 5.2.3.

4.8 Research Methodology Phase 3 (Learning Styles Evaluations)

The research activities performed in this phase can be referred to the diagram as shown in Figure 4.5.

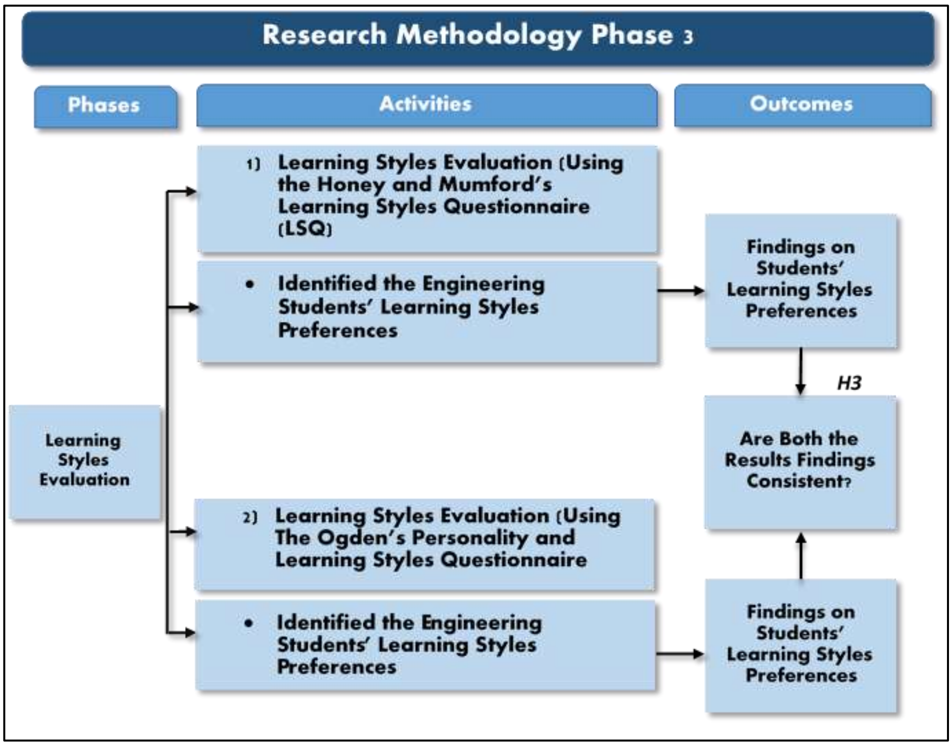

Figure 4.5 Research activities and outcomes performed in Phase 3

In this phase of the research, the Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles Questionnaire were used to evaluate the engineering students learning styles preferences. The outcome of the research findings contributes to evaluate the hypothesis 3 (H_3) (see Figure 4.5) in response to the research question (RQ2): "*What are the learning styles preferences for engineering students?*" and (RQ3): "*Are the learning styles instruments showing consistent results on the students learning styles preference?*" The detail descriptions for this study can be referred to Chapter 5 sections 5.3 and section 5.4.

4.9 Research Methodology Phase 4 (Development of the Enhanced Multimedia TAPS Package with Proposed Patterns of Interactions)

The research activities performed in this phase can be referred to the diagram as shown in Figure 4.6. In this phase of the research, the design and development of the enhanced multimedia TAPS package were conducted through the pre-authoring, authoring and post-authoring stage. The proposed 25 patterns of interactions were integrated as the main interactivity features for the enhanced multimedia TAPS package. The users' requirements gathered (both the learning styles preferences and students learning difficulties) was taken as a main reference for the development of the enhanced multimedia TAPS package. The detail descriptions regarding the development process (authoring process) for the enhanced multimedia TAPS package can be referred to Chapter 6 section 6.5. The outcome of this research phase was the completed enhanced multimedia TAPS package that is ready for usability testing which was conducted in the next phase of the research.

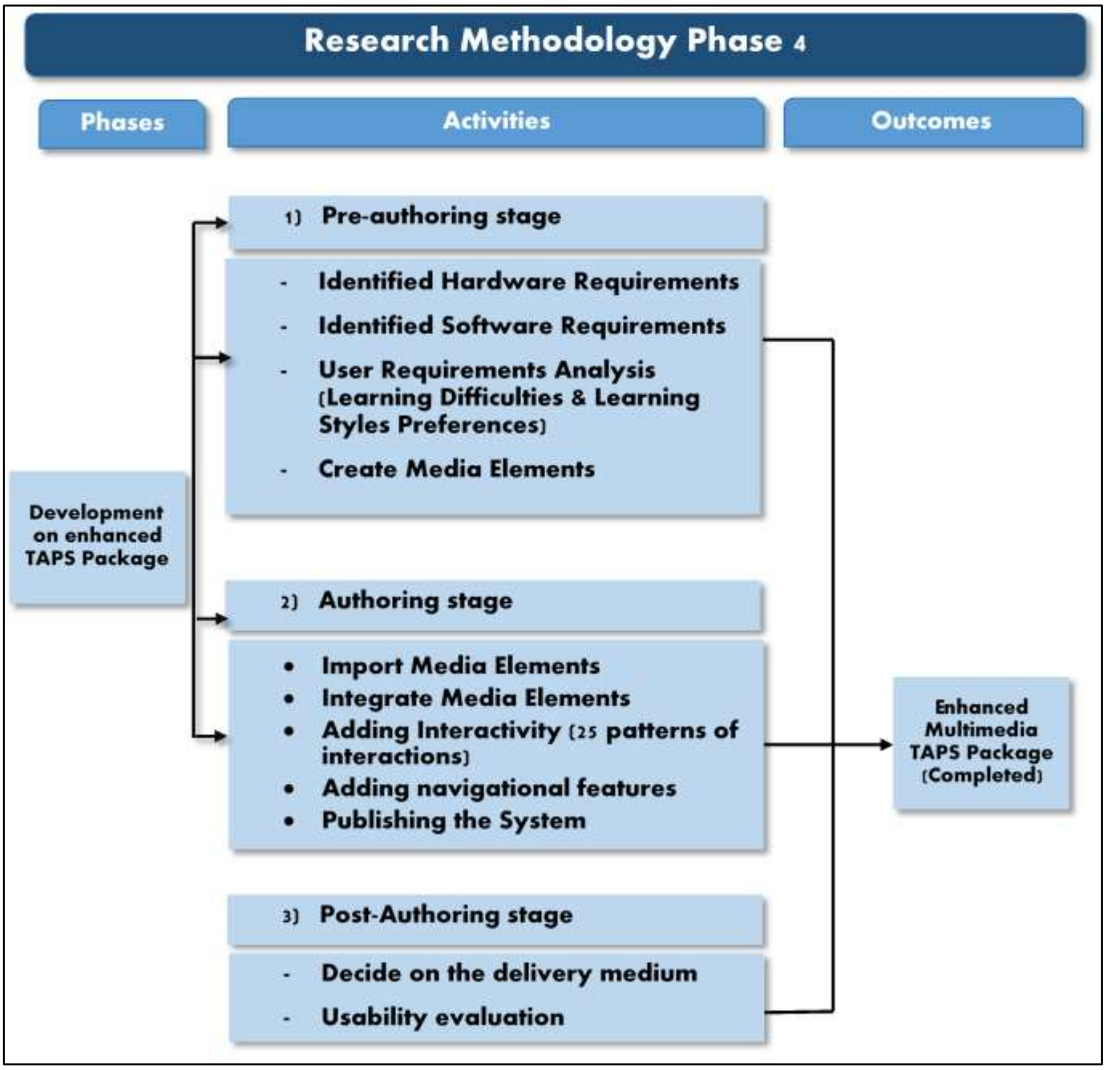

Figure 4.6 Research activities and outcomes performed in Phase 4

4.10 Research Methodology Phase 5 (Usability Evaluation)

The research activities performed in this phase can be referred to the diagram as shown in Figure 4.7. In this phase, both the System Usability Score (SUS) instruments and Post-Study System Usability Questionnaire was used to evaluate the users' perception on the usability for enhanced multimedia TAPS package. The detail descriptions on the procedures to perform the usability evaluation and its findings can be referred to Chapter 7 sections 7.2 and section 7.3.

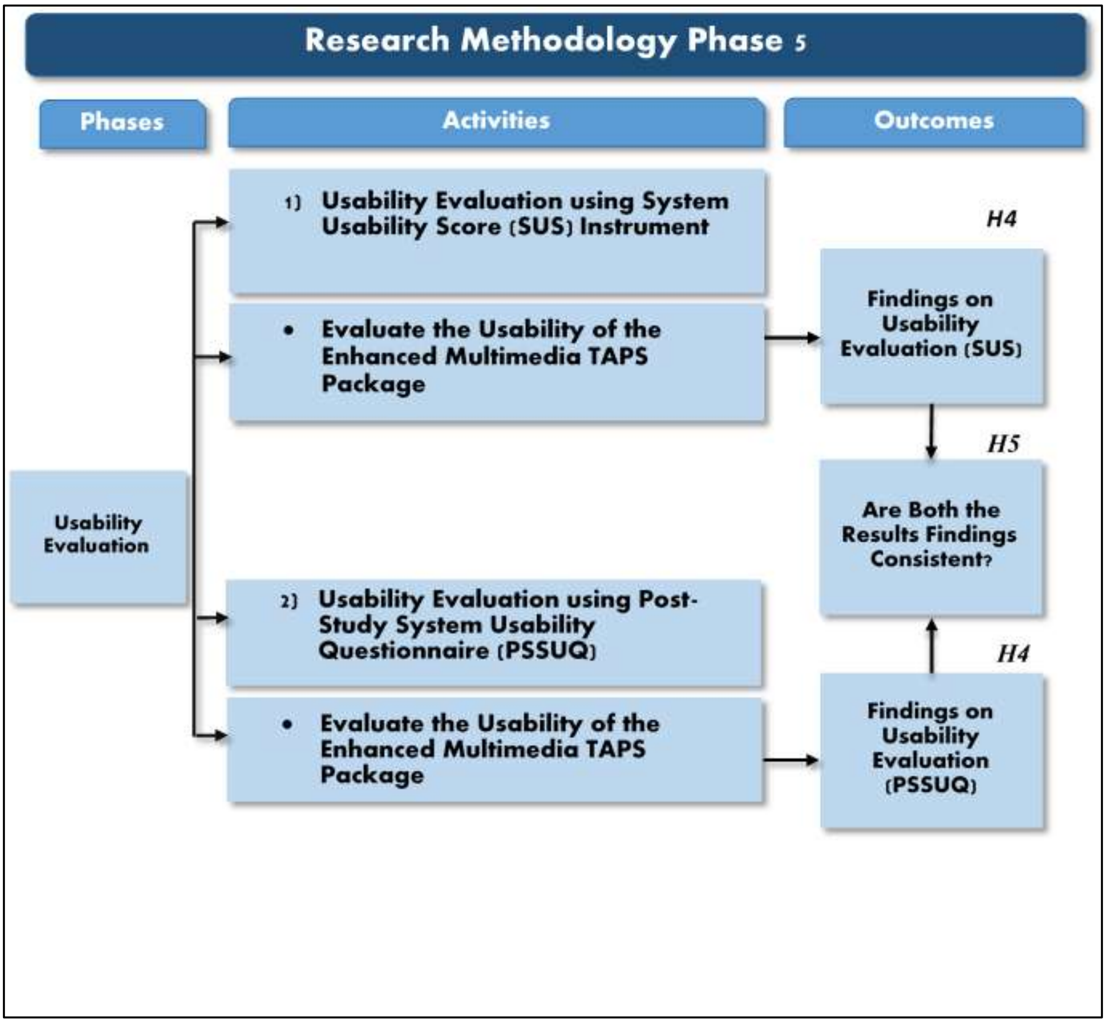

Figure 4.7 Research activities and outcomes performed in Phase 5

The outcome of the research activities in this phase served the purpose to evaluate the hypothesis 4 (H_4) and hypothesis 5 (H_5) (see Figure 4.7) in response to the research question (RQ4): "*Is the enhanced multimedia TAPS package highly usable?*" and research question (RQ5):"*Does the usability results show consistency through various usability instruments?*"

4.11 Research Methodology Phase 6 (Interactions Patterns Categorization)

The research activities performed in this phase can be referred to the diagram as shown in Figure 4.8. In this phase of the study, the 25 proposed patterns of interactions were categories through the statistical approach of exploratory factor analysis to identify any possible grouping for all the proposed patterns. As known, exploratory factor analysis (EFA) is a complex and multivariate statistical technique commonly employed in information systems, social science, education and psychology (Taherdoost, Sahibuddin, & Jalaliyoon, 2014). Factor analysis is divided into two main categories namely, (i) Exploratory Factor Analysis (EFA), and (ii) Confirmatory Factor Analysis (CFA) (William & Brown, 2010). EFA is normally used when the researcher has no expectations of the number or nature of the factors. (Taherdoost et al., 2014). The steps adopted from Taherdoost et al., (2014) towards implementation of exploratory factor analysis can be found in Figure 4.8. In the research study, EFA may serve for different purposes (Pett et al., 2003; Thomspon, 2004) such as:

1) Reduction of number of factors (variables)
2) Assessment of multicollinearity among factors which are correlated
3) Unidimensionality of constructs evaluation and detection
4) Evaluation of construct validity in a survey
5) Examination of factors (variables) relationship or structure
6) Development of theoretical constructs
7) Prove proposed theories

In this research study, the implementation of EFA was to serve the purpose of the reduction of number of factors (variables), in this case, possible grouping for all the proposed patterns. The outcome of the research findings contributed to evaluate the hypothesis (H_6) in response to the research question (RQ7): "*Can the interaction patterns be grouped into few categories?*" The detail descriptions can be found in Chapter 7 section 7.4.

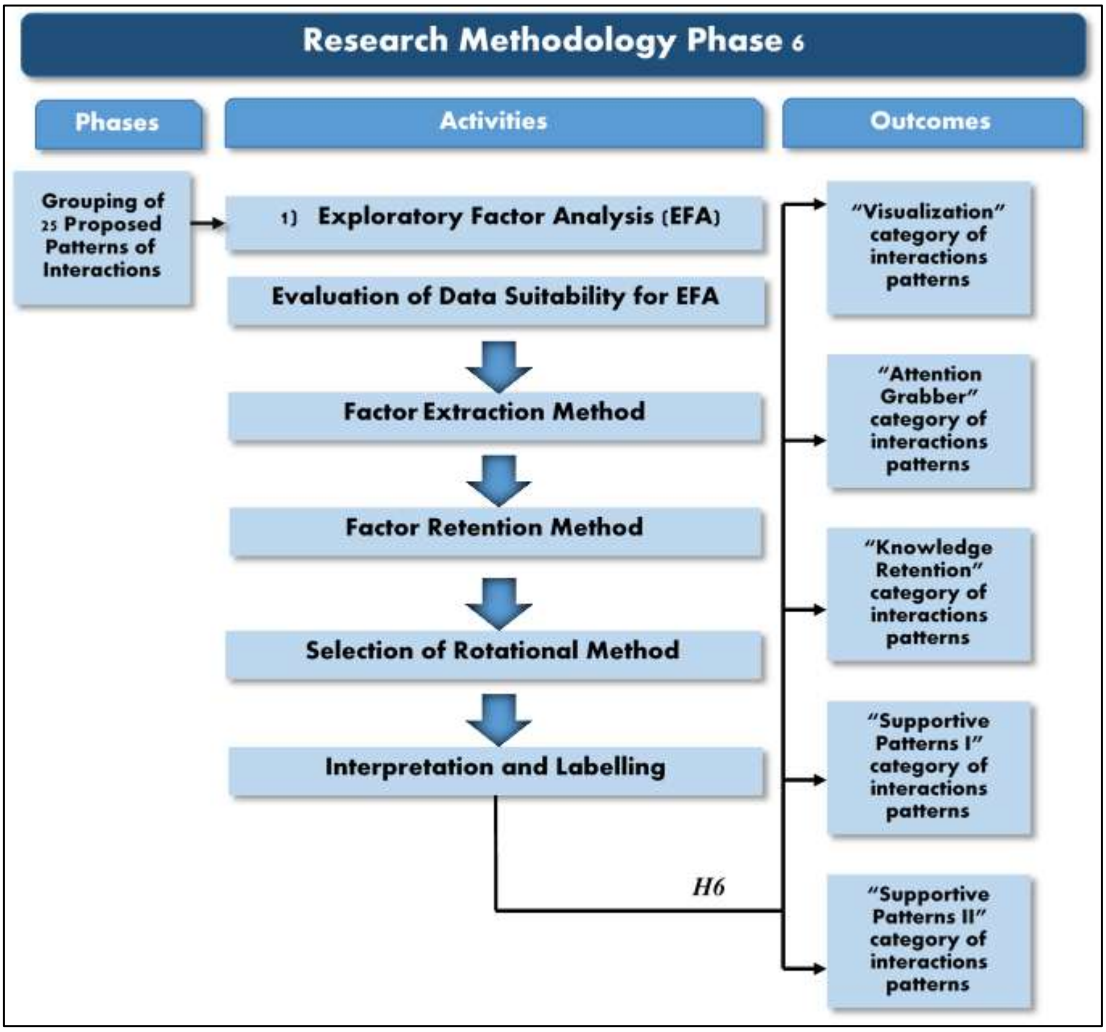

Figure 4.8 Research activities and outcomes performed in Phase 6

4.12 Research Methodology Phase 7 (Investigation on the Relationships between Interactions Patterns and Engineering Problem Solving Tasks)

The research activities performed in this phase can be referred to the diagram as shown in Figure 4.9. In this phase of the study, the five groups of interactions patterns were further investigated through the statistical approach that employed the multiple linear regression analysis to determine the relationship between the groups of interaction patterns (in this case, independent variables (X_A, X_B, X_C, X_D, X_E) and the engineering problem solving tasks (in this case, dependent variable, Y). Multiple regression analysis is a statistical technique that can be used to analyze the relationship between a single dependent variable and several independent variables

(Goi, 2017; Hair et al., 2009; Polonsky & Waller, 2015). By knowing whether there is a casual relationship will be extremely useful especially when making recommendations since there is a strong support for undertaking some action (Polonsky & Waller, 2015).

Normally the regression equation includes the regression coefficient (β_{slope}) and an additive constant ($\beta_{constant}$): $Y = \beta_{constant} + \beta_{slope} * X$. In this research study, the equation could be:

$Y = \beta_0 + \beta_1 * X_A + \beta_2 * X_B + \beta_3 * X_C + \beta_4 * X_D + \beta_5 * X_E$

Where, Y = Problem Solving Tasks,

X_A = Interaction Patterns for '*Visualization*' category,

X_B = Interaction Patterns for '*Attention Grabber*' category,

X_C = Interaction Patterns for '*Knowledge Retention*' category,

X_D = Interaction Patterns for Supportive Patterns I' category,

X_E = Interaction Patterns for Supportive Patterns II' category.

The diagrammatic representation of the independent variables and the dependent variable can be referred to Figure 4.10. The outcome of the research activities in this phase served the purpose to evaluate the hypotheses (*H_7, H_8, H_9, H_{10}, and H_{11}*) in response to the research question (RQ8): "*Does each of these categories (patterns of interactions) significantly associate with engineering problem solving tasks*?" The detail descriptions for this research study can be referred to Chapter 7 section 7.5.

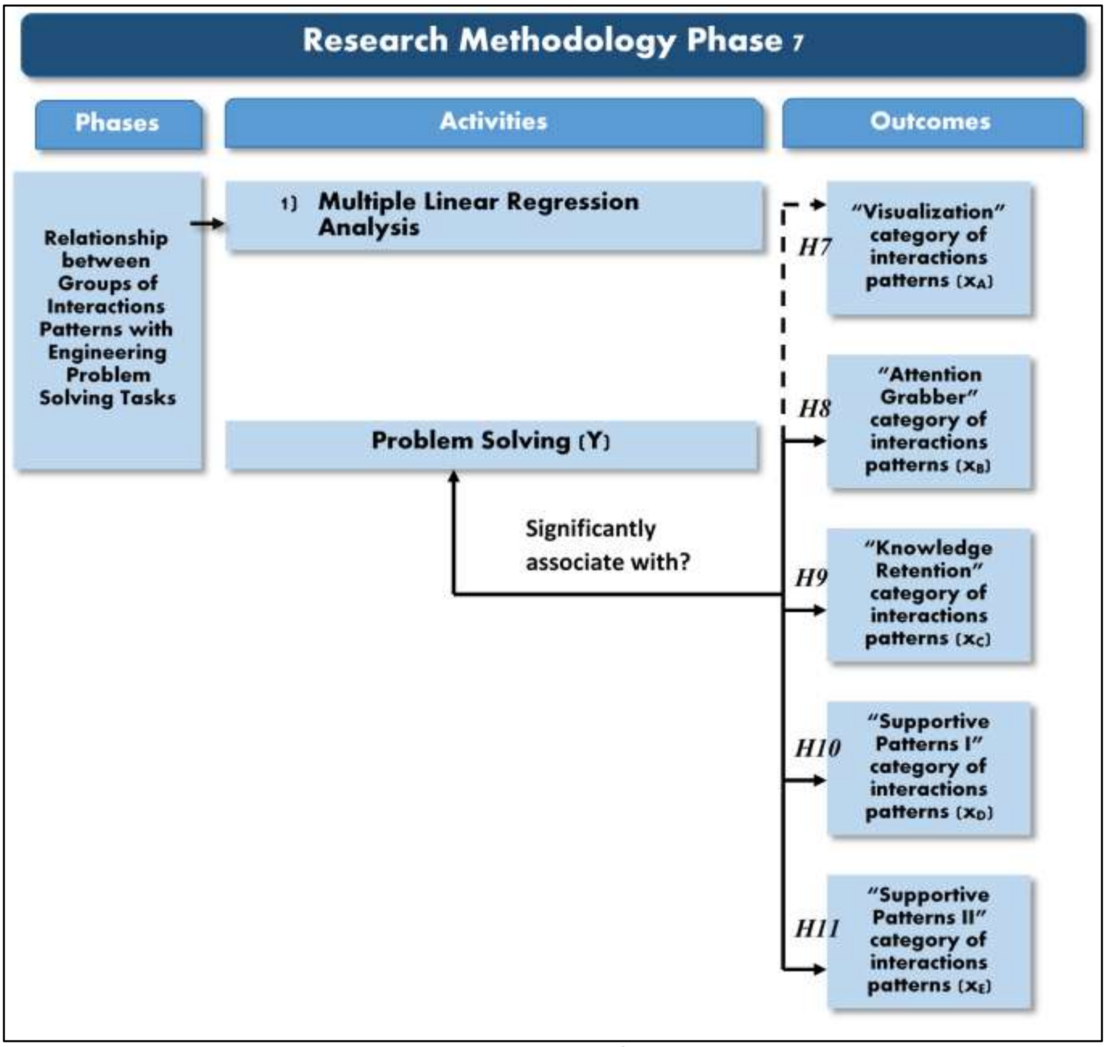

Figure 4.9 Research activities and outcomes performed in Phase 7

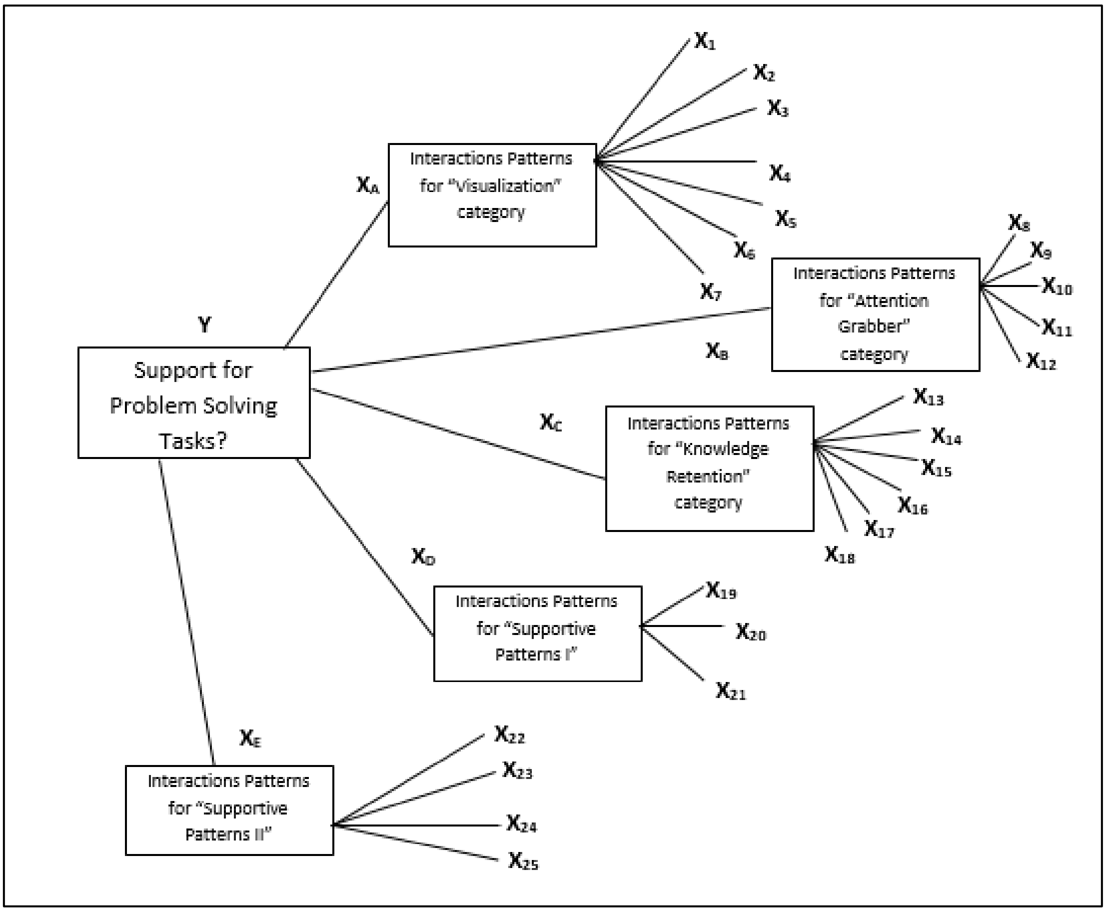

Figure 4.10 Diagrammatic representations of the independent variables (groups of interaction patterns) and the dependent variable (problem solving tasks)

4.13 Ethical Considerations

Ethical practice in empirical research is very important. As defined in Oxford Dictionary (2017), 'ethics' is defined as moral principles that govern a person's behaviour or the conducting of an activity. As emphasis by Cooper & Schindler (2014), the goal of ethics in research was to ensure that no one is harmed or suffers adverse consequences from research activities. Most professions have an overall code of conduct that also governs the way they carry out research (Kumar, 2014).

In this research, approval to collect the data among the participants was obtained from the Mechanical Engineering Department Mechanics Dynamics course coordinator before performing the data collection activities. All the participants were briefed and made aware of the following statements.

- The participant was informed about the goals of the research, their role and the benefits of the research results.
- The participant accepted to participate in the research were aware that the data will be used solely for research purpose.
- The participant was informed and aware that his/her identity will always remain anonymous.
- The participant understood his / her right to withdraw at any time during the process of data collection.

4.14 Summary

In summary, the overall research methodology for this study can be divided into the abovementioned seven phases. Various research activities were conducted to complete the research tasks in each phase. By completing each of the phase, the research hypotheses was evaluated and the outcome was used to answer the research questions. All the research questions answered supported the achievement of the research objectives and provided solutions for the identified problems that contribute towards the completion of this research study.

CHAPTER 5

USER REQUIREMENTS GATHERING & ANALYSIS

5.1 Overview

In this Chapter, the study and findings of the students' learning difficulties both from the students and instructors perspective to understand the students' requirements for the enhanced multimedia TAPS packages development are discussed. This Chapter also evaluates the students learning styles preferences using Honey and Mumford Learning Styles instrument (LSQ) and Ogden's Personality and Learning Styles instrument. Students learning styles preference was identified and comparison study was performed to show the consistency results gained through different learning styles instruments.

5.2 User Requirements Gathering (Students' Learning Difficulties)

5.2.1 The Importance of User Requirements Gathering

Requirements gathering is defined as the activity of identifying, documenting and organizing requirements from the surrounding system into something understandable and meaningful for the design (Aryana et al., 2015). It is an important phase in the design process of the software development to understand the users' requirements and expectations.

As claimed by Mifsud (2013):

"*The more you understand your users, their work and the context of their work, the more you can support them in achieving their goals – and hence, the more usable your system will be!*"

In the context of this research study, the survey (questionnaire) approach (refer to the next section) was used to collect the students learning difficulties in mechanics dynamics course and their perceptions towards the usage of multimedia based learning software in assisting the learning in mechanics dynamics domain. The interviews method was used to collect information from the mechanical engineering instructors who are involved in the teaching of mechanics dynamics course regarding the students learning condition and difficulties. In addition, the Honey and Mumford's Learning Styles Questionnaire (see section 5.3) and Ogden's Personality and Learning Styles Questionnaire (see section 5.4) were employed to evaluate and gather the students learning styles preferences in the mechanics dynamics course. All this information (students learning difficulties and preferred learning styles) would be the main reference for the design and development of the enhanced multimedia TAPS package (see Chapter 6).

5.2.2 Methodology

The main objective of this preliminary study was to find out the students' difficulties in learning mechanics dynamics both from the perspective of students and instructors. In this study the survey questionnaire was employed to collect the students' feedback. The sample questionnaire can be referred to Appendix A. The sample questionnaire was derived and compiled as the outcome from the discussion with the engineering instructors from UNITEN. The data collection took approximately a month (30th July 2012 - 27th August 2012). If a class had more than 30 students, it was minimized to 30 students per section. Therefore five sections of the students who have taken the mechanics dynamics subject were invited to participate in this study. The questionnaire was prepared and administrated to the students (printed hard copies) with the help from two mechanical engineering academic staff by distributing the questionnaires to the students 15 minutes before the class ended. Short briefing was provided for the students on how to fill in the survey questionnaire. Each of the student took on an average 10-12 minutes to complete the questionnaire.

5.2.3 Findings and Analysis

A total of 150 set of questionnaires were distributed to the students and 127 respondents completed the questionnaires which showed the response rate of 84.67%. Basic statistical method (descriptive technique) was used to assess the students' responses. Through Table 5.1, it can be identified that almost half of the students (49.6%) expressed their perception that the mechanics dynamics is a difficult subject. Meanwhile, 42.5% of the students thought that this subject is logical. However, 39.4% of the students thought that this is an interesting subject.

A detailed summary of students' response generally in learning mechanics dynamics is compiled and listed as shown in Table 5.2. Based on the 127 respondents, it can be clearly identified that more than 60% of the students (agree + strongly agree) agreed that the new concepts (e.g. the equation of motion, curvilinear motion, relative motion analysis, kinetic energy and etc.) are the most difficult part for this course. Besides that, it was found that approximately 40% of the students fall in the category of 'often' and 'always' when dealing with the understanding of the material in the textbook. It can also be identified that almost half (47.3%) of the students often and always try to do some exercises from the text to reinforce their problem solving techniques. Regarding the problems in understanding the contents due to the static figures shown, 26.8% of the students often faced this problem while 39.4% of the students sometimes faced this problem. In general, more than half (60%) of the students did more or less face the problems on this issue. For the visualization problems, more than 70% of the students at least faced this issue sometimes throughout their study. In contrast, it is a good sign to find out that more than 50% of the students found the step-by-step approach shown in the sample solutions useful to aid their understanding which is similar to the findings of Manjit (2006). For the level of knowledge for this subject, 55.1% of the students rate their level of knowledge to be moderate.

Table 5.1 General perception about mechanics dynamics

Perception	Frequency (n=127)	Percentage (%)
Difficult	**63**	**49.6**
Easy	3	2.4
Fun	27	21.3
Interesting	**50**	**39.4**
Boring	14	11
Logical	**54**	**42.5**
Of no concern to me	4	3.1

Table 5.2 General summary of students' response in learning mechanics dynamics

General Question	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
New concepts are the most difficult part of the course. (e.g. the equation of motion, curvilinear motion, relative motion analysis, kinetic energy and etc.)	1 (0.8%)	16 (12.6%)	27 (21.3%)	66 (52%)	17 (13.4%)
Working with the textbook	**Always**	**Often**	**Sometimes**	**Seldom**	**Never**
I understand the material in the textbook.	6 (4.7%)	45 (35.4%)	50 (39.4%)	22 (17.3%)	4 (3.1%)
I try to do some of the exercises from the text to reinforce my problem-solving techniques.	11 (8.7%)	49 (38.6%)	50 (39.4%)	14 (11%)	3 (2.4%)
I have problems in understanding the contents because the	10 (7.9%)	34 (26.8%)	50 (39.4%)	24 (18.9%)	9 (7.1%)

figure(s) shown is/are static (no animations).					
I have problems in visualizing the scenario as described in the text.	14 (11%)	24 (18.9%)	58 (45.7%)	27 (21.3%)	4 (3.1%)
The step-by-step approach shown in the sample solutions was sufficient to aid my understanding.	28 (22%)	37 (29.1%)	51 (40.2%)	8 (6.3%)	3 (2.4%)
Knowledge level	**Very Good**	**Good**	**Moderate**	**Bad**	**Very Bad**
Overall, I think my level of knowledge for this subject is very good / good/ moderate /bad /very bad	4 (3.1%)	44 (34.6%)	70 (55.1%)	8 (6.3%)	1 (0.8%)

Problem solving ability is important in the learning process of mechanics dynamics. Table 5.3 provides a summary regarding the responses of students' problem solving ability in mechanics dynamics. As referred to Table 5.3, only one third (35.4%) of the students fall in the category of 'always' or 'often' in/with regards to clearly understanding the problem. However more than 50% of the students did not always clearly understand the problem that need to be solved. Regarding the ability to clearly identify the given and unknown in problem solving process, approximately 45.6% of the students can often perform while others still face the problems on this issue. It can be identified that more than 60% of the students' response to have the ability to draw and label the diagrams. However, it can also be identified that only 45.6% of the students provide responses that they can often / always think of a plan for the solution. It is interesting to further identify that only approximately 31.5% of the students often/always have the ability to provide alternative ways of solving the problem. Less than 50% of the students can often /always describe the steps that they perform while solving the problem. This is consistent with the finding that less than 50% of the students can often explain the obtained results after the problem is solved. Through Table 5.3, it was noted that more than 75% of the students often/always preferred to use examples solved in the class as a model for solving other similar problems.

Table 5.3 Summary of students' problem solving ability in mechanics dynamics

Problem Solving Ability	Always	Often	Sometimes	Seldom	Never
I clearly understand the problem.	5 (3.9%)	40 (31.5%)	69 (54.3%)	11 (8.7%)	2 (1.6%)
I can clearly identify the given and the unknown.	13 (10.2%)	45 (35.4%)	52 (41%)	17 (13.4%)	0 (0%)
I can draw and label diagram.	20 (15.7%)	62 (48.8%)	30 (23.6%)	15 (11.8%)	0 (0%)
I can think of a plan for the solution.	6 (4.7%)	52 (40.9%)	54 (42.5%)	15 (11.8%)	0 (0%)
I can see alternative ways of solving the problem.	5 (3.9%)	35 (27.6%)	58 (45.7%)	22 (17.3%)	7 (5.5%)
I can describe step by step what I did.	13 (10.2%)	45 (35.4%)	48 (37.8%)	18 (14.2%)	3 (2.4%)
I can explain the obtained results.	7 (5.5%)	50 (39.4%)	51 (40.2%)	17 (13.4%)	2 (1.6%)
I used examples solved in the class as a model for solving problems.	54 (42.5%)	43 (33.9%)	22 (17.3%)	7 (5.5%)	1 (0.8%)

Apart from the previously mentioned problems, feedbacks were collected from three of the mechanical engineering instructors regarding the problems faced by students in mechanics dynamics through the short interviews performed between June to August 2012. The summary of the instructors' feedbacks on problems faced by students was compiled as shown in Table 5.4. It can be clearly identified that three of the instructors shared the same opinions by which they realized that the students did face the difficulties in visualization especially on the dynamic movement that involved the z-axis. Furthermore, two of the instructors also shared the same views that some of the students did not build up a strong foundation in physics and mathematics. This lead to the difficulties in understanding of certain concepts in mechanics dynamics. One of the instructors mentioned that some of the students are too focused on how to solve the problems by using formula in order to reach the final outcome without having the ability to justify the steps involved or lacked the understanding about the logical flow of the solution steps. In addition, one of the instructors further identified that some of the students did not acquire a strong understanding about the importance of engineering mechanics dynamics especially the fundamental principles and knowledge, which lead to the difficulties faced while moving into the mechanical design subjects.

Table 5.4 Instructors feedbacks on problems faced by students

Instructors	Problems faced by students
1	▪ Difficulties in visualization (dynamic representation) ▪ Foundation in physics and mathematics not strong ▪ Lack the understanding on the purpose of study (overall picture for engineering profession) ▪ Low learning interest
2	▪ Visualization problems - static image and bored discussion in the textbook. ▪ No interaction involved in the understanding of the application (engineering problems) –static representation of the image ▪ Students too focused on how to solve the problems using formula & target for the final outcome/results (neglect the fundamental understanding on (i) formula derivation (ii) why the steps come in (lack the ability to justify the steps that lead to the final answer / logical flow of the solution steps) (iii) tend to memorise steps (refer to the example & do it similarly). ▪ Not aware / not understand about the importance of engineering mechanics dynamics– how to link all these fundamental principles & knowledge for the later application (mechanical design)
3	▪ Foundation of students especially in physics not strong ▪ Visualization problems (dynamic movement that involved x-axis, y-axis and z-axis.)

The students' response on learning using the general learning software is summarized as stated in Table 5.5. From this Table, it can be identified that more than half (58.3%) of the students were aware of the learning software in engineering whereas the remaining 41.7% of the students were not aware about the technologies used in learning. There were 44.1% of the students who believed that some contents can be learned faster when using a computer whereas 42.5% of the students were unsure about this. It was identified that 44% of the students agreed and believed that they will engage in the learning by employing computer simulations while 48% of the students were unsure about this. There were almost half (49.6%) of the students who believed that the user interaction performed with the computer simulation on engineering models may enhance the learning process. Furthermore, it was interesting to find out that more than 50% of the students believed that the 2-D and 3-D animation on engineering model may help to support the visualization process.

Table 5.5 Summary of students' response on learning using courseware

Learning courseware					
Aware of / expose to the use of learning courseware	Yes: 74 (58.3%)		No: 53 (41.7%)		
	Strongly Disagree	**Disagree**	**Unsure**	**Agree**	**Strongly Agree**
I believe that some contents can be learned faster when using a computer.	2 (1.6%)	15 (11.8%)	54 (42.5%)	39 (30.7%)	17 (13.4%)
I believe I will engage in the learning with the use of /by employing computer simulations.	3 (2.4%)	7 (5.5%)	61 (48%)	44 (34.6%)	12 (9.4%)
I believe that the user interaction performed with the computer simulation on engineering models may enhance the learning process.	2 (1.6%)	7 (5.5%)	55 (43.3%)	52 (40.9%)	11 (8.7%)
I believe that the 2-D animation on engineering model may support the visualization process.	3 (2.4%)	8 (6.3%)	50 (39.4%)	52 (40.9%)	14 (11%)
I believe that the 3-D animation on engineering model may enhance the visualization process.	2 (1.6%)	3 (2.4%)	49 (38.6%)	50 (39.4%)	23 (18.1%)

5.2.4 Discussion

The results of this preliminary study revealed that the difficulties in learning mechanics dynamics are the problems that need to be solved as reflected in Chapter 1 section 1.4. This is especially referring to the visualization problems (see Table 5.2) that students faced throughout the process of learning. The findings on the visualization problems faced by students are consistent both from the students' response and the instructors' feedback. The visualization problems may arise due to few potential factors such as the use of text descriptions and the static representation of the figures in order to illustrate the dynamic movement of the mechanism that limit the visualization ability of the students. The use of information and communication technologies (ICT) such as the multimedia technologies may aid to enhance the students' visualization ability by using the interactive and animated contents representation in 2-D and 3-D. The proposed enhanced multimedia TAPS package with series of patterns of interactions would be discussed in details in Chapter 6.

The results of this research also indicated that the students faced difficulties in problem solving especially their ability to justify the steps involved or the lack of understanding about the logical flow of the solution steps as shown in Table 5.3. The detail guidance through the step-by-step approach can be provided in order to aid in the students understanding. This can be achieved through the help from the use of the ICT software (coach based approach) to guide the students following the step-by-step approach to the solution of the problem. Interaction with each of the step provided with useful hints and tips to guide the students may aid to enhance the students understanding. The interaction patterns that are grouped under the categories of knowledge retention and attention grabber are discussed more in details in Chapter 6 and Chapter 7. In addition, the ICT software constructed using multimedia technologies supports the characteristics by which the delivery of information (through multiple media / format), the organization in which it is delivered and the timing of that delivery can be controlled by the user (Cairnscross & Mannion, 1999; Manjit, 2006). This will give greater learning flexibility for the students (in engineering learning).

Furthermore, the results of this preliminary study also indicated that there is a huge potential in utilizing the ICT tools to aid in the engineering learning for mechanics dynamics subject. As referred to Table 5.5, it can be identified that there are still large number of students who are unsure about the potential benefits of ICT software in learning. Thus, further empirical research is urged to validate the potential of ICT software in realizing the educational benefits especially in the context of engineering education for a better or revolutionized engineering learning environment. The proposed enhanced multimedia TAPS package are discussed in Chapter 6 and the empirical results illustrate the usefulness of the enhanced multimedia TAPS package with proposed interaction patterns to support the engineering problem solving can be found in Chapter 7.

5.3 Learning Styles Preference (Using Honey and Mumford’s LSQ instrument)

5.3.1 Overview of Learning Styles in Engineering Education

In order to improve the quality of teaching and learning in engineering education, the student’s preference in learning is an important factor that should not be neglected by the education practitioners. This refers to the learning styles of the students. Learning styles are defined as the characteristic cognitive, affective, and psychological behaviours that serve as relatively stable indicators of how learner perceives, interacts with, and responds to the learning environment (Keefe, 1991). According to Felder (1996), learning style refers to the characteristics strengths and preferences in the way people take in and process information. As the engineering instructor, we should be aware that different students are comfortable with different learning styles (Felder & Brent, 2005). A better understanding of the students learning styles may help the educator to design for better teaching and learning strategies that may suit for different students’ preferences in learning. The literature review and details descriptions on learning styles can be referred to Chapter 2 section 2.5.

5.3.2 Methodology

In this study the Honey and Mumford's Learning Styles Questionnaire (LSQ) was employed. The questionnaire was prepared and administrated to the students in the hardcopy form during the mid of the first study semester in July 2012. Five sections of the year 3 mechanical engineering students were involved and out of 120, a total of 107 samples were collected. Two mechanical engineering academic instructors were involved in the survey by distributing the questionnaires to the students for approximately 20 minutes before the class ended. A short briefing was provided for the students before the questionnaire was distributed. Each student took approximately 12 to 15 minutes to complete the questionnaire. Two weeks before the survey was conducted, the pilot questionnaire was distributed to two of the academic staff and two of the final year engineering students. The distribution of the pilot questionnaires served two purposes (Lowery, 2009): firstly to determine the duration for completion and secondly to identify potential problem(s) with the questionnaire design (layout and readability). Feedbacks were collected through the pilot study and remedial steps were taken. Regarding the readability issue, some of the terms or phrases used in the questions were found to be slightly difficult for the non-native English speaking students to understand. This may lead to the misunderstanding of the listed questions, thus created the potential to affect the results findings. Therefore, additional description for certain terms and phrases were added to aid in the students understanding. Furthermore, the duration for the questionnaire completion was noted to be at least 15 minutes. A sample questionnaire of the Honey and Mumford's Learning Styles Questionnaire (LSQ) can be referred to Appendix B.

5.3.3 Findings and Analysis

A total of 107 students returned the completed LSQ questionnaires. Since three (3) of the questionnaires were incomplete, the total numbers of questionnaires that were used for data analysis were 104. For the purpose of data interpretation and analysis, Honey and Mumford's scoring norm in the UK (1992) was used as the main reference (see Table 5.6). Through the scoring norm's Table, it can be identified that the scores are divided into five groups from very strong preference to very low preference. If the respondents score in the LSQ survey was found to be above the average, it is likely to indicate that the respondents are having the greater preference in a particular learning style. Otherwise, it is likely to indicate that the respondents are having lower preference in a particular learning style.

Table 5.6 Scoring norm in the UK (*n = 3500*) as defined by Honey and Mumford (Honey & Mumford, 1992)

	Activist	**Reflector**	**Theorist**	**Pragmatist**
Very strong preference (highest score 10 per cent)	13-20	18-20	16-20	17-20
Strong preference (next 20 per cent)	11-12	15-17	14-15	15-16
Moderate preference (middle scoring 40 per cent)	7-10	12-14	11-13	12-14
Low preference (next 20 per cent)	4-6	9-11	8-10	9-11
Very low preference (lowest 10 per cent)	0-3	0-8	0-7	0-8
Mean score	9.3	13.6	12.5	13.7

A detailed distribution of engineering student's preferences is compiled and listed as shown in Table 5.7. Based on the 104 respondents, it can be clearly identified that almost three fourth (78%) of the engineering students scored within the range of strong to very strong preference towards the activist learning style. More than half (63%) of the engineering students scored within the strong to very strong preference range for the reflector style. For theorist learning style, more than half (68%) of the engineering students scored within the range of strong to very strong preference. Only 43% of the engineering students scored within the range of strong to very strong preference.

Table 5.7 Detailed distribution of UNITEN engineering student's preferences according to LSQ

Preference	Student's Learning Styles (*n=104*)			
	Activist	**Reflector**	**Theorist**	**Pragmatist**
Very strong	64 (61.54%)	29 (27.88%)	38 (36.54%)	18 (17.31%)
Strong	18 (17.31%)	37 (35.58%)	33 (31.73%)	28 (26.92%)
Moderate	20 (19.23%)	30 (28.85%)	28 (26.92%)	45 (43.27%)
Low	1 (0.96%)	7 (6.73%)	4 (3.85%)	13 (12.5%)
Very Low	1 (0.96%)	1 (0.96%)	1 (0.96%)	0 (0%)
Mean score	13	15.53	14.52	14.19

In order to know the respondents preference in learning style, the mean scores of the engineering students' LSQ were generated and listed in Table 5.7. Through the comparison of the means scores between the engineering students with the general norms in the UK, it can be identified that students show relatively higher preferences in the activist, reflector and theorist categories. As referred to Table 5.6, students have very strong preference in activist while strong preference in reflector and theorist. However, students only achieved moderate preference in the pragmatist learning style. This is the learning style that students may need enhancement. Referring to Table 5.8, the results of the mean score of engineering students indicated that all the learning styles preferences are above average. This shows balanced learning styles preference for the engineering students and is a good indicator for learning through various methods. It was noted from the research result that engineering students in UNITEN have quite a balance in their learning styles while likely weak in the pragmatist preference which could be due to lack of opportunities to express their ideas relating to real life applications. This may be further due to the teacher-centered teaching approach used (passive and less interactive) rather than the student-centered approach used throughout the learning process in UNITEN.

Table 5.8 Comparison of the mean scores between engineering students in UNITEN with the general norms in UK

	Range	**Mean**	**Honey and Mumford 1992 norm** (Honey & Mumford, 1992)
Activist	2-20	13	9.3
Reflector	6-20	15.53	13.6
Theorist	7-20	14.52	12.5
Pragmatist	9-19	14.19	13.7

5.3.4 Discussions

The results of this research study showed that UNITEN students have a very strong preference towards the activist learning style. As known, activist learners are those learners that like to learn through the trial and error process. They have the strong willingness in trying new things. This indicated that the engineering students are open minded in the process of learning and willingly to act towards new form of learning experience. The traditional one way (passive) teaching and learning strategies in the engineering education may limit their learning potentials. This is a good indication by which the information and communication technology (ICT) software can be proposed and utilized in order to aid the engineering students in their formal learning process. For example, the utilization of ICT software in creating interactive learning environments for the engineering students to interact and experiment with 2-D or 3-D mechanics models may lead to better visualization. In fact, the smart ICT software such as the use of interactive multimedia educational applications that utilize the text, graphics, audio, video and animation elements in delivering the engineering concepts may further enhance the learning experience of the students to acquire the techniques for engineering problem solving.

Through the research findings, the students also showed strong preferences towards theorist and reflector styles of learning. For theorist, as known in the literature, they are the ones that emphasize more on logical thinking and are likely to involve in the process of analyzing and synthesizing based on principles and theories. This indicated that the students may prefer to learn and solve the engineering problems by following the step-by-step logical approach. Thus, the teaching and learning strategies should emphasize more on the sequential and systematic way of problem solving to enhance the students learning abilities in knowledge absorption. It is suggested that the use / incorporation of coach based interactive multimedia applications that provide the step-by-step guidance features may aid the students learning process according to their own time and pace (Manjit, 2006). For reflector, they are the types that prefer to collect as much data thoroughly before coming to any conclusion. They prefer listening and observing before reaching any conclusion. Thus, in the design of the teaching and learning strategies, the engineering educators should be aware of the reflector style of learning in providing comprehensive background knowledge to aid the students learning. They are the types that like to grasp the 'whole picture' of the scenario for the engineering problems before proposing any solutions. Digital storytelling that utilizes the interactive multimedia technologies to deliver the presented knowledge contents in both the visual and verbal way may aid in the background understanding of the engineering scenario for the students. One of the strengths of digital storytelling is to increase the learners' comprehension of contents (Lowenthal & Dunlap, 2010). However, the research studies on the educational use of digital storytelling in engineering education is still in its infancy state that could be explored further.

The least preference style of learning for engineering students in UNITEN is the pragmatist style as compared to the others. Pragmatist learners are keen on trying out new ideas, apply the new ideas and strongly prefer demonstrations using real examples or real life situation. These findings raised an important issue for the engineering educators that the students are not aware of the importance or not likely to cultivate the behavior of generating new ideas or keen to try out new ideas into practice. As known, in the knowledge driven era, the creative ideas are the main source for the innovation efforts. Currently, the innovation efforts are the main competitive advantage for survival in the knowledge driven global era. As emphasized in (Duderstadt, 2008), one of the new paradigms in engineering education is to cultivate the ability not only to adapt to change but to actually drive change in the global market environment. The ability to drive change in the engineering industries may refer to those organizations that continuously introduced new products, technologies, services and process as the sustainable market leaders. This tied strongly with the ability to innovate (creative ideas and implementation).

5.4. Learning Styles Preference (Using Ogden's Personality and Learning Styles Questionnaire)

5.4.1 The importance of Learning Styles in Engineering Education

In the era of knowledge society, paradigm shift in engineering education is unavoidable in response to the rapid changes in the global market environment that emphasize on the innovation efforts for competitive advantage. Many practitioners in the engineering industry looked seriously into this issue and proposed for new paradigms of engineering education in response to the changes in today's increasingly knowledge driven environment. The details can be found in numerous research papers and reports (Chua, 2014; Froyd et al., 2012; Mistree et al., 2014; National Academies of Science, Engineering, and Medicine, 2007; National Science Board, 2007; Prados, 1998; Rajala, 2012; Rosen, 2007; Wince-Smith, 2005). (Refer to Chapter 2 for detail descriptions). In order to further enhance the quality of teaching and learning in engineering education, the students' preference in learning is an important factor that should raise the attention of the education practitioners. This referred to the learning styles of the students. Learning styles are defined as "*the characteristic cognitive, affective, and psychological behaviors that serve as relatively stable indicators of how learner perceives, interacts with, and responds to the learning environment*" (Keefe, 1991, p. 4). As the engineering instructors, we should be aware that different students are comfortable with different learning styles (Felder & Brent, 2005). The understanding of students' preferences may contribute to the adjustment of teaching strategies and the design of learning instructions that will better accommodate for students learning needs (Cavanagh & Coffin, 1994; Chen & Chiou, 2012; Graf, 2007; Graf et al., 2007; Noguera&Wageman, 2011; Pedrosa de Jesus et al., 2004).

5.4.2 Methodology

The study for this section aimed for two objectives. Firstly is to investigate the learning preference for engineering students in UNITEN by means of the Personality and Learning Styles instruments. Secondly is to compare the current research finding with the previous learning styles research (see section 5.3) on engineering students in UNITEN.

In this study, the personality and learning styles questionnaire designed by Ogden (2007) was adopted. This is because (i) it is primarily intended for those in an academic environment and may suit to engineering education, (ii) it provides customized and constructive feedback for each individual regarding their learning behavior and preferences and (iii) it is free and easily available online with prompt response on the student's learning styles preference. The current findings were compared with two of the previous research in learning styles as discussed in the next section (5.4.4). The personality and learning styles questionnaire is comprehensive and is about 12-15 pages long. It is available online without any charges. In the questionnaire, students are asked to respond themselves against the 76 statements using a five (5) point Likert Scale. The sample of the personality and learning styles questionnaire designed by Ogden can be referred to Appendix C. Once the student submitted the questionnaire online, an instant report was generated and suggestions on how the student can utilize his/her mind and adapt their behavior to learn more effectively was provided.

In August 2012, five sections (150 students) of the 3rd year mechanical engineering students from Universiti Tenaga Nasional (UNITEN) were invited to participate in this research study and a total of 122 samples were collected through online questionnaire. The response rate of the survey achieved was 81.3%. Two mechanical academic staff were involved in assisting the students throughout the process. Short briefing was provided regarding the purpose of this research and the procedures needed to complete the questionnaire before the students started to fill in the questionnaire. Each student took approximately 15-20 minutes to complete the online questionnaire. The reports generated were collected for analysis purpose using descriptive statistical method.

Two weeks before the actual survey, two of the academic staff and three of the final year students were invited to try on the pilot questionnaire. The questionnaire design (layout and readability) was found to be professional (simple and clear to understand). The duration for the questionnaire completion was recommended to be 15 to 20 minutes. The data was collected and the details were analyzed as referred in the following section.

5.4.3 Data analysis and results

Through the reports generated, the students (respondents, n=122) were classified as adopting a particular learning style preference, based on the score obtained on individual scale using the personality and learning style questionnaire. According to Ogden (2007), the learning model for each student comprises of three key areas, each split down the middle into two opposite styles (Figure 5.1). The student’s response may fall in either side of the key area and this indicated a “type” or preference in learning as shown in Figure 5.1. If the student is not scoring much out of the middle band for a particular area (the higher the scale scored, the stronger the preference), this showed that the student does not have a strong preference one way or the other in that area, which means the student is likely to take a balanced approach.

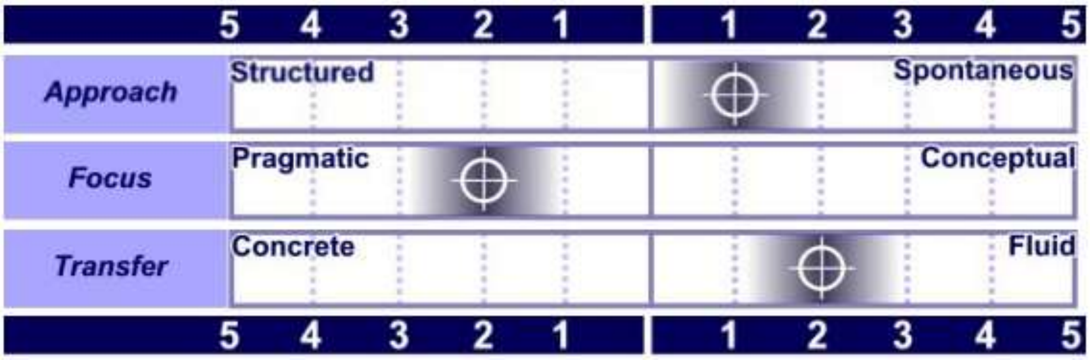

Figure 5.1 Sample graph indicated a student's learning preference according to three key areas.

As referred to Ogden (2007) and discussed in Chapter 2, section 2.5.2.5, the model explores three key areas, highlighting how the student may prefer to go about learning things or approaching tasks. Based on the data collected from 122 students, the learning preference scale score and its distributions are compiled as shown in Table 5.9.

Table 5.9 Learning preference scale score of the engineering students (*n*=122)

Key areas	towards <-----------	Scale										towards ----------->
		5	4	3	2	1	1	2	3	4	5	
Approach	structured	0	0	3	2	4	15	55	36	7	0	spontaneous
Focus	pragmatic	9	19	51	26	10	4	3	0	0	0	conceptual
Transfer	concrete	2	13	43	29	28	2	4	1	0	0	fluid

The graph shown in Figure 5.2 illustrates the distribution of students' learning preference scale score that was derived from data in Table 5.9. According to the student's learning preference in three key areas, there were eight possible combinations of learning preferences. A detailed distribution of the engineering student's preferences according to the eight combinations of learning preference is compiled and listed as shown in Table 5.10.

From the 122 respondents (see Figure 5.2 and Table 5.10), it can be clearly identified that 77.87% of the engineering students have the learning preference on spontaneous + pragmatic + concrete style. This is followed by 10.66% of the engineering students having the learning preference on spontaneous + pragmatic + fluid style. While 4.1% of the students have the learning preference on the structured + pragmatic + concrete style and spontaneous + conceptual + concrete style. The remaining 3.3% of the students prefer the learning in structured + conceptual + concrete style.

As discussed in the previous section, the student learning preference can also be represented using "Hemispheric Map" diagram (see Chapter 2, Figure 2.7). It is based on the same scales and data as shown in the graph (see Figure 5.1) previously, but presents data in an alternative way. The eight possible combinations of learning preferences according to the 3 key areas can be further categorized into either the left hemispheric preference or right hemispheric preference. Table 5.11 shows the detailed categorization of students' scoring and learning preferences according to the hemispheric map. It was noted that almost two third (80%) of the students have the left preference side of brain when processing information. Only 14.76% of the students' response indicated for right preference side of brain when processing information.

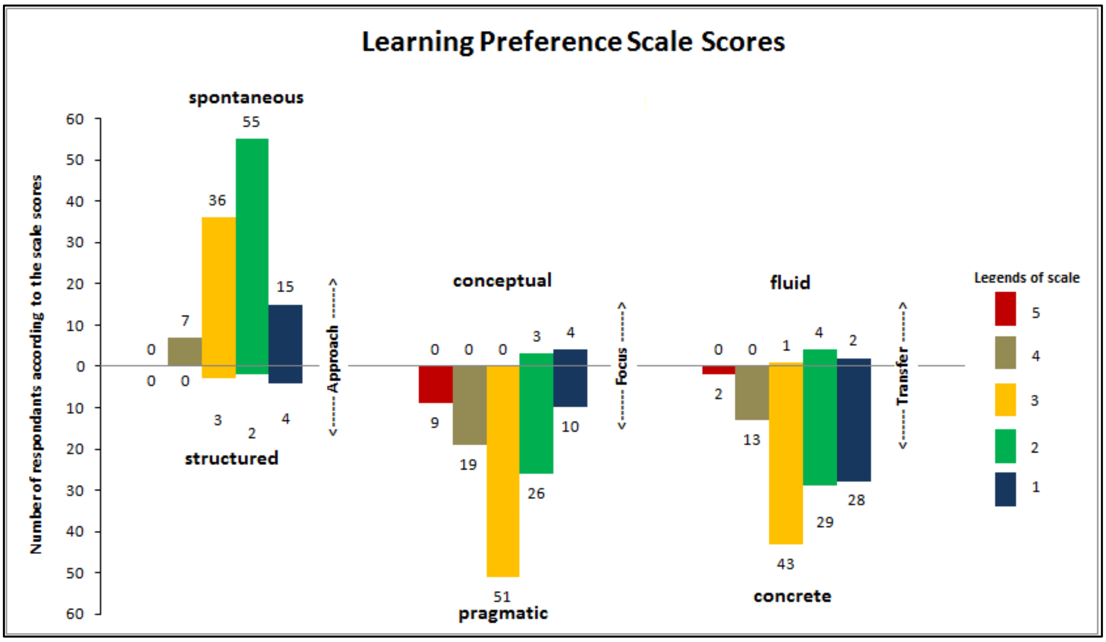

Figure 5.2 Distribution of students' learning preference scale scores (3 key areas)

Table 5.10 Detailed distribution of UNITEN engineering student's learning preferences (3 key areas)

Learning preferences	Sample (*n*)	Percentage (%)
Structured + Pragmatic +Fluid	0	0
Structured +Pragmatic + Concrete	5	4.1
Structured + Conceptual + Concrete	4	3.3
Structured + Conceptual + Fluid	0	0
Spontaneous + Conceptual + Fluid	0	0
Spontaneous + Pragmatic + Fluid	13	10.66
Spontaneous + Pragmatic + Concrete	95	77.87
Spontaneous + Conceptual +Concrete	5	4.1
	122	100

Table 5.11 Categorization of students' learning preference according to the hemispheric map

Left hemisphere preference	Percentage (%)	Right hemisphere preference	Percentage (%)
Structured + Pragmatic +Fluid	0	Structured + Conceptual + Fluid	0
Structured +Pragmatic + Concrete	4.1	Spontaneous + Conceptual + Fluid	0
Spontaneous + Pragmatic + Concrete	77.87	Spontaneous + Pragmatic + Fluid	10.66
Structured + Conceptual + Concrete	3.3	Spontaneous + Conceptual +Concrete	4.1
	85.27		14.76

5.4.4 Discussion

Through the research findings, it was identified that 75% of the engineering students preferred the spontaneous + pragmatic + concrete style and a preference for using the left side of the brain. Spontaneous style learners get the best out of learning when they are allowed to get stuck quickly and try things for themselves. Furthermore, they prefer to learn through the "trial and error" process with sufficient "doing" activities. They will easily get bored with routine and will need lot of variety learning activities to keep them focused. Meanwhile, pragmatic style learners are more focused on the practical, tangible and immediate benefits of learning things. They learn more with "hands-on" exercises, easily get bored with learning about theories or concepts that are complex or less relevant and prefer to keep things simple and easy-to-understand.

The strong preference towards spontaneous style and pragmatic style of learning are consistent with the findings in section 5.3. In the previous findings (see Table 5.12), engineering students showed a very strong preference in activist learning style using the Honey and Mumford's LSQ. As known, activist learners are those learners that learn best when they are actively involved in new tasks. They are highly involved in tasks, prefer new challenge and likely to learn through the trial and error process. The research findings also showed that engineering students had higher preference in active dimension as compared to the reflective dimension using Felder and Silverman's learning styles questionnaire (see Table 5.12). This is also consistent whereby the research findings for engineering students in other universities reported the same (higher preference towards active dimension (see Chapter 2, Table 2.12).

As defined by Felder and Silverman (1988), active learners learn by doing and participating through engagement in physical activity or discussion. Thus, Martínez Cartas (2012) recommended the instructors to provide practical troubleshooting methods or drill exercises to provide practice in order to accommodate the learning preference for active learners. This clearly provides evidence that the traditional “chalk and talk,” passive and one way delivery of the teaching and learning process for the engineering subjects would not fit well with the students’ learning preference. More variety of learning activities that actively involved the students in performing new tasks should be introduced, for example: practical troubleshooting methods and active experimentation.

Table 5.12 Comparison of three research studies on UNITEN engineering students learning preferences

Learning style instruments	**The Felder-Silverman ILS**	**Personality and learning styles questionnaire**	**Honey and Mumford’s LSQ**
Survey conducted	(Manjit Sidhu, 2009)	August 2012	(see section 5.3)
Respondents (*n*)	*n* =60	*n*= 122	*n* = 104
Findings (Learning Preferences)	85% geared towards sensing learners 100% geared towards visual learners 90% geared towards active learners 86.7% geared towards sequential learners	(1) More than 80% of the respondents have the preference to use the left side of the brain for thinking and learning. (2) Left hemisphere preference: (i) solves problems in a step-by-step, logical manner (ii) prefers established, more objective types of information (iii) Likes things with a clear answer or predictable outcome (iv) Less open or valuing of feelings (v) Looks for cause and effect	(1) Very strong preference towards activist learning style (2) strong preference towards theorist and reflector styles (3) Likely weak in the pragmatist preference

With the advancement in Information and Communications Technology (ICT), many technologies can be utilized to aid in the formal teaching and learning of engineering education (Fernandez et al., 2011; Yueh et al., 2014). In the next Chapter (Chapter 6), the enhanced multimedia TAPS software was proposed and developed to assist the students in their learning in engineering problem solving. About 25 proposed patterns of interactions were embedded and tested in the enhanced multimedia TAPS software to assist the students leaning. In addition, the development of engineering simulation tool such as the Desktop Virtual Reality featured (see Table 5.13) would help the students (with spontaneous and pragmatic learning style) to experience the operations process of the engineering mechanism through the interaction with 2-D and 3-D animations. The problem solving mechanism in the engineering software tool provides timely feedback and assessment directly related to learner's interactions. This will lead to exploratory approach in learning and better visualization of the engineering concepts especially those problem that involves dynamic motion. Other researches also support that visualization skill is important in engineering and science (Ault & John, 2010; Pedrosa et al., 2014).

As for the concrete style learners, they are good at applying their learning to clearly define problems or questions. They prefer to follow a step-by-step approach to learn a well-defined task or a clear, straightforward subject area. This finding is consistent with the previous research study that engineering students have higher preferences towards sequential dimension in Felder and Silverman learning style model (see Table 5.12).

As described by Felder and Silverman (1988), sequential learners preferred linear thinking process rather than holistic thinking process and usually will learn through small incremental steps. This indicated that the engineering students have the preferences to learn and solve the engineering problems through the logical step-by-step approach. In order to maximize the learning experience for better knowledge absorption, the teaching and learning strategies should emphasize more on the systematic and sequential step-by-step approach for engineering problem solving.

Table 5.13 Recommended ICT tools to support the learning styles of engineering students

<table>
<tr><th>Style of learning</th><th>Characteristic</th><th>ICT</th><th>General outcome and benefits</th></tr>
<tr><td rowspan="2">Spontaneous</td><td>-prefer to learn through the "trial and error" process with sufficient "doing" activities</td><td rowspan="5">3-D Desktop Virtual Reality TAPS package
-employed 2-D graphics, 3-D geometric model, colors, sound and "tweening" technique to produce animation (Wu et al., 2006)
-employed simple expert system rules to coach user in a 3-D dynamic problem solving environment with dynamic feedbacks
-provide animated and static stereoscopic images to enhance visualization (Hueser et al., 2006)</td><td rowspan="5">-Allow student to experiment simulated problem-solving in 3-D environment (Boggess & Harding, 2007) for better interaction and visualization
-With simulations, students are able to take a more active role in learning.
-Dynamic representations enable more efficient communication of complex engineering concepts
- The problem solving environment provides timely feedback and assessment directly related to user's interactions.
- The stereoscopic images and animated models could create the great interest and enthusiasm in learning.</td></tr>
<tr><td>-easily get bored with routine and will need lot of learning activities to keep them focused.</td></tr>
<tr><td rowspan="3">Pragmatic</td><td>-prefer to learn more with "hands-on" exercises</td></tr>
<tr><td>-easily get bored with learning about theories or concepts that are complex or less relevant</td></tr>
<tr><td>-prefer to keep things simple and easy-to-understand</td></tr>
<tr><td>Concrete</td><td>-prefer to follow a step-by-step approach to learna well-defined task or a clear, straightforward subject area.</td><td>Coach based TAPS package
-employed simple expert system rules to coach user through the sequential order in engineering problem solving task
- employed 2-D graphics, colors, sound and "tweening" technique to produce digital learning environment</td><td>-Coaching is provided to enhance the user's problem solving experience while performing complex tasks in 2-D environment (Horvath, 2017)
-The problem solving environment provides timely feedback and assessment directly related to the user's interactions.
-The feedback helps increase the user's ability to reason and analyze the problem solving environment.</td></tr>
</table>

Currently, it can be clearly identified that the teaching and learning in engineering for problem solving did emphasize on the sequential step-by-step approach. However, it was found that there was insufficient justification for each of the step involved throughout the problem solving process especially those sample questions provided in the engineering textbooks. Although many of the engineering instructors did perform verbal explanations regarding the steps involved by using the limited sample problems provided in the textbook, many of the students (especially those slow learners in term of engineering domain) still face the difficulties in gaining the understanding regarding the steps involved and the justification for it. Thus, it is suggested that coach based interactive Technology Assisted Problem Solving (TAPS) package can be used to aid in the students learning process through the step-by-step guidance procedure (Manjit, 2006, see Table 5.13). This may enhance the students understanding regarding the "what," "why" and "how" for each of the step involved for the engineering problem solving according to their own learning time and pace. More details regarding the design and development of TAPS packages can be referred to (Manjit Sidhu, 2006).

From the research findings, it can be identified that more than 80% of the students (see Table 5.11) have the preference for using the left side of the brain. For the left brain dominant learners, the students will be more comfortable to learn and solve problems in a step-by-step, logical manner. This is useful when dealing with complex engineering problems whereby the students will normally break the complex problem into different parts and solve the problem part by part in a sequential order till the final outcome is achieved. Through this, the students may be able to see the logical flow of the questions and this is an effective way of solving the engineering problem.

In order to strike a balanced learning approach, the engineering instructors may put in some efforts to guide and train the students to exercise their right brain by relating the thinking sense in a wider picture. This means that the students should be trained to think how to relate a specific problem to the main topic in learning and how does it fit to the learning outcomes and learning objectives. At the same time, how this particular problem solving may relate to the real life applications and how does it benefit / contribute to the welfare of the society should also be part of the concern for the students (as the open ended questions for thought) besides the traditional learning in developing the problem solving skills. So, in the long run and for developing balanced learning skills, students should be well equipped with solving the engineering problems both through the bottom-up approach (exercise the use of left brain) and the top-down approach (exercise the use of right brain). As stressed by Franzoni and Assar (2009), "whole brain" learning is known to be a far more effective way to learn.

In order to exercise the right brain, the students may try to think out of the box when solving the engineering problems by providing the “what-if” alternative solution. This may train the students to start valuing the problem by providing not only the standard solution but also some alternative creative ideas for it. Regarding this issue, the engineering instructors are encouraged to create the opportunity in the teaching space to allow students to think out of the box and propose new ideas. Ideas are more important and students should be provided with the opportunity and space to raise their ideas. Creative ideas are the main source for radical innovation that may lead to potential paradigm shift in the near future. The learning activities such as the brainstorming session in a small group, ideas presentation should be encourage and embedded in the class especially for engineering design subjects. This provides the opportunity for the students to express their thoughts, opinions and feeling towards engineering design and at the same time cultivate their interest to appreciate the previous design and the current design. This is consistent with the discussion on the new paradigm of engineering education as can be found in Duderstadt (2008).

Through the research findings, it can be identified that engineering students in UNITEN shared a common learning style preferences that they preferred to learn in sequential, logical way with various hands-on practical activities. They are “open-minded” and prefer to try out new forms of learning activities. However, the current teaching and learning approach may not fully accommodate the learning preference of the students. The efforts on how to shape a balance learning approach by utilizing the current learning preference and strengthen the less preference way of learning is a great challenge faced by the engineering instructors. Carefully designed and well-structured multimedia TAPS software that match the learning styles of engineering students could strengthen their problem solving skills. The findings in this Chapter (students learning difficulties from both the students and instructors feedbacks from section 5.2.3 and the students learning styles preferences from section 5.3.3 & 5.4.3) acted as the main supporting references for the development of the enhanced multimedia TAPS package with proposed patterns of interactions as discussed in the next Chapter.

CHAPTER 6

ENHANCED MULTIMEDIA TAPS FOR MECHANICS DYNAMICS

6.1 Overview

In this Chapter the teaching and learning of mechanics dynamics in UNITEN from which the learning problems were identified are discussed. The development process for an enhanced multimedia TAPS package embedded with twenty five proposed patterns of interactions to facilitate the learning process of students in engineering problem solving in the context of mechanics dynamics is also discussed.

6.2 Engineering Education in UNITEN

Universiti Tenaga Nasional (UNITEN) is one of the established private universities since 1997. UNITEN is well known among the private universities in Malaysia especially for its engineering education. UNITEN offers the engineering education courses on mechanical engineering, electrical and electronic engineering, electrical power engineering, computer and communication engineering and civil engineering. In the mechanical engineering course, mechanics dynamics serve as a core and fundamental course for the mechanical engineering programme (Gray, Costanzo & Plesha, 2013; Ha & Fang, 2015; Hibbler, 2015; Merriam & Kraige, 2007). In UNITEN, the mechanics dynamics course is a three credit hours course that is offered during the first and second semester, every year. This course serve three purposes: (i) to instill an appreciation for the role of kinematics and kinetics in engineering problem solving (ii) to provide students the required knowledge in the theory and application of engineering mechanics and (iii) to enable students to apply the knowledge of dynamics in the design of engineering systems. The pre-requisite for this course is mechanics statics. Based on the course outline provided by the course coordinator (Department of Mechanical Engineering, 2016),

> "*This course enables the student to understand the importance of dynamics in Engineering systems, the acquisition of sufficient knowledge of the theory of dynamics and to apply them in the analysis of dynamic system as well as to apply the knowledge of dynamics in the design of engineering systems*."

6.3 The Teaching and Learning of Mechanics Dynamics in UNITEN

The mechanics dynamics course is conducted through the lecture and tutorial sessions. Based on the interview with respective course coordinators, in-class observations and from the descriptions in course outline (Department of Mechanical Engineering, 2016), the teaching and learning of mechanics dynamics in UNITEN still focuses more on the teacher-centered approach although there exists in-house built TAPS packages for the students to aid them in their learning. Teacher-centered approach focus more on one way delivery mode by which instructor plays an active role both in the lecture and tutorial sessions. Passive student's participation throughout the learning process was identified (see section 5.2.3).

In the lecture sessions, the instructor delivers the new topics verbally with the aid of PowerPoint slides presentation. Sometimes, the new concepts are further illustrated using the white board especially on the descriptions of theory, drawing of free-body diagram and the derivation of equations. Additionally, there are tutorial sessions in order to assist the students in understanding the concepts learned in the lecture sessions. The students are provided with some tutorial questions that serve to enhance the students understanding on the new concepts and theory learned before. The tutorials are usually given in a form of few problems that are similar to the sample problem found in the textbook. The sample solutions will be provided and discussed by the tutors for the students during the tutorial sessions. Many of the students keep waiting for the sample solutions without trying to think or solve the problems given. Thus, the student highly relies on the tutors for sample solutions. Beside the lecture and tutorial sessions, the assessments for the students are performed through the short quizzes in class, mid-term test, assignment and final examination.

Recently, the University management did encourage the design, development and implementation of technology assisted learning through the intensive use of ICT technologies and equipment. As such the UNITEN teaching staff is taking the efforts to introduce the technology enabled learning activities. For example some of the instructors took the initiative to implement the video based learning in the lecture session by which the video materials were used to demo some of the concepts for mechanics dynamics. This helped the students to partially visualize the dynamic movements of the engineering model. However, the limitation in the nature of video format is that it is still linear form of presentation with lack of engagement with the students. The students cannot interact further with the contents in the video (passively view the contents). This is one of the common problems raised in the literatures that just video format material may not be enough to engage the students in visualization tasks (Cairncross & Mannion, 1999; Fang, 2012; Kabouridis, 2010; Makarova, 2015; Pocsova et al., 2016).

The use of learning software to facilitate the teaching and learning process is highly recommended in UNITEN. Some of the instructors did take the initiative to introduce some engineering learning software in the lecture sessions. This is a good initiative in response to the new paradigm shift in engineering education that emphasize on the use of ICT to facilitate the teaching and learning process. Some of the existing software in UNITEN was found to be good especially on the graphical representation. However, it involved only 2-D animations with lack of interactivity.

Although this may help the students to support their visualization for x-axis and y-axis representation of the engineering model, it is not sufficient since some of the topics in dynamics course not only involve the understanding of x-axis and y-axis, but also the z-axis. Without proper understanding of the dynamic movement of the engineering model that involved x, y and z-axis, the students may fail to acquire a better visualization of the engineering model thus directly affect their effort in engineering problem solving. Dynamic engineering problems are better understood by students especially when they are represented in a 3-D environment.

Previous software developed by staff and used by students in UNITEN was found to be limited for the contents presentation since the sample solution just directly indicated the final answer (values) without showing the proper steps (working procedures in detail) that lead to the final answers. Engineering students normally preferred to solve the problem through the step-by-step approach (see the research findings in Chapter 5 Sections 5.3.3 and 5.4.3).

As mentioned above although some of the engineering learning software did provide the working steps for the students (showing the HOW) in a sequential order but it was found to be limited especially to facilitate the students' reasoning (knowledge comprehension) behind each of the step involved (showing the WHY) that associated with the engineering principle learned previously. This reflected the concern through the feedbacks collected from the engineering instructors (see Chapter 5 Section 5.2.3) that students were found to be lacking (unable to relate and comprehend the theory learnt in class thus have weak foundation in solving the particular problem) was the ability to justify the steps involved or lacked the understanding about the logical flow of the solution steps. Failure to acquire a strong understanding especially the fundamental principles and knowledge would lead to the difficulties faced while moving into the final year mechanical design courses.

On the other hand, some of the interface design of the engineering learning software did not follow the proper human computer interface design guidelines, thus may confuse the students when interacting with the software. Proper design of the user interface is important since the students (learners) will directly interact with the interface while performing the learning activities (Atoum & Bong, 2015; Savin-Baden, 2010; Zaharias & Mehlenbacher, 2012). More discussions on the interface design and the importance of usability associated with learning can be found in Chapter 3. Since there are insufficient findings regarding the valid usability testing of the interface design for the engineering learning software currently used, the software may not fit to the students learning preferences in engineering problem solving. Therefore extensive empirical studies are needed to further explore the usability aspects of the respective software.

Based on the results findings in Chapter 5 (users requirements gathering and analysis), the enhanced multimedia TAPS package embedded with 25 proposed patterns of interactions was developed and tested (see Chapter 7) to aid the students in engineering problem solving. In the next section, the enhancement of the multimedia TAPS packages embedded with the 25 proposed patterns of interactions is discussed in details.

6.4 Enhanced TAPS Package with Proposed Patterns of Interactions

The attributes and the features for multimedia TAPS packages were discussed in details as stated in Chapter 2 Section 2.4.3. Based on the suggestions by Manjit (2006), the multimedia TAPS packages can be further enhanced with proposed patterns of interactions embedded in a standard user interface (this is due to the availability of better technological software development tools and changing trends of the user interface). The interaction patterns referred to / defined as the features or interaction objects (metaphors) that are available on the user interface of the multimedia TAPS packages. This may aid to facilitate the engineering problem solving using multimedia TAPS packages since the students would highly interact with the features (different interaction patterns) available on the user interface while solving the engineering problem. Thus, it is necessary to investigate the usage of the proposed patterns of interactions for TAPS package for engineering problem solving. In this research, 25 proposed patterns of interactions were proposed to be embedded into the enhanced multimedia TAPS package (based on the survey feedback that was done on learning styles prior to designing the TAPS package). The descriptions of the 25 proposed patterns of interactions can be found in Table 6.1 and Appendix H. Exploratory factor analysis statistical method was performed (see Chapter 7 Section 7.4) to investigate the categorization of these 25 proposed patterns of interactions. The patterns of interactions can be grouped into five main categories, namely the "visualization", the "attention grabber", the "knowledge retention", "supportive patterns 1" and "supportive patterns 2". The diagrammatic representation of these 25 proposed patterns of interactions can be referred to Figure 6.1.

As referred to Table 6.1, the "visualization" category consists of seven patterns of interactions that are related to support the visualization tasks when the students interact with the enhanced multimedia TAPS package. Five out of seven of the interaction patterns are designed in order to support the student's interaction in the 3-D module which is the 3-D model controller, stereoscopic 3-D viewer, multi-dimensional 3-D viewer, 3-D trail generator & controller and zooming features. Whereas the graph generator controller is designed to support the student's interaction with the graph generation in the graph module. The 2-D animation controller is designed to support the student's interaction with the 2-D animation to see the movement possibility for the 2-D engineering mode (in this case, refers to the rotating-axes).

Table 6.1 Detail descriptions of the 25 proposed patterns of interactions for enhanced multimedia TAPS

No.	Categories	Interaction Patterns	Purpose
1	**Interaction Patterns for Visualization**	Graph generator controller	To control the parameters set for graphs (allow the users to interact with the graph through different parameters settings to visualize different situations of the dynamic movement with different value sets)
2		2-D animation controller	Allow the users to interact with the 2-D model using the controller to see the dynamic movement of the 2-D model.
3		3-D model controller	Allow the users to have basic interactions with the 3-D model to 'play' around with the model for better visualization
4		Stereoscopic 3-D viewer	-Provide the views of different angles for the 3-D model (to aid in visualization with 3D glass) -Evoke the interest of the students
5		Multi-dimensional 3-D viewer	Provide the views of different angles for the 3-D model (to aid in visualization)
6		3-D trail generator & controller	Assist the students in understanding /visualizing how the motion trail looks like in dynamic 3-D form
7		Zooming	Allow the users to zoom in (enlarge) / zoom out (minimize) the view of the 3-D models for clearer view
8	**Interaction Patterns for Attention Grabber**	'expand/hide' effect	To support the expansion of contents or hiding the unnecessary contents
9		Blinking effect	Visual cue for attention grabber
10		Animated line	Visual cue for attention grabber used as a highlighter)
11		Animated arrow	Visual cue for attention grabber used as a highlighter)
12		Mouse over 'highlighting' effect	Visual cue for attention grabber (used as a highlighter)
13	**Interaction Patterns for Knowledge Retention**	Interactive 'point-click-response' feature	To allow the students to choose the options for the answers and provide instant feedback based on chosen answer
14		'interesting fact' feature	Support the students learning through the explanation provided regarding different graphs scenario
15		Answer checker	Provide feedbacks for the students on answers key in
16		'fill-in-the-blank' feature	To let the students to key in the answers
17		'pop-up hints/ tips' window	To assist as a reminder regarding the fundamental concepts for mechanics dynamics
18		Hovering effects	Mouse over certain object, the object will be highlighted and few selections can be further performed based on the options offered.
19	**Supportive Patterns I**	Nomenclature	Support the explanation for the definition of the SI unit and its purpose
20		Help feature	The description for the icons used in the system
21		Glossary feature	Support the searching of the technical terms and its definition
22	**Supportive Patterns II**	Sticky Notes	Support the purpose of notes taking
23		Calculator	To support the problem solving process especially during the calculation steps
24		Notes recording pad	To support some basic notes taking and calculation purpose
25		Narrated sound on / off	Assist / guide the students throughout the problem solving steps

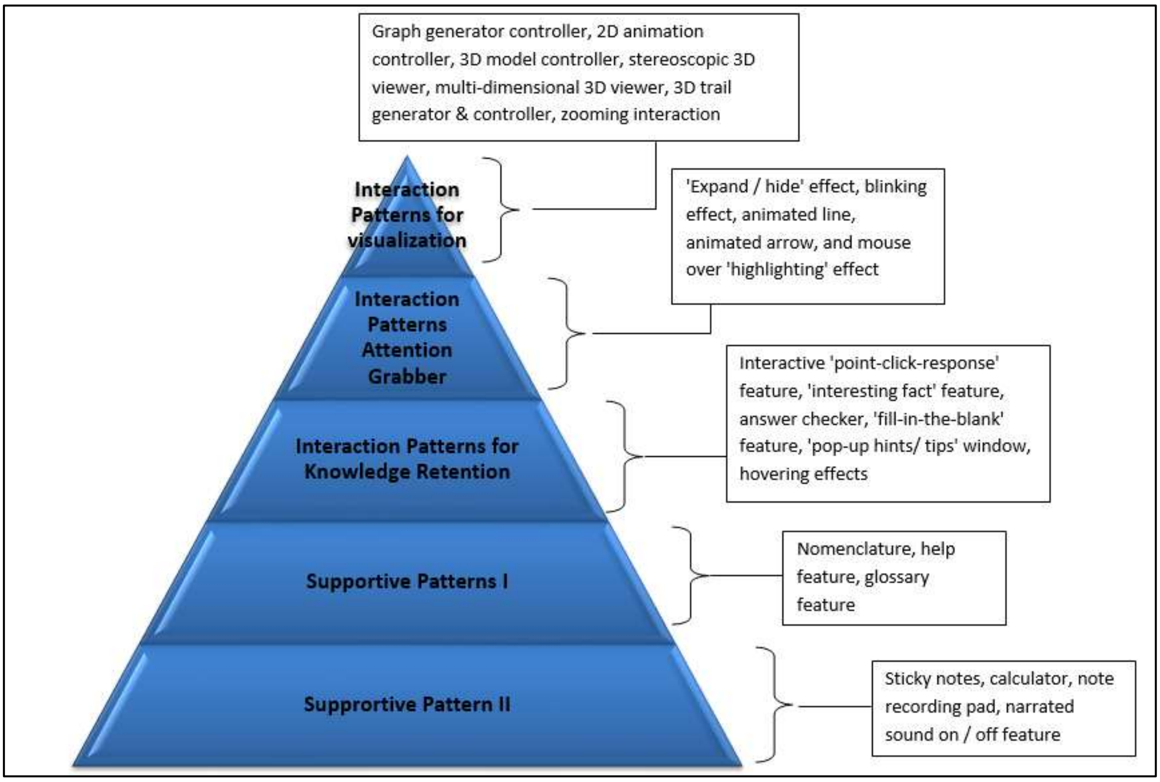

Figure 6.1 Diagrammatic representation of the 25 proposed patterns of interactions

The second category is labeled as “attention grabber” category. The “attention grabber” category consists of five patterns of interactions that are designed to grab or retain the student’s attention when user interacts with the TAPS package(s) for problem solving. All these five interaction patterns are mainly available in the problem module and solution module. The ‘expand/hide’ effect interaction pattern played the role to expand the contents or hide unnecessary contents for the TAPS package. This would allow the student to focus on certain portion of the contents that are needed at that instant without losing the focus when following the procedure for problem solving. However, the student can choose to hide or expand the contents according to their personal needs and preferences. This may help to accommodate to different students preference in learning.

The blinking effect, animated line and animated arrow are the interaction patterns that would lead the student’s eye to focus on the important statement or Figure when solving the engineering problem. The blinking effect is used to attract the student’s attention especially on the initial stage of problem solving. For example, when certain variables are required for problem solving, the variables would be blinking for few times, thus grab the student's attention to identify given variables that are needed for calculation. The animated line is used to highlight the necessary equations that are required in calculation based on the movement of the model at specific instant. Animated arrows that are normally used in the engineering diagram to pin point the part that the student needs to focus at each step especially the specific location and movement of the collar or rod at certain instant in the illustrative engineering diagram (refer to Figure 6.12 in Chapter 6 section 6.6).

Mouse over 'highlighting' effect is designed to support the student's interaction with the text based contents that are associated with the details shown in the illustrative engineering diagram. For example, when certain text is highlighted, the illustrative engineering diagram would display extra information.

The third category of the interaction patterns is labeled as "knowledge retention" category. The "knowledge retention" category consists of six interaction patterns that are designed to support / facilitate the purpose of knowledge retention. Knowledge retention here is referred to recall the knowledge learned previously or to revise the fundamental knowledge of the mechanics dynamics or strengthen the knowledge / principles needed to solve the engineering problem for this particular topic.

The interactive 'point-click-response' feature is available in the exercise module by which the student may interact with the options available for each of the exercise question. The system would response immediately right after the student performed the selection. The student may receive the feedback directly through the system. This may strengthen the understanding of the student. The 'interesting fact' feature is available on the graph module to strengthen the student's understanding on different dynamic movement of the engineering model that lead to generate different form of graphs (e.g. position, velocity & acceleration of the particular collar based on x-axis, y-axis and z-axis).

The remaining four interaction patterns (answer checker, ‘fill-in-the-blank’ feature, ‘pop-up hints/tips’ window and hovering effects) are available in the solution module. The ‘pop-up hints/tips’ window would act as a ‘reminder’ to remind the student regarding the fundamental concept / principle in mechanics dynamics. For example, the assumptions that the student needs to know if the initial linear velocity and initial linear acceleration were mentioned in the engineering problem. Hovering effect act as the interaction pattern by which when the mouse move over the particular text or graphic elements, some information would be displayed and opt for further selection that the student need to perform. The ‘fill-in-the-blank’ feature and answer checker are two of the interaction patterns that allow the student to key in the correct answer for certain steps in problem solving. Based on the answers given, the answer checker may provide the instant feedback based on the student attempt in answering the questions. Few attempts from the students are allowed before the accurate answer is provided together with explanation.

As referred to Figure 6.1, the “supportive patterns I” category consists of three interaction patterns which are the nomenclature, help feature and glossary feature. Nomenclature provides the basic explanation regarding the definition of the SI unit and its purpose for mechanics dynamics course. Help feature assists the student to use the features in TAPS package whenever it is necessary. The glossary feature supports the explanation of the engineering technical terms use in dynamics course.

The fifth category of interaction patterns is labeled as “supportive patterns II”. This category consists of four interaction patterns which are the sticky notes, calculator, notes recording pad and narrated sound on/off feature. This group of interaction patterns provides the supporting tools for the students throughout the learning process. The sticky notes can be used to record the notes (in short form) as a reminder throughout the problem solving process. While the notes recording pad act as a mechanism/means for students to key in their own study notes related to dynamics course. The calculator may be used by the student when dealing with complex calculations. The narrated sound on/off feature would be used to on or mute the narration sound in the TAPS package. This provides an option for the visual learning preference student to off the narration sound if it is found to be unnecessary or cause any disturbance.

Based on the proposed patterns of interactions, the enhanced multimedia TAPS package development process is discussed in details in the next section.

6.5 Development Process for the Enhanced Multimedia TAPS Package

6.5.1 Overview of the Authoring Process

The development of enhanced multimedia TAPS package followed the multimedia authoring process. Multimedia authoring is a process of creating a multimedia production, sometimes called as “movie” or “presentation”. It involves assembling or sequencing different media elements, adding interactivity, and then packaging the production for distribution to the end users (Neo & Neo, 1999). Normally the authoring process can be divided into three main stages which involve the pre-authoring, authoring and post authoring process. Each of this three stages is further divided into more sub tasks / activities.

According to Neo and Neo (1999) (see Figure 6.2), pre-authoring stage involved two tasks where the multimedia software developer would 1) select the multimedia computer and its components and 2) acquire the multimedia elements and the necessary software for creating and editing. The multimedia computer and its components referred to the identification of the computer hardware requirements that are needed for the project development. This commonly referred to the specifications for central processing unit (CPU), video cards, random access memory (RAM) and the hard drive. Meanwhile, the acquiring of the multimedia elements such as text, graphics, audio, video and animation were performed in pre-authoring stage as well. Different media software is needed for creating and editing different media elements such as graphics, image, sound, movie and animation. In the development process of the TAPS package, all the media elements were created or edited before importing into the authoring software for further integration.

For the authoring stage (see Figure 6.2), it involved (1) choosing an authoring tool to best suit the project needs and (2) use the chosen authoring tool to import the media and add special effects, navigation and interactivity. This is important as different authoring tool support different multimedia project nature, such as small scale project, medium to large scale project and etc. The consideration also involved the expenditure cost for the purchased authoring tool. Once the authoring tool was identified, all the prepared media elements were imported into the authoring tool for further integration and compilation. The required special effects, navigation and interactivity were also added respectively throughout the authoring process by utilizing the features in the authoring tool. Sometimes, the complex navigation and interactivity did involve the usage of programming language to embed specific instructions. The authoring process further linked all the content modules and compiled to be a complete multimedia project.

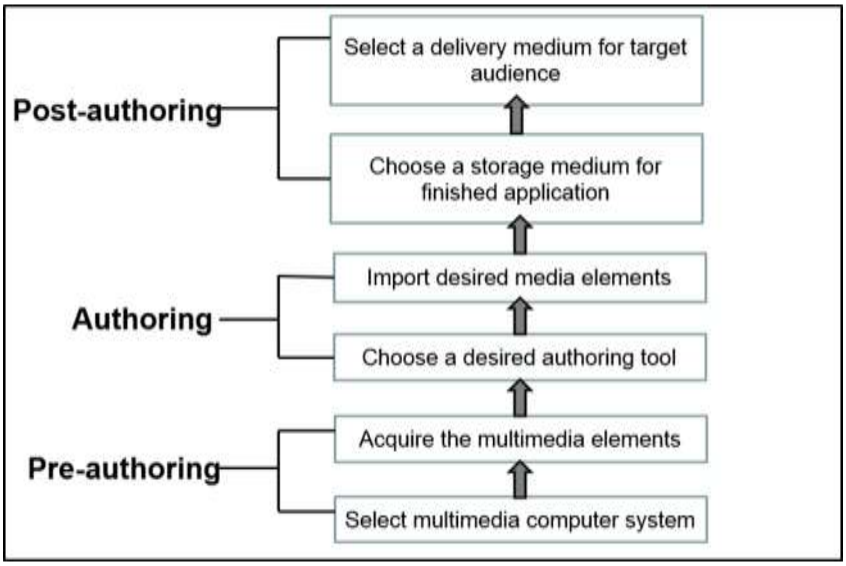

Figure 6.2 Three stages in multimedia authoring (Adopted from Neo & Neo, 1999)

For the post-authoring stage (see Figure 6.2), the multimedia software developer 1) decided on a storage medium for the finished interactivity multimedia application and 2) decided on a delivery medium for the audience. The storage medium can be referred to CD based / DVD based / cloud storage. Meanwhile, the delivery medium can be referred to either offline based or online based (web-based / mobile based). The detail authoring process (pre-authoring, authoring and post authoring) of the enhanced multimedia TAPS package are discussed in the next section.

6.5.2 Pre-Authoring Process for the Enhanced Multimedia TAPS Package

During the pre-authoring process, the users' requirements were gathered and identified. The data collection and findings regarding the students learning difficulties both from the students' perspective and instructors' perspective were collected and analyzed as discussed in Chapter 5. Besides that the students learning styles preferences were identified through the use of Honey and Mumford' Learning Styles Questionnaire (see Chapter 5 section 5.3) and Ogden's Personality and Learning Styles Questionnaire (see Chapter 5 section 5.4). The findings (see Chapter 5 section 5.4.4) from both the learning styles instruments together with the previous research (Manjit, 2006) conducted through Felder and Silverman's Index of Learning Styles (ILS) revealed the consistent results that the engineering students in UNITEN preferred to learn in sequential, logical way with various hands-on practical activities. They are "open-minded" and prefer to try out new forms of learning activities. All these information would be the main supporting reference for the enhanced multimedia TAPS packages development.

During the pre-authoring stage, the contents knowledge for dynamics course was obtained from the respective dynamics course coordinators from the College of Engineering (COE), Mechanical Engineering department, UNITEN. Based on the suggestion from the respective course coordinators, challenging topics were included as the contents knowledge (e.g. Planar Kinematics of a Rigid Body that include the rotation about a fixed axis; relative motion analysis – velocity; relative motion analysis – acceleration) for the enhanced multimedia TAPS package. The original details of the sources for contents knowledge related to Planar Kinematics of a Rigid Body can be referred to Appendix I. The challenging topics referred to those topics that firstly, the students faced the difficulties to visualize the concept in learning due to a mix of mathematical equations, schematic diagrams, text & numeric data and secondly, the topic that involved multiple steps in order to reach the final solution and thirdly the topics that involved the dynamic motion in x-axis, y-axis and z-axis.

The hardware requirements and software requirements to support the development of TAPS package were identified and summarized as shown in Table 6.2 and Table 6.3 respectively. The software requirements (see Table 6.3) included the specific software required to create and design the media elements such as the text, graphics (both raster and vector images), audio, video and animations (both 2-D and 3-D) for the TAPS package.

Table 6.2 Hardware requirements for the development of enhanced TAPS package

Hardware	**Minimum Requirement**	**Optimal Requirement**
Central Processing Unit (CPU)	1GHz Intel Core i3	2.4GHz Intel Core i7
Number of cores	Dual-Core	Quad-Core
Random Access Memory (RAM)	1GB MB RAM	4GB, DDR4, 2400MHz
Video card	Intel® HD Graphics 500 with shared graphics memory	NVIDIA® GeForce® GTX 1050 Ti with 4GB GDDR5 graphics memory

Table 6.3 Software requirements for the development of enhanced TAPS package

Multimedia Elements	**Specific Software**
Audio	Audacity 2.1.0, Natural Reader
2-D animation	Adobe Animate CC
3-D animation	Autodesk Maya
Text	Microsoft Word 2013
Raster Image	Adobe Photoshop CS6, UleadPhotoImpact XL
Vector graphic	Adobe Illustrator CS6
Video	Corel Video Studio Pro X7

The system flow diagram that illustrates the modules integrated in the enhanced multimedia TAPS package is shown in Figure 6.3.

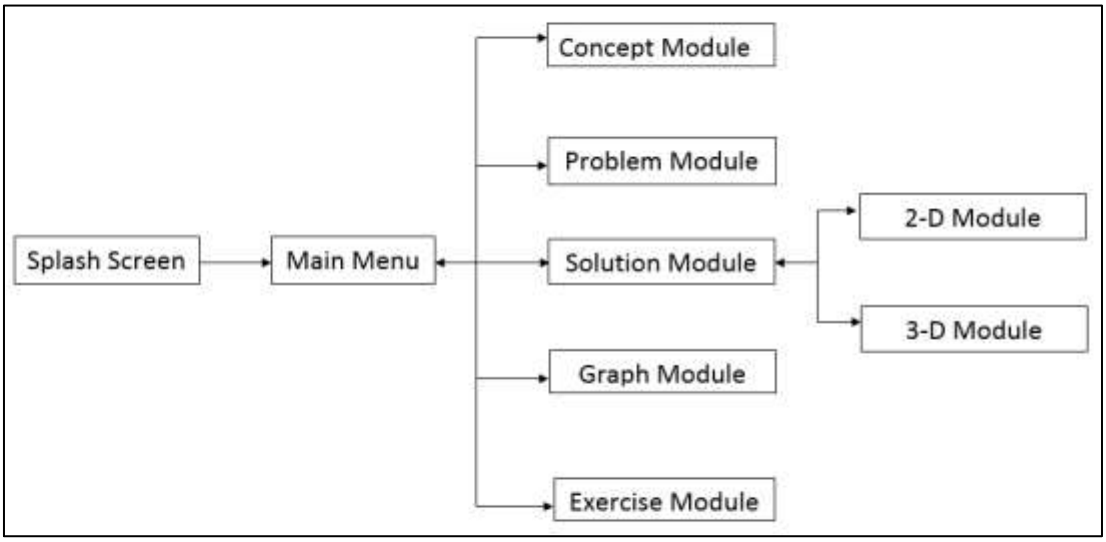

Figure 6.3 System Flow Diagram for enhanced multimedia TAPS package

There are five main modules which consist of the (1) concept module, (2) problem module, (3) solution module, (4) graph module and (5) exercise module in the TAPS packages. Two of the sub-modules that consists of 2-D animation module and 3-D animation module to support the visualization of the students when solving the identified engineering problem. These two sub-modules can be linked from solution module. As referred to Figure 6.3, one directional arrow referred to the navigational pathway in one direction whereas the two directional arrows indicated the navigational pathway that follows the non-linear fashion (users may navigate freely among the modules). The system flow diagram would act as a main reference in the integration process during the authoring stage.

6.5.3 Authoring Process for the Enhanced Multimedia TAPS Package

The authoring process involved the integration of media elements by adding the interactivity and navigational elements to produce a complete multimedia project. The duration to perform the authoring process for enhanced multimedia TAPS package took around six months. The authoring tool, Adobe Director was used as a main platform to perform the authoring tasks. The authoring process for enhanced multimedia TAPS package involved six main steps as listed in Figure 6.4.

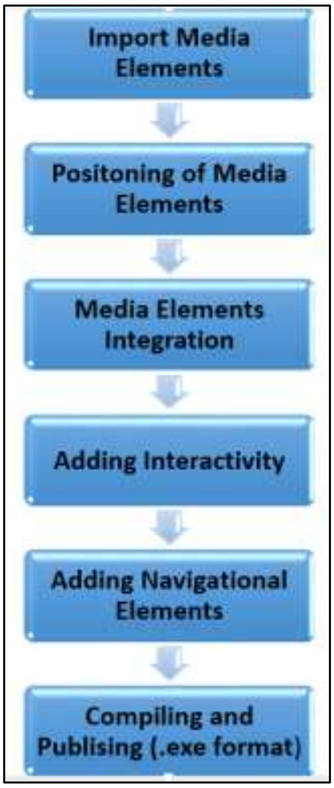

Figure 6.4 Authoring steps for enhanced multimedia TAPS package

All the media elements created were imported into the authoring tool as the cast members. Next, the arrangement of the media elements was performed in order to construct the interface design and contents presentation for the TAPS package. Interactivity and navigational elements were added in order to integrate all the required module into a complete application. The authoring process screen shots can be referred to Figure 6.5 and Figure 6.6 respectively. The final step involved in the authoring process was to perform the publishing task (to convert the source files that well integrated to become a standalone executable format) by using the build-in features supported by the authoring tool.

Figure 6.5 Screen shot of the authoring process

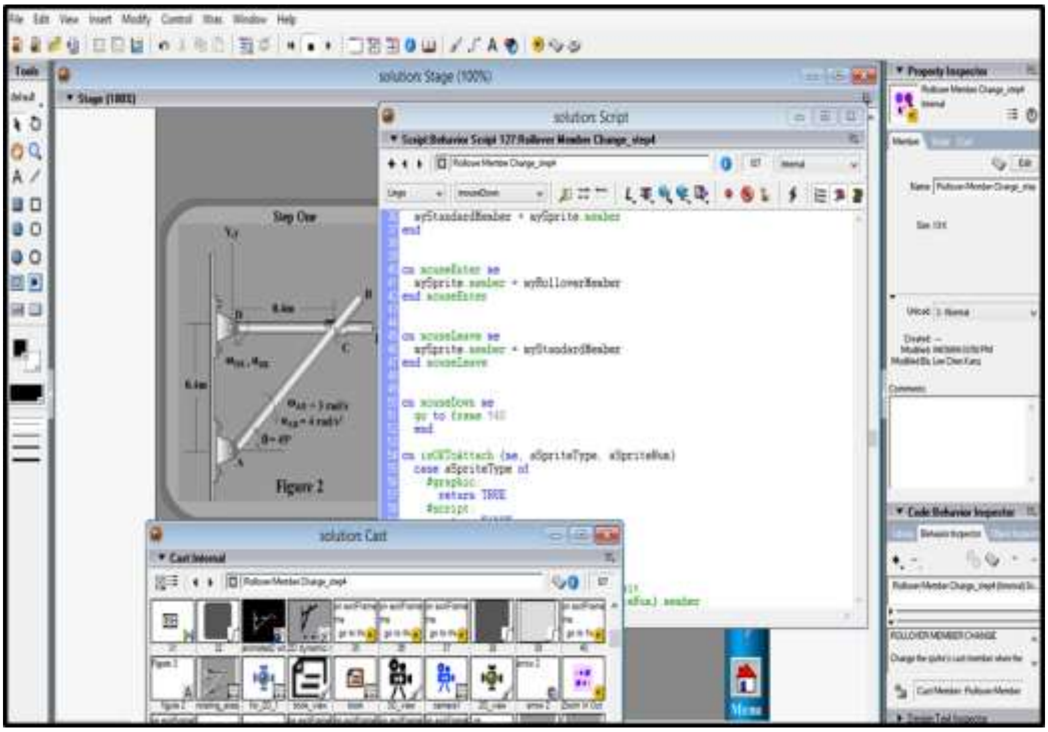

Figure 6.6 Screen shot of the authoring process (Lingo scripting)

Secondly, the user-centered design (UCD) approach was used to develop the enhanced multimedia TAPS package. User-centered design is also called as human-centered design (Yu et al., 2015). As referred to the documentation of International Organization for Standardization ISO, "*an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system (by focusing on the users, their needs and requirements) and applying human factors/ergonomics and usability knowledge and techniques*" (ISO, 2010). The needs and requirements including the learning styles preferences for engineering students were taken into consideration when designing and developing the enhanced multimedia TAPS package. The main aim of user-centered design is usability, and is it referred to "*the extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specific context of use*" (ISO, 1998).

As emphasized by Maguire (2013), usability is always been treated as a quality objective forming part of the user experience that focus on the user's ability to achieve the objectives or tasks. The main purpose of the enhanced multimedia TAPS package embedded with 25 proposed patterns of interactions was to facilitate the engineering problem solving tasks for mechanics dynamics domain, thus the user interface needs to be carefully designed. Without a proper user interface that may engage the students to better interact with the TAPS package, it may directly influence the user experience in engineering problem solving. Thus, ISO 9241-11 and ISO 9241-210 standard was taken as a main reference and the guideline for user interface design for the enhanced multimedia TAPS package. According to the ISO 9241-201 standard (ISO, 2010), there are four essential activities which should be undertaken in order to incorporate user needs into the software development process. The four essential activities are:

- Understand and specify the context of use;
- Specify the user and organisational requirements;
- Produce design solutions;
- Evaluate designs against requirements

All the four previously mentioned activities have been incorporated throughout this research study. The first activity (understand and specify the context of use) was performed as discussed in Chapters 1, 2 and 3. The second activity (specify the user and organisational requirements) was completed as referred to Chapter 5 on the users' requirements gathering and analysis that emphasize on students learning difficulties and students learning styles preferences. Whereas, the third activity (produce design solutions) was completed and tested as referred to Chapter 6 and Chapter 7. The fourth activity (evaluate designs against requirements) was completed through the usability testing performed in year 2016 with the respective mechanical engineering students through the SUS and PSSUQ usability evaluation instruments. The findings and discussions of the usability testing can be referred to Chapter 7 sections 7.2 and section 7.3. More details literature descriptions regarding the ISO 9241-11 and ISO 9241-210 standards can be referred to Chapter 3. The selected interface designs of the enhanced multimedia TAPS package can be seen through the screen shots as shown in Figures 6.7 - 6.11.

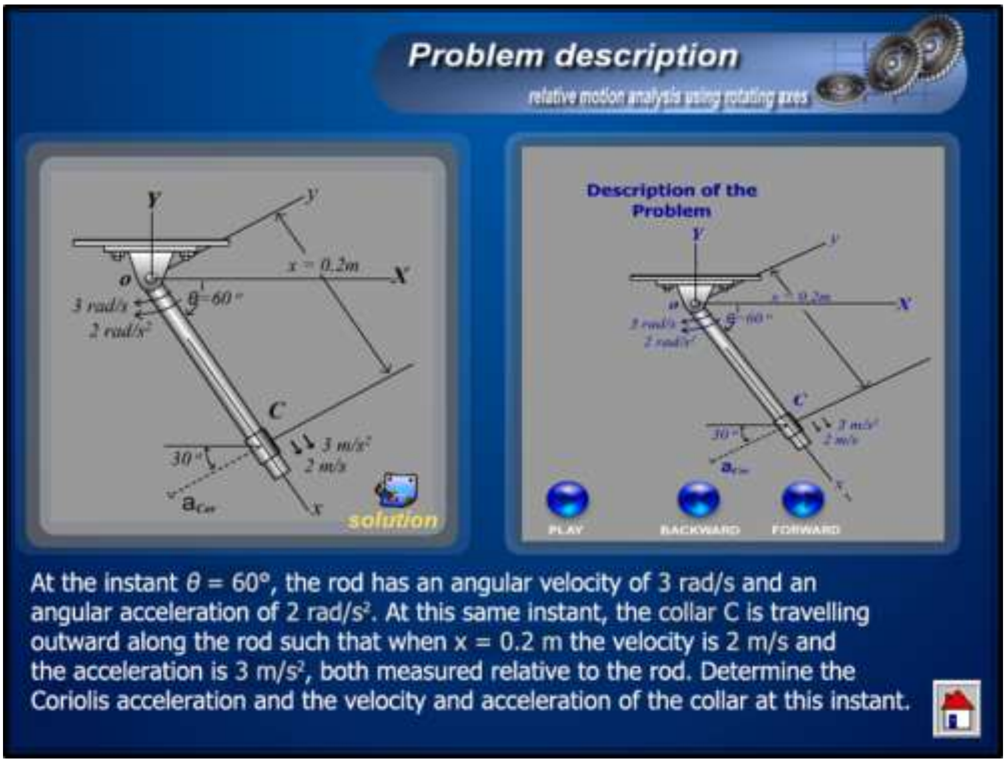

Figure 6.7 Screen shot of the problem module

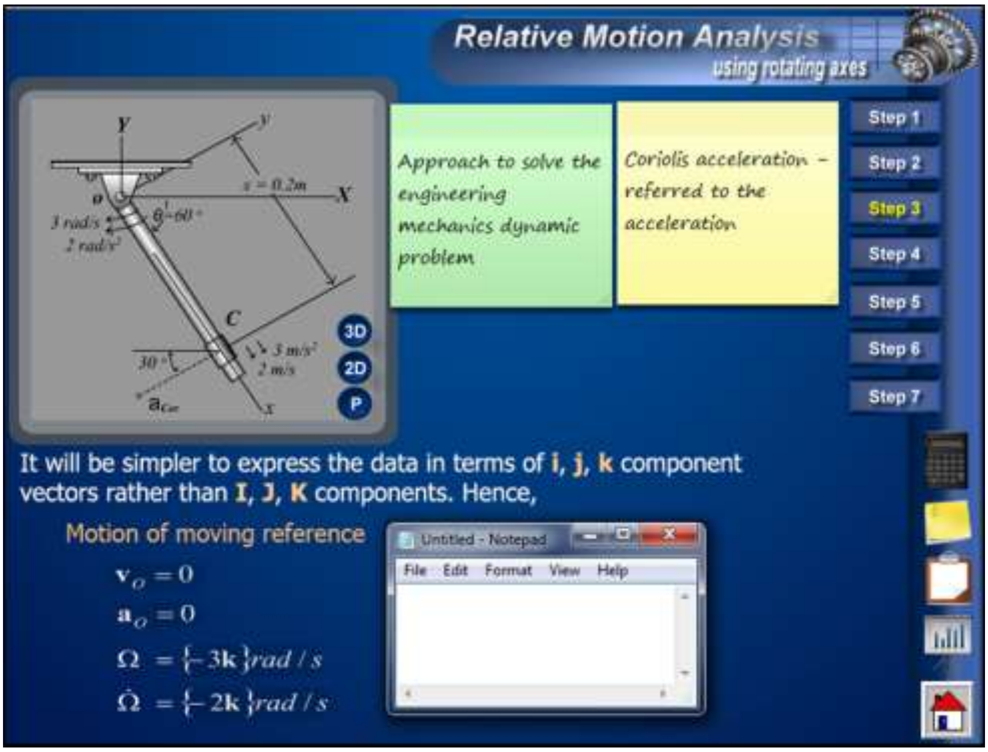

Figure 6.8 Screen shot one of the solution module

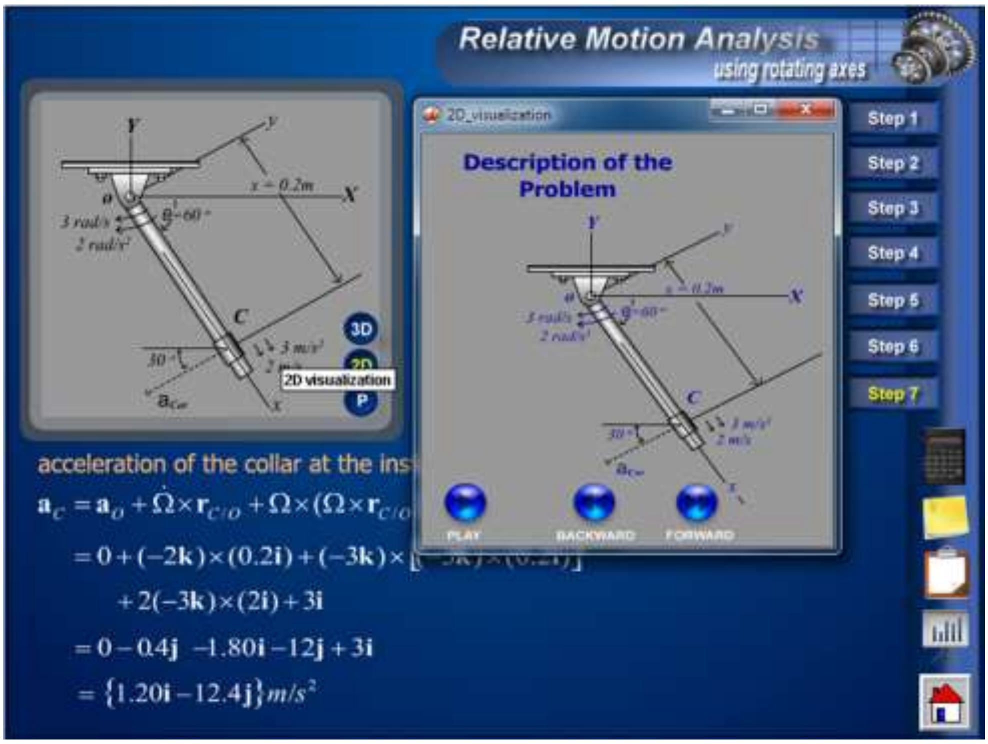

Figure 6.9 Screen shot two of the solution module

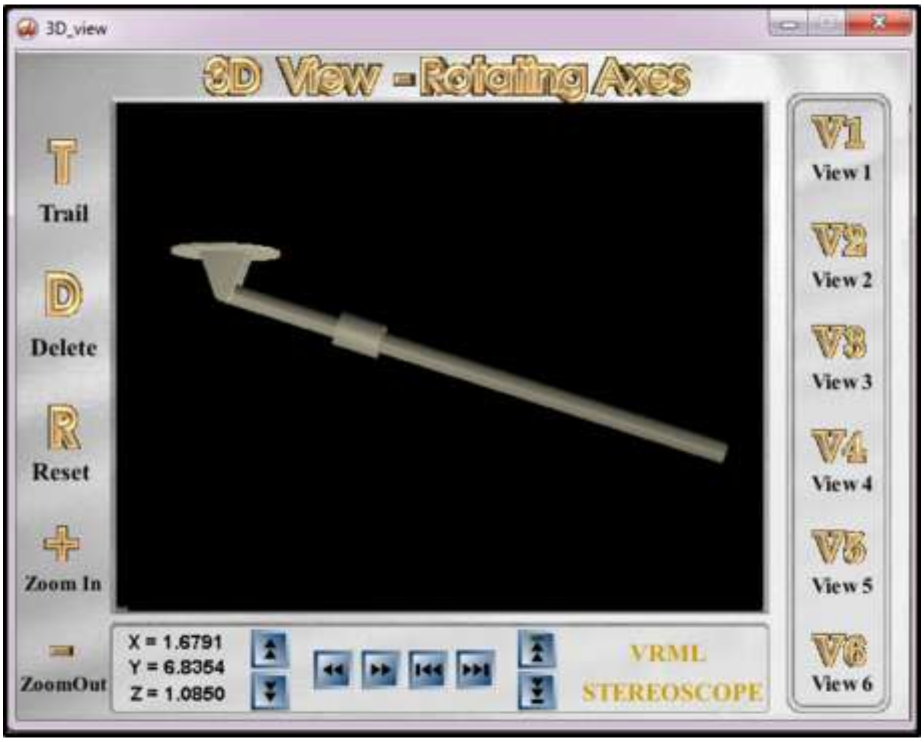

Figure 6.10 Screen shot of the 3-D module

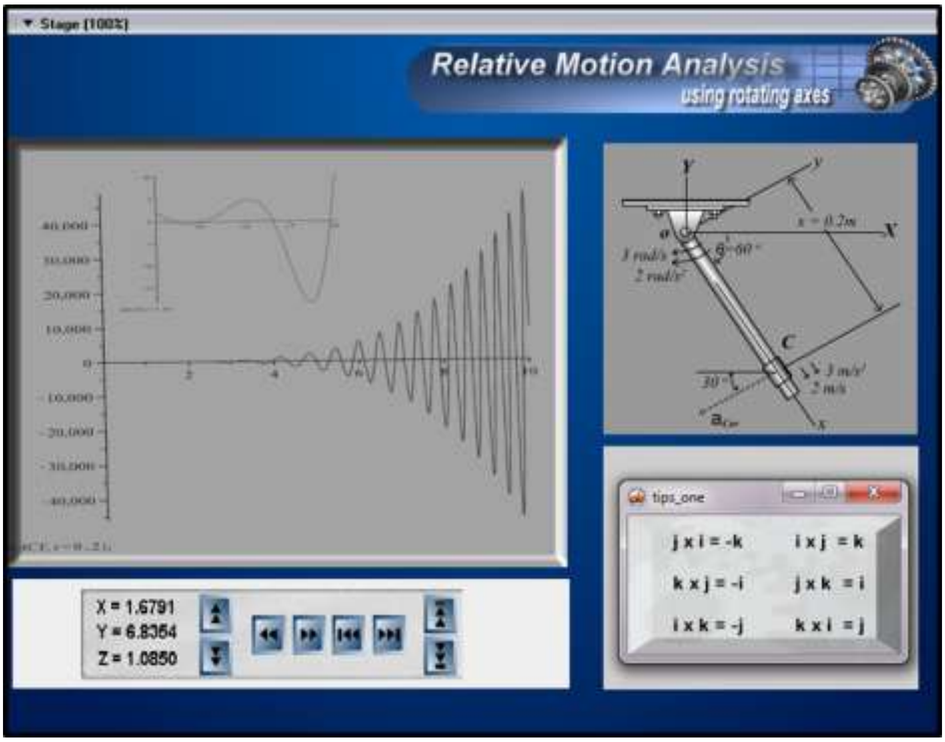

Figure 6.11 Screen shot of the graph module

6.5.4 Post Authoring Process for the Enhanced Multimedia TAPS Package

The post authoring process involved the setup and delivery of the enhanced multimedia TAPS package. The enhanced multimedia TAPS package could be delivered in desktop based (offline based) or web based (online based). For the testing and evaluation purpose, the enhanced multimedia TAPS package was delivered in executable format so that it could be delivered to the mechanics dynamics course students for further testing. The installation was performed in the computer labs of UNITEN to setup the system. Usability evaluation was performed and feedbacks were collected. This included the participation of human computer interaction expert, Prof. Mark Billinghurst to review and validate the interface designs for the enhanced multimedia TAPS package (see Appendix G). Furthermore, two usability testing instruments (SUS and PSSUQ) have been adopted to evaluate the usability of the enhanced multimedia TAPS package. Positive feedbacks were gained through the evaluation using the SUS and PSSUQ usability instruments. Detailed descriptions can be found in Chapter 7 section 7.2 and section 7.3 respectively.

6.6 Knowledge Acquisition (the use of Enhanced Multimedia TAPS Package)

The enhanced multimedia TAPS package is not intended to replace the role played in the lecture and tutorial sessions rather to supplement the learning, especially to facilitate the learning in engineering problem solving for mechanics dynamics domain. The integration of enhanced multimedia TAPS package in the learning process to solve the students learning difficulties in mechanics dynamics is proposed and empirically tested (see Chapter 7).

One of the challenging topics faced by the engineering students when learning mechanics dynamics is the topic of planar kinematics of a rigid body (as discussed in Section 6.5.2). One of the sub topics under the planar kinematic of a rigid body is the relative motion analysis of velocity and acceleration using a rotating frame of reference. For example, the rod in Figure 6.12 has an angular velocity of 3 rad/s and an angular acceleration of 2 rad/s^2, at the instant $\theta = 60^o$. At this same instance, the collar labeled *C* is traveling outward along the rod such that when x = 0.2m, the velocity is 2 m/s and the acceleration is 3 m/s^2, both measured relative to the rod. The student is required to determine the velocity and the acceleration of the collar, *C* at this instant.

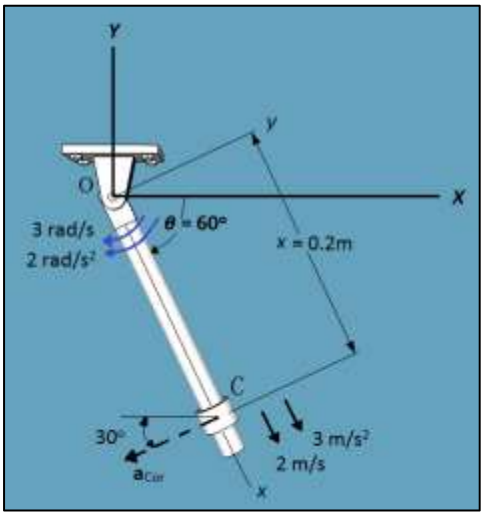

Figure 6.12 Sample Problem of Relative Motion Analysis

In order to reach the solution for this problem, a series of systematic procedure to solve the problem were identified and which is summarized in Figure 6.13.

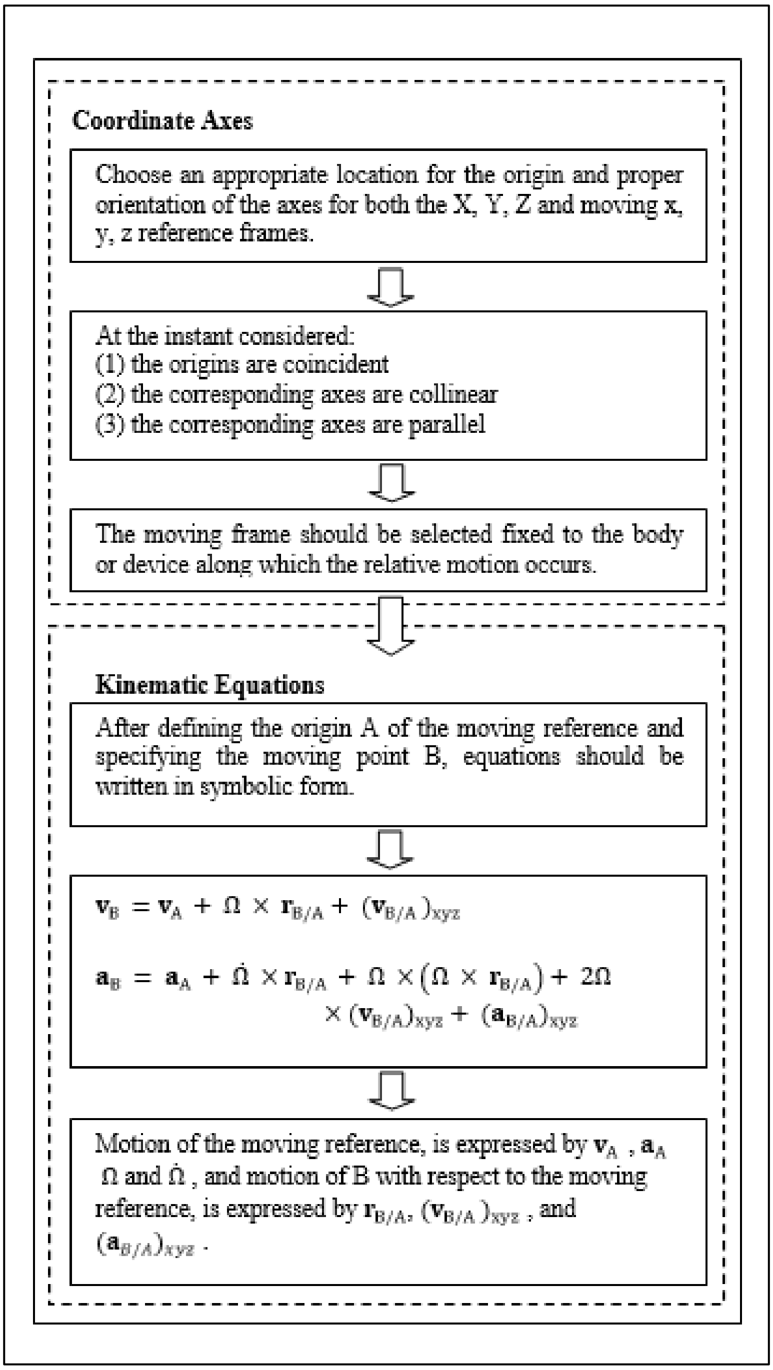

Figure 6.13 Procedures for problem solving

Besides that, two mathematical equations are required in order to reach the solution for this problem, each for the velocity and the acceleration of Collar *C* at this instant. The basic derivation of the equation to determine the velocity is shown in Figure 6.14 while the basic derivation of the equation for the acceleration is shown in Figure 6.15.

$$\mathbf{v}_B = \mathbf{v}_A + \frac{d\mathbf{r}_{B/A}}{dt}$$

$$\mathbf{v}_B = \mathbf{v}_A + (\mathbf{v}_{B/A})_{xyz} + \Omega \times (x_B\mathbf{i} + y_B\mathbf{j})$$

$$\mathbf{v}_B = \mathbf{v}_A + (\mathbf{v}_{B/A})_{xyz} + \Omega \times \mathbf{r}_{B/A}$$

$$\mathbf{v}_B = \mathbf{v}_A + \Omega \times \mathbf{r}_{B/A} + (\mathbf{v}_{B/A})_{xyz}$$

Figure 6.14 Equation derived to determine the velocity

$$\mathbf{a}_B = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{B/A} + \Omega \times \frac{d\mathbf{r}_{B/A}}{dt} + \frac{d(\mathbf{v}_{B/A})_{xyz}}{dt}$$

$$\mathbf{a}_B = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{B/A} + [\Omega \times (\mathbf{v}_{B/A})_{xyz} + \Omega \times (\Omega \times \mathbf{r}_{B/A})] + \frac{d(\mathbf{v}_{B/A})_{xyz}}{dt}$$

$$\mathbf{a}_B = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{B/A} + [\Omega \times (\mathbf{v}_{B/A})_{xyz} + \Omega \times (\Omega \times \mathbf{r}_{B/A})] + [(\mathbf{a}_{B/A})_{xyz} + \Omega \times (\mathbf{v}_{B/A})_{xyz}]$$

$$\mathbf{a}_B = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{B/A} + \Omega \times (\Omega \times \mathbf{r}_{B/A}) + 2\Omega \times (\mathbf{v}_{B/A})_{xyz} + (\mathbf{a}_{B/A})_{xyz}$$

Figure 6.15 Equation derived to determine the acceleration

The first difficulty that the students faced when dealing with this problem (refer to Figure 6.12) is the understanding of the requirements of the problem and the visualization of the dynamic motion of the model by which it is usually described through the text with the aid of static image. By using the enhanced multimedia TAPS package, the static image will be converted into 2-D and 3-D model supported with animation that may help the students to visualize the problem and requirements better. In addition, interactivity was added to provide the opportunity for the students to further explore the model in different conditions. This helped the students to construct a holistic view and expand their visualization ability towards the problem given. This will further lead the students to the second procedure to identify the known and un-known requirements to solve the problem.

In the second procedure to solve the problem, the students will need to identify the known and un-known requirements of the problem. This information can be acquired from the descriptions of the problem provided. From here, the students can start to figure out the requirements to solve the problem. This is a process to cultivate the problem solving skills which is one of the important elements in the new paradigm of engineering education requirement. The students should be provided with the opportunity to think and analyze in the first place before any ‘spoon-feed’ solution is provided. Most of the time, however, majority of the students will forget to make the assumption (refer to Figure 6.13) and need to consider that (i) the origins are coincident (ii) the corresponding axes are collinear and (iii) the corresponding axes are parallel. In this sort of situation, an ‘interesting fact’ feature was provided by the enhanced multimedia TAPS package and acted as a reminder to remind the student for this particular step before proceeding further. In addition, the justification was provided to the student in the form of patterns of interactions such as the pop-up ‘hints/tips’ window to inform why the considerations are important in leading towards the solution.

In the third procedure, the students need to be reminded that the moving frame should be selected fixed to the body or device along which the relative motion occurs. Here, the enhanced multimedia TAPS package played an important role to remind the students through the use of patterns of interactions in the category of “attention grabber” such as the ‘blinking effect’ and ‘animated arrows’ that occur on the 2-D or 3-D model regarding the moving frame. This lead those weak students (in term of learning mechanics dynamics) to understand which rod refers to the moving frame and where the relative motion will occur. These visual indicators/cues of using the ‘blinking effect’ and the ‘animated arrows’ would avoid the students from skipping this particular procedure or unintentionally by pass the step.

In the fourth procedure, the students are required to use the equations derived as shown in Figure 6.14 and Figure 6.15 in order to calculate the respective velocity and acceleration for the collar denoted with *C*. By substituting the known parameters in the equations, the students should be able to calculate the respective velocity followed by the respective acceleration for the collar denoted with *C* with the help of the calculator. This is the traditional way of learning by which the students will apply the equations to get the respective results. By using the enhanced multimedia TAPS package, the mathematical equations could be designed into the form of computer algorithms. The algorithms can then produce the graph of position, velocity and acceleration with respect to the change in time for collar denoted with *C* (the graph module in enhanced TAPS package). This will lead the student to gain better understanding regarding the movement change from time to time beyond the current instant stated in the problem given. Students are able to grasp more holistic understanding regarding the changes of the position, velocity and acceleration in a timely basis. This help to provide extra knowledge and understanding for the students regarding the topic learned. At the same time, some control features (refer to Table 6.1 - interactions patterns in the “visualization” category and “knowledge retention” category) were provided for the students to interact with the dynamic model given in the problem and the graph will change accordingly based on the interaction of the students. This may create the opportunity for the students to perform exploratory study while likely to increase their interest in learning.

In addition, the systematic step-by-step approach was used as a guide to lead the students in the process of solving the problem (integrated in the solution module of the TAPS package). Through the step-by-step approach of solving the problem, the students were provided with suitable guidance in the form of electronic hints using pop-up menu function. This was optional for those weak students (in terms of weak foundation in mathematics and physics) to assist them in understanding about the equations used, its derivation and its importance. This approach may enhance the students understanding regarding the steps involved and the reasoning behind each step of solving the problems in a systematically order.

This is the example by which the enhanced multimedia TAPS package aided the students in engineering problem solving that can be integrated with the lecture based and tutorial based teaching and learning procedures.

6.7 Summary

In summary, by using the enhanced multimedia TAPS package embedded with the 25 proposed patterns of interactions to facilitate the engineering problem solving, students were able to expand their learning capabilities to explore further on the application of the concepts learned previously. For example, the concepts learnt in mechanics dynamics will build up the fundamental knowledge for machine design in the third year studies and the real life applications contributed from the concept of mechanics dynamics. This lead the students to appreciate the knowledge contents that they learned in mechanics dynamics and be prepared earlier in their mind set for the issue of mechanical design and its real life application in various context.

CHAPTER 7

EVALUATION AND FINDINGS

7.1 Overview

In this Chapter, the findings of the perceived usability for the enhanced multimedia TAPS package through the questionnaires adapted from the System Usability Scale (SUS) instrument and the Post-Study System Usability Questionnaire (PSSUQ) version 3 are discussed. In this Chapter, the categorization for the proposed patterns of interactions through the use of exploratory factor analysis (EFA) is performed. Multiple linear regression analysis was performed to identify the relationship between the dependent variable (problem solving tasks) and the independent variables (different groups of interaction patterns).

7.2 Usability Evaluation Study I – SUS Instrument

The System Usability Scale (SUS) questionnaire was adopted as the usability evaluation instrument to gain the understanding of the perceived usability of the enhanced multimedia TAPS package. SUS is a simple, ten-item scale instrument which was developed by Brooke (1986). It is generally used after the respondents have used the system or product which is evaluated and to ensure that they have not been involved in any orientation or discussion yet (Suominen, 2013). SUS instrument was chosen for this study because it was found to be a reliable tool to measure the overall system usability and user satisfaction (Bangor, Kortum, & Miller, 2008; Lewis & Sauro, 2009; Tullis & Stetson, 2004; Wozney et al., 2016). According to Brooke (2013), SUS has been cited in more than 1,200 publications and is incorporated into commercial usability tool kits such as Morae (one of the leading usability software tools on the market). Moreover, SUS can be used to assess the usability of any software system, device or service (Orfanou, Tselios, & Katsanos, 2015). SUS has been widely used in many research studies and currently is referred to as an “industry standard” in several publications (Larsson, 2016). The detail descriptions on the literature of SUS can be found in Chapter 3.

7.2.1 Participants

The SUS questionnaires were prepared and administrated to the students in the hardcopy form during the mid of the first study semester in July 2016. Sample questionnaire for SUS is shown in Appendix D. The respondents were exposed to the usage of the enhanced multimedia TAPS package before the administration of the questionnaire. The enhanced multimedia TAPS package had been installed one day earlier prior to the administration of the questionnaire. The questionnaire was self-administered to respondents after their classes to ensure high participation rate. The respective lecturers did help to brief the respondents regarding the voluntary initiative to participate in the research study. The respondents were briefed by the author regarding the objectives of the research survey before the questionnaires were distributed to them. Respondents were given 30 minutes to interact with the enhanced multimedia TAPS package before filling in the questionnaires. The questionnaires were collected back after 45 minutes. Out of the total 162 questionnaires distributed to the students, only 150 questionnaires were noted to be complete, providing a 92.6% response rate.

7.2.2 Procedure

Pilot test was conducted two weeks before the actual distribution of the usability questionnaires. Pilot test is a crucial element of a good study design (Edwin & Hundley Vanora, 2002). A total of 30 respondents were involved in the pilot study. Feedbacks were collected and amendments were made to the questionnaire on the following aspects:

1) Respondents should be given more than 30 minutes to interact with the enhanced multimedia TAPS package.
2) The time to fill in the questionnaires should be at least 15 minutes.
3) Some additional description for certain terms and phrases were added to aid in the students understanding (e.g.: Question 8 in SUS questionnaire).

7.2.3 Method (SUS Instrument)

The SUS questionnaire consists of ten questions (items), each with five point Likert scale (ranging from strongly disagree to strongly agree). The odd-numbered items have a positive tone; the tone of the even-numbered items is negative (Sauro & Lewis, 2012). The respondents are required to answer all the ten questions. If the respondent cannot decide or respond to any item, they should select the center point of the scale (Ganapathy, Shuib, & Azizan, 2016).

According to the elaboration by Sauro & Lewis (2012), the first step in scoring a SUS is to determine each item's score contribution, which will range from 0 to 4. For positively worded items (odd numbers), the score contribution is the scale position minus 1 (xi-1). For negatively worded items (even numbers), the score contribution is 5 minus the scale position (5- xi). To get the overall SUS score, multiply the sum of the item score contributions by 2.5. Thus, overall SUS scores range from 0 to 100 in 2.5-point increments.

7.2.4 Results and Findings

Internal consistency for SUS items was firstly analyzed to determine the strength of the relationship among the items within each SUS scale. From Table 7.1, it can be observed that the Cronbach alpha value for positively worded items was 0.78 while the Cronbach alpha value for negatively worded items was 0.73. Both the values exceed the conventional 0.70 value (Nunnally, 1978). The SUS questionnaire items shared good internal consistency in this study.

Table 7.1 Internal Consistency of SUS Items

Items category	**Cronbach's Alpha**	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
Q1, Q3, Q5, Q7, Q9	0.780	0.778	5
Q2, Q4, Q6, Q8, Q10	0.728	0.733	5

The descriptive statistics of each SUS item is shown in Table 7.2. As mentioned previously in section 7.2.3, the SUS questionnaire consists of 10 items rated on a five-point Likert scale (1= strongly disagree and 5 = strongly agree), in which odd-numbered items were worded positively and even-numbered items were worded negatively. As for the positively worded items, the 7^{th} item of the SUS questionnaire gained the highest mean value, which scored more than 4.20 (mean = 4.23). This indicates that most of the respondents agreed that they learnt to use the enhanced multimedia TAPS package very quickly. Specifically, respondents agreed that they would like to use the enhanced multimedia TAPS package frequently (mean = 4.06), the enhanced multimedia TAPS package was easy to use (mean = 4.11), the various functions in the enhanced multimedia TAPS package were well integrated (mean = 4.12) and the respondents felt very confident using the enhanced multimedia TAPS package (mean = 4.06). Overall, the mean values for all the positively worded items ranged from 4.06 to 4.23, suggesting respondents' agreement towards the usability of the multimedia TAPS package.

As for the negatively-worded items, the 2nd, 4th, 6th, 8th, and 10th items, their mean values were found to be between 2.3 to 2.55, suggesting that majority of the respondents disagreed to the negative aspects of the enhanced multimedia TAPS package. They disagreed that the enhanced multimedia TAPS package was unnecessarily complex (mean = 2.55), disagreed that they would need the support of a technical person to be able to use the enhanced multimedia TAPS package (mean = 2.23), disagreed that there was too much inconsistency in this enhanced multimedia TAPS package (mean = 2.3), disagreed that the enhanced multimedia TAPS package was very complex to use and disagreed that they need to learn a lot of things before they could get going with this enhanced multimedia TAPS package (mean = 2.46).

Table 7.2 Descriptive Statistics of each SUS Item

	SUS Item[a] (*n*=150)	Mean	95% CI	SD	Median	Min	Max
1	I think that I would like to use this system frequently.	4.06	3.96-4.16	0.65	4	2	5
2	I found the system unnecessarily complex.	2.55	2.39-2.71	0.97	2	1	5
3	I thought the system was easy to use.	4.11	4-4.22	0.67	4	2	5
4	I think that I would need the support of a technical person to be able to use this system.	2.23	2.08-2.38	0.94	2	1	5
5	I found the various functions in this system were well integrated.	4.12	4.02-4.22	0.61	4	3	5
6	I thought there was too much inconsistency in this system.	2.3	2.17-2.43	0.79	2	1	5
7	I would imagine that most people would learn to use this system very quickly.	4.23	4.12-4.34	0.67	4	1	5
8	I found the system very cumbersome to use.	2.43	2.29-2.57	0.89	2	1	5
9	I felt very confident using the system.	4.06	3.95-4.17	0.68	4	2	5
10	I needed to learn a lot of things before I could get going with this system.	2.46	2.3-2.62	1.02	2	1	5

7.2.4.1 Overall SUS Score

The SUS questionnaire offers a simple formula for the researchers to analyze the system or product usability in which the overall SUS score ranges from 0 to 100. Brooke (2013) provided a standard scoring method to calculate for an overall SUS score that turns the raw individual survey ratings into a single SUS score as a measurement for overall usability of a certain system or software for easy interpretation. The higher the score is, the more useful the system or product is perceived to be (Ng, Lo, & Chan, 2011).The calculation of the overall SUS score was discussed in section 7.2.3. The descriptive statistics for the overall SUS score in this study is summarized in Table 7.3.

Table 7.3 Overall SUS Score

	N	**Mean**	**Median**	**Min**	**Max**	**SD**
Statistics	150	71.52	72.5	50	100	10.08

In order to interpret the overall SUS score, Bangor et al. (2009) suggested that a good system scores between 70 to 80 points of the overall SUS score while an exceptional one scores 90 or more. If the system scores between 50 to 70 points of the overall SUS score, Bangor, Kortum, & Miller (2009) stated that it should be be marginally acceptable, while any score less than that is considered as not acceptable. As referred to Table 7.3, the mean SUS score of the usability evaluation of the enhanced multimedia TAPS package is 71.52, median is 72.5, minimum value is 50 and maximum value is 100. This indicated that the enhanced multimedia TAPS package (mean score = 71.52) managed to achieve the rate of good system scores above 70 as referred to Figure 7.1. In addition, according to Sauro (2011), the average SUS score obtained from 500 studies in which a score that is above 68 is considered as above average and anything below 68 is below average (referred to Figure 7.2). Therefore this indicated that the enhanced multimedia TAPS package is above average and in the range of good system score.

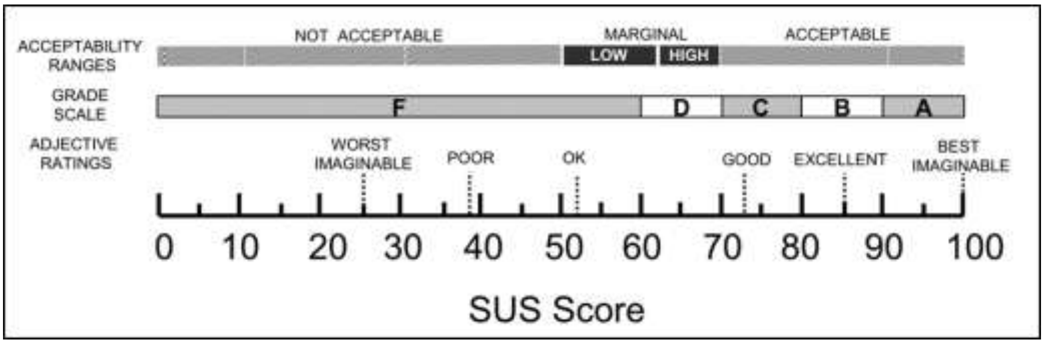

Figure 7.1. Grade rankings of SUS score (Bangor et al., 2009)

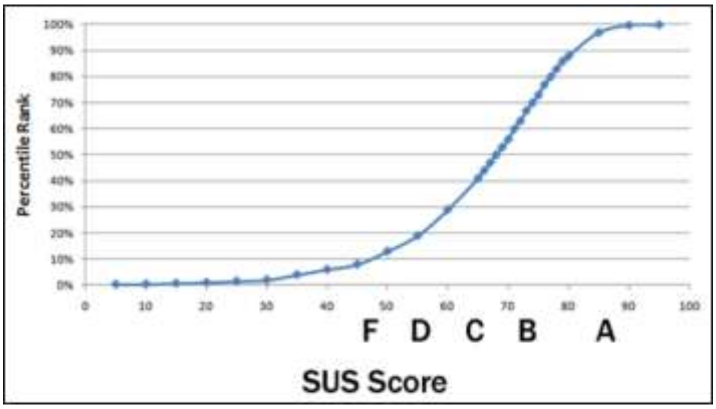

Figure 7.2: Percentile rankings of SUS scores (Sauro, 2011)

7.2.5 Discussion

Findings from this study provide several important insights on the usability of the enhanced multimedia TAPS package as a problem solving tool for engineering Mechanics Dynamics course. Firstly, the SUS score for the enhanced multimedia TAPS package indicated that it is above average and fall in the category of good system score in term of usability design as illustrated in section 7.2.4.1. Analysis of the results support the research hypothesis that the enhanced multimedia TAPS package met the users' expectations. As known, good usability design is important for the enhanced multimedia TAPS package as an engineering problem solving tool for Mechanics Dynamics course. When the learning tool is well designed, user perception contributes to higher motivation for, positive attitude towards, and greater interest in, using the learning tool, which increases the probability for user satisfaction and successful learning experience (Koohang, 2004a); (Koohang, 2004b). Including the usability testing as part of the evaluation is important to improve the quality and effectiveness of the computer-mediated instruction (Crowther, Keller, & Waddoups, 2004).

According to Nielsen (2012), usability is a quality attribute that assesses how easy user interfaces are to use. Nielsen (2012) further proposed five qualities components (learnability, efficiency, memorability, errors and satisfaction) that defined usability. The comparison Table (see Table 7.4) matches the SUS items with the usability 5 qualities components proposed by Nielsen. The positive results finding for SUS items score revealed that it has higher usability and is consistent with the usability quality as recommended by Nielsen. The interface design of the enhanced multimedia TAPS package for engineering problem solving follow the simplicity design by which only the related information are displayed for the students at one time (step-by-step approach). This would not increase the cognitive load for the students during the process of problem solving. The student only needs to focus on the contents displayed for problem solving. The embedded patterns of interactions under the attention grabber category (e.g. animated line, animated arrow, blinking effect etc.) would lead the students to focus their attention on the procedures in engineering problem solving. In addition, when necessary, the students may choose to interact with the interaction patterns under the category of knowledge retention (e.g. hints /tips window, ‘interesting facts’ feature’, hovering effect etc.) to remind themselves regarding the fundamental mechanics dynamics concepts to support their understanding in problem solving.

Table 7.4 Matching between SUS items with Nielsen's 5 qualities components

5 Qualities Components for Usability (Nielsen, 2012)	SUS items	SUS score (mean)
Learnability	I needed to learn a lot of things before I could get going with this system.	2.46
	I would imagine that most people would learn to use this system very quickly.	4.23
Efficiency	I found the system unnecessarily complex.	2.55
	I found the various functions in this system were well integrated.	4.12
Memorability	I thought the system was easy to use.	4.11
	I felt very confident using the system.	4.06
Errors	I think that I would need the support of a technical person to be able to use this system.	2.23
Satisfaction	I think that I would like to use this system frequently.	4.06

7.3 Usability Evaluation Study II – PSSUQ Instrument

The Post-Study System Usability Questionnaire (PSSUQ) is a questionnaire designed to assess users' perceived satisfaction with computer systems or applications (Sauro & Lewis, 2012). The PSSUQ items produce four scores – one overall and three subscales. The rules for computing them are:

- Overall: Average responses for Item 1 through 16 (all the items)
- System Quality (SysQual): Average Items 1 through 6
- Information Quality (InfoQual): Average Items 7 through 12
- Interface Quality (IntQual): Average Items 13 through 15

The PSSUQ does not require any license fee and it showed very high scale and subscale reliability (Overall: 0.94, SysQual: 0.9, InfoQual: 0.91, IntQual: 0.83) (Sauro & Lewis, 2012). All of the reliabilities exceed 0.8, including sufficient reliability to be useful as standardized usability measurements (Anastasi, 1976; Landauer, 1997; Nunnally, 1978).

7.3.1 Participant

The PSSUQ questionnaires was prepared and administrated to the students in the hardcopy form during the mid of the first study semester in July 2016. Sample questionnaire for PSSUQ is shown in Appendix E. The respondents were exposed to the usage of the enhanced multimedia TAPS package before the administration of the questionnaire. The enhanced multimedia TAPS package had been installed one day earlier prior to the administering of the questionnaire. The questionnaire was self-administered to respondents after their classes to ensure high participation rate. The respective lecturers did help to brief the respondents regarding the voluntary initiative to participate in the research study. The respondents were further briefed by the author regarding the objectives of the research survey before the questionnaires were distributed to them. Respondents were given 30 minutes to interact with the enhanced multimedia TAPS package before filling in the questionnaires. The questionnaires were collected back after 45 minutes. Out of the total questionnaire distributed (n=162), only 150 questionnaires were noted to be complete, providing a 92.6% response rate.

7.3.2 Procedure

A pilot test was conducted together with the SUS instrument two weeks before the actual distribution of the usability questionnaires. A total of 30 respondents were involved in the pilot study. Feedbacks were collected based on the following aspects:

1) Respondents should be given at least 30 minutes to interact with the multimedia TAPS package.
2) 15 minutes to fill in the PSSUQ questionnaire is more than sufficient.
3) The phrases used in the PSSUQ questionnaire were easy to understand.

7.3.3 Method (PSSUQ Instrument)

The PSSUQ instruments version 3 (see Appendix E) was used to gather the respondents' feedbacks regarding the usability evaluation. The respondents need to fill in the PSSUQ questionnaire after interacting with the enhanced multimedia TAPS package (around 30 minutes). The resulting scores for each item can take values between 1 and 7, with lower scores indicating a higher degree of satisfaction (Sauro & Lewis, 2012). The PSSUQ items produce four types of scores – one overall and three subscales. The rules of computing are stated as follow:

- Overall: Average responses from Item 1 through 16 (all the items)
- System Quality: Average Items 1 though 6
- Information Quality: Average Items 7 through 12
- Interface Quality: Average Items 13 through 15

Each of the mean value for the four types of scores mentioned above was calculated. The information of the mean values was used to perform the comparison with the PSSUQ version 3 norm Table for further interpretation.

7.3.4 Results and Findings

Internal Consistency of PSSUQ items was firstly analyzed to identify the reliabilities both for the overall scale and three subscales. The details are shown in Table 7.5. It can be identified that all of the reliabilities exceed Cronbach's alpha value 0.8, which indicate sufficient reliability to be useful in usability measurements (Anastasi, 1976; Landauer, 1997; Nunnally, 1978).

Table 7.5 Internal Consistency of PSSUQ Items

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Overall	0.952	0.952	16
System Quality	0.916	0.916	6
Information Quality	0.926	0.928	6
Interface Quality	0.832	0.840	3

7.3.4.1 Descriptive Statistics of each PSSUQ Item

In order to interpret the results gained through the PSSUQ instrument, the understanding of PSSUQ norms and interpretation of normative patterns are necessary. An updated lists of the best available norms for PSSUQ Version 3 (means and 99% confidence intervals) can be referred to (Sauro & Lewis, 2012) as shown in Table 7.6. The respective norm used the original alignment in PSSUQ instrument such that the lower scores are better than higher scores. The scores gained (mean value) for each of the items in PSSUQ instrument of the current study were obtained and listed as shown in Table 7.7. The comparison of the scoring scales between the current studies with the norm patterns can be further identified (see Table 7.6). For items 1, 3, 6, 7, 8, 9, 10, 11, 12, 14, 15 & 16, the mean value for each of the item score were lower than the norm data. While for items 2, 4, 5, 13, the mean value for each of the item score were slightly higher than the norm data.

Table 7.6 Comparison between the current study with the PSSUQ Version 3 Norms

Item	Item Text	Lower Limit		Mean		Upper Limit	
		Norm	Study	Norm	Study	Norm	Study
1	Overall, I am satisfied with how easy it is to use this system.	2.6	2.38	2.85	2.63	3.09	2.88
2	It was simple to use this system.	2.45	2.45	2.69	2.72	2.93	2.99
3	I was able to complete the tasks and scenarios quickly using this system.	2.86	2.46	3.16	2.71	3.45	2.96
4	I felt comfortable using this system.	2.4	2.54	2.66	2.81	2.91	3.07
5	It was easy to learn to use this system.	2.07	2.26	2.27	2.52	2.48	2.80
6	I believe I could become productive quickly using this system.	2.54	2.28	2.86	2.53	3.17	2.79
7	The system gave error messages that clearly told me how to fix problems.	3.36	2.3	3.7	2.55	4.05	2.79
8	Whenever I made a mistake using the system, I could recover easily and quickly.	2.93	2.16	3.21	2.39	3.49	2.62
9	The information (e.g., online help, on-screen messages, and other documentation) provided with this system was clear.	2.65	2.16	2.96	2.40	3.27	2.64
10	It was easy to find the information I needed.	2.79	2.14	3.09	2.39	3.38	2.64
11	The information was effective in helping me complete the tasks and scenarios.	2.46	2.05	2.74	2.27	3.01	2.50
12	The organization of information on the system screens was clear.	2.41	2.21	2.66	2.46	2.92	2.71
13	The interface of this system was pleasant.	2.06	2.10	2.28	2.29	2.49	2.49
14	I liked using the interface of this system.	2.18	2.16	2.42	2.39	2.66	2.61
15	This system has all the functions and capabilities I expect it to have.	2.51	2.27	2.79	2.50	3.07	2.74
16	Overall, I am satisfied with this system.	2.55	2.01	2.82	2.25	3.09	2.50

7.3.4.2 Overall PSSUQ Score

The PSSUQ items can produce four types of the scales for the usability evaluation. The lower the mean score, which is better for the evaluation. The comparison takes the norm data as the main reference. If the obtained scale score was less than the mean value of the norm data, this indicated positive result for the usability evaluation. As referred to the discussion in section 7.3.3, the average for items 1-6 lead to the system quality scale score. Through Table 7.7, it can be observed that the obtained mean score for the system quality was 2.66 which is less than the mean value (2.8) of the norm data. This indicated that the system quality for the enhanced multimedia TAPS package is better than the norm.

For the information quality scale (average of items 7-12), the obtained mean score was 2.41 which is much lesser than the mean value (3.02) of the norm data. This also indicated that the information quality delivered through the enhanced multimedia TAPS package is better than the norm. For the interface quality (average of items 13-15), the obtained mean score was 2.39 which is also less than the mean value (2.49) of the norm data. This indicated that the interface design of the enhanced multimedia TAPS package was well accepted by the respondents. For the overall usability scale score (average of items 1-16), the obtained mean score was 2.49 which is less than the mean score (2.82) of the norm data. This indicated that the usability evaluation for the enhanced multimedia TAPS package is better than the mentioned PSSUQ norm.

Table 7.7 Comparison of the four scoring scales between the current study with PSSUQ Version 3 Norms (Means and 99% Confidence Intervals)

Item	**Item Text**	**Lower Limit**		**Mean**		**Upper Limit**	
		Norm	**Study**	**Norm**	**Study**	**Norm**	**Study**
Scale	**Scale Scoring Rule**						
System Quality	**Average Items 1-6**	2.57	2.64	2.8	2.66	3.02	2.68
Information Quality	**Average Items 7-12**	2.79	2.39	3.02	2.41	3.24	2.43
Interface Quality	**Average Items 13-15**	2.28	2.37	2.49	2.39	2.71	2.41
Overall	**Average Items 1-16**	2.62	2.45	2.82	2.49	3.02	2.53

7.3.5 Discussion

This study examined whether users perceived the enhanced multimedia TAPS package as an aid in engineering problem solving for Mechanics Dynamics. In addition, this study attempted to answer the following question: Does the usability evaluation vary through different usability evaluation instruments (for this case: SUS and PSSUQ instruments)? As referred to the research findings in section 7.2.4.1 and section 7.3.4.2, the evaluation study of the usability design for the enhanced multimedia TAPS package, both using the SUS and PSSUQ instruments showed consistent feedbacks (positive) from the same group of respondents (*n=150*). Thus, the hypothesis that the enhanced multimedia TAPS package is highly usable was supported by the evidence from two different usability evaluation instruments (SUS and PSSUQ) indicated consistent results for the usability score. This further indicated that the design and development of the enhanced multimedia TAPS package-was tailored according to the learning styles preferences of the engineering students and it fulfills the needs of the learners (especially their experience to interact with the software). As a measurement tool, usability measures the quality of the user's experience while interacting with a product or system (Dumas & Redish, 1993; Nielsen, 1993, 2000; Rubin, 1994; Sorenson, 2016).

7.4 Factor Analysis (Interaction Patterns Categorization)

7.4.1 Overview

The patterns of interaction proposed in Chapter 6 were further analyzed through Exploratory Factor Analysis (EFA). The term 'exploratory factor analysis' is used as a generic expression for variable reduction techniques (Glynn et al., 2011; Nunnally & Bernstein, 1994; Oreg, 2003). The detail descriptions of EFA and generic methodology was discussed in Chapter 4. In this section, the procedure and methods to conduct the EFA would be discussed.

7.4.2 Participants

A total of 162 undergraduates taking the Mechanics Dynamics course from UNITEN were randomly selected to participate as the respondents in this research study. The respondents participated in the survey study voluntarily. In total the data was collected from 150 respondents for further analysis. The remaining 15 respondents' data set were rejected since they were incomplete. The average age for the respondents was 21 years old.

7.4.3 Materials

The patterns of interaction questionnaires were distributed to the respondents in the lecture session through the arrangement and help from the Mechanics Dynamics course instructors. The data collection took approximately two weeks (16th August 2016 – 26th August 2016). Sample of the questionnaire can be referred to Appendix F. The discussion regarding the grouping of the patterns of interactions for the questions shown in Appendix F can be refer to Chapter 6 section 6.4. The questionnaire consists of 50 questions which include the 25-items of interaction patterns. The respondents need to rate each of the question consist in the questionnaire. Responses were on a Likert-type scale, ranging from 1 = "Strongly disagree", 2 = "disagree", 3 = "Unsure", 4 = "agree" and 5 = "strongly agree". This study focused on the use of EFA method to reduce the numbers of variables (25-items of interaction patterns) into few factors, without expectations of the number or nature of the factors (Pett, Lackey, & Sullivan, 2003; Taherdoost et al., 2014; Thompson, 2004).

7.4.4 Procedure

The respondents were exposed to the usage of the enhanced multimedia TAPS package before the administering of the questionnaire. The enhanced multimedia

TAPS package had been installed one day earlier prior to the administering of the questionnaire. The questionnaire was self-administered to respondents after their classes to ensure high participation rate. The data was collected and analyzed using the SPSS for Windows (version 19).

7.4.5 Results and Findings

7.4.5.1 Sample Size

Sample size is a significant issue for factor analysis, there are different ideas and several guiding rules of thumb in the literature (Gorsuch, 1983; Hogarty, Kromrey, Ferron, & Hines, 2004; Tabachnick & Fidell, 2006). For this research study, the minimum amount of data for factor analysis was satisfied, with a final sample size of 150. This is consistent with the general rule of thumb that one should have at least 50 observations (preferably 100 or larger) and at least 5 times as many observations as variables (Habing, 2003; Hair, Black, Babin & Anderson, 2009).

7.4.5.2 Exploratory Factor Analysis

Initially, the factorability of the 25-items was examined. Several well-organized criteria for the factorability of a correlation were used. Firstly, 25-items correlated more than 0.0001 with at least one other item, suggesting reasonable factorability. As stated by Field (2000), if the determinant is greater than 0.00001, then there is no multicollinearity. Secondly, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was above the recommended value of 0.6, and Bartlett's test of sphericity was significant ($p < .05$). The diagonals of the anti-image correlation matrix were all over 0.65, supporting the inclusion of each item in the factor analysis. Finally, the communalities were all above 0.3 (see Table 7.8), further confirming that each item shared some common variance with other items.

Given these overall indicators, factor analysis was conducted with all 25 items which was divided into few groups by applying the principle component analysis (PCA) approach, to examine cross-loadings and select items with a high factor loading (>0.5). The principle component analysis (PCA) approach was chosen due to the following reasons as supported by the literature.

1) PCA is suggested to be used when no prior theoretical basis or model exists (Gorsuch, 1983)
2) PCA is recommended in establishing preliminary solutions in EFA (Pett et al., 2003)
3) If the researcher has initially developed an instrument with several items and is interested in reducing the number of items, then the PCA is useful (Netemeyer, Bearden, & Sharma, 2003).

Each of the proposed group of interaction patterns were examined by EFA using principle component analysis (CPA) with eigenvalue >1, and coding items with factor loading below 0.5 were omitted. Hair et al., (2009) recommended ±0.5 and above to be practically significant for the factor loadings to have a meaningful effect on the variables. Furthermore, the internal consistency of each variable was examined by computing the Cronbach's alpha, which was greater than 0.7 and so reliable. The exploratory factor analysis of the 25 items revealed a five-factor solution by which the details are presented in Table 7.8.

Table 7.8 Exploratory Factor Analysis Findings

	N= 150	Factor loadings					Communality
	Item (Interaction Patterns)	F1	F2	F3	F4	F5	
1	Graph generator controller	.669					.45
2	2-D animation controller	.594					.35
3	3-D model controller	.848					.72
4	Stereoscopic 3-D viewer	.807					.65
5	Multi-dimensional 3-D viewer	.847					.72
6	3-D trail generator & controller	.803					.64
7	Zooming	.690					.48
8	‘expand/hide’ effect		.700				.49
9	Blinking effect		.690				.48
10	Animated line		.824				.68
11	Animated arrow		.865				.75
12	Mouse over ‘highlighting’ effect		.738				.55
13	Interactive ‘point-click-response’ feature			.564			.32
14	‘Interesting fact’ feature			.611			.37
15	Answer checker			.721			.52
16	‘Fill-in-the-blank’ feature			.785			.62
17	‘pop-up hints /tips’ window			.768			.59
18	Hovering effects			.649			.42
19	Nomenclature				.778		.61
20	Help feature				.828		.69
21	Glossary feature				.819		.67
22	Sticky notes					.758	.57
23	Calculator					.782	.61
24	Notes recording pad					.803	.65
25	Narrated sound on / off					.713	.51
	Note: Factor loadings <0.5 will be omitted						

7.4.6 Discussion

The first group (F1) was labeled as “visualization” which evaluates the interaction patterns of “graph generator controller”, “2-D animation controller”, “3-D model controller”, “stereoscopic 3-D viewer”, “multi-dimensional 3-D viewer”, “3-D trail generator & controller” and “zooming” coding items. The result of the factor analysis revealed that these 7 coding items were loaded on a single factor (F1) with eigenvalue = 4.009, which is >1, and Cronbach’s alpha value = 0.87.

The second group (F2) was labeled as “attention grabber” which evaluates the following interaction patterns of “expand/hide effect”, “blinking effect”, “animated line”, “animated arrow”, and “mouse over highlighting effect” coding items. The result of the factor analysis revealed that these 5 coding items were loaded on a single factor (F2) with eigenvalue = 2.938, which is >1, and Cronbach’s alpha value = 0.82.

The third group (F3) was labeled as “knowledge retention” which evaluates the following interaction patterns of “interactive point-click-response feature”, “interesting fact feature”, “answer checker”, fill-in-the-blank feature”, “pop-up hints/tips window” and “hovering effects” coding items. The result of the factor analysis revealed that these 6 coding items were loaded on a single factor (F3) with eigenvalue = 2.840, which is > 1, and Cronbach’s alpha value = 0.77.

The fourth group (F4) was labeled as “supportive patterns 1” which evaluates the following interaction patterns of “nomenclature”, “help feature”, and “glossary feature” coding items. The result of the factor analysis revealed that these 3 coding items were loaded on a single factor (F4) with eigenvalue = 1.961, which is > 1, and Cronbach’s alpha value = 0.73.

The fifth group (F5) was labeled as "supportive patterns 2" which evaluates the following interaction patterns of "sticky notes", "calculator", "notes recording pad" and "narrated sound on/off" coding items. The result of the factor analysis revealed that these 4 coding items were loaded on a single factor (F5) with eigenvalue = 2.340, which is >1, and Cronbach's alpha value = 0.76.

7.5 Multiple Regression Analysis

7.5.1 Results and Findings

Based on the previous empirical findings (refer to section 7.4.5.2), we would like to further identify whether all these groups of interaction patterns (independent variables): "visualization", "attention grabber", "knowledge retention", "supportive patterns 1" and "supportive patterns 2" had significant association with engineering problem solving (dependent variable). The first variable "visualization" was assigned as X1, the second variable "attention grabber" was assigned as X2, the third variable "knowledge retention" was assigned as X3, the fourth variable "supportive patterns 1" was assigned as X4 and the fifth variable" supportive patterns 2" was assigned as X5. The dependent variable (problem solving tasks) was labeled as Y. Correlation and multiple linear regression analysis were conducted to determine if engineering problem solving score (dependent variable, Y) could be predicted from visualization score (independent variable, X1), attention grabber score (independent variable, X2), knowledge retention score (independent variable, X3), supportive patterns 1 score (independent variable, X4) and supportive patterns 2 score (independent variable, X5).

The following hypotheses were evaluated empirically through multiple linear regression analysis.

H_0: The interaction patterns does not significantly associate with engineering problem solving.

H_7: The "visualization" interaction pattern significantly associates with engineering problem solving.

H_8: The "attention grabber" interaction pattern significantly associates with engineering problem solving.

H_9: The "knowledge retention" interaction pattern significantly associates with engineering problem solving.

H_{10}: The "supportive patterns 1" interaction pattern significantly associates with engineering problem solving.

H_{11}: The "supportive patterns 2" interaction pattern significantly associates with engineering problem solving.

A variance inflation factor (VIF) test against each regressor was performed to test the no-multicollinearity assumption. The maximum VIF obtained in the model was 2.68, substantially below 5, by which if above 5 multicollinearity would be considered high (Ryan, 2009). The means, standard deviations and correlations of regression variables were shown in Table 7.9.

Table 7.9 Means, standard deviations and correlations of regression variables

Variable	Mean [a]	SD [a]	1	2	3	4	5	6
1 Problem Solving	5.56	0.94	1.00					
2 Visualization	4.05	0.53	0.40***	1.00				
3 Attention Grabber	3.97	0.56	0.57***	0.57***	1.00			
4 Knowledge Retention	4.08	0.49	0.61***	0.65***	0.69***	1.00		
5 Supportive Patterns 1	3.97	0.63	0.57***	0.52***	0.67***	0.68***	1.00	
6 Supportive Patterns 2	3.90	0.72	0.43***	0.29***	0.42***	0.42***	0.47***	1.00
Notes:[a] *n* = 150. ***P<0.01								

Table 7.10 summarizes the empirical results from the regression analysis. According to the empirical results, it can be identified that four out of five group of interaction patterns (attention grabber, knowledge retention, supportive patterns 1 and supportive patterns 2) are significantly associated with engineering problem solving. As referred to Table 7.11, the F-value is 23.888, which indicates the significance level well below 0.1%; thus, we soundly reject the null hypothesis for H2, H3, H4 and H5 that the four variables together have no effect on problem solving. Furthermore, the values for R^2 and adj. R^2 were 0.45 and 0.43, respectively. Therefore, statistically, based on the adj. R^2 obtained in the study, we may conclude that X2, X3 , X4 and X5 together explain only 43% of the variation of the problem solving. This suggests that there are many other factors which influence the problem solving that were not included in this study. Overall, the model generated high F-statistics and low p-values, indicating that the model is significant.

Table 7.10 Results of regression analysis

Variables	Model 1 Coefficients/ Standard Errors
Constant	0.31 (0.53)
Visualization	-0.11 (0.15)
Attention Grabber	0.34 ** (0.16)
Knowledge Retention	0.63 *** (0.19)
Supportive Pattern 1	0.27* (0.14)
Supportive Pattern 2	0.18* (0.09)
R^2	0.45
Adj. R^2	0.43
F	23.888***
n	150
Notes: *p<0.10; **p<0.05; ***P<0.01 (two-tailed). [a] standard errors are shown in parentheses.	

7.5.2 Discussion

According to the regression result shown in Table 7.10, the “knowledge retention” interaction patterns is most influential in aiding the engineering problem solving with coefficient equal to 0.63. This is due to the reasons that the interaction patterns (refer to Table 6.1 in Chapter 6) under the “knowledge retention” group such as the “interesting facts feature”, “pop-up hints / tips window, “hovering effects” were designed to serve the purpose in helping the students to recall or clarify the basic understanding on the concept needed in the process of problem solving thus increase the knowledge retention rate. This is consistent with the various efforts to improve the students’ knowledge retention for engineering problem solving as discussed in the literature (Rondon, Sassi, & Furquim de Andrade, 2013; Vasquez, Fuentes, & A., 2012; Vasquez, Fuentes, & Kypuros, 2015).

The “attention grabber” interaction patterns is also significantly associated with engineering problem solving with coefficient equal to 0.34 (see Table 7.10). The “attention grabber” interaction patterns included the ‘expand/hide’ effect, blinking effect, animated line, animated arrow and mouse over ‘highlighting’ effect. These patterns of interactions designed to serve the purpose in guiding the learners especially in the sequential step-by-step process of engineering problem solving. By interacting with the patterns, the learners may stay focus and remain engage on the contents for problem solving. As discussed previously in Chapter 2, engineering problem solving for mechanics dynamics involved complex calculations with different equations usage for different conditions that not only involved the x-axis and y-axis but also the z-axis, thus required longer attention span. Attention occurs prior to cognitive information processing (Wu, 2017). As claimed by Unsworth, McMillan, Brewer, & Spillers (2012), environmental distraction and mind-wandering are the major causes of attention failure among university student. Such disruption in attention may lead to incomplete coverage of the learning and longer task processing time (Bowman et al., 2010). The enhanced multimedia TAPS package embedded with the “attention grabber” interaction patterns may help to increase the attention span in solving the engineering problem. Furthermore, these interaction patterns may highlight the important contents for the learners such that it act as the visual cues to guide the learners throughout the process of problem solving.

Through Table 7.10, it can be identified that the “supportive patterns 1” and “supportive patterns 2” interaction patterns are also significantly associated with engineering problem solving. Those patterns under the category of “supportive pattern 1” refer to nomenclature feature, glossary feature and help feature. These patterns are labelled as supportive patterns since it act as supportive tools (optional) to clarify some technical engineering terms in case needed by the learners. In case the learner forgot some basic technical term, he or she may refer back to the nomenclature page or glossary page for further reference in clarifying the understanding. For the interaction patterns under the category of “supportive patterns 2” (e.g. the calculator, ‘sticky notes’, notepad etc.), these patterns are needed as a basic supportive tool in engineering problem solving especially those subject like mechanics dynamics that involved complex calculations.

CHAPTER 8

CONCLUSION

8.1 Overview

This final Chapter revisits the objectives of the research work as stated in Chapter 1 and discusses the findings / implications through the research conducted. This Chapter also discusses possible limitations of this research and propose recommendations for the future research works.

8.2 Research Findings

This section revisits the specific objectives set out in the first chapter of this thesis:

1) To identify the learning difficulties faced by the students in learning mechanics dynamics.

The first objective has been achieved by which the research question was answered with the findings obtained in Chapter 5 section 5.2.3. The students did face the difficulties especially in the learning process (for engineering problem solving tasks) in mechanics dynamics course both from the perspectives of students and the course instructors.

Hypothesis H_1:

Students faced difficulties in learning Mechanics Dynamics course (students perspective)

Hypothesis H_2:

Students faced difficulties in learning Mechanics Dynamics course (instructors perspective)

These two hypotheses were supported by the study (see Chapter 5 section 5.2.3), both feedbacks from the students and instructors are consistent and revealed that learning difficulties were found for engineering students in the mechanics dynamics course.

2) To examine the preferred learning styles for engineering students through the use of Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles Questionnaire.

The second objective has been achieved by which the engineering students in UNITEN were identified to share a common learning style preferences that they preferred to learn in sequential, logical way with various hands-on practical activities. They are "open-minded" and prefer to try out new forms of learning activities. More discussions can be referred to Chapter 5 section 5.4.4.

Hypothesis H_3:

The engineering students learning styles preferences evaluated through Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles instrument are consistent.

This hypothesis was supported by the study. As refer to Chapter 5, Table 5.12 shown consistent findings on the students learning styles preferences both using the Honey and Mumford's Learning Styles Questionnaire (LSQ) and Ogden's Personality and Learning Styles Instrument.

3) To measure students' perception towards the usability of the enhanced multimedia TAPS package.

The third objective has been achieved by which the students' perception towards the usability of the enhanced multimedia TAPS package are encouraging with positive result indicated (see Chapter 7 section 7.2.4 and section 7.3.4).

Hypothesis H_4:

The usability evaluation for the enhanced multimedia TAPS package is better than the standard norm value.

This hypothesis was supported by the study. The SUS usability score indicated that the enhanced multimedia TAPS package (mean score = 71.52) managed to achieve the rate of good system scores above 70 (see Chapter 7, Figure 7.1). Furthermore, the PSSUQ usability score indicated that the overall usability scale score (mean score was 2.49) which is less than the mean score (2.82) of the norm data. This indicated that the usability evaluation for the enhanced multimedia TAPS package is better than the mentioned PSSUQ norm.

Hypothesis H_5:

The evaluation study of the usability design for enhanced multimedia TAPS package indicated consistent findings (using different usability evaluation instruments).

This hypothesis was supported by the study. Both the usability evaluation for the enhanced multimedia TAPS package using the SUS and PSSUQ instruments indicated consistent findings (good usability result gained) (see Chapter 7 section 7.3.5).

4) To propose series of patterns of interactions for the enhanced multimedia TAPS package.

The fourth objective has been achieved by which 25 proposed patterns of interactions embedded with the enhanced multimedia TAPS package were designed and tested (refer to Chapter 6 section 6.4 for details).

5) To explore the categorization of the proposed patterns of interactions for the enhanced multimedia TAPS package.

The fifth objective has been achieved by which the 25 proposed patterns of interactions can be further categorized into five main categories.

Hypothesis H_6:

The proposed 25-items of interactions patterns can be grouped into few categories.

This hypothesis was supported by the study. Through the exploratory factor analysis, the 25 proposed patterns of interactions was grouped into five main categories, namely the "visualization" interaction patterns, the "attention grabber" interaction patterns, the "knowledge retention" interaction patterns, the "supportive patterns I" interaction patterns and the "supportive patterns II" interaction patterns. Detail descriptions can be refer to Chapter 7 section 7.4.5.2.

6) To investigate the relationships between the groups of interaction patterns as associated with the engineering problem solving tasks for the enhanced multimedia TAPS package.

The sixth objective has been achieved by which four out of five of the groups of interaction patterns were found to be significantly associated with engineering problem solving.

Hypothesis H_7:

The "visualization" interaction patterns significantly associate with engineering problem solving.

This hypothesis shows evidence of being denied by the study by which the p-value ($p<0.05$) was not significant (refer to Chapter 7 Table 7.10). The seven patterns of interactions under the category of "visualization" needs further study in order to identify the reasons why in overall it is not significantly associated with engineering problem solving tasks. This may due to few reasons: first, the design of the patterns are too complex thus confuse the leaners. Second, the interaction patterns should assist the problem solving tasks but not distract the learner's attention to interact with it. Each of the pattern of interactions in this category may need further investigation to identify its usability and its relationship individually as associated with engineering problem solving tasks in the near future.

Hypothesis H_8:

The "attention grabber" interaction patterns significantly associate with engineering problem solving.

Hypothesis H_9:

The "knowledge retention" interaction patterns significantly associate with engineering problem solving.

Hypothesis H_{10}:

The "supportive patterns I" interaction patterns significantly associate with engineering problem solving.

Hypothesis H_{11}:

The "supportive patterns II" interaction patterns significantly associate with engineering problem solving.

These hypotheses (H_8, H_9, H_{10} and H_{11}) were supported and supported by the study by which the p-values were significant ($p<0.05$) for H_8 and H_9 while ($P<0.10$) for H_{10} and H_{11} (refer to Chapter 7 Table 7.10). Thus these four groups of interaction patterns were found to be significantly associated with engineering problem solving tasks.

The results gained from all studies are thus very encouraging. The enhanced multimedia TAPS package embedded with the interaction patterns (four groups out of five) is significantly associated with the engineering problem solving tasks.

8.3 Research Contribution and Implications

The primary contribution of this research lies in the novel area of computer aided learning (CAL) domain for engineering education. The empirical investigations and validations process lead to the outcome of this research that the enhanced multimedia TAPS package with proposed patterns of interactions (four out of five groups) associated significantly with engineering problem solving tasks (in the context of mechanics dynamics). Due to the nature of the mechanics dynamics course, students not only need to understand the concept and principles but also need to apply the engineering principles in problem solving tasks. Practically, the research findings acted as a main reference for the mechanics dynamics instructors to adopt the enhanced multimedia TAPS package to facilitate the students learning process in problem solving tasks. Thus, the enhanced multimedia TAPS package acted as a supplement tool to facilitate the current teaching and learning practices in the University (in the context of mechanics dynamics). By acquiring the necessary knowledge and skills learned in mechanics dynamics, this would construct a strong foundation basis for the students. The students can adapt further in the advance mechanical courses such as the structural mechanics, system dynamics & control and machine design that highly emphasize on problem solving skills. This is in line with the new trend of paradigm shift in engineering education that recommended changes in pedagogical style which accommodate active learning approach engage with problem solving skills as mentioned in Chapter 2 section 2.2.1.

The second novel contribution of this research was the consistent findings of the learning styles preferences for engineering students through the use of Honey and Mumford's Learning Styles Questionnaire and the Ogden's Personality and Learning Styles Questionnaire that significantly contributed to the body of knowledge in the literature of engineering education domain on students learning styles preferences. The outcome of the research findings identified that engineering students in UNITEN shared a common learning style preferences that they preferred to learn in sequential, logical way with various hands-on practical activities. They are "open-minded" and prefer to try out new forms of learning activities. This lead to create an opportunity for the use of advanced ICT technologies (e.g. Augmented Reality and Holography technologies) to facilitate the learning process of engineering students. Furthermore, the outcome of this research findings on learning styles preferences of engineering students can be used as a sample of reference for future research in other Malaysian universities on the issues of learning styles preferences in the context of engineering education.

The third contribution of this research was the consistent findings on the usability evaluation using the SUS and PSSUQ instruments for enhanced multimedia TAPS package. This research finding contributed as part of the efforts to close the gap of knowledge in the literature regarding the limited findings on the valid usability testing for the interface design of the engineering learning software, specifically in the context of mechanics dynamics (see Chapter 2 section 2.4.2 and Chapter 6 section 6.3). Furthermore, the outcome of the usability testing by using the SUS and PSSUQ instruments for the enhanced multimedia TAPS package could be used as a frame of reference for future studies in the similar context of computer aided learning in engineering education.

8.4 Limitations of the Study

Throughout the research study, the following limitations were identified:

1) The contents knowledge for the enhanced multimedia TAPS package was limited and focus on the topic of Planar Kinematics of a Rigid Body. The recommended patterns of interactions are significantly associated with the engineering problem solving tasks in the mechanics dynamics sub domain knowledge on Planar Kinematics.

2) Observation technique was not implemented in the evaluation of the usability for enhanced multimedia TAPS package to observe the interaction process between the students and the TAPS package.

8.5 Recommendation for Future Work

1) The research study can be further extended to collect more qualitative data regarding the learners' perceptions on the usage of enhanced multimedia TAPS package in supporting their learning.

2) The "visualization" category of interaction patterns can be further investigated to identify each of the interaction patterns relationships and its correlation with engineering problem solving through different statistical approaches.

3) The implementation of enhanced multimedia TAPS package in the blended learning environment and its impact on learning effectiveness could be further explored.

4) Extend the scope of enhanced multimedia TAPS package to incorporate other approaches in designing such as augmented reality and holography technologies in facilitating the students learning experience and aiding in problem solving tasks.

5) The comparative study between / among few universities in Malaysia in the context of engineering education to evaluate the students learning styles preferences to investigate further the learning preferences among the engineering students.

6) Intensive comparative study is recommended between / among few universities in Malaysia regarding the efficacy of the enhanced multimedia TAPS package with students learning performance.

8.6 Closing Remarks

The primary contribution of this research study is the design and development of the enhanced multimedia TAPS package embedded with proposed patterns of interactions that significantly associated with engineering problem solving tasks. The encouraging results gained contribute to the body of knowledge in the context of computer aided learning for engineering education that was carefully designed with the interaction patterns which match with the students learning styles preferences significantly aid the students in engineering problem solving tasks. For the design and development of the new computer aided learning application, the learning styles preferences of the users should be taken as main consideration and reference to create a better user experience with the computer aided learning application to facilitate the learning process. Moreover, the usability testing through the use of validated usability evaluation instruments are essential to ensure better user experience especially for the application/software aim to support or facilitate the positive learning environment.

The implications of this research study raised the concern for education practitioners that the usability evaluation plays a significant role in contributing to the learning performance of the students through the use of computer aided learning application / software. Furthermore, the empirically tested interaction patterns recommended in this research study can act as the main reference to be embedded in the newly developed computer aided learning application / software in the context of engineering education especially in the sub-domain of mechanics dynamics to facilitate engineering problem solving tasks.

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Appendix A

<u>Questionnaire on Learning Mechanics Dynamics</u>

All Questions Are Based On and Related to (ENGINEERING MECHANICS DYNAMICS) ONLY.
Reminder: When answering the questions, try to reflect back the experience and the process when you took the subject of Mechanics Dynamics.

Year of study:
Do you ever take the subject on Mechanics Dynamics? Yes No
This subject is:
Please tick (√)on the relevant answer. You may tick more than one answer.

	Difficult		Hardest One of the most difficult subject ever taken		Easy		Fun
	Interesting		Boring		Logical		Of no concern to me

Section A:

	General Questions	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
1	I can see clearly the structure of whole course.					
2	New concepts are the most difficult part of the course.					
3	Lectures are a necessary part of the course.					
4	I learn this subject by homework assignments only.					
5	I learn the same from tutorials as in the lecture.					
6	To learn this subject the textbook is needed.					
7	This subject will be useful for my future profession.					
8	I gained sufficient knowledge from this subject.					
9	I got from this subject everything that I expected.					
10	I manage to link what I learn from this subject to the real life engineering applications /practices.					
11	I manage to understand the importance of each topic delivered (learning outcomes).					
	Problem Solving Ability	Always	Often	Sometimes	Seldom	Never

12	I clearly understand the problem.					
13	I can clearly identify the given and the unknown.					
14	I can visualize the problem.					
15	I can draw and label diagram.					
16	I can think of a plan for the solution.					
17	I can see alternative ways of solving the problem.					
18	I can describe step by step what I did.					
19	I can explain the obtained results.					
20	I can make a conclusion.					
21	I never forget to check units.					
22	I used examples solved in the class as a model for solving problems.					
23	I do all homework assignments.					
	Working with the textbook	**Always**	**Often**	**Sometimes**	**Seldom**	**Never**
24	I read the textbook carefully.					
25	I read the textbook on a regular basis.					
26	I understand the material in the textbook.					
27	I try to do some of the exercises from the text to reinforce my problem-solving techniques.					
28	I take notes while working with the textbook.					
29	I have problems in understanding the contents because the figure(s) shown is /are static (no animations).					
30	I have problems in visualize /visualizing the scenario as described in the text.					
31	The step-by-step approach shown in the sample solutions was sufficient to aid my understanding.					
		Very Good	**Good**	**Moderate**	**Bad**	**Very Bad**
32	Overall, I think my level of knowledge for this subject is					

Section B:

Did the lecture sessions help?

Yes / No. Why? (*Please justify your answers*)

____

____

___

Did the tutorial sessions help?

Yes / No. Why? (*Please justify your answers*)

____

____

___

List the difficulties that you faced before in this subject:

____

___

How do you overcome the difficulties in learning Mechanics Dynamics?

____

___

Is there anything you would like to add in regard to the teaching and learning of this subject (Mechanics Dynamics) in specific?

____

___

Teaching methods: Please rate the effectiveness of each method below for learning course contents. (Very effective; Somewhat effective; Neutral, Less effective, Not effective).

- Lecture

  □ Very effective; □ Somewhat effective; □ Neutral; □ Less effective; □ Not effective

- In-class activities (Peer discussion, Q&A, etc)

  □ Very effective; □ Somewhat effective; □ Neutral; □ Less effective; □ Not effective

- In-class demonstrations (video, animation etc)

  □ Very effective; □ Somewhat effective; □ Neutral; □ Less effective; □ Not effective

- In-class part examples

  □ Very effective; □ Somewhat effective; □ Neutral; □ Less effective; □ Not effective

- Assignments

  □ Very effective; □ Somewhat effective; □ Neutral; □ Less effective; □ Not effective

- Exams /Quizzes

  □ Very effective; □ Somewhat effective; □ Neutral; □ Less effective; □ Not effective

Section C:

Are you aware of /expose to the use of learning courseware (web based / CD based) to assist in learning Mechanics Dynamics?

□ Yes *(please proceed to the following questions)* □ No

		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
I	I believe that some contents can be learned faster when using a computer.					
II	I believe I will engage in the learning with the use of /by employing computer simulations.					
III	I believe that the user interaction performed with the computer simulation on engineering models may enhance the learning process.					
IV	I believe that the 2D animation on engineering model may support the visualization process.					
V	I believe that the 3D animation on engineering model may enhance the visualization process.					

Based on your opinions, in what condition does the learning courseware (web based / CD based) useful?

____

____

Thanks for your feedbacks ☺

Appendix B

LEARNING STYLES QUESTIONNAIRE

This questionnaire is designed to find out your preferred learning style(s). Over the years you have probably developed learning 'habits' that benefit more from some experiences than from others. Since you are probably unaware of this, this questionnaire will help you pinpoint your learning preferences so that you are in a better position to select learning experiences that suit your style.

There is no time limit to this questionnaire. It will probably take you 10-15 minutes. The accuracy of the results depends on how honest you can be. There are no right or wrong answers. If you agree more than disagree with a statement pt a tick by it ( ). If you disagree more than you agree put a cross by it (x). Be sure to mark each item with either a tick or cross.

- ☐ 1. I have strong beliefs about what is right and wrong, good and bad.
- ☐ 2. I often 'throw caution to the winds'.
- ☐ 3. I tend to solve problems using a step-by-step approach, avoiding any 'flights-of-fancy'.
- ☐ 4. I believe that formal procedures and policies cramp people's style.
- ☐ 5. I have a reputation for having a no-nonsense, 'call a spade a spade' style.
- ☐ 6. I often find that actions based on 'gut feel' are as sound as those based on careful thought and analysis.
- ☐ 7. I like to do the sort of work where I have time to 'leave no stone unturned'.
- ☐ 8. I regularly question people about their basic assumptions.
- ☐ 9. What matters most is whether something works in practice.
- ☐ 10. I actively seek out new experiences.
- ☐ 11. When I hear about a new idea or approach I immediately start working out how to apply it in practice.
- ☐ 12. I am keen on self discipline such as watching my diet, taking regular exercise, sticking to a fixed routine, etc.
- ☐ 13. I take pride in doing a thorough job.
- ☐ 14. I get on best with logical, analytical people and less well with spontaneous, 'irrational' people.
- ☐ 15. I take care over the interpretation of data available to me and avoid jumping to conclusions.
- ☐ 16. I like to reach a decision carefully after weighing up many alternatives.
- ☐ 17. I'm attracted more to novel, unusual ideas than to practical ones.
- ☐ 18. I don't like 'loose-ends' and prefer to fit things into a coherent pattern.
- ☐ 19. I accept and stick to laid down procedures and policies so long as I regard them as an efficient way of getting the job done.
- ☐ 20. I like to relate my actions to a general principle.
- ☐ 21. In discussions I like to get straight to the point.
- ☐ 22. I tend to have distant, rather formal relationships with people at work.
- ☐ 23. I thrive on the challenge of tackling something new and different.
- ☐ 24. I enjoy fun-loving, spontaneous people.

- ❑ 25. I pay meticulous attention to detail before coming to a conclusion.
- ❑ 26. I find it difficult to come up with wild, off-the-top-of-the-head ideas.
- ❑ 27. I don't believe in wasting time by 'beating around the bush'.
- ❑ 28. I am careful not to jump to conclusions too quickly.
- ❑ 29. I prefer to have as many sources of information as possible – the more data to mull over the better.
- ❑ 30. Flippant people who don't take things seriously enough usually irritate me.
- ❑ 31. I listen to other people's point of view before putting my own forward.
- ❑ 32. I tend to be open about how I'm feeling.
- ❑ 33. In discussions I enjoy watching the manoeuvrings of the other participants.
- ❑ 34. I prefer to respond to events on a spontaneous, flexible basis rather than plan things out in advance.
- ❑ 35. I tend to be attracted to techniques such as network analysis, flow charts, branching programmes, contingency planning etc.
- ❑ 36. It worries me if I have to rush out a piece of work to meet a tight deadline.
- ❑ 37. I tend to judge people's ideas on their practical merits.
- ❑ 38. Quiet, thoughtful people tend to make me feel uneasy.
- ❑ 39. I often get irritated by people who want to rush headlong into things.
- ❑ 40. It is more important to enjoy the present moment than to think about the past or future.
- ❑ 41. I think that decisions based on a thorough analysis of all the information are sounder than those based on intuition.
- ❑ 42. I tend to be a perfectionist.
- ❑ 43. In discussions I usually pitch in with lots of off-the-top-of-the-head ideas.
- ❑ 44. In meetings I put forward practical realistic ideas.
- ❑ 45. More often than not, rules are there to be broken.
- ❑ 46. I prefer to stand back from a situation and consider all the perspectives.
- ❑ 47. I can often see inconsistencies and weaknesses in other people's arguments.
- ❑ 48. On balance I talk more than I listen.
- ❑ 49. I can often see better, more practical ways to get things done.
- ❑ 50. I think written reports should be short, punchy and to the point.
- ❑ 51. I believe rational, logical thinking should win the day.
- ❑ 52. I tend to discuss specific things with people rather than engaging in 'small talk'.
- ❑ 53. I like people who have both feet firmly on the ground.
- ❑ 54. In discussions I get impatient with irrelevancies and 'red herrings'.
- ❑ 55. If I have a report to write I tend to produce lots of drafts before settling on the final version.

❑ 56. I am keen to try things out to see if they work in practice.
❑ 57. I am keen to reach answers via a logical approach.
❑ 58. I enjoy being the one that talks a lot.
❑ 59. In discussions I often find I am the realist, keeping people to the point and avoiding 'cloud nine' speculations.
❑ 60. I like to ponder many alternatives before making up my mind.
❑ 61. In discussions with people I often find I am the most dispassionate and objective.
❑ 62. In discussions I'm more likely to adopt a 'low profile' than to take the lead and do most of the talking.
❑ 63. I like to be able to relate current actions to a longer term bigger picture.
❑ 64. When things to wrong I am happy to shrug it off and 'put it down to experience'.
❑ 65. I tend to reject wild, off-the-top-of-the-head ideas as being impractical.
❑ 66. Its best to 'look before you leap'.
❑ 67. On balance I do the listening rather than the talking.
❑ 68. I tend to be tough on people who find it difficult to adopt a logical approach.
❑ 69. Most times I believe the end justifies the means.
❑ 70. I don't mind hurting people's feelings so long as the job gets done.
❑ 71. I find the formality of having specific objectives and plans stifling.
❑ 72. I'm usually the 'life and soul' of the party.
❑ 73. I do whatever is expedient to get the job done.
❑ 74. I quickly get bored with methodical, detailed work.
❑ 75. I am keen on exploring the basic assumptions, principles and theories underpinning things and events.
❑ 76. I'm always interested to find out what other people think.
❑ 77. I like meetings to be run on methodical lines, sticking to laid down agenda, etc.
❑ 78. I steer clear of subjective or ambiguous topics.
❑ 79. I enjoy the drama and excitement of a crisis situation.
❑ 80. People often find me insensitive to their feelings.

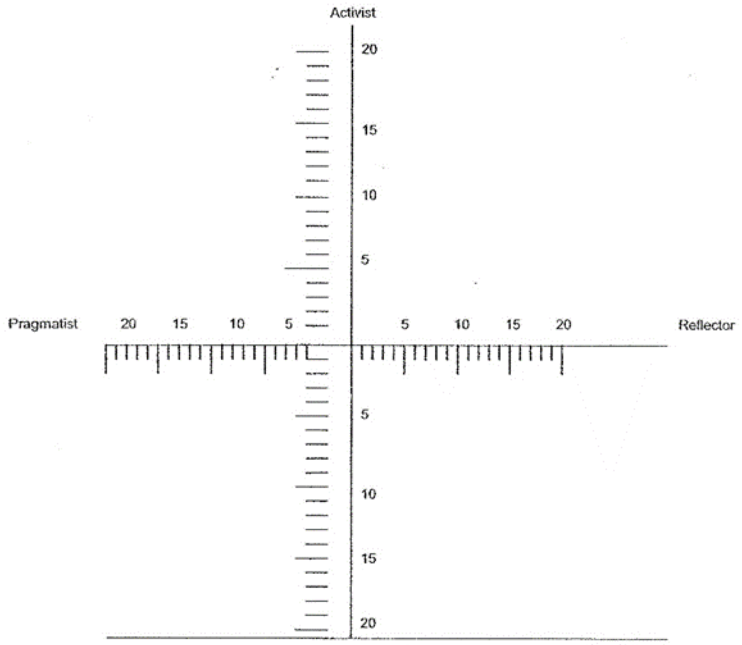
LEARNING STYLES QUESTIONNAIRE – SCORING

You score one point for each item you ( ). There are no points for items you cross (x).

Simply indicate on the lists below which items were ticked.

	2	7	1	5
	4	13	3	9
	6	15	8	11
	10	16	12	19
	17	25	14	21
	23	28	18	27
	24	29	20	35
	32	31	22	37
	34	33	26	44
	38	36	30	49
	40	39	42	50
	43	41	47	53
	45	46	51	54
	48	52	57	56
	58	55	61	59
	64	60	63	65
	71	62	68	69
	72	66	75	70
	74	67	77	73
	<u>79</u>	<u>76</u>	<u>78</u>	<u>80</u>
Totals				
	—	—	—	—
	Activist	Reflector	Theorist	Pragmatist

Plot the scores on the arms of the cross below .


Activist
20
15
10
5
Pragmatist
20
15
10
5
5
10
15
20
Reflector
5
10
15
20

LEARNING STYLES – GENERAL DESCRIPTIONS

ACTIVISTS

Activists involve themselves fully and without bias in new experiences. They enjoy the here and now and are happy to be dominated by immediate experiences. They are open-minded, not sceptical, and this tends to make them enthusiastic about anything new. Their philosophy is: 'I'll try anything once'. They dash in where angels fear to tread. They tend to throw caution to the wind. Their days are filled with activity. They revel in short term crisis fire fighting. They tackle problems by brainstorming. As soon as the excitement from one activity has died down they are busy looking for the next. They tend to thrive on the challenge of new experiences but are bored with implementation and longer term consolidation. They are gregarious people constantly involving themselves with others but, in doing so, they hog the limelight. They are the life and soul of the party and seek to centre all activities around themselves.

REFLECTORS

Reflectors like to stand back to ponder experiences and observe them from many different perspectives. They collect data, both first hand and from others, and prefer to chew it over thoroughly before coming to any conclusion. The thorough collection and analysis of data about experience and events is what counts so they tend to postpone reaching definitive conclusions for as long as possible. Their philosophy is to be cautious, to leave no stone unturned. 'Look before you leap'; 'Sleep on it'. They are thoughtful people who like to consider all possible angles and implications before making a move. They prefer to take a back seat in meetings and discussions. They enjoy observing other people in action. They listen to others and get the drift of the discussion before making their own points. They tend to adopt a low profile and have a slightly distant, tolerant, unruffled air about them. When they act it is as part of a wide picture which includes the past as well as the present and others' observations as well as their own.

THEORISTS

Theorists adapt and integrate observations into complex but logically sound theories. They think problems through in a vertical, step by step logical way. They assimilate disparate facts into coherent theories. They tend to be perfectionists who won't rest easy until things are tidy and fit into their rational scheme. They like to analyse and synthesise. They are keen on basic assumptions, principles, theories models and systems thinking. Their philosophy prizes rationality and logic. 'If it's logical it's good'. Questions they frequently ask are: "Does it make sense?" "How does this fit with that?" "What are the basic assumptions?" They tend to be detached, analytical and dedicated to rational objectivity rather than anything subjective or ambiguous. Their approach to problems is consistently logical. This is their 'mental set' and they rigidly reject anything that doesn't fit with it. They prefer to maximise certainty and feel uncomfortable with subjective judgements, lateral thinking and anything flippant.

PRAGMATISTS

Pragmatists are keen on trying out ideas, theories and techniques to see if they work in practice. They positively search out new ideas and take the first opportunity to experiment with applications. They are the sort of people who return from management courses brimming with new ideas that they want to try out in practice. They like to get on with things and act quickly and confidently on ideas that attract them. They don't like 'beating around the bush' and tend to be impatient with ruminating and open-ended discussions. They are essentially practical, down to earth people who like making practical decisions and solving problems and opportunities 'as a challenge'. Their philosophy is: 'There is always a better way' and 'If it works it's good'.

Appendix C

Personality and Learning Styles Questionnaire

Name:

Age:

Email:

		Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
1	It is important to me that I can convince others to my point of view.					
2	I am more conforming than I am different.					
3	I value the advice and views of others highly					
4	I do not think much about why people do things					
5	I change my behavior to suit the situation.					
6	There is little room for theory in the real world.					
7	I require objective evidence to reach acceptable conclusions.					
8	I am not particularly imaginative.					
9	I am good at spotting the flaws in proposals or suggestions.					
10	I do not need much order in my work.					
11	I always seek to finish things to a high standard.					
12	I prefer to finish a task before starting on an new one.					
13	I need a lot of variety in my work.					
14	I do not like following strict instructions.					
15	I reach conclusions quickly.					
16	I prefer caution to taking risks.					
17	I feel nervous before important events.					
18	I rarely spend time analyzing myself.					

		Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
19	I do not think things are ever crystal clear.					
20	I am not interested in changing the minds of other people.					
21	I generally have strong, independent views.					
22	I prefer to make decisions alone.					
23	I like to analyse why people behave the way they do.					
24	I act consistently across different situations.					
25	I like dealing with abstract matters.					
26	I am happy to act without needing facts or figures about a situation.					
27	I am an ideas person.					
28	I do not like critically reviewing information or ideas.					
29	I am concerned to get all the details right.					
30	I often leave tasks unfinished.					
31	I like to have several things on the go at one time.					
32	I prefer a consistent routine.					
33	I follow rules and regulations closely.					
34	I like to deliberate over matters at length.					
35	I am prepared to take big risks for big returns.					
36	I feel calm and collected before important events.					
37	After an event I often replay my behavior in my mind.					
38	I never bother analyzing things in any great depth.					
39	I am keen to impress my point of view on others.					
40	I prefer to follow consensus.					
41	I prefer to seek the views of the others before reaching a conclusion.					
42	I rarely question why people behave the way they do.					
		Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree

43	I consciously change the impression I give to different people.					
44	I am not interested in hypothetical debate.					
45	I prefer dealing with things that can be accurately measured.					
46	I prefer to build on the ideas of others than produce them myself.					
47	I have a critical and evaluative mind.					
48	I would rather just start work than think carefully about it first.					
49	I am uncomfortable leaving things unfinished.					
50	I like to have a good run at one task at a time.					
51	I dislike routine.					
52	I am good at following detailed instructions.					
53	I make up my mind quickly.					
54	I would rather settle for smaller victories than take a big risk.					
55	I get worried before events that need to go well.					
56	I rarely think back over my past behavior.					
57	I find that things are rarely as simple as they may appear.					
58	I do not try to influence those who disagree with me.					
59	I often disagree with the majority way of looking at things.					
60	I seldom consult with others before making decisions.					
61	I am interested in how other people think.					
62	I do not adapt my behavior for other people.					
63	I like thinking about different theories or concepts.					
64	I do not need logical proof to believe in things.					
65	I spend a lot of time 'playing' with ideas in my mind.					
		Strongly Disagree	**Disagree**	**Don't Know**	**Agree**	**Strongly Agree**
66	I do not tend to look for drawbacks or problems in things.					

67	I like to plan work carefully before starting.					
68	I do not need to finish things perfectly.					
69	I prefer to deal with different tasks that I can switch between quickly.					
70	I prefer familiar work.					
71	I am happy to follow laid-down procedures.					
72	I do not like to make decisions quickly.					
73	I value risk over caution.					
74	I feel confident before key occasions.					
75	I often analyze my own behavior.					
76	Most problems are quite simple and clear.					

Appendix D

SET A

System Usability Scale (SUS)

Strongly disagree — Strongly agree

		1	2	3	4	5
1	I think that I would like to use this system frequently.					
2	I found the system unnecessarily complex.					
3	I thought the system was easy to use.					
4	I think that I would need the support of a technical person to be able to use this system.					
5	I found the various functions in this system were well integrated.					
6	I thought there was too much inconsistency in this system.					
7	I would imagine that most people would learn to use this system very quickly.					
8	I found the system very cumbersome to use.					
9	I felt very confident using the system.					
10	I needed to learn a lot of things before I could get going with this system.					

APPENDIX E

The PSSUQ Survey

The Post-Study Usability Questionnaire	Strongly Disagree					Strongly Agree			

		1	2	3	4	5	6	7		NA
1	Overall I am satisfied with how easy it is to use this system.									
2	It was simple to use this system									
3	I was able to complete the tasks and scenarios quickly using this system.									
4	I felt comfortable using this system.									
5	It was easy to learn to use this system.									
6	I believe I could become productive quickly using this system.									
7	The system gave error messages that clearly told me how to fix problems.									
8	Whenever I made a mistake using the system, I could recover easily and quickly.									
9	The information (such as the pop-up message, help section and other documentation) provided with system was clear.									
10	It was easy for me to find the information I needed.									
11	The information was effective in helping me complete the tasks and scenarios.									
12	The organization of information on the system screens was clear.									
13	The interface* of this system was pleasant.									
14	I liked using the interface of this system.									
15	This system has all the functions and capabilities I expect it to have.									
16	Overall, I am satisfied with this system.									

The “interface” includes those items that you use to interact with the system. For example, some components of the interface are the buttons, pop-up menu, dragging features etc. (including their graphics and language).

APPENDIX F

UNIVERSITI TENAGA NASIONAL

SET B

Enhanced 3D Interactive Multimedia Engineering Problem Solving Tool

Questionnaire

<u>This information will be kept strictly confidential.</u>

**The author is currently doing his research as partial fulfillment of the requirement for the degree of PhD in ICT. The purpose of this questionnaire is to help the author to gain some information in identifying the usability of the engineering tool and suitability of the interaction patterns for engineering problem solving. All the information provided is confidential and will not be used for any other purposes.*

Section One: Participant Information

Course: ___________________________________ Year/Semester: _______________________

Age: _______________________ Gender: ______________________________

How long have you been using the computer? ___________________________________

With regard to Information and Communication Technology (ICT) in general, how would you describe yourself?

Advanced user?	Intermediate user?	Novice user?

Can you program in any computer languages? Yes ☐ No ☐

Have you used any computer aided learning packages before? Yes ☐ No ☐

If YES, was it in engineering subjects? Yes ☐ No ☐

Please specific the topics covered……………………………………………………………..................................

Section Two: Usability Testing (Patterns of Interactions) Questionnaires

		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
		1	**2**	**3**	**4**	**5**
	Interaction Patterns for Visualization					
1	The design of the "**graph generator controller**" is appropriate?					
2	The "**graph generator controller**" is useful to assist in visualization?					

3	The design of the "**2-D animation controller**" is appropriate?					
4	The "**2-D animation controller**" is useful to assist in visualization?					
5	The design of the "**3-D model controller**" is appropriate?					
		Strongly Disagree	**Disagree**	**Unsure**	**Agree**	**Strongly Agree**
	Interaction Patterns for Visualization	**1**	**2**	**3**	**4**	**5**
6	The "**3-D model controller**" is useful to assist in visualization?					
7	The design of the "**stereoscopic 3-D viewer**" is appropriate?					
8	The "**stereoscopic 3-D viewer**" is useful to assist in visualization?					
9	The design of the "**multi-dimensional 3-D viewer**" is appropriate?					
10	The "**multi-dimensional 3-D viewer**" is useful to assist visualization?					
11	The design of the "**3-D trail generator & controller**" is appropriate?					
12	The "**3-D trail generator & controller**" is useful to assist in visualization?					
13	The design of the "**zooming**" is appropriate?					
14	The "**zooming**" is useful to assist in visualization?					
	Interaction Patterns for Attention Grabber					
15	The design of the "**expand/hide effect**" is appropriate?					
16	The "**expand/hide effect**" is useful to assist in problem solving?					
17	The design of the "**blinking effect**" is appropriate?					
18	The "**blinking effect**" is useful to assist in problem solving?					
19	The design of the "**animated line**" is appropriate?					
20	The "**animated line**" is useful to assist in problem solving?					
21	The design of the "**animated arrow**" is appropriate?					
22	The "**animated arrow**" is useful to assist in problem solving?					
23	The design of the "**mouse over highlighting effect**" is appropriate?					
24	The "**mouse over highlighting effect**" is useful to assist in problem solving?					

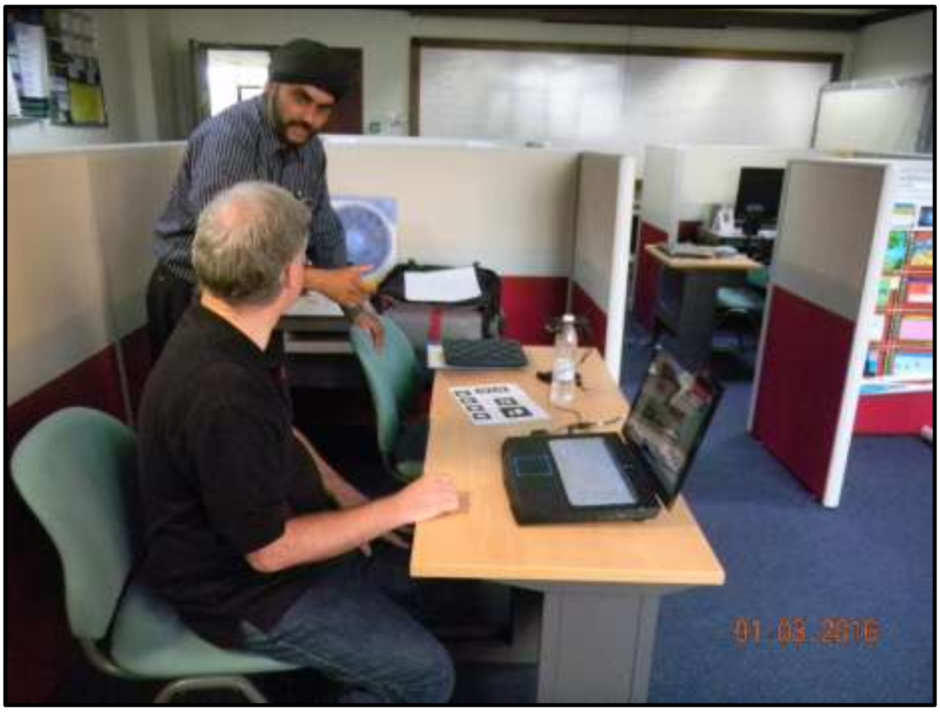
		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
		1	**2**	**3**	**4**	**5**
	Interaction Patterns for Knowledge Retention					
25	The design of the "**interactive point-click-response feature**" is appropriate?					
26	The "**interactive point-click-response feature**" is useful to assist in problem solving?					
27	The design of the "**interesting fact feature**" is appropriate?					
28	The "**interesting fact feature**" is useful to assist in problem solving?					
29	The design of the "**answer checker**" is appropriate?					
30	The "**answer checker**" is useful to assist in problem solving?					
31	The design of the "**fill-in-the-blank feature**" is appropriate?					
32	The "**fill-in-the-blank feature**" is useful to assist in problem solving?					
33	The design of the "**pop-up hints / tips window**" is appropriate?					
34	The "**pop-up hints / tips window**" is useful to assist in problem solving?					
35	The design of the "**hovering effects**" is appropriate?					
36	The "**hovering effects**" is useful to assist in problem solving?					
	Supportive Patterns					
37	The design of the "**nomenclature**" is appropriate?					
38	The "**nomenclature**" is useful as a supportive tool?					
39	The design of the "**help feature**" is appropriate?					
40	The "**help feature**" is useful as a supportive tool?					
41	The design of the "**glossary feature**" is appropriate?					
42	The "**glossary feature**" is useful as a supportive tool?					
		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
		1	**2**	**3**	**4**	**5**
	Supportive Patterns					

43	The design of the "**sticky notes**" is appropriate?					
44	The "**sticky notes**" is useful as a supportive tool?					
45	The design of the "**calculator**" is appropriate?					
46	The "**calculator**" is useful as a supportive tool?					
47	The design of the "**notes recording pad**" is appropriate?					
48	The "**notes recording pad**" is useful as a supportive tool?					
49	The design of the "**narrated sound on/off**" is appropriate?					
50	The "**narrated sound on/off**" is useful as a supportive tool?					

Thanks for your feedbacks ☺

APPENDIX G

(Heuristic Evaluation by HCI expert)



APPENDIX H

No.	Categories	Interaction Patterns	Purpose	References
1	**Interaction Patterns for Visualization**	Graph generator controller	To control the parameters set for graphs (allow the users to interact with the graph through different parameters settings to visualize different situations of the dynamic movement with different value sets)	(Jenny et al., 2015)
2		2-D animation controller	Allow the users to interact with the 2D model using the controller to see the dynamic movement of the 2D model.	(Cooper et al., 2014; Jenny et al., 2015)
3		3-D model controller	Allow the users to have basic interactions with the 3D model to 'play' around with the model for better visualization	(Cooper et al., 2014; Jenny et al., 2015)
4		Stereoscopic 3D viewer	-Provide the views of different angles for the 3D model (to aid in visualization -extra 3D effects with 3D glass) -Evoke the interest of the students	(Jenny et al., 2015)
5		Multi-dimensional 3D viewer	Provide the views of different angles for the 3D model (to aid in visualization)	(Cooper et al., 2014; Jenny et al., 2015)
6		3-D trail generator & controller	Assist the students in understanding /visualizing how the motion trail looks like in dynamic 3-D form	(Jenny et al., 2015)
7		Zooming	Allow the users to zoom in (enlarge) and zoom out (minimize) the view of the 3-D models for clearer view	(Jenny et al., 2015; Raskin,2000)
8	**Interaction Patterns for Attention Grabber**	'expand/hide' effect	To support the expansion of contents or hiding the unnecessary contents	(Cooper et al., 2014)
9		Blinking effect	Visual cue for attention grabber	(Koning et al., 2011)
10		Animated line	Visual cue for attention grabber (act as a highlighter)	(Koning et al., 2011)
11		Animated arrow	Visual cue for attention grabber (act as a highlighter)	(Boucheix & Guignard, 2005; Koning et al., 2011;Tversky et al., 2008)
12		Mouse over 'highlighting' effect	Visual cue for attention grabber (act as a highlighter)	(Cooper et al., 2014; Norman, 2013)
13	**Interaction Patterns for Knowledge Retention**	Interactive 'point-click-response' feature	To allow the students to choose the options for the answers and provide instant feedback based on chosen answer	(Cooper et al., 2014)
14		'interesting fact' feature	Support the students learning through the explanation provided regarding different graphs scenario	(Cooper et al., 2014)
15		Answer checker	Provide feedbacks for the students on answers key in	(Cooper et al., 2014)
16		'fill-in-the-blank' feature	To let the students to key in the answers	(Cooper et al., 2014; Tidwell, 2011)
17		'pop-up hints/ tips' window	To assist as a reminder regarding the fundamental concepts for mechanics dynamics	(Cooper et al., 2014)
18		Hovering effects	Mouse over certain object, the object will be highlighted and few selections can be further performed based on the options offered.	(Cooper et al., 2014; Norman, 2013)
19	**Supportive Patterns I**	Nomenclature	Support the explanation for the definition of the SI unit and its purpose	(Cooper et al., 2014)
20		Help feature	The description for the icons used in the system	(Cooper et al., 2014)

21		Glossary feature	Support the searching of the technical terms and its definition	(Cooper et al., 2014)
22	**Supportive Patterns II**	Sticky Notes	Support the purpose of notes taking	(Probst et al., 2011)
23		Calculator	To support the problem solving process especially the calculation steps	(Streif & Naples, 2003_
24		Notes recording pad	To support some basic notes taking and calculation purpose	(Cooper et al., 2014)
25		Narrated sound on / off	Assist / guide the students throughout the problem solving steps	(Cooper et al., 2014)

APPENDIX I

Chapter 16 : Planar Kinematics of a Rigid Body

16.8 Relative-Motion Analysis Using Rotating Axes

- Translating coordinate system
  - describes relative motion analysis for velocity and acceleration
  - determines the motion of the points on the same rigid body
  - determines the motion of points located on several pin-connected rigid bodies
- Rigid bodies are constructed such that *sliding* occur at their connections

16.8 Relative-Motion Analysis Using Rotating Axes

- Coordinate system
  - Use for kinematics analysis
  - use for analyzing motion of two points on a mechanism which are not located in the same rigid body
  - use for specifying kinematics of particle motion when the particle is moving along a rotating path

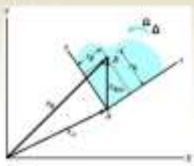
16.8 Relative-Motion Analysis Using Rotating Axes

- In the following analysis, 2 equations are developed to relate the velocity and acceleration of 2 points, one of which is the origin of a moving frame of reference subjected to both a translation and rotation in the plane
- The 2 points can represent either 2 points moving independently of one another or 2 points located on the same (or different rigid bodies)

16.8 Relative-Motion Analysis Using Rotating Axes

Position

- Consider 2 points *A* and *B*, whose location are specified by $\mathbf{r}_A$ and $\mathbf{r}_B$, measured from the fixed *X*, *Y*, *Z* coordinate system



(a)

16.8 Relative-Motion Analysis Using Rotating Axes

- Base point *A* represent the origin of the *x*, *y*, *z* coordinate system assumed to be both translating and rotating with respect to *X*, *Y* and *Z* system
- Position of *B* with respect to *A* is specified by the relative position vector $\mathbf{r}_{B/A}$
- Components of this vector can either be expressed in unit vectors along the *X*, *Y* axes i.e. **I**, **J** or by unit vectors along the *x*, *y* axes i.e. **i** and **j**

16.8 Relative-Motion Analysis Using Rotating Axes

- For developed $r_{B/A}$ will be measured relative to the moving *x, y* frame of reference
- If *B* has coordinates (x_B, y_B)

$$\mathbf{r}_{B/A} = x_B\mathbf{i} + y_B\mathbf{j}$$

- Using vector addition,

$$\mathbf{r}_B = \mathbf{r}_A + \mathbf{r}_{B/A}$$

16.8 Relative-Motion Analysis Using Rotating Axes

- At the instant considered, point *A* has a velocity $\mathbf{v}_A$ and an acceleration $\mathbf{a}_A$, while angular velocity and angular acceleration of the *x, y* and *z* axes are Ω and $\dot{\Omega} = d\Omega/dt$ respectively
- All these vectors are measured from the *X, Y* and *Z* axes of reference although they may be expressed in terms of either **I**, **J** and **K** or **i**, **j** or **k** components

16.8 Relative-Motion Analysis Using Rotating Axes

- Since planar motion is specified, by the right hand rule, Ω and $\dot{\Omega}$ are always directed *perpendicular* to the reference plane of motion whereas $\mathbf{v}_A$ and $\mathbf{a}_A$ lie on this plane

Velocity

- For velocity of point *B*,

16.8 Relative-Motion Analysis Using Rotating Axes

- The last term of this equation is evaluated as

$$\frac{d\mathbf{r}_{B/A}}{dt} = \frac{d}{dt}(x_B\mathbf{i} + y_B\mathbf{j})$$

$$= \frac{dx_B}{dt}\mathbf{i} + x_B\frac{d\mathbf{i}}{dt} + \frac{dy_B}{dt}\mathbf{j} + y_B\frac{d\mathbf{j}}{dt}$$

$$= \left(\frac{dx_B}{dt}\mathbf{i} + \frac{dy_B}{dt}\mathbf{j}\right) + \left(x_B\frac{d\mathbf{i}}{dt} + y_B\frac{d\mathbf{j}}{dt}\right)$$

16.8 Relative-Motion Analysis Using Rotating Axes

- The two terms in the first set of parentheses represent the components of velocity of point *B* as measured by an observer attached to the moving *x, y* and *z* coordinate system, being denoted by vector $(\mathbf{v}_{B/A})_{xyz}$
- In the second set of parentheses, the instantaneous time rate of change of unit vectors **i** and **j** is measured by an observer located in a fixed *X, Y* and *Z* system

16.8 Relative-Motion Analysis Using Rotating Axes

- These changes $d\mathbf{i}$ and $d\mathbf{j}$ are due to only an instantaneous rotation $d\theta$ of the *x, y* and *z* axes, causing **i** to become $\mathbf{i}' = \mathbf{i} + d\mathbf{i}$ and **j** to become $\mathbf{j}' = \mathbf{j} + d\mathbf{j}$
- Magnitudes of both $d\mathbf{i}$ and $d\mathbf{j}$ = 1 $(d\theta)$ since $\mathbf{i} = \mathbf{i}' = \mathbf{j} = \mathbf{j}' = 1$
- The direction of $d\mathbf{i}$ is defined by $+\mathbf{j}$ since $d\mathbf{i}$ is tangent to the path described by the arrowhead of **i** in the limit as $\Delta t \rightarrow dt$

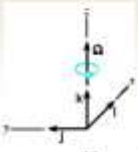
16.8 Relative-Motion Analysis Using Rotating Axes

• Likewise, $d\mathbf{j}$ acts in the $-\mathbf{i}$ direction, hence

$$\frac{d\mathbf{i}}{dt} = \frac{d\theta}{dt}(\mathbf{j}) = \Omega\mathbf{j} \qquad \frac{d\mathbf{j}}{dt} = \frac{d\theta}{dt}(-\mathbf{i}) = -\Omega\mathbf{i}$$

• Viewing the axes in 3D, noting that $\Omega = \Omega\mathbf{k}$,

$$\frac{d\mathbf{i}}{dt} = \Omega \times \mathbf{i} \qquad \frac{d\mathbf{j}}{dt} = \Omega \times \mathbf{j}$$


(c)

16.8 Relative-Motion Analysis Using Rotating Axes

• Using the derivative property of the vector cross product

$$\frac{d\mathbf{r}_{B/A}}{dt} = (\mathbf{v}_{B/A})_{xyz} + \Omega \times (x_B\mathbf{i} + y_B\mathbf{j}) = (\mathbf{v}_{B/A})_{xyz} + \Omega \times \mathbf{r}_{B/A}$$

• Hence

$$\mathbf{v}_B = \mathbf{v}_A + \Omega \times \mathbf{r}_{B/A} + (\mathbf{v}_{B/A})_{xyz}$$

16.8 Relative-Motion Analysis Using Rotating Axes

Acceleration

• Acceleration of *B*, observed from the *X*, *Y* and *Z* coordinate system, may be expressed in terms of its motion measured with respect to the rotating or moving system of coordinates by taking the time derivative

$$\mathbf{a}_B = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{B/A} + \Omega \times \frac{d\mathbf{r}_{B/A}}{dt} + \frac{d(\mathbf{v}_{B/A})_{xyz}}{dt}$$

16.8 Relative-Motion Analysis Using Rotating Axes

• Here $\dot{\Omega} = d\Omega/dt$ is the angular acceleration of the x, y, z coordinate system

• For planar motion, Ω is always perpendicular to the plane of motion and therefore $\dot{\Omega}$ measures *only the change in the magnitude* of Ω

• For the derivative of $d\mathbf{r}_{B/A}/dt$,

$$\Omega \times \frac{d\mathbf{r}_{B/A}}{dt} = \Omega \times (\mathbf{v}_{B/A})_{xyz} + \Omega \times (\Omega \times \mathbf{r}_{B/A})$$

16.8 Relative-Motion Analysis Using Rotating Axes

• Finding the time derivative of $(\mathbf{v}_{B/A})_{xyz} = (\mathbf{v}_{B/A})_x\mathbf{i} + (\mathbf{v}_{B/A})_y\mathbf{j}$

$$\frac{d(\mathbf{v}_{B/A})_{xyz}}{dt} = \left[\frac{d(\mathbf{v}_{B/A})_x}{dt}\mathbf{i} + \frac{d(\mathbf{v}_{B/A})_y}{dt}\mathbf{j}\right] + \left[(\mathbf{v}_{B/A})_x\frac{d\mathbf{i}}{dt} + (\mathbf{v}_{B/A})_y\frac{d\mathbf{j}}{dt}\right]$$

16.8 Relative-Motion Analysis Using Rotating Axes

• The first two terms in the first set of brackets represent the components of acceleration of point *B* as measured by an observer attached to the moving coordinate system, as denoted by $(\mathbf{a}_{B/A})_{xyz}$

• The terms in the second bracket can be simplified by

$$\frac{d(\mathbf{v}_{B/A})_{xyz}}{dt} = (\mathbf{a}_{B/A})_{xyz} + \Omega \times (\mathbf{v}_{B/A})_{xyz}$$

16.8 Relative-Motion Analysis Using Rotating Axes

- Rearranging terms,

$$\mathbf{a}_B = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{B/A} + \Omega \times (\Omega \times \mathbf{r}_{B/A}) + 2\Omega \times (\mathbf{v}_{B/A})_{xyz} + (\mathbf{a}_{B/A})_{xyz}$$

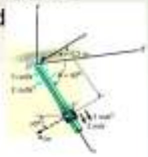
- The term $2\Omega \times (\mathbf{v}_{B/A})_{xyz}$ is called the *Coriolis acceleration*, representing the difference in the acceleration of *B* as measured from the non-rotating and rotating *x, y, z* axes

16.8 Relative-Motion Analysis Using Rotating Axes

- As indicated by the vector cross-product, the Coriolis acceleration will always be perpendicular to both Ω and $(\mathbf{v}_{B/A})_{xyz}$

Example 16.19

At the instant $\theta = 60°$, the rod has an angular velocity of 3 rad/s and an angular acceleration of 2 rad/s². At the same instant, the collar *C* is travelling outward along the rod such that when *x* = 2 m the velocity is 2 m/s and the acceleration is 3 m/s², both measure relative to the rod. Determine the Coriolis acceleration and the velocity and acceleration of the collar at the instant.



Example 16.19

Coordinate Axes. The origin of both coordinate systems is located at point O. Since motion of the collar is reported relative to the rod, the moving x, y, z frame of reference is *attached* to the rod.

Kinematic Equations

$$\mathbf{v}_C = \mathbf{v}_O + \Omega \times \mathbf{r}_{C/O} + (\mathbf{v}_{C/O})_{xyz}$$

$$\mathbf{a}_C = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{C/O} + \Omega \times (\Omega \times \mathbf{r}_{C/O}) + 2\Omega \times (\mathbf{v}_{C/O})_{xyz} + (\mathbf{a}_{C/O})_{xyz}$$

Example 16.19

It will be simpler to express the data in terms of **i**, **j**, **k** component vectors rather than **I**, **J**, **K** components. Hence,

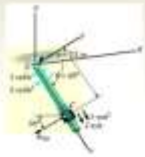
Motion of moving reference	*Motion of C with respect to moving reference*
$\mathbf{v}_O = 0$	$\mathbf{r}_{C/O} = \{0.2\mathbf{i}\} m$
$\mathbf{a}_O = 0$	$(\mathbf{v}_{C/O})_{xyz} = \{2\mathbf{i}\} m/s$
$\Omega = \{-3\mathbf{k}\} rad/s$	$(\mathbf{a}_{C/O})_{xyz} = \{3\mathbf{i}\} m/s^2$
$\dot{\Omega} = \{-2\mathbf{k}\} rad/s$	

Example 16.19

Therefore Coriolis acceleration is defined as

$$\mathbf{a}_{Cor} = 2\Omega \times (\mathbf{v}_{C/O})_{xyz} = 2(-3\mathbf{k}) \times (2\mathbf{i}) = \{-12\mathbf{j}\} m/s^2$$

This vector is shown in figure. If desired, it may be resolved in **I**, **J** components acting along the *X* and *Y* respectively.



Example 16.19

The velocity and acceleration of the collar are determined by substituting the data in the previous 2 equations and evaluating the cross products, which yields,

$$\mathbf{v}_C = \mathbf{v}_O + \Omega\times\mathbf{r}_{C/O} + (\mathbf{v}_{C/O})_{xyz}$$
$$= 0 + (-3\mathbf{k})\times(0.2\mathbf{i}) + 2\mathbf{i}$$
$$= \{2\mathbf{i} - 0.6\mathbf{j}\}\,m/s$$
$$\mathbf{a}_C = \mathbf{a}_O + \dot{\Omega}\times\mathbf{r}_{C/O} + \Omega\times(\Omega\times\mathbf{r}_{C/O}) + 2\Omega\times(\mathbf{v}_{C/O})_{xyz} + (\mathbf{a}_{C/O})_{xyz}$$
$$= 0 + (-2\mathbf{k})\times(0.2\mathbf{i}) + (-3\mathbf{k})\times[(-3\mathbf{k})\times(0.2\mathbf{i})] + 2(-3\mathbf{k})\times(2\mathbf{i}) + 3\mathbf{i}$$
$$= \{1.20\mathbf{i} - 12.4\mathbf{j}\}\,m/s^2$$

Example 16.20

The rod *AB*, shown in Fig. 16–34, rotates clockwise such that it has an angular velocity $w_{AB} = 3rad/s$ and angular acceleration $\alpha_{AB} = 4rad/s^2$ when $\theta = 45°$. Determine the angular motion of rod *DE* at this instant. The collar at *C* is pin connected to *AB* and slides over rod *DE*.

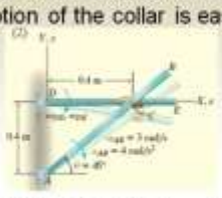
Example 16.20

Solution

Coordinate Axes.

The origin of both the fixed and moving frames of reference is located at *D*, Fig. 16–34. Furthermore, the *x, y, z* reference is attached to and rotates with rod *DE* so that the relative motion of the collar is easy to follow.

Kinematic Equations.



$$\mathbf{v}_C = \mathbf{v}_O + \Omega\times\mathbf{r}_{C/D} + (\mathbf{v}_{C/D})_{xyz} \quad (1)$$
$$\mathbf{a}_C = \mathbf{a}_O + \dot{\Omega}\times\mathbf{r}_{C/O} + \Omega\times(\Omega\times\mathbf{r}_{C/D}) + 2\Omega\times(\mathbf{v}_{C/D})_{xyz} + (\mathbf{a}_{C/D})_{xyz} \quad (2)$$

Example 16.20

All vectors will be expressed in terms of **i**, **j**, **k** components.

Motion of moving reference

$$\mathbf{v}_D = 0$$
$$\mathbf{a}_D = 0$$
$$\Omega = -w_{DE}\mathbf{k}$$
$$\dot{\Omega} = -\alpha_{DE}\mathbf{k}$$

Motion of C with respect to moving reference

$$\mathbf{r}_{C/D} = \{0.4\mathbf{i}\}\,m$$
$$(\mathbf{v}_{C/D})_{xyz} = (v_{C/D})_{xyz}\mathbf{i}$$
$$(\mathbf{a}_{C/D})_{xyz} = (\mathbf{a}_{C/D})_{xyz}\mathbf{i}$$

Example 16.20

Motion of C: Since the collar moves along a *circular path*, its velocity and acceleration can be determined using Eqs. 16–9 and 16–14.

$$\mathbf{v}_C = \omega_{AB}\times\mathbf{r}_{C/A} = \{1.2\mathbf{i} - 1.2\mathbf{j}\}\,m/s$$
$$\mathbf{a}_C = \alpha_{AB}\times\mathbf{r}_{C/A} - \omega^2_{AB}\mathbf{r}_{C/A} = \{-2\mathbf{i} - 5.2\mathbf{i}\}\,m/s^2$$

Substituting the data into Eqs. 1 and 2, we have

$$\mathbf{v}_C = \mathbf{v}_D + \Omega\times\mathbf{r}_{C/D} + (\mathbf{v}_{C/D})_{xyz}$$
$$1.2\mathbf{i} - 1.2\mathbf{j} = 0 + (-\omega_{DE}\mathbf{k})\times(0.4\mathbf{i}) + (v_{C/D})_{xyz}\mathbf{i}$$
$$(v_{C/D})_{xyz} = 1.2m/s$$
$$\omega_{DE} = 3rad/s \curvearrowright$$

Example 16.20

$$\mathbf{a}_C = \mathbf{a}_D + \dot{\Omega}\times\mathbf{r}_{C/D} + \Omega\times(\Omega\times\mathbf{r}_{C/D}) + 2\Omega\times(\mathbf{v}_{C/D})_{xyz} + (\mathbf{a}_{C/D})_{xyz}$$
$$-2\mathbf{i} - 5.2\mathbf{j} = 0 + (-\alpha_{DE}\mathbf{k})\times(0.4\mathbf{i}) + (-3\mathbf{k})\times[(-3\mathbf{k})\times(0.4\mathbf{i})]$$
$$+ 2(-3\mathbf{k})\times(1.2\mathbf{i}) + (\mathbf{a}_{C/D})_{xyz}\mathbf{i}$$
$$(a_{C/D})_{xyz} = 1.6m/s^2$$
$$\alpha_{DE} = -5rad/s^2 = 5rad/s^2 \circlearrowright$$