AN INSTRUMENT TO MEASURE INFORMATION AND COMMUNICATION TECHNOLOGY USER-SKILLS ABILITY FOR ENGINEERING LEARNING

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DEDICATION

To my family

Husband:	Rusli bin Alias
Children:	Nurhani bt Nasaruddin
	Abdul Hakim bin Nasaruddin

And in loving memory of

My father:	Ali bin Shariff
My mother:	Rakiah bt Kassim
My mother-in-law:	Sabariah bt Mohd Ta'i
and	Nasaruddin bin Zenon

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ABSTRACT

Some of the most important skills for engineering education in today's digital world are information and communication technology (ICT) user-skills. This research concerned two main issues regarding ICT user-skills of engineering students. The first issue was the lack of a reliable and valid instrument to measure ICT user-skills ability for engineering learning. The second issue was the lack of profile information on students' existing ICT user-skills, such as what their ICT skills level were, how they acquired the skills, their conception of ICT user-skills, to what extent ICT user-skills support engineering learning, as well as the difficulties faced in acquiring those skills. This information would provide the basis for student ICT skills improvement strategies. Thus, this research sought to address these issues by developing an instrument to measure students' ICT user-skills and subsequently establishing the ICT user-skills profile. This study adopted an across-stage mixed method design, combining quantitative and qualitative approaches. The research process comprised eight major phases: problem identification, literature review, determining problem statement and research objectives, instrument design and development, sample selection, data collection, data analysis, discussion and conclusion. Instrument development and validation were performed in five phases: determining what to measure, a review and assessment of major existing instruments, drafting a new instrument, getting expert reviews and student feedback, pilot testing the instrument, checking the internal consistency and refining the instrument, testing the modified instrument, and finally conducting the main study using a stratified random sample. Reliability and validity of the instrument were established using a Rasch model. Quantitative data analyses were performed using the PASW and WINSTEPS software. Thematic analysis of interview transcriptions was conducted to corroborate quantitative findings. The outcomes of this study were a new survey instrument to measure ICT user-skills within context of the study population, and a profile of engineering students' ICT user-skills.

ABSTRAK

Antara kemahiran terpenting untuk pendidikan kejuruteraan dalam dunia digital hari ini ialah kemahiran ICT. Kajian ini adalah berkaitan dua isu utama penggunaan kemahiran ICT di kalangan pelajar kejuruteraan. Isu pertama ialah kurangnya instrumen dengan kebolehpercayaan dan kesahihan yang tinggi untuk mengukur tahap kemahiran pelajar kejuruteraan menggunakan ICT. Isu kedua ialah kurangnya maklumat tentang kemahiran ICT semasa pelajar. Contoh maklumat penting ialah tahap kemahiran ICT pelajar, jenis kemahiran ICT yang dimiliki, konsep ICT pelajar, sejauh mana kemahiran ini membantu pelajar kejuruteraan, jenis kemahiran ICT yang perlu ditingkatkan, dan masalah yang dihadapi dalam memperolehi kemahiran ICT. Maklumat ini perlu sebagai asas strategi pembaikan kemahiran ICT. Kajian ini menggunakan pendekatan kaedah-bercampur yang menggabungkan pendekatan kuantitatif dan kualitatif. Terdapat lapan fasa dalam kajian ini: mengenalpasti masalah, kajian literatur, menentukan masalah dan objektif kajian, pembangunan dan rekabentuk instrumen, memilih sampel, pengumpulan data, analisis data, perbincangan dan kesimpulan. Fasa pembangunan dan rekabentuk instrumen mengandungi lima fasa: menentukan konstruk yang hendak diukur, membuat kajian literatur terhadap instrumen sedia ada, memghasilkan draf bagi instrumen baru, mendapatkan maklumbalas dari pakar bidang dan pelajar, membuat kajian rentas terhadap instrumen, memeriksa kebolehpercayaan dalaman dan kesahihan instrumen, menguji instrumen yang telah diubahsuai, dan menjalankan kajian utama menggunakan sampel rawak berstrata Kebolehpercayaan dan kesahihan instrumen ditentukan dengan menggunakan model Rasch. Analisis data kuantitatif dilakukan menggunakan perisian PASW dan WINSTEPS. Analisis tema terhadap transkripsi temubual dilakukan untuk mengukuhkan dapatan kuantitatif. Hasil kajian ini ialah satu instrumen yang mempunyai kebolehpercayaan dan kesahihan yang tinggi bagi mengukur kemahiran ICT untuk pengajian kejuruteraan dan suatu profail tentang kemahiran ICT pelajar kejuruteraan.

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LIST OF ABBREVIATIONS

ABET	-	Accreditation Board for Engineering and Technology
ACRL	-	Association of College and Research Libraries
AEC	-	Architecture, Engineering and Construction
AERA	-	American Educational Research Association
APA	-	American Psychological Association
BEM	-	Board of Engineers, Malaysia
CAD	-	Computer-Aided Design
CAE	-	Computer-Aided Engineering
CAI	-	Computer-Assisted Instruction
CAM	-	Computer-Aided Manufacturing
CAx	-	Computer-Aided Applications
CBI	-	Computer-Based Instruction
CIT	-	Critical Incident
CNC	-	Computer Numerical Control
CSP	-	Computer Skills Placement
CST	-	College of Science and Technology
CT	-	Communication Technology
CTT	-	Classical Test Theory
DES	-	Discrete Educational Software
DIF	-	Differential Item Functioning
DMU	-	Digital MockUp
EAC	-	Engineering Accreditation Council
EC	-	Engineering Criteria
EDA	-	Electronic Design Automation
ETS	-	Educational Testing Service
FJA	-	Functional Job Analysis
ICC	-	Item Characteristic Curve

ICT	-	Information and Communication Technology
IEM	-	Institution of Engineers Malaysia
ILS	-	Integrated Learning System
IRT	-	Item Response Theory
ISS	-	Information Skills Survey
IT	-	Information Technology
JMLE	-	Joint Maximum Likelihood Estimation
KR20	-	Kuder-Richardson Formula 20
MCED	-	Malaysian Council of Engineering Deans
MEEM	-	Malaysian Engineering Education Model
MNSQ	-	Mean Square Statistics
MOE	-	Ministry of Education
MOHE	-	Ministry of Higher Education
MPM	-	Manufacturing Process Management
NCME	-	National Council on Measurement in Education
OBE	-	Outcome-Based Education
OPAC	-	Online Public Access Catalogue
PAQ	-	Position Analysis Questionnaire
PCA	-	Principal Component Analysis
PCB	-	Printed Circuit Boards
SAILS	-	Standardized Assessment of Information Literacy Skills
SEM	-	Standard Error of Measurement
SPSS	-	Statistical Packages for the Social Sciences
TAIT	-	Prentice Hall Train & Assess IT
UCON	-	Unconditional Maximum Likelihood Estimation
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
UTM	-	Universiti Teknologi Malaysia
VAR	-	Variance
WPS	-	Work Profiling System
XMLE	-	Extra-Conditional Maximum Likelihood Estimation
ZPD	-	Zone of Proximal Development
ZSTD	-	Standardized Fit Statistics

LIST OF SYMBOLS

B_n	-	ability of person n
D_i	-	difficulty level of item i
E	-	random error
G_p	-	person separation index
MSE_p	-	mean square measurement error of person p
P_n	-	probability of person *n*
P_{ni}	-	probability of person *n* with ability B_n succeeding on item *i* with difficulty level D_i.
P_{nix}	-	probability of person *n* with ability B_n on the latent variable being observed in category *x* of item *i* with difficulty D_i
R	-	estimated reliability
R_p	-	person separation reliability
R_i	-	item separation reliability
S_n	-	standard error for each person measure
SD_x	-	sample raw score standard deviation
τ_x	-	step difficulties or Rasch thresholds.
τ_{ix}	-	step difficulty or Rasch threshold of item *i* in category x
T	-	true score
T_n	-	total score of person *n*
x_{ni}	-	observed score of person *n* to item *i*
X	-	observed score

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CHAPTER 1

INTRODUCTION

1.1 Preamble

Information and communication technology (ICT) has penetrated the 21st century lifestyle at all levels: personal, academic and professional. ICT is most crucial in the fields that need to respond quickly to the needs of the society. One of these disciplines is engineering, a dynamic field that requires students to be technically up-to-date or risk having obsolete technological skills and scientific knowledge (Fortenberry, 2006; National Academy of Engineering, 2005). Engineering graduates also need to be competitive, entrepreneurial, and innovative to face new global challenges in technology, economy, society, politics and environment (Bajunid, 2002).

When engineering graduates work in business environment, they need to be able to analyze large volume of information and convert it into competitive knowledge timely and efficiently (Radin, 2006). They also need good communication and presentation skills to express ideas clearly and succinctly, and to sell ideas to executives who make corporate decisions (Roman, 2006). Thus, engineering students need to acquire a variety of skills including problem solving, information, communication, presentation, and project management skills for self-directed learning and future work. Many of these skills require the mastery of ICT skills to make the process of learning and skill acquisition more efficient and effective.

The widespread nature of ICTs and breakthroughs in technology has significantly changed the type of skills that students use to construct knowledge (Dede, 2005). ICT has not only become an indispensible tool, but in some developed countries is gradually changing the learning environment and culture. ICT skills are the basis for ICT literacy, which is one of the multiliteracies described by the New London Group (2000). The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines the three dimensions of ICT literacy as knowledge, skills and attitude (UNESCO, 2008a). The skills dimension consists of technical or ICT user-skills.

ICT user-skills constitute the ability to use digital tools and processes, and can be distinguished into three major categories. The first category comprises the skills to use generic application software and Internet-based services. The second category includes the skills to use advanced professional application software. The final category encompasses information skills, which include the ability to define access, evaluate, and use information (UNESCO, 2008a). An information literate engineering student has the skills to recognize when and what information is required, knows how to evaluate information, and more importantly is able to use relevant information effectively and ethically in context of engineering learning (Messer *et al.*, 2005).

This study examined the ICT user-skills profile of engineering students at a Malaysian college and developed a survey instrument based on self-assessment to measure students' ICT user-skills ability in engineering education. Students' collective perceptions about their acquired ability affect to a large extent, the measurement of a program's success in meeting its learning outcomes (Perez, 2002).

1.2 Background of the Problem

The major suppliers of ICT–skilled professionals are colleges, universities and training institutions. Hence, these institutions play an important role to ensure graduates possess high-quality ICT skills relevant to the industry. To know whether the curricula succeed in producing such graduates, assessment of students' skills should be performed regularly. Appropriate measuring instruments need to be used and new ones need to be developed, if necessary as a basis for sound assessment. In fact, assessment is considered by the Engineering Education Research Colloquies (EERC, 2006) as one of the five major research areas to ensure continuous improvement in engineering education.

The use of ICT in education is classified into three broad categories: Pedagogy, Training and Continuing Education (UNESCO, 2004). An important pedagogical aspect of ICT is the development of the necessary ICT knowledge and skills to support learning. From the researcher's experience of teaching diploma-level engineering subjects, students seemed to have common problems in conducting effective information search, evaluating information and using digital databases. Analysis of project reports often revealed lack of use of up-to-date journals as references. Many students were not familiar with using the correct citation style for various types of information sources. Even though most students seemed to have little problem in using general-purpose software such as Microsoft Word and Excel, many mentioned their lack of skills in using engineering-related software such as AutoCAD and SimuLINK.

The researcher's observations on the lack of ICT skills among students were supported by recent reports on the quantity and quality of ICT-skilled professionals. A study by the Organization of Economic Co-operation and Development found that graduates lack ICT skills to cope with the fast-changing knowledge economy (OECD, 2007). Omar *et. al.* (2006) found that only fifty seven percent of employers were satisfied with ICT skills among engineering graduates. The Star Online Report (2007) highlighted a very big gap between the demand and supply of ICT-skilled workers. Human resource development in the Asia-Pacific region showed an increasing gap between the supply and demand of ICT skills (Ravi, 2007). Furthermore, many employers in this region found the quality of fresh graduates' ICT skills inferior.

These observations and findings motivated the researcher to investigate empirically engineering students' ICT skills, to compare these skills across gender, engineering specialization and year of study. Significant increase in skills level with respect to the year of study would seem to indicate the effectiveness of the engineering curriculum as a whole. The researcher also looked into the relationship between ICT skills level and the frequency of practicing these skills during the study years.

The problem of the lack of ICT skills among students is not confined to the Asia-Pacific region. Numerous studies in other parts of the world have shown that employers sought workers who have good ICT skills (NaHERI, 2007; Herman, 2000; Mikulecky and Kirkley (1998); Tomei (1999). Yet recent studies found that college students still lack the necessary ICT skills to participate in a technologically advanced society (Salaway and Caruso, 2007; Hilberg and Meiselwitz, 2008). Thus, there is continuing global concern among educators, governments and potential employers about the ICT proficiency of graduates who will become leaders of change and innovation in their profession and society.

1.3 Statement of the Problem

A recent report by UNESCO (2011) describes the quality gap between the skills of engineering education graduates and the skill requirements of the regional and global market. This calls for regular measurement of skills to monitor the skill levels among engineering students as the first step towards improvement. However, the extent of skills development can only be assessed if there is a reliable and valid measurement instrument. A measurement instrument must be designed to suit the population of interest to get accurate and dependable information that serves the purpose of assessment (Chatterji, 2003). Since engineering students need to use information skills and both generic and engineering-specific software in the course of study, a survey instrument must have questionnaire items that reflect this ability. Yet, no instrument has been specifically designed to measure the ability of using ICT for engineering learning. De Vellis (2003a) stresses the importance of assessing whether the constructs of an instrument correspond with the actual experience, perceptions and conceptions of the population of interest. Thus, there was a need to develop an instrument that would take into account the ICT skills employed in all stages of the engineering problem-solving within the context of the population under study.

A reliable and valid measurement instrument could be used to produce and examine engineering students' ICT user-skills profile. The profile would describe the ICT user-skills used to perform engineering-learning tasks, where and how the skills were acquired, the problems faced in obtaining those skills, and which skills needed to be further developed. This profile documentation is important because it can serve as an assessment tool and provide the basis for intervention planning and implementation to make learning more effective. However, there is a lack of studies on students' ICT skills, particularly in Malaysian engineering education environment.

1.4 Purposes of the Study

There were two general purposes for the study. The first general purpose was to develop an instrument to measure students' ability in using ICT skills for engineering learning. Measures of students' user-skills ability would serve as the empirical evidence of their skill levels. The study examined the psychometric properties of the instrument, which included the establishment of its validity and reliability.

The second general purpose was to examine engineering students' ICT user-skills profile. The profile would describe students' ICT-related attributes such as computer ownership, internet access, usage of computers, where and how students acquire ICT skills, students' conception of ICT skills, the perception on how the skills help them learn engineering, and the problems students faced in using ICT for engineering learning.

1.5 Objectives of the Study

Detailed objectives of the study were as follows:

1. To develop a survey instrument to measure students' ability to use ICT skills for engineering learning by:
   - i) identifying the constructs of ICT skills for engineering learning.
   - ii) relating engineering learning activities requiring ICT skills with each of the constructs.
   - iii) determining the effectiveness of the rating scale in supporting the construction of measures.
   - iv) examining the psychometric properties of the measurement instrument.
   - v) determining the dimensionality of the instrument.
   - vi) checking the assumptions of the measurement model.
   - vii) establishing the face, content and construct validity of the instrument.
   - viii) establishing the reliability of the instrument.

2. To describe engineering students' ICT user-skills profile by:
   - i) determining students' computer ownership, internet access and hours of computer use.
   - ii) identifying where and how students acquire ICT skills.

iii) ascertaining students' perceptions of the role of ICT skills in helping them learn in engineering courses.

iv) describing students' conception of ICT skills.

v) obtaining students' input on the problems faced in acquiring ICT skills.

3. To determine if there are significant differences in students' ICT user-skills ability with respect to their demographic characteristics (gender, engineering specialization and year of study).
4. To determine the relationship between the perceived usefulness of ICT user-skills for learning and the frequency of performing engineering learning activities.
5. To ascertain the relationship between the frequency of performing engineering learning activities and students' ICT user-skills ability.
6. To determine if there are significant differences in the frequency of performing engineering learning activities with respect to gender, engineering specialization and year of study.
7. To explore engineering students' conception of ICT skills and their experience of using ICT in terms of the benefits and the problems encountered.
8. To determine the distribution of students according to their ICT user-skill levels of proficiency.

1.6 Research Questions

To meet the objectives of this study, answers to the following research questions (RQ) would be used as guides:

Objective 1: To develop a survey instrument to measure students' ability to use ICT skills for engineering learning.

RQ 1: What are the components of the ICT user-skills construct and the associated ICT user-skills for engineering learning?

RQ 2: What are the psychometric properties of the measurement instrument?

a) To what extent is the rating scale effective in supporting the construction of measures?
b) Are the assumptions of Rasch measurement met?
c) Does the instrument fulfill the criteria for face validity?
d) Does the instrument fulfill the criteria for construct validity?
    i) What is the evidence for the content aspect of validity?
    ii) What is the evidence for the substantive aspect of validity?
    iii) What is the evidence for the structural aspect of validity?
    iv) What is the evidence for the generalizability aspect of validity?
    v) What is the evidence for the interpretability aspect of validity?
e) Does the instrument exhibit differential item functioning (DIF) with respect to:
    i) gender
    ii) year of study
    iii) engineering specialization

Objective 2: To describe engineering students' ICT user-skills profile**.**

RQ 3a): What are the characteristics of the study sample with respect to each of the following variables?

i) gender
ii) year of study
iii) engineering specialization
iv) computer ownership
v) of computer use for
    - study
    - recreational activities
vi) where and how students acquire ICT skills.

vii) students' perceptions of how ICT skills support engineering learning.

RQ 3b): Is there an association between gender, year of study, and engineering specialization with each of the following variables?

i) computer ownership
ii) internet access
iii) hours of computer use for study
iv) hours of computer use for recreational activities

Objective 3: To determine if there are significant differences in students' ICT user-skills ability with respect to their demographic characteristics (gender, engineering specialization and year of study).

RQ 4a): Is there a significant difference in ICT user-skills ability between male and female students?
RQ 4b): Is there a significant difference in ICT user-skills ability between students in different engineering specializations?
RQ 4c): Is there a significant difference in ICT user-skills ability between students in different years of study?

Objective 4: To determine the relationship between the perceived usefulness of ICT user-skills for learning and the frequency of performing engineering learning activities.

RQ 5: What is the correlation between the perceived usefulness of ICT user-skills for learning and the frequency of performing engineering learning activities?

Objective 5: To ascertain the relationship between the frequency of performing engineering learning activities and students' ICT user-skills ability.

RQ 6: What is the correlation between the frequency of performing engineering learning activities and students' ICT user-skills ability?

Objective 6: To determine if there are significant differences in the frequency of performing engineering learning activities with respect to gender, engineering specialization and year of study.

RQ 7a): Are there significant differences in the frequency of performing engineering learning activities between male and female students?
RQ 7b): Are there significant differences in the frequency of performing engineering learning activities between students in different engineering specialization?
RQ 7c): Are there significant differences in the frequency of performing engineering learning activities between students in different year of study?

Objective 7: To explore engineering students' conception of ICT skills and their experience of using ICT in terms of the benefits and the problems encountered.

RQ 8a): What is engineering students' conception of ICT skills?
RQ 8b): What are the benefits of using ICT for engineering learning?
RQ 8c): What are the problems encountered in using ICT for engineering learning?

Objective 8: To determine the distribution of students according to the ICT user-skills levels.

RQ 9): What is the frequency distribution of students according to their ICT user-skills levels?

1.7 Research Hypotheses

To answer the research questions, the study sought to test the following research hypotheses against the null hypothesis H_0.

Hypotheses for RQ 4a):

H_0: There is no significant gender difference in ICT user-skills ability.

H_1: There is a significant gender difference in ICT user-skills ability.

Hypotheses for RQ 4b):

H_0: There is no significant difference in ICT user-skills ability among students in different engineering specializations.

H_2: There is a significant difference in ICT user-skills ability among students in different engineering specializations.

Hypotheses for RQ 4c):

H_0: There is no significant difference in ICT user-skills ability among students in Year 1, 2, and 3.

H_3: There is a significant difference in ICT user-skills ability among students in Year 1, 2, and 3.

Hypotheses for RQ 5:

H_0: There is no correlation between the perceived usefulness of ICT user-skills for learning and the frequency of performing engineering learning activities.

H_4: There is a correlation between the perceived usefulness of ICT user-skills for learning and the frequency of performing engineering learning activities.

Hypotheses for RQ 6:

H_0: There is no correlation between the frequency of performing engineering learning activities and students' ICT user-skills ability.

H_5: There is a correlation between the frequency of performing engineering learning activities and students' ICT user-skills ability.

Hypothesis for RQ 7a):

H_0: There is no significant difference in the frequency of performing engineering learning activities between male and female students.

H_6: There is a significant difference in the frequency of performing engineering learning activities between male and female students.

Hypothesis for RQ 7b):

H_0: There is no significant difference in the frequency of performing engineering learning activities among students in different engineering specializations.

H_7: There is a significant difference in the frequency of performing engineering learning activities among students in different engineering specializations.

Hypothesis for RQ 7c):

H_0: There is no significant difference in the frequency of performing engineering learning activities among students in Year 1, 2, and 3.

H_8: There is a significant difference in the frequency of performing engineering learning activities among students in Year 1, 2, and 3.

1.8 Conceptual Framework

A conceptual framework is important because it explains how research questions are framed in the study and links the relevant concepts and theories to the research methodology, data analysis and the interpretation of findings (Bodner, 2007). The main aim of this study was to produce a reliable and valid survey instrument for measuring engineering students' ICT user-skills ability. The research framework was based on measurement and learning theories. Measurement theories and concepts framing the study were Classical Test Theory (CTT), Item Response Theory (IRT) and Rasch measurement model. Learning theories that explain how ICT skills could support engineering learning are constructivist, behavioral, social development and transformative learning theories.

Quality of an instrument is indicated by two psychometric properties: reliability and validity. The measure for reliability used under CTT was Cronbach's alpha (KR20). In a Rasch model, two indices of reliability are person separation reliability and item separation reliability. Construct validity relevant in this study are content, substantive, structural, generalizability, and interpretability. Indicators of construct validity in a Rasch model include content validity index, frequency distribution of scores between different groups, item and person fit statistics, item-measure correlations, item strata, percentage of variance across principal components of residuals, and item maps (Cavanagh and Waugh, 2011).

In Rasch model approach, data must conform to the specified model to ensure valid inferences (Sijtsma and Molenaar, 2002). Thus to determine whether the study data fit the model, data characteristics were examined. Evidence for unidimensionality, local independence, monotonicity of the latent trait, and nonintersecting item response curves were sought. The effectiveness of Rasch rating scale in producing accurate and precise measures influences the quality of resultant measures (Linacre, 2002). Thus, effectiveness of the rating scale in this study was examined with respect to the specified criteria.

This research was carried out at a Malaysian College of Science and Technology (CST) that conducts diploma-level courses in various disciplines of engineering, science, and management. The engineering programs offered are civil, electrical and mechanical engineering. These programs prepare students for engineering degrees and technical jobs in engineering disciplines. Having ICT skills will be beneficial for their future undertaking and improvement of the skills should start as early in their academic programs as possible (NaHERI, 2007). Thus diploma students were selected for this study.

Teaching and learning methods in engineering programs at CST implement the outcome-based education (OBE) approach. OBE is a student-centered learning philosophy that focuses on mastering the necessary knowledge, skills and attitudes to achieve the intended outcomes (Olivier, 1998). Engineering program learning outcomes at CST are based on the standards set by the Malaysian Engineering

Education Model (MEEM) which complies with the Accreditation Board for Engineering and Technology (ABET) criteria. The learning outcomes are developed according to Bloom's Taxonomy of Educational Objectives.

For the purpose of developing the rating scale, engineering learning activities were identified based on the engineering problem-solving process. This process comprises five steps: problem definition, data collection, generating possible solutions, analyzing and selecting the best option, and implementing the solution (Khandani, 2005). These activities were mapped to the engineering learning outcomes. Information literacy standards set by the Association of College and Research Libraries (ACRL) were used to guide the construction of information skills items for the survey.

To be able to use ICT skills in engineering learning, students must first acquire the necessary ICT skills. At CST, ICT skills are instilled through formal ICT courses, laboratory work, class assignment and project activities. Doing activities associated with learning and having hands-on experience is as important as thinking (Johnson and Aragon, 2002). Thus to inculcate ICT user-skills, students need to discover and construct knowledge by doing, rather than become passive receivers of knowledge (Salomon, 1998).

Formal stand-alone ICT courses in the Diploma of Engineering Programs at CST are:

i) Computer programming courses for all engineering programs.
ii) An introductory to IT course for civil engineering students.
iii) Engineering software course for electrical engineering students.
iv) Software engineering course for electrical engineering students.

ICT user-skills measures produced by the instrument were used to describe engineering students user-skills ability in the profile which includes information on students' computer ownership, internet access, usage of computers, where and how they acquire ICT skills, their conception of ICT skills, their perception on how the skills help them learn engineering, and the problems faced in using ICT for engineering learning. Students' conception of ICT skills was explored by performing thematic analysis of interview data.

Technology acceptance model (TAM) would be used to explain the adoption of ICTs among engineering students. The TAM has been widely used in educational settings to quantitatively study the factors that influence technology acceptance (Baker-Eveleth *et al*., 2007; Cheng-Chang *et al.*, 2005; Ndubisi, 2006). Davis (1989) identified two key perception characteristics of individuals that affect the eventual adoption of technology. These were the perceived ease of use of technology and the perceived usefulness of technology. This study investigated the relationship between the perceived usefulness of ICT and the frequency of using ICT user-skills for specific purposes. This was then followed by a study of the relationship between the frequency of using ICT user-skills for specific purposes and the ability of using ICT user-skills for those purposes. Statistical analyses were also performed to correlate ICT user-skills ability with student variables in the study, namely gender, year of study, and engineering specialization.

Four learning theories underpinned this study. These are the constructivist learning theory, behaviorism, transformative learning theory and social development theory. Theories of learning could provide guidance in designing learning environment and activities (O'Donnell *et al.*, 2009).

The constructivist learning theory considers the main purpose of education is to engage students in meaningful learning (Jonassen *et al.*, 1999). It emphasizes the role of the individual in learning and regards technology as a means to facilitate thinking and knowledge construction. Technology will result in meaningful learning if it is used as a tool that helps students think (Jonassen *et al.*, 1999). ICT can support learning by providing opportunities for students to learn, think critically and discuss with their peers (Olsen, 2000). The constructivist learning theory also holds that new knowledge is built on the foundations of previous learning and that learning environments should be student-centered (Kanuka and Anderson (1999). According to the constructivist learning theory, every student actively constructs his or her unique and subjective understanding of new experiences or content in a given learning situation or context (Brown, Collins and Duguid, 1989; Lave and Wenger, 1990). Thus students would have their unique conception of knowledge and skills. This study incorporated students' conception of ICT user-skills in the development of the measurement instrument, specifically in the selection of survey items.

Behaviorist learning theory emphasizes the importance of learning environments to generate desirable behaviors such as ICT skills and self-regulatory capacities. Changes in the environment are believed to cause changes in behavior when students adapt to the environment. To promote mastery of ICT skills, students would need an environment that encourages them to practice using those skills as frequently as possible. This is in accordance with Thorndike's law of exercise in the behaviorist theory of learning which stresses learning by doing. The law states that stimulus-response connections that are repeated are strengthened, while stimulus-response connections that are not used are weakened (Hergenhahn, 2005). This study investigated the relationship between students' ICT user-skills ability with the frequency of performing ICT-related activities for engineering learning.

According to transformative learning theory, learning process is enhanced through reflective thinking and making an interpretation of one's experience (Mezirow, 1997). The goal of learning is to develop autonomous thinking by critically reflecting and assessing one's purposes, assumptions, beliefs, feelings and judgment. To be an effective member of the workforce, a student should be able to adapt to changing study and working conditions, new technology systems and engage in collaborative decision-making. Critical reflection helps students to not only construct new knowledge and information, but more importantly to transform their approach to thinking and learning. At CST, engineering students have the opportunity to view their ICT skills critically in relation to their study through formal assessment of their performance in ICT courses and through informal self-assessment of their ICT skills. Reflecting on how much their skills have progressed, identifying which skills need to be polished and taking remedial action could eventually help students learn independently (Boud, 2003). This was the motivation for developing an instrument based on students' self-reporting of their ICT user-skills.

Vygotsky's social development theory stresses on the role of social interactions in cognitive development. Zone of Proximal Development (ZPD) is defined as

> the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers.
>
> (Vygotsky, 1978: 86)

According to Vygotsky's ZPD principle, a person can learn more with the guidance from a more knowledgeable and skilful person than learning it independently. Vygotsky (1978) describes the ZPD as the area where instruction, training or guidance should be given to enhance existing skills or develop new skills. In this study, the ZPD principle was used to justify what, when and why specific ICT skills training should be provided to increase students' ICT skills for engineering learning.

The theories and concepts underlying the process of developing and validating a measurement instrument for engineering learning are summarized in Figure 1.1 and Figure 1.2.

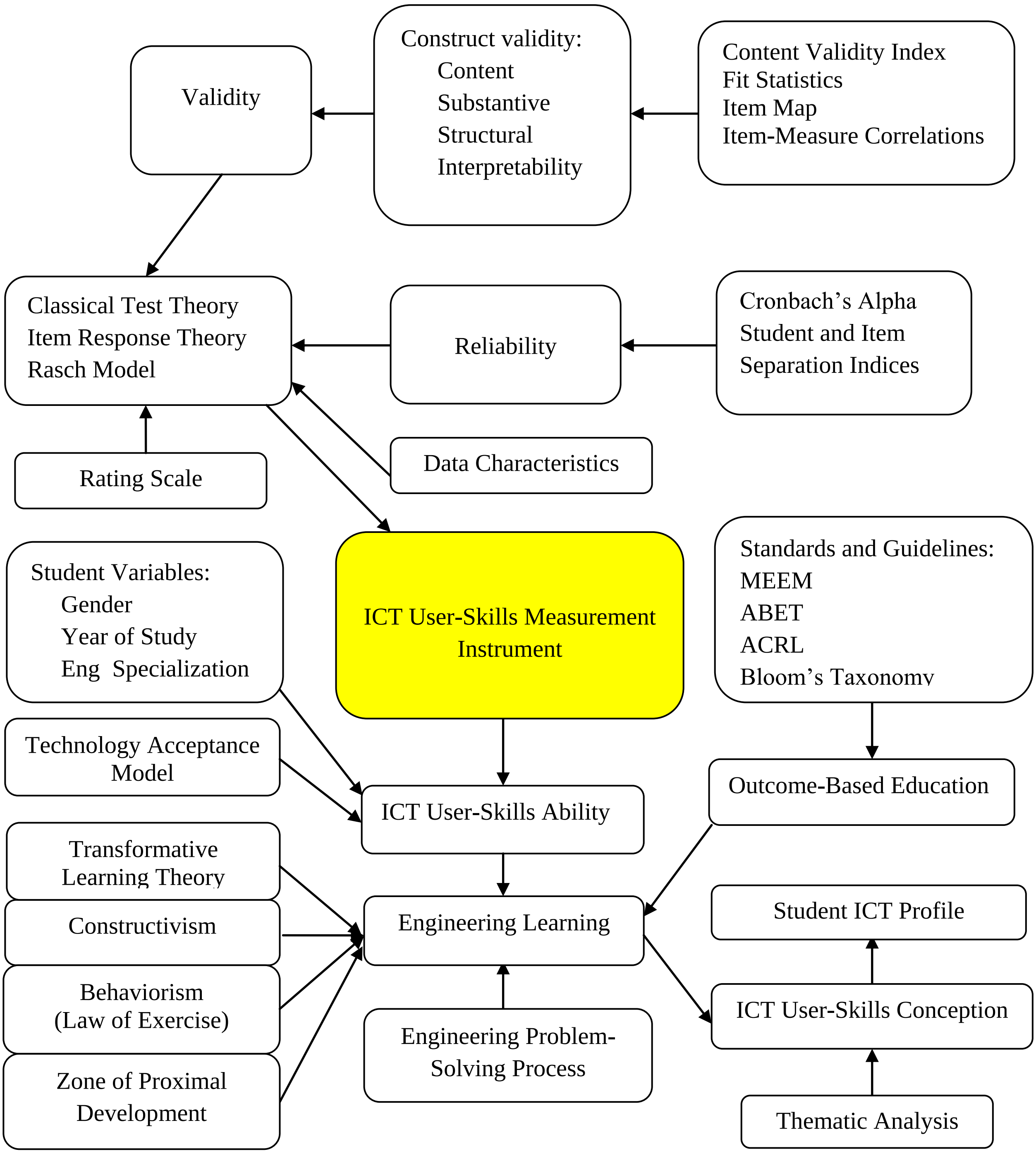


Figure 1.1: Conceptual framework for the study

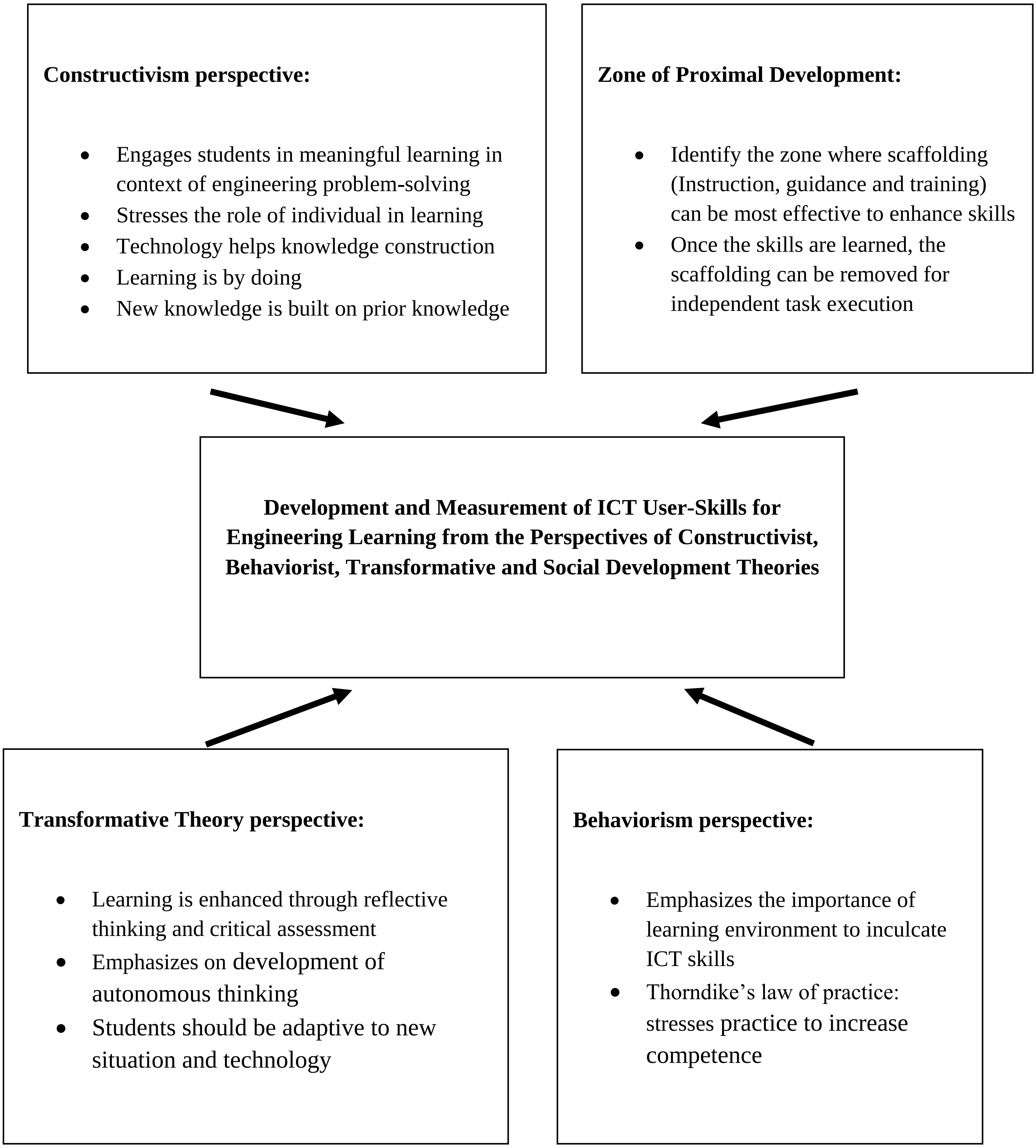


Figure 1.2: Theories underlying the development and measurement of ICT skills for engineering learning

1.9 Significance of the Study

This study developed a reliable and valid measurement instrument in the form of a survey questionnaire on the ICT skills most relevant to engineering education. Questionnaire items consisted of questions related to ICT user-skills such as self-reported skill levels and the frequency of performing ICT-related engineering learning activities. This instrument may be adopted by researchers interested in investigating the ICT skills of engineering students in other colleges and universities.

Even though the study was limited to one particular campus for the reasons described in Section 1.9, the methodology employed in this research may be replicated at other institutions of higher learning. The findings can identify the ICT user-skills that need to be remediated and integrated in the engineering curriculum, so that they can be better retained and subsequently applied in future study and work. Furthermore, the findings of similar studies could be used as cases in a meta-analysis research.

This research also addressed the need for an empirical study on engineering students' ICT skills ability and the extent to which ICT skills were used to support engineering learning. So far, not much research had been carried out to examine the profile of ICT user-skills among engineering students. Most studies on ICT literacy in higher education concerned the ICT skills of non-engineering students, and those few that involved engineering students focused on limited aspect of ICT skills such as the use of information literacy skills and their general-purpose ICT skills. Thus, there has been limited information to guide decision-making in ICT skills improvement programs, especially among engineering students who need to face the challenges of fast-changing technology, explosion of information and the requirements to be creative and innovative. This study encompassed the three most important aspects of ICT user-skills required in engineering learning, namely the skills to use general-purpose and engineering software, and information skills.

1.10 Operational Definition

This section explains the operational definition of the terms used in context of the study.

1. Assessment is one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes and program educational objectives (ABET, 2009a). Assessment is process-oriented and provides feedback on performance by identifying strengths, areas of improvement and insights.

2. A construct is a theoretical behavior that cannot be observed, and therefore cannot be measured directly. To measure a construct, researchers need to capture directly observable indicators, believed to represent the construct accurately (Byrne, 1998).

3. Evaluation is the comparison of assessment data to a standard for the purpose of judging worth or quality (Huitt *et al.*, 2001). Evaluation is product-oriented and determines whether a standard is met, and whether a program is a success or failure.

4. Engineering learning is the process of acquiring disciplinary knowledge, forming an identity as an engineer, and navigating through engineering education. Engineering disciplinary knowledge can be acquired through attending lectures, doing laboratory work and performing project activities. These activities, in particular open-ended problem solving in upper-level courses develop engineering identities. Engineering identities are the characteristics of engineers described by the MEEM and ABET criteria of engineers. Navigation through higher education comprises official academic courses and non-official student activities (Stevens *et al.*, 2008). In context of the study, official academic courses comprise engineering and non-engineering courses and co-curricular activities in the Civil, Electrical, and Mechanical diploma programs at CST. Non-official student activities are optional

and voluntary engineering-related activities performed outside official study hours such as taking part in design competition organized by private corporations.

5. According to UNESCO, ICT user-skills comprise:

i) The ability to perform ICT device operations. ICT devices include digital equipment, communication tools, and/or networks.

ii) The ability to use application software and Internet-based services.

iii) The ability to define, access, evaluate, and use information in an information search process. To define information is to identify the information needs of a problem. To access information is to be able to search, collect and/or retrieve information. To evaluate information is to judge the quality, relevance, usefulness, and accuracy of information. To use information is to be able to identify main and supporting ideas, conflicting information, point of view, identify solutions and/or make informed decisions.

In this study, ICT User-Skills for Engineering Learning consist of:

i) The ability to use general-purpose software for engineering learning.

ii) The ability to use engineering software.

iii) The ability to use information skills for engineering learning.

6. A measure of a magnitude of an attribute is its ratio to the unit of measurement. The unit of measurement is that magnitude of the attribute whose measure is 1 (Michell, 1999).

7. Measurement is the process of quantifying the attributes of a physical object, event, or condition relative to some established rule or standard. A particular way of assigning numbers or symbols to the attributes is called a scale of measurement. (Kizlik, 2011).

8. Program Learning Outcomes are statements that describe what students are expected to know and be able to do by the time of graduation. These relate to the

skills, knowledge, and behaviors that students acquire in their matriculation through the program (ABET, 2009b).

9. Rasch Measurement is the process of discovering ratios in respondents' attributes with a unit value that maintains its value along the whole scale (Bond and Fox, 2007).

10. Student Learning Outcomes are statements of observable student actions that serve as evidence of the knowledge, skills, and attitudes acquired in a course (Felder and Brent, 2003a).

1.11 Scope of the Study

There were two major parts of the study. The first part was the development and validation of an instrument to measure ICT user-skills ability of engineering students. The second part described the profile of ICT user-skills of engineering students including the usage, acquisition, and conception of ICT skills and analyzed engineering students' ICT user-skills ability with respect to gender, year of study and specialization.

1.12 Limitations of the Study

The researcher faced several limitations in this study. The first limitation concerned the study sample. As previously described, one of the objectives of this study was to compare ICT user-skills of students in different study years. The best way to do this would be to conduct a longitudinal study using the same sample of students from Year 1 through graduation. However, since it was not practical to conduct a longitudinal study due to time constraint, the researcher had to use cross-sectional data while ensuring as homogeneous sample as possible. Homogeneity of sample would reduce biases and enable inferences be made about skill level differences among students in different study years while reducing the effects of different academic curriculum, learning environment and a big age gap between respondents. Thus, the sample of students was selected from one particular college that conducts full-time programs.

The second limitation was that the sample of students was from only three engineering specializations, namely civil, electrical and mechanical at diploma-level because the college only offered those courses. Only full-time students were considered because these students lived on campus, and thus had similar learning facilities, resources and environment.

The third limitation was that not all categories of ICT user-skills were included in the study. The user-skills were limited to the skills to use general-purpose software, engineering software, and information skills. In the researcher's opinion, the ability to operate and manage ICT gadgets such as the personal computer can be deduced from other survey items. An example was item 2 in Part C2: *Using a computer to access engineering data*. This item implicitly implied that a student is able to operate a computer. Omitting items that can be deduced from other items would keep the survey short and simple. Long surveys are known to discourage people from responding and would probably result in low response rates (Yammarino, Skinner and Childers, 1991).

The fourth limitation was that the assessment of ICT skills was based on students' own perceptions, and thus may be biased due to factors such as the level of respondents' confidence and subjective interpretation and evaluation of their capability. The researcher also had to assume the students were being honest in their responses. To reduce the possibility of fake responses, the researcher stressed the objective of the questionnaire as being for students' self-understanding and self-improvement and to provide data for future program improvement. Students were also told that the survey would not be used for grading purposes.

1.13 Organization of the Thesis

This thesis contains five chapters. Chapter 1 introduces the research topic, presents the background of the problem, statements of the problem, the research purposes, the research objectives, the research questions, the research hypotheses, the conceptual framework, the significance of the study, the scope and limitations of the study. Chapter 2 consists of the review of literature which includes a description of the role of ICT skills in engineering learning, the characteristics of future engineers, existing measurement instruments for ICT skills, and previous findings related to students' ICT skills. Chapter 3 describes the research methodology comprising the research design, the sampling techniques, data collection procedures and data analysis techniques. Chapter 4 presents the findings of both quantitative and qualitative analyses. Chapter 5 discusses the research findings and presents the implications and conclusions of the study and suggests recommendations for future work.

1.14 Summary of the Chapter

This chapter is an introduction to the research topic and describes the foundation of the study. It details the background to the study, the research purposes, problem statement, research objectives, research questions and research hypotheses in the study. It also states the importance, scope and limitation of the study. It presents the conceptual framework which connects all concepts, theories, processes, and variables in the study. Chapter 2 comprises the review of literature, highlights the gap in related research work, and connects it with the need to conduct this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review and synthesis of the literature pertaining to the key themes in the study, the conceptual framework and research questions. The different dimensions of ICT skills are described. Discussion on the assessment and measurement of ICT user-skills ability, and a review of the findings from previous ICT literacy studies are also presented. The chapter also overviews the engineering discipline and profession, describes the characteristics of engineers in the 21st century, and presents the definition of engineering program learning outcomes by ABET and MEEM. Engineering problem-solving process along with ICT-supported engineering activities are presented. A mapping of engineering learning activities to engineering program learning outcomes was given. A summary of the chapter and the findings and gaps in previous related studies conclude the chapter.

2.2 ICT Literacy

In today's ICT society, the concept of literacy is no longer confined to the functional skills of reading, writing, speaking and listening, but extends to include other forms of literacies along with the rapid technological developments (New Media Consortium, 2007; Kay and Honey, 2005; Daley, 2003; Warschauer, 2001;

Kellner, 2000; New London Group, 1996; Simonson *et al*., 1987). One of the critical skill clusters identified in the report of *enGauge 21st Century Skills for 21st Century Learners* (2003) is digital-age literacy which includes information literacy and ICT literacy.

ICT is a combination of Information Technology (IT) and Communication Technology (CT). IT is the use of hardware and software to manage information. It deals with storing, protecting, processing, transmitting and retrieving the information as necessary. CT is the technology used to transmit data. It may be either analogue or digital. The term ICT is an umbrella term that is now used increasingly by global industry and academics due to the convergence between information and communication technologies. ICT literacy reflects the need for students and workers to develop technology-aided learning skills that will enable them to think critically, to obtain, to analyze, to communicate information and to use it in problem solving.

The National Higher Education ICT Initiative developed the following definition of ICT literacy in the higher education context:

> ICT literacy is the ability to use digital technology, communication tools, and/or networks appropriately to solve information problems in order to function in an information society. This includes the ability to use technology as a tool to research, organize, evaluate, and communicate information and having a fundamental understanding of the ethical/legal issues surrounding the access and use of information.
>
> (Educational Testing Service, 2003:3)

Digital technology is the technology that utilizes the binary system of computing. The technology enables a huge amount of data to be recorded, edited, stored and retrieved as sets of zeroes and ones using devices as the computer, hard drives, compact disc recorders, and digital video camcorders. The quality of digital data does not degrade over time. The durability, portability and compatibility of digital media with audio and video devices make them a popular choice today.

Communications technology consists of electronic systems used for communication between individuals or groups. It facilitates communication between individuals or groups who need not be physically present at the same location. Systems include telephones, telex, fax, radio, television, and video, as well as more recent computer-based technologies, such as electronic data interchange and e-mail.

Communications network is an organization of stations capable of intercommunications, but not necessarily on the same channel (US Department of Defence, 2005). Links and nodes are arranged so that messages may be passed from one part of the network to another over multiple links and through various nodes. Communications network encompasses telecommunications network that include computer network, the internet, telephone network and telex.

UNESCO defines the three dimensions of ICT literacy as consisting of:

i) Knowledge: Awareness and appreciation of ICTs and their relevance to personal and professional life.
ii) Skills: Technical skills to deal with information, that is the ability to use ICT features and applications to access, retrieve, store, manage, integrate, evaluate, create and communicate information.
iii) Attitude: A person's critical assessment of the information and knowledge that is assessed, managed, integrated, created, and communicated through ICT. This should lead to a responsible and ethical use of technology.

(UNESCO, 2008a:13)

Key competencies for technical skills include the ability to:

i) use ICT devices and software applications
ii) access and search websites
iii) use internet-based services
iv) gather and process electronic data
v) use ICTs to support critical thinking, creativity and innovation for educational, work-related, and leisure purposes
vi) distinguish the credibility of information

The definition of ICT user-skills used in this study was derived from UNESCO's definition of technical competency above.

In summary, the concept of ICT literacy has evolved through times with the development in scientific knowledge and technology, and is supported by innovative communication tools to meet the demands of the society and industry. New ICT tools and skills for teaching and learning processes in higher education might change the role of lecturers and students (UNESCO, 2011a). As ICT evolves and changes the teaching and learning culture, the conception of ICT literacy may change too. Conception refers to the abstraction of ideas or a general representation formed in the mind, inferred from what is common to several specific perceived objects (SEP, 2011). This study explored the conception of ICT literacy, in particular the conception of ICT user-skills among engineering students since conception could indicate the potential for transformative learning using ICT (Somekh and Mavers, 2003).

2.2.1 ICT User -Skills for Learning

UNESCO(2008a) defines ICT user-skills as consisting of:

(i) The ability to perform ICT device operations.

(ii) The ability to use application software and Internet-based services.

(iii) The ability to define, access, select, evaluate and use information.

Many types of ICT devices can be used to support and enhance learning. Common examples are personal computers, laptops, printers, scanners, handheld gadgets such as mobile phones, videos, digital cameras, voice recorders, electronic data collection hardware, and media players. New technologies and thus new uses of technology are constantly emerging. These technologies deliver different kinds of content and for different educational purposes (Marshall, 2002; Lei and Zhao, 2006). Students should have the technical skills to operate the computer, manage files, perform system maintenance, handle audio-visual equipment, and use geographical information system devices and electronic data collection hardware.

An ICT literate student should know how to use general-purpose application software such as word processors, multimedia presentation, e-forums, chat programs and e-mail to promote communication skills; databases and spreadsheet programs to enhance data management and organizational skills; information search tools to access and select information in doing class assignment and research work. It is also advantageous to know a few programming languages and to be able to do concept mapping to support learning (International ICT Literacy Panel Report, 2002).

Educational software packages that help students learn discipline-specific subject matter or courseware have been widely used for more than twenty years (Becker et. al., 1999). They can be classified as Discrete Educational Software (DES), Integrated Learning System (ILS), Computer-Assisted Instruction (CAI), and Computer-Based Instruction (CBI) (Murphy *et al*., 2001). These computer-based software packages are often used to promote interactive and independent learning.

ICT tools which include hardware and software, play a variety of roles in supporting learning activities. Four categories of ICT tools classified by their different mediating roles are: a) informative tools, b) situating tools, c) constructive tools, and d) communicative tools (Wang, 2006; Lim and Tay; 2003). ICT tools serve as informative tools by providing access to huge repositories of information in a variety of formats such as video, graphics and text. Examples of informative tools are online databases, encyclopedias, and all information that can be accessed through the intranet and internet.

Situating ICT Tools are those tools that provide an environment in which the users can experience a situation within a certain context. Examples of situating tools are virtual reality environment such as virtual laboratories, simulation of reality, e-learning, and computer games. Communicative tools facilitate exchange of information beyond the physical set-up and across time zones. Examples of communicative tools are online electronic mails, chat programs, e-forums, teleconferences, and electronic bulletin boards.

Constructive tools are tools that enable construction of tangible or intangible output through data manipulation. Examples of tangible output are project reports, statistical reports, mathematical solution, presentation slides, websites, software packages, and computerized systems. Examples of intangible output are conceptual understanding and an awareness of certain issues. Constructive tools include general-purpose application software and special-purpose software. Examples are Microsoft Office, Photoshop, web authoring software, mind mapping tools, AUTOCAD, MATLAB, and SIMULINK.

With abundance of data and information in electronic form, students must have the skills to handle information. They need to use internet information search tools such as web browsers, web portals, search engines, telnet and file transfer protocols. They must know how to evaluate the authority, accuracy, objectivity and currency of information. Libraries provide wealth of information, which can be accessed via the library catalogues and online public access catalogue (OPAC) system, but students need the skills to make effective use of these resources.

Activities to access, select, retrieve, process, evaluate, and use information include the following steps (Mittermeyer and Quirion, 2003):

a) Identifying the main concepts in a topic

   Key words can be used as search items from various search tools: databases, internet search engines, OPAC.

b) Developing a search strategy

   i) Making a list of similar and related terms for each of the concept identified to get a better chance in finding relevant documents.
   ii) Relating the concepts and synonyms using Boolean operators such as "OR" and "AND".
   iii) Selecting document types such as encyclopedias, books, journal articles, monographs, theses, conference proceedings, and government publications.
   iv) Selecting search tools that will enable the retrieval of the desired

document types.

c) Executing the search

Students enter the search statement using the tool selected.

d) Using search results

i) Students locate and retrieve the documents found using the search tool.

ii) Evaluating the information. Assess the quality of the information according to the reputation and credibility of the author, reliability of the sources, publication date, and accuracy of the information.

The information searching tasks described by Mittermeyer were the information skills that can be enhanced using ICT tools. The information skills test developed by Mittermeyer was adapted and used in a preliminary study on a sample of engineering students at CST. The findings of the study were published in a journal (Ali *et al.*, 2010). In this current study however, the definition of ICT user-skills was broader to include the use of general-purpose software and engineering software, and was adapted from both the UNESCO definition and the definition of information skills by the ACRL.

Information skills are part of the generic skills that should be inculcated in all students to achieve the university's vision and mission in producing graduates who are technically-competent, versatile, creative, and possess high moral and ethical values. The following generic skills are listed as some of the most important skills to help students succeed in studies, career, and life in general (UTM, 2009):

i) Communication Skills
ii) Critical Thinking and Problem Solving Skills
iii) Team working Skills
iv) Information Management and Lifelong Learning Skills
v) Entrepreneurship Skills
vi) Leadership Skills and Proactiveness
vii) Ethics and Integrity

2.3 Malaysian Higher Education System

Formal education in Malaysia is the responsibility of the federal government under the jurisdiction of the Ministry of Education (MOE) and the Ministry of Higher Education (MOHE). MOE is responsible for pre-tertiary education, which encompasses pre-school, primary, secondary, and post-secondary school education. The total duration of pre-tertiary education is 13 years. MOHE is responsible for higher education at both pre-university and university levels.

Tertiary education in Malaysia is conducted at three different types of higher institutions: university, polytechnic and college. Stages of studies at these institutions are either at pre-university or university level studies. Technical and vocational higher education is provided in polytechnics, community colleges, university colleges, industrial training colleges, and teacher training institutes. The duration of studies is between two to three years, after which students would be awarded Certificates or Diplomas. There are three stages of studies at the university level. The first stage leads to the Bachelor's degree taking between three to five years. The Master's degree is conferred after another one to two years of study. The third stage awards the Doctoral degree after a minimum of two years of further study and research (WHED, 2005; Hassan, 2006).

Major stakeholders of engineering education in Malaysia comprise the Ministry of Higher Education (MOHE), the Engineering Accreditation Council (EAC) under the purview of the Board of Engineers, Malaysia (BEM), the Institution of Engineers Malaysia (IEM), the Malaysian Council of Engineering Deans (MCED), taxpayers, parents, students and potential employers. The MCED/IEM Report (2000) recommends six skills of future engineers. These are global and strategic, industrial, humanistic, practical, professional and scientific skills. Global and strategic skills enable students to acquire new knowledge and compete globally. ICT skills are classified as global and strategic skills to prepare engineering students for study, life and professional work in the knowledge-driven 21st century (Malaysian Economic Planning Unit and World Bank Report, 2007; Radin, 2006; Miliszewska, 2008; International ICT Literacy Panel Report, 2002). The above mentioned stakeholders influence to varying degree, the engineering curriculum in Malaysia.

A curriculum encompasses all factors that bring out learning, and is defined as the formal mechanism through which intended educational aims are achieved (Heywood, 2005). Wojtczak (2002) defines curriculum as an education plan that details the goals and objectives to be achieved, which topics to be covered, and which methods to use for teaching, learning, and evaluation. Major components in a curriculum are the curricular policies, goals, fields of study, programs of study, subjects, units of study, and lessons (Glatthorn *et al.*, 2006). Curriculum has been shown empirically to affect students' learning and academic achievement (Schmidt *et al*. 2001; Spicuzza *et al.*, 2001; Thompson and Senk, 2001). Stakeholders determine the skills engineering students should acquire during their study and as such, the curriculum is designed to inculcate these skills.

A meta-analysis study by the British Educational Research Association showed a positive impact of ICT on learning if ICT use was planned, structured and integrated effectively (Higgins, 2003). Approaches to inculcating ICT skills vary from stand-alone subjects to different levels of curriculum integration. Shoemaker (1989) defines an integrated curriculum as an education that cuts across subject-matter lines, bringing together various aspects of the curriculum into meaningful association. Numerous studies on information skills have shown that the skills can be integrated effectively when they directly relate to the curriculum content and to learning activities (Eisenberg and Johnson, 2003).

2.4 Engineering Discipline and Profession

Engineering is the discipline and profession of applying technical and scientific knowledge in practical applications (Dorf, 2005). The field has been defined by the Engineers Council for Professional Development, in the United States, as follows:

> the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property.
>
> (Encyclopedia Britannica Online, 2008)

Engineering is critical to most aspects of modern society because all the elements of infrastructure, which includes everything from roads to aircraft, medical equipment to the internet, require both effective design and construction. The broad discipline of engineering encompasses a range of specialized sub-disciplines that emphasize different fields of applications and technology. The main branches of engineering are civil, mechanical, electrical, chemical and aerospace engineering. New engineering fields emerge with the rapid advancement of technology. Examples are computer engineering, software engineering, industrial engineering, environmental engineering, petroleum engineering, mechatronics, nanotechnology, and molecular engineering.

Diverse engineering specializations however, have similar fundamental nature of engineering (Kemper and Sanders, 2001). Engineers in all specializations convert technical and scientific knowledge into technology, and then convert technology into successful invention and innovation. As such, engineers are agents of change with technology as their primary tool. Technological change underpins global competitiveness and contributes significantly to the economy.

2.5 Characteristics of Engineers in the 21st Century

Engineers require problem-solving and reasoning skills, strong mathematical foundation, creativity in innovation or invention, team working skill, management skill for project work and fulfilling customer needs, and self-directed and experiential learning. In business environment, engineers need to have the ability to analyze a large volume of information and convert it into competitive knowledge timely and efficiently. They need good communication skills to express ideas clearly and succinctly, and to sell ideas to executives who make corporate decisions (Roman, 2006). A study commissioned by the Malaysian Ministry of Higher Education (MOHE) on university curricula and workplace literacy found that some of the skills lacking among the graduates were ICT skills. (Pandian and Abdul Ghani, 2005).

In engineering education, ABET which is based in the United States, accredits engineering curricula for international programs of countries that wish to be a signatory of the multinational Washington Accord (ABET, 2009a). The Washington Accord is an international agreement covering mutual recognition of tertiary-level qualifications in engineering. Malaysia is currently a provisional signatory of the Washington Accord.

In 1997, ABET adopted Engineering Criteria 2000 (EC 2000) as an approach to program accreditation (ABET, 1997). The criteria are used to assess and evaluate programs based on student learning outcomes. Engineering institutions seeking accreditation must demonstrate that their graduates meet Engineering Criterion 3:
Engineering programs must demonstrate that their graduates have:

i) an ability to apply knowledge of mathematics, science, and engineering.
ii) an ability to design and conduct experiments, as well as to analyze and interpret data.
iii) an ability to design a system, component, or process to meet desired needs.
iv) an ability to function in multidisciplinary teams.
v) an ability to identify, formulate, and solve engineering problems.

vi) an understanding of professional and ethical responsibility.

vii) an ability to communicate effectively.

viii) the broad education necessary to understand the impact of engineering solutions in a global and societal context.

ix) a recognition of the need for, an ability to engage in lifelong learning.

x) a knowledge of contemporary issues.

xi) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

(ABET, 2009a)

2.6 Characteristics of Malaysian Engineers in the 21st Century

In Malaysia, the stakeholders of engineering education include educational and professional bodies such as the Ministry of Higher Education (MOHE), the Engineering Accreditation Council (EAC) under the purview of the Board of Engineers, Malaysia (BEM), the Institution of Engineers Malaysia (IEM), the Malaysian Council of Engineering Deans (MCED), and potential employers. The characteristics of Malaysian engineers identified in the MCED/IEM Report (2000) are:

i) Scientific strength, which enables engineers to conduct innovative research and development in traditional and new areas such as biotechnology, nanotechnology, and information technology.

ii) Professional competencies, which enable engineers to be technically proficient in performing specific engineering activities in a world driven by rapid technological advancement.

iii) Multi-skilled, which enables engineers to perform a variety of engineering activities and adapt to different engineering disciplines, and committed to life-long learning.

iv) Well-respected and possess leadership quality, which prepares engineers to lead in business and public service, able to communicate effectively, understand other cultures, and contribute to the wider world.

v) Morally and ethically sound.

2.6.1 Skills Required by Engineering Graduates

The Malaysian Engineering Education Model (MEEM) recommends six skills and competencies to satisfy the five criteria aforementioned. These are global and strategic, industrial, humanistic, practical, professional and scientific skills (Johari *et al.*, 2002).

Global and strategic skills such as ICT skills enable students to acquire new knowledge and compete globally. Industrial skills equip the students with knowledge beyond the scientific and professional disciplines necessary for their career development. This includes knowledge concerning the environment, economics, management, finance, law, human resource management, occupational safety, human relations and communication. Humanistic skills help instill moral and ethical values in an engineer. Practical skills provide hands-on experience in integrating engineering and non-engineering knowledge. Professional skills encompass technical competency in specific engineering areas. Scientific skills provide a strong foundation in engineering science and mathematics to enable students to adapt and respond to changes in science and technology, conduct research and produce innovative design.

2.6.2 Comparison between MEEM, MOHE and ABET Program Learning Outcomes

The MEEM engineering graduate attributes serve as a basis for Malaysian engineering curriculum development in an outcome-based education (OBE). MOHE describes learning outcomes for higher education programs in general. The EAC is making efforts to be accepted as a permanent signatory to the Washington Accord to get the engineering degree programs globally accredited. One such effort is by complying with the Accreditation Board for Engineering and Technology (ABET) program learning outcomes requirements described in the Engineering Accreditation Commission (2007) report. A comparison of the MEEM and MOHE learning outcomes with ABET's learning outcomes are shown in Table 2.1.

Table 2.1: Comparison between MEEM, MOHE and ABET program learning outcomes

	MEEM Learning Outcomes	MOHE Learning Outcomes	ABET Learning Outcomes
1.	An ability to identify, formulate and solve engineering problems.	Knowledge in specific area. Thinking and scientific skills.	3e - An ability to identify, formulate and solve engineering problems.
2.	An ability to be technically proficient in performing specific engineering activities.	Practical skills.	3k – An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
3.	Ability to engage in lifelong learning.	Lifelong learning.	3i – A recognition of the need for and an ability to engage in lifelong learning.
4.	Ability to communicate effectively.	Communication skills.	3g – An ability to communicate effectively.

The researcher had identified four learning outcomes that could be significantly supported by ICT skills. These outcomes are shown in Table 2.2.

Table 2.2: Learning outcomes supported by ICT skills

	ABET-equivalent of MEEM learning outcomes
1.	3e - An ability to identify, formulate and solve engineering problems.
2.	3k – An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
3.	3i – A recognition of the need for and an ability to engage in lifelong learning.
4.	3g – An ability to communicate effectively.

2.7 Definition of Engineering Program Learning Outcomes

The definition of the MEEM/ABET program learning outcomes (Besterfield-Sacre *et al.*, 2000; Mourtos, 2003; UTM Academic Guidelines, 2009) is given in Table 2.3.

Table 2.3: Definition of program learning outcomes

	Outcome	Definition
1.	An ability to identify, formulate and solve engineering problems.	Based on engineering problem solving process which includes the ability to identify a problem, define the problem statement, formulate the problem, collect information and data, translate a model, validate a model, design an experiment, develop a solution, interpret results, implement the solution, prepare documentation, obtain feedback and improve the solution. (Besterfield-Sacre *et al*., 2000)
2.	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Skills and tools include computer software, simulation packages, diagnostic equipment, use of technical library resources and literature search tools. (Besterfield-Sacre *et al*., 2000).
3.	An ability to engage in lifelong learning.	An ability to: observe engineering artifacts carefully and critically. access information effectively and efficiently from a variety of sources. read critically and assess the quality of information available. categorize and classify information. analyze new content by breaking it down, asking key questions, comparing and contrasting, recognizing patterns, and interpreting information. synthesize new concepts by making connections, transferring prior knowledge, and generalizing. model by estimating, simplifying, making assumptions and approximations.

		visual engineering concepts. reason by inferring, using inductions, checking assumptions, inquiry and using lateral thinking. (Mourtos, 2003)
4.	An ability to communicate effectively.	An ability to present information and express ideas clearly using written, oral, graphical, and electronic media. Can deliver a presentation confidently using technology such as the computer and Internet and able to discuss, convince and persuade others to reach an agreement. (UTM Academic Guidelines, 2009)

2.8 Engineering Problem Solving Process

One of the main goals of engineering education is to equip students with the skills required to succeed in their profession. Engineers apply science and mathematics to solve problems or enhance the current solution. Because of rapid technological advances, engineers need to update their knowledge of relevant sciences for their design projects. When there is more than one feasible solution, engineers would select the best design that meets the requirements (Khandani, 2005). A crucial task is to identify and interpret the constraints on a design. Constraints may be the availability of resources, cost, safety, marketability and serviceability of a product. To be successful engineers, students must be trained to be problem solvers who are able to apply their knowledge of science and technology to create products or systems that meet human needs (ABET, 2009a).

Problem solving involves the commonly used five-step process (Khandani, 2005). However, since engineering problems are usually design problems, which are defined more vaguely and have many alternative answers, the process may require revisions of previous steps, and thus is iterative in nature. The five steps used for engineering problem solving are:

1. Define the problem

This initial step requires the problem-solver to:

i) identify and establish the need for a new product, system, or machine
ii) develop a problem statement
iii) establish success criteria

2. Gather relevant information

This step involves searching for information using resources such as scientific encyclopedias, technical handbooks, electronic catalogues, indexes, databases, CD-ROM or search engines.

3. Generate alternative solutions

New solutions can be produced by taking a creative approach to problem solving. The step may involve examining current solutions and their weaknesses, and finding ways to improve by combining new ideas, tools and methods to obtain a unique solution.

4. Analyze and select a solution

Analysis of design solutions may involve:

i) Functional analysis
ii) Ergonomics
iii) Product Safety and Liability
iv) Economic and Market Analysis
v) Mechanical/Strength Analysis

The selection process may require the problem-solver to:

i) create a decision matrix to rank the design solution.

ii) evaluate each design alternative against the stated criteria.

5. Test and implement the solution

Testing, construction, and manufacturing of the solution to the design problem usually involves

i) Prototyping

ii) Concurrent Engineering (Parallel design and analysis)

iii) Documentation

iv) Applying for Patent

The iterative nature of the engineering problem solving process is shown in Figure 2.1.

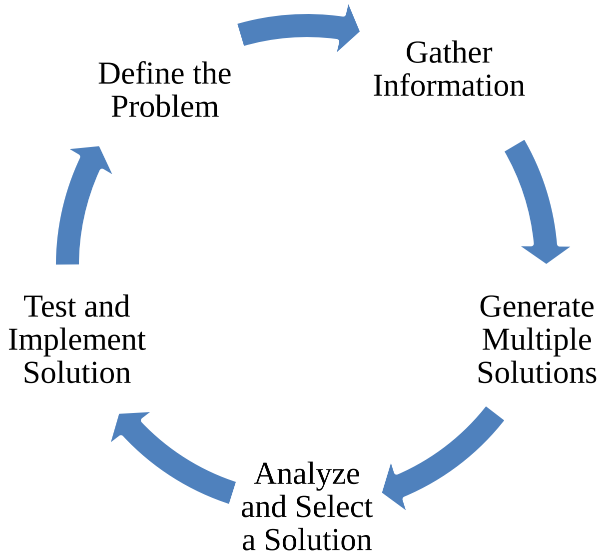


Figure 2.1: Engineering problem solving process (Khandani, 2005)

2.9 Engineering Activities Supported with ICT Skills

Job analysis is a set of activities done to obtain and categorize information about a specific job for a certain purpose (Ghorpade, 1988). There are numerous methods of job analysis such as through direct observation, using critical incident technique (CIT model), interview method, position analysis questionnaire (PAQ model), functional job analysis (FJA model), work profiling system (WPS model) and task inventory.

In this study, the purpose of job analysis was to identify the ICT user-skills that engineers need for problem-solving to generate items for the measurement instrument. The method employed was task inventory, which was based on literature review and subject matter expert evaluation. A task inventory lists all discrete activities related to an engineering job. Creating a task inventory for this study involved describing the desired characteristics of Malaysian engineers defined by the MEEM, mapping engineering program outcomes with the activities in engineering problem-solving process that require ICT skills, categorizing the activities according to the ICT user-skills domain, and consulting experts to validate the content domain of the ICT user-skills scale. The engineering learning activities associated with each step in the problem-solving process are listed in Table 2.4.

Table 2.4: Task inventory of learning activities supported by ICT skills

Engineering Problem Solving Step	Definition	ICT-Supported Learning Activities/Tasks
Define the problem:	Identify and Establish the Need for a New Product, System, or Machine Develop a Problem Statement Establish Success Criteria	Perform internet inquiry to find engineering data and information to identify the need for a new product, system, or machine, develop a problem statement, and establish success criteria.
Gather Information	Search for Information	Use electronic catalogues to search by subject matter, author, or title. Use electronic indexes to find recent articles in journals under various subject headings. Use search engines to locate information.
Generate Multiple Solutions	Consider alternative feasible solutions.	Use software to design alternative solutions.
Analyze and Select a Solution	Analysis of Design Solutions Functional analysis Ergonomics Product Safety and Liability Economic and Market Analysis Mechanical/Strength Analysis The Decision Process Create a decision matrix to rank the design solution. Evaluate each design alternative against the	Perform cost computations. Use computer simulation models. Use statistical analysis software. Use decision analysis software.

	stated criteria.	
Test and Implement the Solution	Testing the prototype, construction, and manufacturing of the solution to the design problem. Concurrent Engineering (Parallel design and analysis) Documentation Applying for Patents	Use computer-aided design (CAD) software to create a preliminary design. Analyze the design using a software. Use 3D computer model of the finished design with computer-aided manufacturing (CAM) to physically create the part. Use software to prepare a technical report. Use multimedia presentation techniques to communicate the solution to the design problem. Use a database to search for existing patents and to apply for patenting.

2.10 Engineering Application Software

There are many computer-aided applications (CAx) specifically developed for engineering. One of the most commonly used tools is computer-aided design (CAD) software that enables engineers to create schematics of their designs, 2D drawings, and 3D models (Riverside, 2007). Computer-aided engineering (CAE) is the use of information technology to support engineers in tasks such as analysis, simulation, design, manufacture, planning, diagnosis, and repair. Digital MockUp or DMU is a concept that allows the description of a product, usually in 3D, for its entire life cycle. CAD is often used together with Digital MockUp (DMU) and CAE software to create designs, which can be analyzed without costly investment in physical prototypes (Chadwick, 2004).

Many computer applications support specific engineering tasks. An example is computer-aided manufacturing (CAM) which generates computer numerical control (CNC) machining instructions. Manufacturing process management (MPM) is a collection of technology and methods used in the manufacturing. MPM describes how products will be manufactured. Electronic design automation (EDA) is the group of tools for designing and producing electronic systems ranging from printed circuit boards (PCBs) to integrated circuits. Architecture, Engineering and Construction (AEC) software is used in civil engineering.

2.11 Bloom's Taxonomy and Engineering Learning using ICT Skills

One popular categorization scheme for the types of learning objectives is Bloom's Taxonomy of Objectives for the Cognitive Domain (Bloom, 1984). Bloom ordered cognitive processes into six categories based on the complexity of the thinking processes involved: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. Each category requires mastery of the previous level. Knowledge is the lowest and easiest level of taxonomy which requires recalling facts and repeating verbatim. Comprehension is the next level which requires understanding of facts, terms and concepts. Application involves using knowledge and skills learnt to solve a problem. Analysis requires the ability to break things down into simpler elements, explaining the theories underlying a phenomenon and producing a model to represent an entity, event or system. Synthesis requires the ability to put ideas and separate elements together to create something new. Evaluation involves making informed judgment and justifying selection of alternatives. It also includes the ability to present a critique from a holistic perspective.

Bloom's taxonomy is widely used to guide the development of learning objectives and relevant activities to promote different levels of thinking skills (Felder and Brent, 2004). ICT skills can be used to support the cognitive development among engineering students through learning activities. Examples of the activities for each category of cognitive processes are shown in Table 2.5.

Table 2.5 : Examples of activities at different levels of the cognitive domain

Cognitive Domain	Engineering Learning Activity
Knowledge	Getting engineering data and information for problem-solving from the Internet.
Comprehension	Using a simulation software to understand circuit theory.
Application	Using software eg EXCEL to calculate the quantity of materials required to achieve certain strength.
Analysis	Using a simulation software to examine the mathematical model of a process.
Synthesis	Using application software to design an engineering solution to a problem.
Evaluation	Determining the accuracy of engineering information on the web based on: authority based on authority, objectivity and currency.

2.12 Mapping of Engineering Learning Activities to Learning Outcomes

An outcome-based education focuses on student learning by providing learning activities which will help students achieve the specified learning outcomes. Mapping of the MEEM outcomes with the equivalent ABET outcomes, and related engineering learning activities is shown in Table 2.6.

Table 2.6.: Mapping of MEEM and ABET outcomes with engineering learning activities

	MEEM Outcomes	Equivalent ABET Outcomes	Activities supported with ICT skills
1.	An ability to identify, formulate and solve engineering problems.	3e - An ability to identify, formulate and solve engineering problems.	Performing internet or CD-ROM inquiry to search for engineering data and information for problem-solving. Using new technology to collect engineering data. Using software eg. Excel, Maple, MathCAD to calculate and solve engineering, scientific and mathematical problems. Using project management software eg MS-Project to plan, schedule and manage an engineering project.
2.	An ability to be technically proficient in performing specific engineering tasks.	3k – An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Using graphics and charting tools in Excel, MATLAB or SPSS to describe and compare statistics and performance of engineering systems. Using programming languages to develop software to solve engineering problems. Using application software eg AutoCAD and MATLAB to design, model and analyze an engineering solution to a problem. Using simulation software eg. Electronics Workbench and SIMULINK to experiment with models of engineering systems eg. to replicate the behavior of an electronic device.
3.	Ability to engage in lifelong learning.	3i – A recognition of the need for and an ability to engage in lifelong learning.	Learning to use application software such as MATLAB using online tutorial. Using E-learning system to support independent learning of engineering courses.

			Determining the accuracy of engineering information on the web based on authority, objectivity and currency of information. Using video/audio tape, digital camera to record engineering projects, field trips, and demonstrations.
4.	Ability to communica effectively.	3g – An ability to communicate effectively.	Using software eg. MS-Word to write a well-formatted engineering project report. Multimedia presentations of engineering projects. Using electronic document management system to share or transfer information among project teams. Communicating through the Internet eg using email, chat, forum with project members.

The engineering-related activities shown in Table 2.6 were used as questionnaire items in the survey on ICT use in learning engineering developed by the researcher. It is shown here that the activities are derived from the engineering problem solving process and are directly related to the engineering learning outcomes.

2.13 Assessment and Measurement of ICT Skills

Assessment and measurement are two major components of an academic curriculum. Assessment is more comprehensive and inclusive than measurement because it includes both quantitative and qualitative description of students. Assessment of student learning is a systematic process that includes any of a variety of procedures used to obtain data about student performance. It starts with the description of learning goals and results in a judgment on how well these goals have been met. Measurement is the process of describing numerically how much of a particular attribute a student possesses (Linn and Miller, 2005). Stevens (1946) introduced the idea of measurement levels with different properties of relations and operations of the numbers or symbols representing the measurements. The most commonly used measurement levels are nominal, ordinal, interval, and ratio.

Two types of assessment are normative and criterion-referenced assessment. Norm-referenced assessment is designed to rank order students for the purpose of selection. Students are compared with the peers in terms of their weaknesses and strengths. Norm-referenced assessment promotes competition among students but it does not compare student achievement to an external standard of performance or criterion. Criterion-referenced assessment compares student achievement to an external standard of performance, relates the achievement to the instructional objectives, and is based on task analysis. Glaser (1963) introduced the term *criterion-referenced measures* of performance based on the nature and order of tasks performed. Glaser (1981) later proposed that performance should be measured on a continuum of skill ability ranging from no proficiency at all to a perfect performance. Performance levels should be used as a description of the stages of increasing competence on a developmental continuum (Griffin, 2007).

There are many purposes of an assessment, the most important of which is for educational improvement. Knowledge of students' existing skills, experiences in using those skills, and difficulties they face in learning the skills provides feedback on how well the program goals are being met. Aggregated group results provide a means to benchmark its achievement to similar groups (Stephens and Moskowitz, 2004; Bromley, 1994). This information can be used to design the curriculum to improve ICT skills, evaluate the effectiveness of the current ICT courses, and evaluate students' readiness for independent study. Course coordinators and academic advisors can use the information to identify the specific ICT skills which students lack and determine the need for intervention.

According to Biggs (2003), assessment tasks, learning environment and the methods of teaching should be aligned with learning activities to achieve the intended learning outcomes. Since measurement is the basis for assessment, this implies that measurement instruments should incorporate items that reflect the learning activities. Thus to measure ICT skill levels would require the measurement of the ability to perform ICT-related activities.

Pelligrino *et al.* (2001) assert that to assess what students know, an educational assessment system should be based on the assessment triangle consisting of i) a model of cognition and learning, ii) observations that reflect students' competency, and iii) interpreting the evidence of competency. In this study, learning theories that explain the relationship between cognition and learning are constructivist learning theory, behaviorist learning theory, transformative learning theory, and social development theory. Evidence of ICT competency is based on students' self-reported rating. Boud (2000, 2003) contends that assessments done by others can promote learning only when it provides informative feedback. He recommends that formative assessment should be done by the learners themselves rather than by others because it is an indispensible aspect of independent learning.

ICT assessment results also provide an empirical basis for higher education administrators and faculty to analyze the effectiveness of existing ICT policies, educational programs, and supporting services. These information will help curriculum developers design courses and programs that can better inculcate ICT skills. The report by the MOHE (2006) recommends that all institutes of higher education take steps to ensure all students master ICT and other skills of the digital era. These skills need to be regularly assessed to provide feedback on the effectiveness of the teaching and learning process.

2.14 Existing Instruments for Assessment and Measurement of ICT Skills

An instrument is the basic tool used to quantify the skill levels of individuals or a group of individuals. Various measurement instruments for ICT skills in the form of surveys and tests have been developed. However, the ICT skills assessed differ to suit the purpose of the survey. Many instruments were developed for specific context, for example: Student teachers training (Suthagar *et al*., 2011; Wong *et al.*, 2009; Kay, 1993; Loyd and Gressard, 1984); healthcare students (Wilkinson *et al.*, 2010; Jayasuria and Caputi, 1996); psychology and economics students (Garland and Noyes, 2004, 2005); medical students (Nurjahan *et al.*, 2002); business professionals (Compeau and Higgins, 1995). Many of these instruments focus on computer operations skills and the use of general application software. Quite a number of surveys focus on information literacy skills, especially those developed by local librarians. Locally developed surveys such as the one provided by Mittermeyer and Quirion (2003) are commonly used to evaluate the curriculum and information literacy intervention programs.

Standardized information literacy surveys are usually developed by a collaboration of researchers. An example of such surveys for higher education is the Standardized Assessment of Information Literacy Skills (SAILS) developed by a consortium of librarians, and based on the Association of College and Research Libraries (ACRL) information literacy competency standards for higher education. Another example is the Information Skills Survey (ISS) developed by the Council of Australian University Librarians (Catts, 2005). The National Higher Education ICT Initiative collaborated with Educational Testing Service (ETS) and seven universities in the United States to develop iSkills (ETS, 2008). The initiative was formed in 2003 to conduct a comprehensive assessment of ICT proficiencies in higher education to obtain diagnostic information regarding the breadth and gaps in ICT literacy (International ICT Literacy Panel, 2002).

SAILS, ISS and iSkills measure different aspects of information literacy. The SAILS only measures information literacy knowledge at the general level of abstraction, and not skills of doing activities. The SAILS measurement tool was designed and developed using latent-trait theory (O’Connor *et al*., 2002). The ISS is a self-report inventory of what respondents do with information. It is based on the information literacy standards of the Australia and New Zealand Institute for Information Literacy and developed using criterion referenced assessment (Bundy, 2004; Catts, 2005). The iSkills provides a simulated computer-based test of information literacy. The assessment was based on three dimensions of ICT literacy: cognitive proficiency, technical proficiency and social or ethical understanding. The assessment procedures were developed using evidence-centered design (Mislevy *et al*., 2003; Messick, 1994).

The Computer Skills Placement (CSP) Test and the Prentice Hall Train & Assess IT (TAIT) Tool are two examples of commercial tools for ICT literacy assessment. The major characteristic of such tools is that they are well designed and can be customized (Robbins and Zhou, 2007). Commercial assessment tests are quite costly, may not be readily available, and may require customization. Many of these tests are objective or multiple-choice tests. Standardized information literacy tests and surveys like the SAILS, ISS and iSkills are not yet available in the Asia Pacific region.

Many studies on ICT skills utilize respondents' self-assessment. In cases where it is not possible to use a direct measurement of ICT skills, the best approach is probably to use self-assessment surveys (UNESCO, 2008b). A self-assessment survey is a time and cost efficient method to capture data, but the accuracy of data is dependent on factors such as honesty of respondents, the wording of the questions, the language skills and cultural background of respondents, and whether there is a perceived advantage to a higher rating (Olds *et al.*, 2005; Strong-Klause, 2000). There is a high degree of consensus among social psychologists that people are neither generally overconfident nor underconfident in estimating their own abilities (Dominguez-Martinez and Swank, 2009).

An important consideration when developing a measurement instrument is the quality of the instrument. Quality of an instrument depends on the accuracy of the measurement obtained to represent the amount of an underlying attribute. As such, instrument design and development must be guided by a measurement theory.

2.15 Measurement Theory

Measurement theory is the foundation for measurement and data analysis. It stresses the importance of establishing correspondence between an attribute and its measurement in order to draw valid conclusions about the attribute based on its measures. Quality of an instrument is indicated by its psychometric properties, namely its validity and reliability. In quantitative research, validity is the extent to which a measure correctly represents the concept of study, and accurately measure what is intended to be measured. Valid measures enable meaningful interpretation of the results (Ary *et al.*, 2010). Reliability is the extent to which a measure is consistent in its values over time. If a research instrument can replicate the same results of a study using a similar methodology, then the instrument is considered reliable (Hair, Jr. *et al.*, 2006).

Two popular measurement theories in test development and data analysis are Classical Test Theory and Item Response Theory. Both theories are concerned with the quality of a test and can predict the outcomes of a psychological test by identifying two parameters. These parameters are item difficulty and the ability of test-takers.

2.15.1 Classical Test Theory

Prior to 1970's, Classical Test Theory (CTT) was the dominant framework for developing and analyzing standardized tests. CTT is based on the assumption that a test-taker has an observed score and a true score. The observed score (X) is made up of a true score (T) plus random error (E). The true score of a test-taker is his mean score after an infinite number of trials. Since it is not possible to take a test infinitely many times, the true score is only hypothetical (Kline, 2005a). Error scores can be due to random sampling error, internal inconsistencies among test items, inconsistencies across different forms of the test, inconsistencies over time or inconsistencies of raters. The random errors are uncorrelated to the true score, T, and expected to be normally distributed, with an expected value of 0. The standard deviation of the random errors around the true score is called the standard error of measurement. The variance of the observed score, VAR (X) equals the variance of the true score, VAR(T) plus the variance of the random error, VAR(E).

2.15.2 Limitations of Classical Test Theory

There are several limitations of using CTT. First, the true score is not an absolute characteristic of a test-taker because the score may vary depending on the difficulty of the test. If the test-taker takes a difficult test, his score may be lower compared to if he takes an easy test. Similarly, items' difficulty depends on the ability of test-takers. The same test items may appear to be easier if the test is taken by above-average students than if it is taken by below-average students. Thus, it is difficult to compare test-takers' ability and items' difficulty. This implies that within CTT, tests are imprecise tools of measurement because measures of test-takers' ability and item difficulty are test and sample dependent (Smith, 2002).

The third limitation is that a CTT reliability estimate only deals with one source of measurement error at one time, and cannot differentiate the effects of different error sources (Embretson and Reise, 2000). CTT regards all errors to be random and do not distinguish systematic error from random measurement error (Kline, 2005). Finally, CTT uses a single estimate of standard error of measurement for all test-takers (Weir, 2005). These shortcomings of CTT are addressed by Item Response Theory.

2.15.3 Item Analysis within Classical Test Theory

Item analysis is about the assessment of survey items in the process of survey development. This involves determining sample-specific item parameters and deleting items based on statistical criteria. Since item statistics depend on the sample selected, it is important to select a random sample representative of the population when CTT is employed.

Within CTT, the psychometric properties used to assess test items are descriptive statistics such as mean and variance, item difficulty level, item discrimination index, and test reliability. The mean and variance of items indicate the usefulness of the items. An item which has a highly-skewed mean or a low variance may not be very informative. In general a useful item is one which has a mean closer to the center of the distribution and a high variability. Item difficulty level is the proportion of correct responses while item discrimination index is the corrected item-total correlation (Impara and Plake, 1997). A poor item is identified by an item difficulty level which is either too high or too low or with a low item-total correlation. In CTT, each test item, regardless of difficulty level or importance is considered as contributing equally to the total test score (Lord, 1977).

Apart from checking the content validity of a survey, the survey items selected should fulfill the criteria of item difficulty and item discrimination. The choice of item difficulty level depends on the purpose of the survey and the anticipated ability distribution of the population. A student self-report survey on ability should be designed to differentiate students with different ability levels. Items with higher discrimination levels are preferred.

In a survey using a Likert scale, item endorsement level is the frequency of survey respondents in a sample that endorses the item. A survey should consist of items with varying frequency of endorsement to differentiate the survey-respondents. Items with extreme values of frequency, either endorsed by all survey-respondents or by none at all are not useful in differentiating the ability of survey-respondents and should be excluded from a survey. Reliability of the survey is measured by calculating Cronbach’s alpha and split-half values.

2.15.4 Item Response Theory

Item Response Theory (IRT) was initially developed to overcome problems in CTT. The concepts and methodology of IRT was introduced by Thurstone (1925) who had placed the survey items of children's mental development and plotted the proportions of success for each task on an age-graded scale. Using the same scale for both entities of ability and the difficulty of a survey item allows them to be compared. This is a major feature that differentiates IRT-based models from CTT-based models.

Since 1970's, IRT has gradually become the major framework for developing and analyzing surveys (Hambleton *et al.*, 1991). IRT is a model-based measurement that calculates the probability of getting the correct response to an item given the ability of a respondent (Kaplan and Sacuzzo, 1997). Respondents at higher levels of ability have a higher probability of responding correctly or endorsing an item. Respondents' ability and item difficulty estimates are obtained using item responses. The probability graph of success for each item is called item characteristic curve (ICC). A typical ICC is shown in Figure 2.2. This logistic function depicts the relationship between the probability of getting a correct response, or endorsing an item and the latent trait.

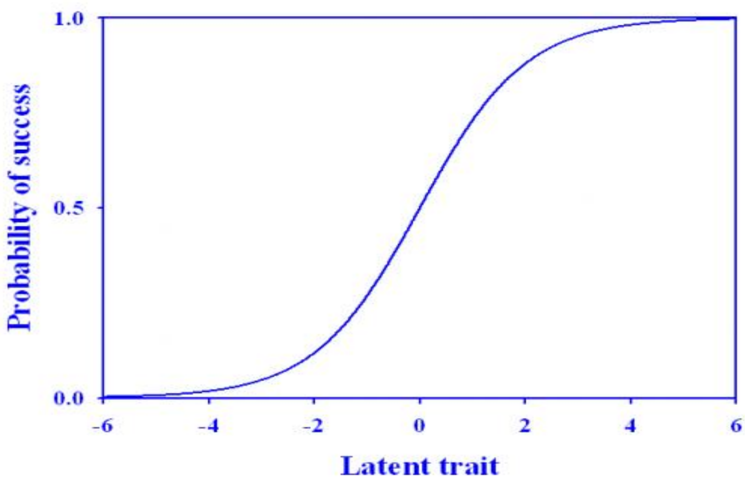


Figure 2.2: A Typical item characteristic curve

An IRT model gives an association between a survey respondent's response to an item and the underlying latent variable. A latent variable, θ represents an individual's level of psychological attribute measured by the survey. Each item is characterized by one or more model parameters. The first parameter is item difficulty, or threshold. Item difficulty is the point on the latent trait scale, where a person has equal chance of responding positively and negatively to an item. The second parameter is item discrimination or the slope of the ICC which indicates how well an item discriminates between persons having trait level above and below the threshold.

IRT item parameters are not dependent on the sample used, and are assumed to be invariant within and across populations. The survey respondent's scale score is computed from the responses to each item, and is thus affected by individual response pattern. This makes the score estimate a better approximation of a respondent's true ability compared to CTT's summated score.

2.15.5 Item Analysis within Item Response Theory

In IRT, item analysis involves determining sample-invariant item parameters and using goodness-of-fit criteria to identify items that do not fit the response model. Having a sample representative of the population is not as important as in CTT as long as there are survey items calibrated for different ability levels for proper item parameter estimation. Poor items are identified through their goodness-of-fit to a model using a statistical test or an analysis of residuals. Items that have low discrimination indices and extreme difficulty indices, either too easy or too difficult, are also considered poor.

As in CTT, selection of survey items in IRT depends on the survey purpose, but in IRT, items are also chosen based on their independent contribution to the test information function. An item provides the most accurate information about the ability of the respondent when the item difficulty matches the respondent's ability, in which case the probability of a correct response is 0.5. The item information function is given by $I_i(\beta, \delta_i) = P_i(\beta, \delta_i).\ Q_i(\beta, \delta_i)$, where $P_i(\beta, \delta_i)$ is the probability of success and $Q_i(\beta, \delta_i)$ is the probability of failure.

A test information function is the sum of item information functions in a test provided items are locally independent. A typical item and test information functions are shown in Figure 2.3 and Figure 2.4 respectively. The shape of information function depends on the values of item parameters. An item with a higher discrimination value has a more peaked shape. An item with a higher difficulty value will have the information function located further to the right. Usually the most precise measurement of a latent trait occurs within the middle of the scale ($-1.0 < \theta < 1.5$), and if there is a good idea of the ability of the respondents, items that maximize test information at any particular region on the ability continuum can be selected.

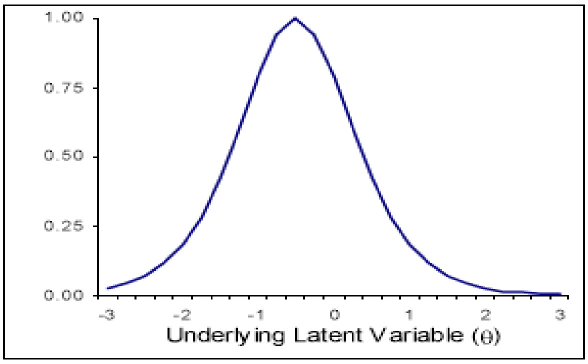


Figure 2.3: Item information curve

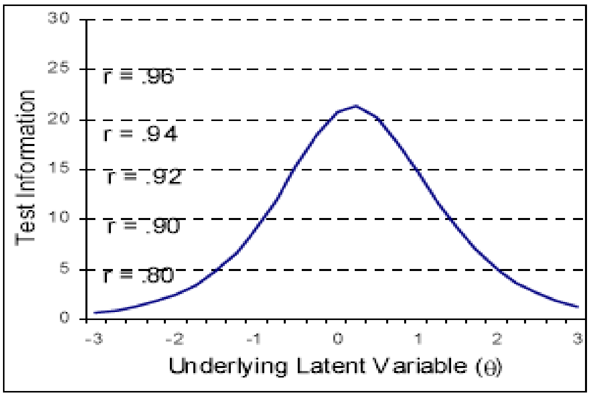


Figure 2.4: Test information curve with test reliability

2.15.6 Differences between Classical Test Theory and Item Response Theory

IRT is generally considered an improvement over CTT. Hambleton and Jones (1993) describe the major differences between the two theories as summarized in Table 2.7. Assumptions in the classical test model, X = T + E where X = Observed survey score, T = True score, E = Error score are that a) there is no correlation between T and E, b) the population mean of error score is zero and c) error scores on parallel surveys are uncorrelated. These assumptions are easier to meet compared to the assumptions required by the item response model.

Table 2.7: Differences between classical test theory and item response theory

Area of Difference	CTT	IRT
Mathematical Model	Linear observed score, X = T + E	Nonlinear probability of a correct response for item i, Pi(θ)
Level	Survey	Item
Assumptions	Weak (Easily met)	Strong (More difficult to meet)
Measure of Ability	Survey scores (Estimated true scores) reported on a survey-score scale	Ability scores reported on the scale -∞ to +∞
Item – Ability Relationship	Not specified	Item characteristic functions
Item statistics	Item difficulty Item discrimination	Item difficulty Item discrimination Item information functions (how much item contributes to ability assessment)
Invariance of item and person statistics	Varies depending on sample	Item and person parameters not dependent on sample if data fits the IRT model

2.15.7 Item Response Models

There are two approaches to model development in item response theory (Thissen and Orlando, 2001). The first approach is to build a model that best fits the item response data. The model identifies item parameters that describe the data accurately. The second approach is to select a hypothesized model with specific measurement properties to which the item response data must fit. Items that do not fit well are diagnosed and may be discarded. This approach is used in Rasch models. The family of Rasch models include the Dichotomous Rasch Model, Rating Scale Model and the Partial Credit Model.

Item response models can also be categorized according to the number of scored responses. If a response can take on one of two values such as True/False, the item is dichotomous. If the response can take any of more than two values, then the item is polytomous. A common example of a polytomous item is Likert-type item with a rating scale value for each response. Some of the common IRT models that can be used in educational research and their respective characteristics are shown in Table 2.8.

Table 2.8: Common IRT Models

Model	Model Characteristics
One Parameter Logistic Model	Equal discrimination across items. Varying threshold across items.
Two Parameter Logistic Model	Varying discrimination across items. Varying threshold across items.
Rating Scale Model	Equal discrimination across items. Equal threshold across items.
Partial Credit Model	Equal discrimination across items. Varying threshold across items.

2.15.8 Rasch Models Overview

Rasch measurement models enable inferences to be constructed from observational data because they can: a) produce linear measures, b) overcome the problem of missing data, c) gives estimates of measurement precision, d) detect misfitting data, and e) separate the model parameters from the measuring instrument (Smith and Smith, 2004). In Rasch paradigm, the measurement model is chosen not because it best fits the data, but because it provides invariant measures of the latent trait and item characteristics. These invariant measures allow comparison of respondents and items according to the principles of specific objectivity. Specific objectivity means item difficulty parameters are independent of which group of respondents being surveyed, and respondents' ability levels are independent of the subset of items being administered. This characteristic is not found in traditional statistical models. Bond (2003) shows that Rasch measurement models have characteristics that can address important issues of validity. These advantages of the Rasch model have prompted the researcher to apply it in developing and validating an instrument for measuring students' ICT user-skills ability for engineering learning.

a) The Dichotomous Rasch Model

The model where the outcome of an event is one of two possible states is described mathematically as a logistic function with argument (B_n – D_i):

$$P_{ni} = \frac{exp\ (B_n - D_i)}{1+\exp(B_n - D_i)} \qquad \text{(Equation 1)}$$

where P_{ni} is the probability of person n with ability B_n succeeding on item i with difficulty level D_i. The dependent variable P_{ni} is a function of the difference between two independent variables, B_n and D_i or (B_n - D_i).

The probability of a correct response as a function of the difference between person ability and item difficulty, (B_n - D_i) for item *i* is called the item response function of item *i* and is shown in Figure 2.5.

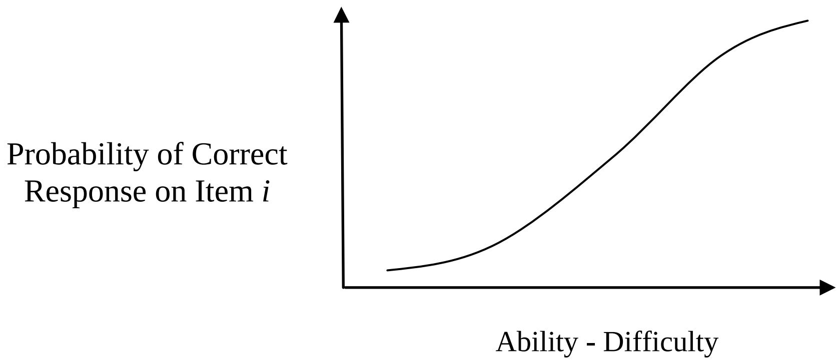


Figure 2.5: Item response function for item i

The sum of the difficulty parameters for all items is constrained to 0, that is $\sum D = 0$. Taking logarithm of both sides in Equation 1 yields:

$$\text{Log}_e \left[\frac{P_{ni}}{1-P_{ni}}\right] = (B_n - D_i);$$

$\text{Log}_e \left[\frac{P_{ni}}{1-P_{ni}}\right]$ is the logit or the log of the odds of success. The odds of success are the ratio of the probability of success over the probability of failure. For example, if the probability of success of an event = 0.6, then the probability of failure = 1 – 0.6 = 0,4. The odds of success = 0.6/0.4 = 1.5. Thus $\log_e$ (1.5) = 0.41.

The log transformation of the odds gives the log of odds (logit). Log transformation, which is also called the logit transformation maps probability values between 0 and 1 to log of odds values between - ∞ to + ∞. Thus the logit scale is the natural logarithm of the probability of getting a correct response over an incorrect response. One logit is the distance along the measurement scale that increases the probability of getting a correct response by a factor of 2.718, the value of e, which is the base of the natural logarithms (Linacre and Wright, 1989).

The log odds of a correct response by a person to one item is the log odds of a correct response to one of two items. For example, if person n responds to item 1, then the log odds of responding to item 1 correctly is

log-odds { X_{n1} = 1 | T_n = 1} = $D_2 - D_{1;}$

where T_n is the total score of person *n* over the two items, and ($D_2 - D_1$) is the difference in the item locations or the difficulty parameters.

Thus an estimate of difficulty parameters, D_i can be obtained using conditional maximum likelihood estimation, without involving the ability parameter of person n, B_n. This Rasch model property is called the principle of invariant comparison.

b) The Rating Scale Model

The Rasch rating scale model (Andrich, 1978) in which the outcomes have more than two response categories transforms ordinal data into interval scale. A common rating scale in social science studies is Likert-scale rating, an ordered rating that represents an increasing inclination towards the concept surveyed. An example of an ordered rating is Strongly Disagree/Disagree/Agree/Strongly Agree. The rating scale model constraints the discrimination power of all items to be equal. The distance between difficulty steps from a category to another category within each item is the same across all items.

A rating scale model which defines the probability P_{nix}, of person *n* with ability B_n on the latent variable being observed in category *x* of item *i* with difficulty D_i is given as:

$$P_{nix} = \frac{\exp \sum_{j=0}^{x} [B_n - (D_i + \tau_j)]}{\sum_{k=0}^{m} \sum_{j=0}^{k} [B_n - (D_i + \tau_j)]}$$

$$\text{or} \quad \log\left(\frac{P_{nix}}{P_{ni(x-1)}}\right) = B_n - (D_i + \tau_x)$$

where the categories are ordered from 0 to m, and τ_x are the step difficulties or Rasch thresholds. A threshold is the point on the category probability curve where the probability of choosing a category is equal to that for the previous category. It is the intersection point on two adjacent categories. Figure 2.6 shows an example of a category probability curve with 4 thresholds.

c) Partial Credit Model

A test or survey is designed to achieve certain objectives, thus can have many different formats. A test can consist of several groups of items to be completed, and the items can have a different number of categories with different thresholds across items. Credits can be given for partially correct answers. In these cases, the partial credit model is useful. This model is similar to the rating scale model except that each item has its own threshold parameters (Masters, 1982; Wright and Masters, 1982). Changing the notation for threshold parameters in the rating scale model to indicate their different values across items, the partial credit model becomes:

$$\log\left(\frac{P_{nix}}{P_{ni(x-1)}}\right) = B_i - (D_i + \tau_{ix})$$

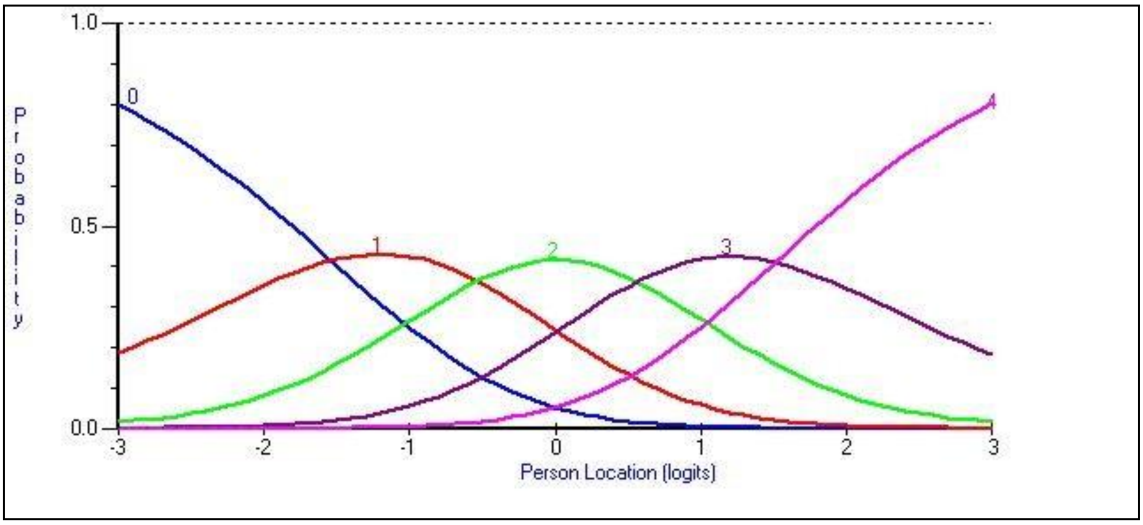


Figure 2.6: Category probability curve for responses of 0, 1, 2, 3 and 4 in the five-category item.

2.15.9 Rating Scale Effectiveness

Rating scales with more than two categories, such as Likert scales are often chosen to capture more information about a latent trait than a dichotomous scale. The categories should be well-defined, ordered, relevant, mutually exclusive, and has an appropriate number of categories that is conceptually exhaustive. A well functioning and effective scale is one that produces accurate and precise measures. This is to ensure sound conclusions based on the data. How well a rating scale functions often depends on the particular sample of respondents that use the scale. Thus, it is important to investigate the functioning of a rating scale.

Linacre (2002) proposes the following guidelines to examine the effectiveness of a rating scale:

i) All items are oriented in the same way to construct a common latent variable. Item polarity should be positive. Items with negative polarity need to be rescored first. Item orientation is indicated by the polarity indices or item-measure correlations such as the point-biserial correlations.

ii) Every response category has at least 10 observations. This is to obtain an accurate step calibration or threshold corresponding to the equal probability to endorse adjacent categories. This calculation depends on the frequencies of adjacent categories and a low frequency would produce potentially unstable calibrations.

iii) Distribution of observations should be regular. The optimal distribution for step calibration is uniform. However, unimodal and bimodal distributions that peak at extreme categories are acceptable.

iv) Average measures should advance monotonically with category. Observations in higher categories should be produced by higher measures to have a useful meaning of the rating scale.

v) Outfit mean-squares should be less than 2.0. Values larger than 2.0 indicate excessive randomness or noise in the data making it not useful for measurement. Model-specified mean-square fit statistic is 1.0.

vi) Step difficulties should advance by at least 1.4 logits for a 3-category scale, and at least 1.0 for a 5-category scale to have substantive meaning.

vii) Step difficulties should advance by less than 5.0 logits for precise measurement.

Fisher (2007) developed a set of criteria shown in Table 2.9 to evaluate the quality of a rating scale instrument based on some important features not included in Linacre's guidelines. Fisher suggested evaluating instrument targeting based on how far the mean student measure is from the mean item measure. If the distance is less than one error of measurement, then the instrument has good targeting.

Table 2.9: Rating scale instrument quality criteria (Fisher, 2007)

Criterion	Poor	Fair	Good	Very Good	Excellent
Targeting	> 2 errors	1-2 errors	< 1 error	< .5 error	< .25 error
Item Model Fit Mean-Square Range Extremes	< .33 - >3.0	.34 - 2.9	.5 - 2.0	.71 - 1.4	.77 - 1.3
Person and Item Measurement Reliability	<.67	.67-.80	.81-.90	.91-.94	>.94
Person and Item Strata Separation	2 or less	2-3	3-4	4-5	>5
Ceiling effect: % maximum extreme scores	>5%	2-5%	1-2%	.5-1%	<.5%
Floor effect: % minimum extreme scores	>5%	2-5%	1-2%	.5-1%	<.5%
Variance in data explained by measures	<50%	50-60%	60-70%	70-80%	>80%
Unexplained variance in contrasts 1-5 of PCA of residuals	>15%	10-15%	5-10%	3-5%	<3%

2.15.10 Characteristics of Data Required for Rasch Modeling

Data must conform to the requirements of the Rasch model to ensure valid inferences from the analysis. These include a) unidimensionality, b) local independence, c) monotonicity of the latent trait, and d) nonintersecting item response curves (Sijtsma and Molenaar, 2002). Unidimensionality means all items measure only one underlying trait. Unidimensionality of a scale is important to avoid confounding effects on the abilities measured and to minimize bias in parameter estimates (Stout, 1987). The majority of item response theory research and applications utilize a unidimensional model because of the greatly increased complexity of a multidimensional model (De Gooijer and Yuan, 2011). Local independence means that a response by one person to one item has no effect on the response on any other item in a survey. This is to ensure accuracy of person ability, item difficulty, and reliability estimates (Smith, 2005). Monotonicity of the latent trait means that as the trait increases, the probability that a person will answer correctly is monotonically nondecreasing. The response curve of a dichotomous item is a function of the probability of a correct response given by

$$P_{ni} = \frac{exp\ (B_n - D_i)}{1 + \exp(B_n - D_i)}$$

Item response curves cannot intersect to preserve the invariance property which means that the order of person ability and the order of item difficulty are invariant. Thus, a person with higher ability should always have a higher probability to get an item correct than a person with lower ability, regardless of which items they encounter. Likewise, a more difficult item should have lower probability of being answered correctly, regardless of the ability of the persons who attempt it (Rasch, 1960; Smith, 2004; Smith and Andrich, 2005). Nonintersecting item response curves for items a, b, and c with different difficulty levels are shown in Figure 2.3. An item is said to be easier if the probability to be answered correctly is higher than another item, given the same ability level. In Figure 2.7, item a is the easiest, and item c is the most difficult.

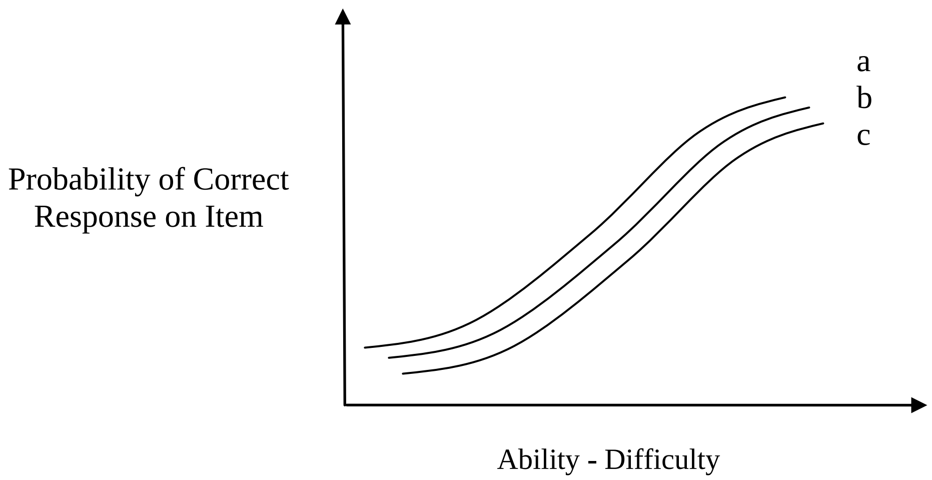


Figure 2.7: Item response function for items a, b, c

Another important feature of the Rasch model is that all the item response functions are parallel to each other, that is, the slope of all the curves is the same. Thus a unit increase in ability raises the probability of a correct answer for all items in the same amount. The items are said to have the same discrimination power.

2.15.11 Parameter Estimation of Rasch Model

Model parameters are estimated from observations. There are many techniques for parameter estimation. Linacre (1999) compared several estimation procedures and concluded that the algorithms produced statistically equivalent estimates which would not have significant impact on the measures. Most parameter estimation procedures use the maximum likelihood method, which discovers parameter values that maximize the likelihood of the data under given constraints. The likelihood of the data set is the product of the probabilities of the data points.

Smith and Smith (2004) describe the iterative Extra-Conditional Maximum Likelihood Estimation (XMLE), which is implemented in the WINSTEPS software. XMLE is an extension of the Joint Maximum Likelihood Estimation (JMLE), also called the Unconditional Maximum Likelihood Estimation (UCON). UCON is a procedure that estimates the person and item parameters simultaneously. Since person and item estimates are not separated, the estimates contain bias.

Linacre (1989) introduced XMLE, an extension of UCON to overcome estimation bias by reducing the probabilities of extreme scores. The XMLE algorithm adopts initial starting values to obtain expected values of the data. Estimates that minimize the discrepancies between observed and expected data are chosen. XMLE is proven robust against missing data (Smith and Smith, 2004).

2.15.12 Precision and Accuracy of Rasch Parameter Estimates

Parameter estimates are characterized by their precision and accuracy. Precision refers to the degree of uncertainty of the location of the measure on the latent variable, when the data fit the Rasch model. Precision is reflected by the standard error of the estimate. The smaller the standard error, the more precise is the measure. Precision can be improved by collecting more relevant data, or by introducing constraints such as normally distributed variables.

Accuracy refers to the departure of observed data from the predicted values, given that the data fit the model. Accuracy is measured by the fit statistics, and can be improved by collecting more data that conform to the Rasch model and by avoiding items that are either too easy or too challenging. Responses that do not contribute to constructing a general measurement system can also be filtered out to increase accuracy.

2.15.13 Fit Analysis in Rasch Models

Fit is a statistic that indicates the degree to which item responses conform logically to an underlying trait of a person. Fit analysis will indicate response patterns that do not correspond with the overall pattern through item or person fit. Item fit is an index that reflects how well an item functions in measuring a trait. Person fit is an index that indicates whether an individual is responding consistently relative to the pattern predicted by the model (Smith, 2001). Both fit statistics are used to determine whether the data fit the model and if the measure is useful. Data which do not meet Rasch model specifications are examined and the reasons that cause misfitting are investigated. Other indicators such as the point measure correlation can be used to complement the fit statistics in deciding whether misfitting data are useful for measurement. Fit statistics in Rasch models are based on the residual estimates for each item. These residuals are the differences between the raw scores and the scores generated by the Rasch Rating Scale Model (Cavanagh and Waugh, 2011).

Two fit statistics that indicate the extent of data-model fit are infit and outfit, which can be expressed as mean square statistics (MNSQ) or standardized statistics (ZSTD). Outfit is an unweighted index that is sensitive to extreme responses or outliers, particularly on tests that had a wide range of item difficulties and person abilities. To overcome this sensitivity to outliers, an index, infit was developed by weighting each mean square or squared standardized residual by the information function (p_{ni} (1 - p_{ni})). The formula for outfit index is given by:

$$\chi_i^2 \quad = \sum_{n=1}^{N} (x_{ni} - p_{ni})^2$$

The formula for the infit index is given by:

$$\chi_i^2 \quad = \frac{\sum_{n=1}^{N} (x_{ni} - p_{ni})^2}{\sum_{n=1}^{N} (p_{ni}(1- \; p_{ni})}$$

where x_{ni} is the observed response for person *n* to item *i* and p_{ni} is the probability of the correct response for person *n* to item *i*.

These chi-square fit indices can be transformed into a mean square by dividing the chi-square by its degree of freedom. This mean square has values ranging from 0 to +∞ and an expected value of 1. Generally, mean square values between 0.7 and 1.3 are considered acceptable (Bond and Fox, 2007). Values above 1.3 is underfitting indicating unpredictability, and those below 0.7 is an overfitting indicating data which are too predictable.

Most calibration programs such as Winsteps use cube-root transformation to convert this mean square into a t-statistic. The resulting statistic is called a standardized fit index (ZSTD). Values of ZSTD between -2 and +2 are considered acceptable fit. Values above +2 is underfitting, and below -2 is overfitting. The advantage of ZSTD as an index to assess the fit of a measurement model is that it can yield common critical values that have equal Type I error rate across sample sizes (Smith and Smith, 2004). However, for polytomous data, t-statistics have been shown to be highly sensitive to sample size, whereas mean square statistics remained relatively stable (Smith *et al.*, 2008). Considering the different advantages of MNSQ and ZSTD, both fit statistics were used to indicate how well the data fit the model.

2.15.14 Principal Component Analysis of Residuals

Residuals are the differences between model-based expected values and observed item responses. Principal component analysis (PCA) is a procedure to determine covariability between items grouped into sets that correlate with other, but are relatively independent of each other. PCA is often used for data reduction or constructing variables, but PCA of the residuals is used to explain variance. The first step in PCA to assess unidimensionality is to fit observed data to the Rasch model to extract the first principal component through parameter estimation (McGill, 2009). The variance accounted for by the principal and residual components are reflected by their respective eigenvalues. The contrast in the residuals that explains the most variance is sought first. If the variance explained by this contrast is small, with an eigenvalue of 2 or less, then the unidimensionality assumption is supported (Linacre, 2009). Otherwise the next contrast will be examined to look for the third dimension.

2.15.15 Reliability of Measures

a) Reliability within Classical Test Theory/True Score Theory

The reliability index, R indicates the reproducibility of a measurement of a variable in a test. There are several measures of test reliability. One of the most common forms of reliability is test-retest reliability, in which the same participants are measured twice or more. R is then estimated by calculating the correlation between the different sets of scores. A correlation of 1.00 indicates perfect agreement between tests, whereas 0.00 represents no agreement whatever. Thus, the higher the correlation, the more reliable is the test.

Another measure of reliability is internal consistency reliability. There are many methods to measure internal consistency reliability. The first one is by averaging the inter-item correlations of all possible pairings of test items. The second measure of internal consistency reliability is the average item- total correlation. The third measure is the split-half reliability in which items measuring the same construct are divided randomly into two sets. The entire set of items is administered to a group of participants and the scores for the separate halves of the test are added for each participant. The split-half reliability estimate is the correlation between these two total scores. Another measure of internal consistency reliability is Cronbach’s alpha (KR20). KR20 is conceptually equivalent to the average of all possible split-half correlations. A higher value of Cronbach’s alpha indicates a higher level of internal consistency reliability.

A reliable instrument consists of items that are highly correlated, reflecting the homogeneity of the items. A correlation coefficient of 1.00 indicates that each item in the instrument is measuring exactly the same thing. An alpha value of 0.7 or more is usually considered acceptable (Nunnally, 1978). Burn and Grove (2009) suggest an alpha value in the range of 0.80 – 0.90 for an instrument to detect different levels of the construct.

KR20 tends to overestimate the error variance of persons with high or low scores, and since raw sores are not linear, no valid mathematical operations can be performed (Smith and Smith, 2004). Thus the value of sample variance can be misleading. The standard error of measurement (SEM) represents an average error variance for the test for a particular sample. It is calculated using every score, including the extreme scores, which are known to be less precise.

The formula for SEM is given by:

$$\text{SEM} = \text{SD}_x \sqrt{(1 - R)}$$

where SD_x is the sample raw score standard deviation, and R is the estimated reliability.

b) **Reliability within Rasch Measurement Theory**

If the data fit the Rasch model, then each person's ability and each item's difficulty can be located on a linear scale of the latent variable. An item's location depends on the number of persons endorsing the item. A person's location depends on the number of items they answer correctly. Items and persons must be separated along the scale to have a meaningful measurement. Item separation indicates how well a sample of respondents can separate the items on a test. Person separation reflects how well a set of items separate the respondents.

The person reliability index indicates the extent to which the person ordering could be replicated along the ability continuum if the same person sample were given a parallel set of items having the same number and distribution of items measuring the same construct (Wright and Masters, 1982). The item reliability index indicates the extent to which the item ordering could be replicated along the difficulty continuum if the same items were given to another person sample of the same size and characteristics.

Modeled error variance for each person's ability and each item's difficulty estimate can be used to calculate internal consistency. Internal consistency is represented by the person separation reliability (R_p) given by the formula:

$$R_p = 1 - \left(\frac{MSE_p}{SD_p^2}\right)$$

where MSE_p ,the mean square measurement error, is given by $MSE_p = \frac{\sum_{n=1}^{N} S_n^2}{N}$

S_n is the standard error for each person measure, and SD_p is the standard deviation of person measures. R_p can be corrected for degrees of freedom, (k/(k – 1)) to yield:

$$\text{Rasch } R_p = (k/(k-1))\ (1-(\frac{MSE_p}{SD_p^2}))$$

However, since R_p is not a linear measure, it is commonly replaced with a person separation index, $G_p = \sqrt{\frac{R_p}{1- R_p}}$ which can take values from 0 to ∞.

Similarly, item separation reliability (R_i) is given by the formula:

$$R_i = 1-(\frac{MSE_i}{SD_i^2}).$$

Higher R_i indicates better separation of the items by the respondents.

2.15.16 Validity of Measures

Since the 1980s, the conception of validity has shifted from being viewed as consisting of multiple types of validity, to a unitary concept. According to the Standards for Educational and Psychological Testing,

> Validity refers to the degree to which evidence and theory support the interpretations of test scores entailed by proposed uses of tests. Validity is, therefore, the most fundamental consideration in developing and evaluating tests. The process of validation involves accumulating evidence to provide a sound scientific basis for the proposed score interpretations. It is the interpretations of test scores required by proposed uses that are evaluated, not

the test itself. When test scores are used or interpreted in more than one way, each intended interpretation must be validated.

(AERA, APA, and NCME, 1999:2)

2.15.17 Threats to Validity

The seminal works of Campbell and Stanley (1963) on the threats to internal and external validity are an authoritative reference in this important aspect of research. Smith and Glass (1987) build on these works to classify external validity threats into three areas: population validity, ecological validity, and operational validity. Onwuegbuzie (2000) extends the description of internal and external validity to non-experimental research designs. Basically, the threats to the validity of quantitative research results relate to two major issues, namely the issues of cause and effect, and the issues of generalizability.

a) Issues of Cause and Effect

The issues of cause and effect relate to the relationship between the casual and effect variables. These issues can be categorized into two aspects: the validity of statistical conclusion, and internal aspect of validity.

b) Issues of the Validity of a Statistical Conclusion

This issue arises from the statistical procedures used in inferring the relationship between variables. Threats to the validity of statistical conclusion can be due to using a test with low statistical power, violation of statistical assumptions, low reliability of measures, and random confounds in the setting. These threats can be respectively minimized by using a large sample size, choosing powerful statistical tests, meeting the assumptions of tests, choosing robust statistics tests, using internally reliable tests, and choosing settings free of confounds.

c) Internal Aspect of Validity

Internal validity issues concern the existence of a cause and effect relationship between variables. Gay and Airasian (2008) define internal validity as the condition when observed differences in the dependent variable are directly caused by the independent variable, not some other variable. Thus, when there could be other plausible explanations of the causes of change in the dependent variable, internal validity is threatened.

The threats to internal validity can arise from history and maturation effects which result from extended time lapse during a study. History effects refer to external events, while maturation effects mean individual development of research participants. Vogt (2007) suggests overcoming history effects by taking frequent measurements of the outcome variable, rather than just once at the end of the study. Other sources of threats to internal validity are procedures relating to testing, instrumentation, and selection of participants. These can be overcome by using random assignment or selection of participants.

d) Issues of Generalizability

The extent the research conclusions can be generalized depends on the construct validity of the cause and effect and external validity.

i) Construct Validity of Cause and Effect Assumption

Validity threat to cause and effect assumption can be due to poor representation of constructs and the measurement level used. These can be overcome by using precise definition of constructs and using continuous (interval or ratio) measures with high validity.

ii) External Aspect of Validity

Johnson and Christensen (2000) describe external validity as the extent to which the findings of a study can be generalized across settings, populations, and times. Threats to the generalizability of the relationship between variables can be due to using unrepresentative sample, settings of a study that do not represent all settings of interest, and the period during which a study takes place does not represent all future times. These threats can be reduced respectively by selecting subjects randomly from a well-defined population, varying the study settings, and replicating the same experiment at different times.

2.15.18 Evidence of Validity

There are different sources of evidence which support different aspects of validity but validity itself is a unitary concept. Validity is the degree to which all the gathered evidence from various sources support the trustworthiness of test scores and the interpretation of test scores. The approach of establishing construct validity by looking for supporting evidence is called the evidential basis of test validity (Baghaei, 2008). The simplest form of validity evidence is based on the appearance of the instrument, or what is often named “face validity”. However, it is also the least valid form of validity evidence of an instrument because the instrument is judged solely on the surface appearance of the measure without the use of statistical methods.

Messick (1989) introduced a unitary concept of validity for which different types of complementary evidence can be integrated to judge for overall construct validity. Construct validity refers to the extent to which scores reflect the underlying trait. Evidence of construct validity is required when inferences are to be made about latent traits (Smith and Smith, 2004). Validity evidence based on statistical methods is often used to inform on construct validity (Messick, 1989, 1995). In this study, five types of validity evidence were examined: content, substantive, structural, generalizability and interpretability.

Fisher (1994) opines that construct validity can be investigated using the Rasch model as a tool. Bond (2003) asserts that the Rasch model encompasses prescriptions for developing measures that can provide construct-related evidence described by Messick (1995). Wolfe and Smith (2007) discussed how Rasch analysis can provide evidence of construct validity in instrument development process. Zain *et al.* (2011) and Abdul Aziz *et al.* (2008) presented applications of Rasch analysis in providing empirical evidence for the construct validity of a survey instrument. In this study, the researcher would use similar approach to gather evidence supporting the construct validity of the ICT user-skills instrument.

a) Evidence of the Content Aspect

Content aspect of validity refers to the appropriate selection of test or survey items and the extent they represent the domain of interest. The purpose of the instrument must be clear and reflected in the research questions. Inferences to be drawn based on the data collected using the instrument must be well-defined. Three major aspects of content-related validity evidence are content relevance, representativeness, and technical quality (Messick, 1989).

Content relevance is normally evaluated by a panel of experts and practicing professionals (Lunz, Stahl, and James, 1989). Constructive feedback on the quality of a newly developed scale would reduce the number of revisions in the evaluation phase. However, since experts' input is subjective, the study is subjected to bias that may exist among the evaluators.

Content-based evidence of validity obtained from expert reviews can be objectively measured using the content validity index (CVI), calculated based on the representativeness of the scale items. CVI for each item is the number of experts who gave a rating of 4 (Agree) or 5 (Strongly Agree) on the representativeness of the item divided by the total number of experts. CVI for the scale is the average CVI across the items. For new scales, Grant and Davies (1997) recommend a minimum CVI of 0.8.

Representativeness is indicated by the spread of item calibrations, or item strata. Item strata are statistically different regions of item difficulty distinguished by the persons. The minimum number of item strata required to interpret the latent variable is 2 for a reliability of 0.8 (Fisher, 1992). In a Rasch variable map, M is the mean of the item distribution, S is one standard deviation, and T is two standard deviations.

Technical quality of the items can be examined using item fit statistics and item-measure correlations. Item fit statistics outside the acceptable range may indicate multidimensionality. Item-measure correlations indicate the extent to which the responses to each item are consistent with the average score of other items representing the latent variable (Wolfe and Smith, 2007). Consistent responses imply that the items share a common underlying dimension. A positive item-measure correlation means the item is positively correlated with the average score of the remaining items. A negative item-measure correlation most probably indicates a reverse-worded item that has not been reverse-scored. An item-measure correlation close to zero may indicate an item that does not measure the construct in the same pattern as the other items.

b) **Evidence of the Substantive Aspect**

This refers to the theoretical and empirical rationales for the observed consistencies in item responses (Messick, 1995). The cognitive processes and item characteristics that contribute to item difficulty can be hypothesized and compared with empirical hierarchy of item calibrations. Patterns in observations and relations to other variables should concur with theory-based expectations or compared to the literature.

c) **Evidence of the Structural Aspect**

Structural aspect of construct validity concerns the construct domain and the credibility of the scoring method based on observations (Messick, 1995). If the construct is unidimensional, then the requirements of a unidimensional model must be satisfied. The scoring structure in Rasch models depends on the mathematical relationship between person ability and item difficulty. Thus, if fit statistics indicate unidimensionality, then only a single score for the whole test is required as a measure of ability. For multidimensional scale, a separate score is required for each dimension.

Another evidence of unidimensionality can be obtained from the PCA of the residuals (Wolfe and Smith, 2007). The total variance accounted for, across all remaining components after extracting the initial Rasch component has been extracted should be uniformly distributed, if unidimensionality holds.

d) **Evidence of the Generalizability Aspect**

Generalizability refers to the extent to which measures maintain their meaning across different contexts (Messick, 1995). In Rasch measurement models, this requires the property of invariance of person and item measures across different categories, depending on the purpose of the assessment. The size of differential item functioning (DIF) is an indicator of the extent of the generalizability of inferences about person measures or item calibrations across different groups, tasks, or time (Wolfe and Smith, 2007). Negligible DIF in Rasch measurement models is an evidence of the invariance of person and item measures across different categories.

e) **Evidence of the Interpretability Aspect**

Interpretability of response patterns refers to the qualitative meaning associated with quantitative measures (Messick, 1995). In Rasch models, person and item measures share a common metric, thus allowing comparison of item difficulty and person ability. The relative position of each item and every person is described graphically in an item-map.

2.15.19 Differential Item Functioning

Differential item functioning (DIF) is a condition when subgroups endorse a survey item differently even when they are at the same ability level (Bond and Fox, 2007). This can be due to respondents' characteristics such as age, gender, ethnic, culture or socio-economic status. Thus DIF is a potential source of bias in ability measurement and items that display DIF should be removed when developing a new instrument to ensure a fair assessment. Other reasons for performing DIF analysis are to identify and deal with potential threats to internal validity and to ascertain test validity and comparability across countries (Zumbo, 2007). DIF is uniform if it is constant across ability levels, and is non-uniform if it varies across ability levels.

DIF can be detected using statistical methods such as contingency tables, IRT, logistic regression, and structural equation modeling. The magnitude and direction of DIF can be displayed using graphical methods such as forest plots, box and whisker plots, and Rasch item information functions (Wolfe and Smith, 2007). In this study, the presence of DIF will be investigated using Winsteps software which employs a logit-linear procedure.

Tennant and Pallant (2007) used simulated dataset to show that given satisfactory fit to the Rasch model, if person measures differ by less than 0.5 logits then the impact of DIF is considered trivial and can be ignored. Linacre (2009) gives general guidelines for the size and significance of the DIF that has significant impact, that is the size of DIF > 0.5 logits and t-statistic > 2.0.

2.16 Findings from Previous Studies on Students' ICT Skills

Awareness of the growing importance of ICT literacy for study, professional and life in general has driven many higher learning institutions to make systematic provision for the development of ICT literacy of their students (UNESCO, 2004). To develop an ICT literacy strategy, various stakeholders of the education system have conducted studies to gather information regarding students' ICT experience, skills and attitudes.

2.16.1 Survey Results of Malaysian Students' ICT Skills

a) A survey was conducted on student teachers at a Malaysian university by Suthagar, *et al*. (2011) to assess their attitudes, knowledge and usage of ICT. The findings of this study indicate active ICT engagement is influenced by culture and education, and not an intuitive behavior as posited by the Net Generation Theorists.

b) A survey instrument was developed and used to investigate the use of Web 2.0 technology by Malaysian students. The findings of this survey show that Malaysian students are moderately familiar with Web 2.0 applications and can use most of them with confidence for learning purposes. However, Malaysian students tend to be passive rather than active contributors to knowledge construction (Zakaria *et al*., 2010).

c) An empirical analysis of Malaysian pre-university students was conducted by Teck and Lai (2011). The findings show that in general, the levels of ICT competencies for both male and female students are moderate. There was a significant gender difference only in computer maintenance competency, where male students outperformed female students. There were no significant gender differences with regard to computer usage and experience.

d) A study by Hisham *et al.* (2006) on students in a public university found that students' use of IT facilities was positively influenced by their satisfaction with the facilities. They found that the *frequent use of digital cameras* was the rarest to be endorsed, while the *frequent use of search engine, world wide web, and word processor* was endorsed most frequently.

e) Edzan (2008) reviews information literacy development in Malaysia and summarizes findings in local information literacy case studies. The author also describes the efforts made by various bodies to enhance information literacy among the citizens and to create knowledge workers in line with Vision 2020.

2.16.2 Survey of the European Universities Skills in ICT of Students and Staff (SEUSISS) Project

This long-term project funded by the European Commission was completed in 2003. It involved 10 years of data collection, and was a collaboration between seven European universities (European Commission, 2001). Among the purposes of this project was to gather data on students' ICT skills, their attitudes towards ICT and their confidence in using it.

The survey results showed that most students were young adults studying fulltime, with females outnumbering males. Ownership of personal computers including internet access was high. The students reported themselves as having good basic ICT skills, which include using word processors, web browsers, email and chat. New students reported having lower level of skills with presentation software such as PowerPoint and bibliographic databases.

The survey findings show that students reported getting the help and support for ICT skills development from friends, family, classes and self-tuition. They considered ICT important in future careers and graduating students were confident with their ICT skills. Owning a personal computer was strongly associated with self-assessed skills, confidence and frequency of ICT use in studies. In general, female students reported less highly skilled on ICT skills, and less confidence of their own ICT skills.

2.16.3 iSkills Case Studies

Preliminary data on information literacy survey collected from 6300 survey respondents using iSkills show positive and negative findings. Seventy percent of survey respondents selected the best question to clarify an assignment, and most could recognize that .edu and .gov sites are less likely to contain biased material than .com sites. Negative findings include that most survey respondents could not identify relevant information and narrow the results in a web search. According to more recent findings, the three most challenging ICT activities are to identify trustworthy and useful information, to manage abundant information, and to communicate information effectively (ETS, 2006).

Universities use the iSkills for various purposes such as to measure ICT skills, to understand how students acquire ICT skills, to identify best practices to integrate ICT into the curricula, to assess the impact of ICT skills on overall academic achievement, and to improve ICT teaching and learning infrastructure (ETS, 2008).

Findings from these case studies include:

i) Educators should find ways to engage students who believe they are ICT competent.
ii) Educators should make learning relevant to the students' needs.
iii) Educators should create active learning activities to engage students.
iv) Educators should assess the impact of ICT instruction on student learning outcomes.

2.16.4 The ECAR Study of Undergraduate Students and Information Technology, 2008

EDUCAUSE Center for Applied Research (ECAR) which is based in the United States, is a nonprofit organization that conducts annual survey research on ICT use in higher education since 2003. The surveys provide information on students' ownership of technology as well as use, experience, and self-reported skills of ICT. The 2008 survey was conducted on 27,000 students in higher education institutions.

Key findings of the 2008 survey by Caruso and Salaway (2008) are:

a) Technology ownership, access, and use
   i) 99 percent of respondents own a computer.
   ii) Students report extensive use of ICT for study and recreation, spending almost 20 hours per week on online activities.
   iii) Over 90 percent of students use library web sites.
   iv) On general application software use:
   Presentation software (Over 90 percent); Spreadsheet (86 percent); Elearning (82 percent); Graphics software (74 percent); Video-audio creation software (33 percent).

b) Students' self-assessment of their technology skills using 5-point scale (not at all skilled, not very skilled, fairly skilled, very skilled or expert):
   i) Students rated themselves highly (fairly skilled and very skilled) on their skills to use presentation software, library web sites, spreadsheets, and course management softwares.
   ii) Students rated themselves fairly skilled and not very skilled on maintenance and graphics software.
   iii) Students rated themselves as very skilled or expert at using the internet to search for information.

c) ICT in courses

i) 59 percent of students prefer only moderate ICT use in courses; 25 percent prefer extensive use, and 16 percent prefer limited or no ICT in courses.

ii) Applications used in courses: Library web sites (68 percent); presentation software (64 percent); spreadsheets (43 percent); graphics (20 percent).

iii) 44 percent of respondents perceive that most or almost all of their instructors use ICT effectively in their courses.

d) ICT's impact on the academic experience

i) 66 percent of students agree that ICT makes their course activities more convenient.

ii) Only 46 percent of students agree that ICT improves their learning.

iii) Respondents who are more positive about ICT's impact on courses prefer more ICT in their courses, and more frequently believe that their lecturers use ICT effectively in their courses.

2.16.5 Study of Information Literacy of Incoming First-Year Undergraduates in Quebec

This study was conducted by the working group on library instruction of Quebec universities (Mittermeyer and Quirion, 2003). The purpose of the study was to investigate information literacy skills of incoming students to Quebec universities. The survey instrument consists of 20 multiple-choice questions based on the ACRL standards for information literacy, and built upon the five central themes described in Section 2.2. The number of respondents was 3000 and this large number increases the confidence on the representativeness of the survey results. The results of the study based on the themes and the associated problems identified are shown in Table 2.10. The study provides empirical evidence that students lack knowledge in some key areas of information literacy.

Table 2.10: Results and problems by theme (Mittermeyer and Quirion, 2003)

Theme	Problems Identified
Concept Identification	Difficulty eliminating non-significant words
Search Strategy	Incorrect use of Boolean terms and search indexes within the catalogues. Do not know the tool to identify controlled vocabulary in a database.
Document types	Cannot define the characteristics of scholarly journals
Search tools	Cannot differentiate between library catalogues and bibliographic databases.
Use of Results	Cannot identify the citation to a journal article, do not know when to cite a source and have difficulty evaluating information on the internet.

2.16.6 Summary of the Previous Studies

The SEUSISS project, the ECAR annual studies and the iSkills case studies assess ICT literacy of students in higher education in developed countries. Both the SEUSISS and the ECAR studies use self-assessment methodology to assess ICT literacy, while iSkills use simulated ICT activities. Commercial computer-based ICT surveys using multiple-choice questions on basic ICT knowledge are also available. Many universities including Malaysian universities collaborate with libraries to assess students' information research skills. However, none of the survey instruments used in these studies included a detailed investigation into the extent of ICT skills usage in engineering learning.

2.17 Student Demographic Variables in ICT Studies

Certain demographic characteristics of ICT learners have been the focus of many ICT literacy studies to discover the effects on learning. Findings of these studies have been used to design pedagogical approaches to improve learning. Some of the characteristics of ICT learners that have been researched are gender and the year of study. The researcher included engineering specialization as another variable to investigate the differences in skill levels among civil, electrical and mechanical students. The results from previous ICT studies with respect to gender, the year of study and the geographical location of the study subjects are shown in Table 2.11. No published study on the relationship between engineering specialization and ICT skills have been found.

Table 2.11: Findings in ICT studies with respect to gender and year of study

	Findings
Gender	
1. Teck and Lai (2011) - Malaysia	No significant gender differences with regard to computer usage and experience. Male and female students report moderate ICT skills. Male reported higher computer maintenance skill than female.
2. Moghaddam (2010) - World	Gender gap in access and use of ICT exists among all nations but is wider in developing nations. In developed nations, there is gender difference in internet usage.
3. Nosek *et al*. (2009) - World	Gender gap in the choice of majors within science and engineering.
4. ECAR (2009) – the United States	A study on technology adoption practice shows that males do more audio and video creation than females.
5. ECAR (2008) - the United States	No significant gender differences in usage of social network services such as facebook.
6. Freehill, Javurek-Humig and	Gender gap still exists in traditional fields of

Jeser-Cannavale (2006) – the United States	engineering such as Mechanical and Electrical engineering, but the gap is smaller in relatively new engineering fields such as biomedical engineering.
7. Kvavik and Caruso (2005) - the United States	Gender differences in perceived ICT skills levels are small and declining. Both gender are more comfortable using general-purpose software such as email than specialized software.
8. Liff and Shepherd (2004) – the United Kingdom	Male dominates internet use, and uses the computer more than female for recreation. Gender divide continues to exist in terms of the amount and type of use.
9. Ono and Zavodny (2004) – Japan and the United States	Gender gap in computer and internet usage which existed in Japan and the United States during the mid-1990s has disappeared among American users but has persisted among the Japanese.
10. Fenwick (2004) - Canada	Gendered inequity persists both in access to and experience of learning opportunities.
11. SEUSISS (2003) - Europe	Female students reported having fewer ICT skills and lower ICT skill levels. Computer ownership is strongly associated with self-reported ICT skills and the frequency of ICT use in studies.
12. Bailyn (2003) - the United States	Gender gap exists in academic engineering at all stages: undergraduate, graduate, post-doctorate and faculty.
13. Looker and Thiessen (2003) - Canada	Gender differences are not large, but seem to be persistent. Patterns of use seem to differ. Males perceive higher skill levels and are more comfortable with computers. Males are more likely to use computers out of interest.
14. OECD – 2003 (Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the	Gender does not affect computer access much, but the type of use differs. Males are more likely to use the computer for gaming. Little gender difference in the frequency of electronic communication. Fewer students report a frequent use of educational

Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States)	programs and software than using ICT for the Internet and entertainment.
15. Compaine (2001) - the United States	Gap in access to new technology exists due to economic reasons but with declining cost and natural acculturation the gap should become narrower.
16. Turner and Bowen (1999) – the United States	Gender differences exist in the choice of majors within science and engineering discipline.
Year of Study	
1. Jung (2006) - China	First year students rated their ICT skills levels significantly lower in most computer applications compared to the other groups.
2. Kvavik and Caruso (2005) – the United States	Skill levels for using general-purpose software are more or less similar across study years, but seniors reported higher skill levels for specialized software.

2.17.1 Gender

Gender gap in the choice of majors within the field of science and engineering has not lessened since the past few decades (Nosek *et al.*, 2009; Bailyn, 2003; Turner and Bowen, 1999). Many ICT studies found gender differences regarding ICT use, internet use, access, adoption, experience, and learning opportunities (Moghaddam, 2010; Fenwick, 2004; Liff and Shepherd, 2004; Looker and Thiessen, 2003; OECD, 2003). The ECAR (2009) study found gender difference in technology adoption practices and preferences. The study discovered that females do less audio and video creation than males.

Some studies found no gender differences in core technology use among students (Kvavik and Caruso, 2005; Compaine, 2001; Freehill, Javurek-Humig and Jeser-Cannavale, 2006). The size of gender gap might change in some countries and might remain more or less the same in others. For example, Ono and Zavodny (2004) found significant gender differences in computer and internet usage in Japan and the United States during the mid-1990s but noticed the gap has disappeared among American users while it has persisted among the Japanese.

These different findings motivated the researcher to investigate if significant gender differences existed in ICT skill levels and how differently these skills were used for learning between genders. Gender differences in ICT skill levels may indicate that different approaches should be taken to improve ICT proficiency of male and female students. The majority of the students at CST are male, and to reduce the imbalance, engineering should be made more appealing to female students. The small number of female students should also be encouraged to stay in the engineering discipline by giving them assistance in their studies. ICT may be one of the ways to do this.

2.17.2 Year of Study

Year of study represents the academic experience students have. This variable was chosen to investigate possible significant differences in the level of ICT skills between students in different years of study. Very few studies have been conducted for this purpose. A study by Jung (2006) found differences in the perceived levels of ICT skills among students in different years of study. Those in the first year rated their ICT skills levels significantly lower in most computer applications compared to the other groups. Kvavik and Caruso (2005) found that students in different years of study report the same skill levels for using general-purpose software but seniors reported higher skill levels for specialized software than students in lower years of study. This current study would provide more empirical data on the association between the year of study and ICT skill levels, specifically among engineering students.

2.17.3 Engineering Specialization

There is little literature on the effect of engineering specialization on ICT skill proficiency. At the diploma level at CST, the first two years consist of common engineering and general subjects. During the third year, students take specialized and elective courses according to their majors. These courses integrate and require ICT skills to a varying degree. Civil engineering program offers an ICT subject during the first year. Previous research on the effect of an ICT course on ICT skills level by Karsten and Roth (1998) found that a stand-alone ICT course had no effect on ICT proficiency. A study by Wong *et al.* (2009) on the effect of a stand-alone ICT course for student teachers in a Malaysian university showed some evidence of the benefits on students' perceived ICT skill proficiency. Jung (2006) found that engineering students rated themselves to have the lowest skills in creating graphics, video/audio files and web authoring. No known study has investigated the relationship between engineering programs and ICT skill levels. Thus, this study would enrich the literature on the possible effects of engineering courses on ICT proficiency.

2.18 Summary of the Chapter

This chapter reviews the literature on the key themes in the study, which include the concept of ICT literacy, assessment and measurement of ICT skills as well as previous studies of students' ICT skills in higher education. The researcher has identified the gap in previous works, which are very few ICT proficiency studies among engineering students and the absence of an instrument to measure ICT skills ability within the context of engineering domain. The researcher has subsequently described the possible uses of ICT user-skills in engineering learning based on the engineering problem-solving cycle and mapped engineering-related ICT activities to four engineering learning outcomes as outlined by ABET and MEEM. These provide the foundation for survey item identification and selection in the instrument development process.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the methodological aspects of the study. It describes the research design, study setting, participants, data collection, time horizon of the study, and research operations involved. Operations include sampling procedures, survey construction process, data collection method and data analysis procedures. This study aimed to meet the two major objectives, which were to describe engineering students' ICT user-skills profile and to develop an instrument to measure students' ability in using ICT user-skills for engineering learning. To meet these goals, the study specifically addressed the research questions described in chapter 1.

3.2 Research Design

A research design is a strategy, plan and structure for an enquiry. A rigorous research design is important to ensure that the research is valid, reliable, and yields convincing answers to the research questions (Creswell, 2005). This study uses a mixed method design, utilizing both quantitative and qualitative approaches. A mixed method way of thinking is based on the assumption that there are multiple legitimate approaches to complex social inquiry such as an educational research on teaching and learning (Greene, 2007; Berliner, 2002). Mixed methods are based on the pragmatism philosophy and combines inductive reasoning in the qualitative approach with deductive reasoning in the quantitative approach (Morgan, 2007). Mixed methods use an approach that combines subjective qualitative research with objective quantitative research. This approach emphasizes mutual understanding and shared meaning in communicating the research outcomes. In a qualitative research, the results are influenced by the social setting (Lincoln and Guba, 1985a), and are thus generally context-bound, whereas in a quantitative research, the results are generalized.

A mixed method design can provide the strengths of both quantitative and qualitative researches. An advantage for using the quantitative approach in this study was that it enabled the researcher to generalize the findings within the research setting by using stratified random sampling of the participants. An advantage of using the qualitative approach in this study was a deeper understanding of the participants' conception of ICT user-skills, their personal experiences and the problems they encountered in local context. Qualitative data provide a rich description, interpretation and expression of psychological events by the researcher and research participants and allow the theory to emerge instead of being predetermined (Gavin, 2008). The focus in qualitative research is more on the credibility and transferability of data, and less on data validity and reliability.

Credibility is the extent to which the research findings represent a "credible" conceptual interpretation of the data drawn from the participants' original data (Lincoln and Guba, 1985b). Transferability is the degree to which the findings of this study can apply or transfer to other settings. To address credibility, the researcher engaged two independent reviewers during the research process. The first was a senior librarian responsible for the library information skills programs who gave feedback on the interview questions. Another reviewer who was a senior consultant on IT human resource was engaged to extract the major themes based on the interview transcription. The themes were then compared with those extracted by the researcher. To address transferability, the researcher included the interview guide and an excerpt of the interview checklist table used for data collection and analysis in Appendix G and H respectively. The complete interview checklist table is available upon request. Thematic maps representing the qualitative research findings were presented in this thesis. This document access would enable other researchers to transfer the conclusions of this inquiry to other cases, or to repeat, as closely as possible the procedures of this study.

The mixed method design selected to conduct this study was an across-stage design, in which the mixing of methods take place across the stages of the research process (Johnson and Onwuegbuzie, 2004). The dominant paradigm is the quantitative approach, and both quantitative and qualitative data were collected concurrently. This mixed method study consists of eight major research stages, namely problem identification, literature review, determining problem statement and research objectives, instrument design and development, sample selection, data collection, data analysis, discussion and conclusion. Figure 3.1 shows the flow diagram of the research design. The activities within each stage are detailed in Section 3.9 which describes the operational framework of the study.

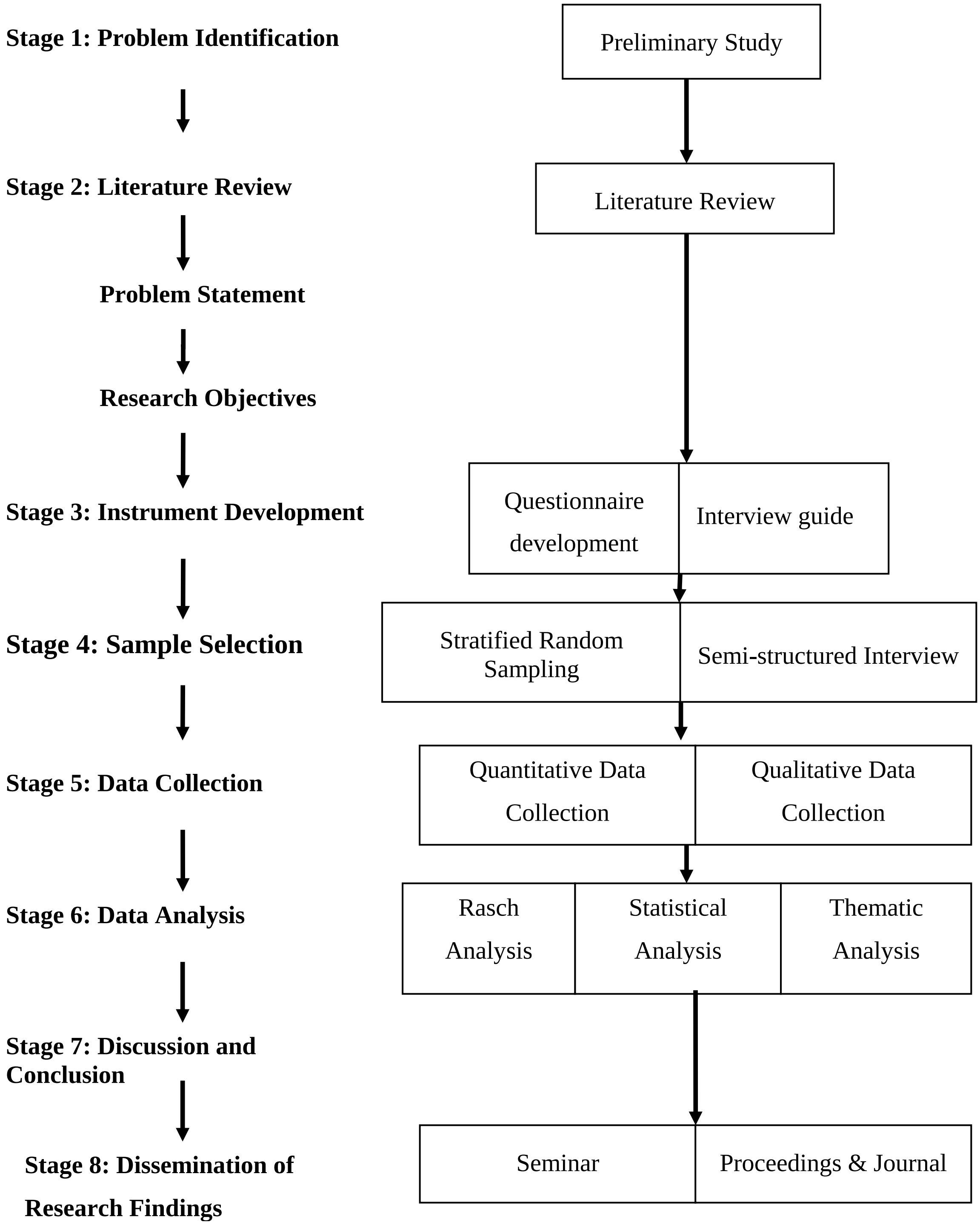


Figure 3.1: Flow diagram of the mixed method research design

The goals of mixing quantitative and qualitative methods in this study were twofold: Triangulation and Expansion of understanding. Triangulation is defined as a designed combination of data from different sources or several methods with offsetting biases in investigating the same phenomena to strengthen the validity of results (Greene, Caracelli, and Graham, 1989; Creswell, 2003; Johnson and Onwuegbuzie, 2004). In this study, quantitative and qualitative data were collected to build the ICT user-skills profile of engineering students which include students' ICT user-skills measurement and their conception of ICT literacy. Interviews provided a better understanding of students' experience in using ICT skills in engineering learning.

3.3 Research Setting

The study was conducted at a college of science and technology in the capital city of Malaysia. The college is under the jurisdiction of the Ministry of Higher Education (MOHE) and conducts diploma-level courses in various disciplines of engineering, science, technology, and technology management. The college aims to produce semi-professionals who may opt to go for further study or join the workforce. The college currently offers seven diploma-level engineering programs conducted by the departments of civil, electrical and mechanical engineering. The diploma program duration is between three to five years, comprising between six to ten semesters.

Diploma-level education in Malaysia aims to balance theory with practical applications. The curricular policy for higher education is detailed in the Malaysian Qualifications Framework of the National Higher Education Plan (MOHE, 2007). The action plan aims for holistic human capital development and provides guidelines for higher education institutions in producing dynamic and competitive graduates who can apply their knowledge and skills in a contemporary society. The curricular policy determines the entry requirement for an academic program. A diploma program typically requires a completion of a minimum of ninety credit hours of formal lessons. The duration of study is normally between two to three years and a fulltime course is often conducted within four to six semesters.

During the study programs, engineering students will take one or more ICT courses as prescribed in the curriculum of each discipline. Current ICT Courses in Diploma of Engineering Programs at CST are:

i) An introductory to IT course for civil engineering students.
ii) Computer programming courses for all engineering programs.
iii) Engineering software course for electrical engineering students.
iv) Software engineering course for electrical engineering students.

(UTM, 2009)

During the first week of study at the college, students attend an inductive library talk and participate in a tour, which normally takes about two hours. However, students may request for library ICT skills courses anytime during their study to enhance their library skills.

3.4 Participants

Participants of this study were full-time diploma-level students enrolled in engineering programs at the college described above. Full-time students of a diploma program are usually between 17 – 23 years old and possess the secondary school certificate Sijil Pelajaran Malaysia (O level equivalence), which is equivalent to the GCE O Level. Diploma students must complete between 97 – 99 credit hours of courses before graduation. The total enrolment of engineering students in Year 2009 was 837.

3.5 Preliminary Study

In the problem identification phase, a preliminary study was conducted to obtain data on engineering students' ICT user-skills ability (Ali, 2010). Specifically, the objectives of this study were (a) to determine which information skills students need to improve on, and (b) to identify the type and format of resources students most frequently use in course assignments. Data for this study were obtained using the test adapted from Mittermeyer (2003). The test consists of 20 multiple-choice questions related to information skills. The five themes used in the test are: 1) Concept Identification, 2) Search Strategy, 3) Document Types, 4) Search Tools, and 5) Use of Results. The test items were modified to make them specifically relevant to local engineering students. The content validity of the information skills questionnaire was evaluated by a Malaysian information literacy specialist with more than twenty years working experience in the field.

A convenience sample of second year engineering students was used. Seventy take-home test papers were distributed, with a response rate of 70%. Analysis of the forty-nine returned test papers showed that the participants lack knowledge of information skills. The percentage of correct answers was less than 50% in all but one information skills area. Most respondents seemed to be most familiar with using a search engine such as Google to find information. This was not surprising as they are part of today's digital natives. However, they seemed to lack the search skills required for academic research, including an awareness of the ethics in using information.

Nineteen group essay assignments on current issues in mechanical engineering from the same group of students were examined to triangulate the test score data. Students worked in a group of three or four to encourage sharing of ideas and resources. They were advised to include a bibliography of the resources used. The type of resources was then classified as either scholarly or non-scholarly by the instructor. The format of resources was also analyzed. The status of journals and conference proceedings, whether scholarly or non-scholarly were checked using Ulrichweb, an online version of Ulrich's International Periodicals Directory.

Examination of student essays and bibliographies showed that the percentage of scholarly resources was 48%, slightly lower than non-scholarly resources. Most of the scholarly resources used were books in print format, followed by journals and conference proceedings. For scholarly resources, the print format was more popular (81%), while for non-scholarly resources, the electronic format was used more often (77%). Examination of the bibliographies shows that most students were not aware of the proper format of citation. These results seemed to indicate that students' usage of electronic scholarly resources in their course assignments was very minimal and agree with the findings from the test, which indicated lack of students' skills to search for and use electronic scholarly resources.

The findings of this preliminary study implied the need to assess students' information skills as part of the process to evaluate and improve the effectiveness of an information skills program integrated in the curriculum. However, any assessment program must be supported by a measurement instrument developed and validated for a specific discipline within the local context. This research sought to address this lack of reliable and valid instrument to measure engineering students' ICT user-skills. Thus, this preliminary study served as an initial investigation for the study described in the following sections.

3.6 Sampling Technique and Sample Size

A cross-sectional study design was carried out over one semester to describe a population of students with respect to their ICT user-skills ability for engineering learning. Sampling in context of this study is the process of selecting a number of students from the defined population. Sampling of the participants was necessary to save time and money but since the sample was taken from the whole population, a carefully designed random sampling and a high response rate would make the results generalizable to the population. There are many sampling techniques for both quantitative and qualitative data that can be chosen to achieve the research purposes (Creswell, 2005).

3.6.1 Quantitative Data

Quantitative data required to describe engineering students' ICT user-skills profile and measure their ICT skills ability were data on demographics, computer ownership, internet access, uses of computers, where and how students acquire ICT skills, the problems students faced in acquiring those skills, the ways in which ICT skills help them learn engineering, students' self-reported ICT skill levels, and the frequency of utilizing ICT skills for engineering learning.

The quantitative approaches used in this study are traditional statistical analysis based on classical test theory and Rasch analysis. For both types of analysis, stratified random sampling was used to select the participants in this study to ensure a highly representative sample of students based on gender, year of study and engineering disciplines. This sampling technique allows generalization of the statistical results to the entire student population. To create a stratified random sample, the following steps were taken:

a) **Defining the population**

In this study, the population was the 837 engineering students taking diploma courses with specializations in civil, electrical, and mechanical engineering at a Malaysian college in the capital city of Kuala Lumpur.

b) **Choosing the strata**

To answer the research questions, the strata chosen were gender, engineering specializations, and the year of study.

c) **Listing the population**

All of the 837 students were identified using AIMS2000, the academic information management system. Permission was obtained from the Student Records department to access the list of all students. The list was then filtered according to the chosen stratification. The distribution of student population according to the stratification is shown in Table 3.1.

d) **Choosing the sample size**

Sample size is important in a study that involves hypothesis testing because it determines the statistical power. Statistical power is the probability that a significant test will indicate a difference when it exists. In hypothesis testing, the null hypothesis states that differences are caused solely by chance, and the opposite claim is the alternative or test hypothesis which states that real difference exists. A decision criterion, the alpha level is set for rejecting the null hypothesis. Usually alpha is set at 0.05. If the probability (p-value) that the difference is purely due to chance is equal or less than the alpha level, then the null hypothesis is rejected and the difference is considered statistically significant.

The hypothesis testing process is subjected to two types of errors: Type I and Type II. A Type I or false-positive error occurs when the null hypothesis is wrongly rejected, thus implying a significant difference when actually there is none. A Type II or false-negative error occurs when the null hypothesis is wrongly accepted, thus implying no significant difference when there actually is. Statistical power is conventionally set at 0.80 or 80% (Prajapati *et al*., 2010). Thus there is a probability of 0.20 or 20% of Type II error, or incorrectly accepting the null hypothesis. The probability of Type II error is denoted as beta (β). Thus statistical power = $1 - \beta$.

Table 3.1: Distribution of student population according to year of study, gender and engineering discipline

Course			Gender		
			male	female	Total = 837
Civil	Year of Study	First	26	17	43
		Second	16	11	27
		Third	37	16	53
	Total		79	44	123
Electrical	Year of Study	First	88	31	119
		Second	83	33	116
		Third	170	49	219
	Total		341	113	454
Mechanical	Year of Study	First	77	7	84
		Second	55	10	65
		Third	101	10	111
	Total		233	27	260

Generally, in both statistical and Rasch analysis, the larger the sample size, the higher is the power, and the more precise and robust are the estimates. However, using a large sample size would be more costly, time consuming, and a waste of resources when a smaller sample size would suffice. Factors that affect sample size calculations are the p value, power, and effect size of a treatment. If the desired p value is small, or the power to detect differences is high or the effect of a treatment is low, then the required sample size is large (Whitley and Ball, 2002). Effect size is the smallest difference or effect that is considered relevant. Details on sample size and power of the test for classical and Rasch analysis are as follows:

i) Sample Size and Power for Traditional Statistical Analysis

There are several procedures and formulae incorporating the p value, power and effect to calculate the minimum sample size. One convenient method is by using statistical power analysis software called GPower3 (Prajapati *et al*., 2010; Faul *et al*., 2009). This software takes as input the ratio between sub-populations to suggest the minimum number of sample size for various tests. Table 3.2 shows the ratios of sub-populations and the recommended minimum sample sizes for various statistical tests. The output of this GPower3 showing the minimum sample sizes for t-tests and ANOVA are shown in Figure 3.2 and Figure 3.3. The type of power analysis chosen was a Priori, in which the sample size was computed as a function of the power level, the significant level, and the effect size. Cohen (1988) suggested standardized "small", "medium", and "large" effect sizes for different types of tests. For example, to test for a significant difference between two means, an effect size 0.20 is small, 0.5 is medium, and 0.80 is large. From Table 3.2, the overall minimum sample size to conduct t-tests and ANOVA is 260.

Table 3.2: Minimum Sample Size for t-test and ANOVA

Sub-population	Ratio of Sub-Population	Minimum Sample Size for Tests	
		Means : t-test	**ANOVA**
Male/Female	653/184 = 3.5	252	
Year 1/Year 2	246/208 = 1.18	176	
Year 1/Year 3	246/383 = 0.64	184	
Year 2/Year 3	208/383 = 0.54	192	
Civil/Electrical	123/454 = 0.27	260	
Civil/Mechanical	123/260 = 0.47	202	
Electrical/Mechanical	454/260 = 1.75	190	
Year 1/Year 2/Year 3	-	-	252
Civil/Electrical/Mechanical	-	-	252

Bartlett *et al.* (2001) and Cochran (1977) proposed a procedure to determine the sample size for continuous and categorical data by considering the alpha level and the margin of error. The alpha level used in most educational research studies is either 0.05 or 0.1 (Ary, Jacobs, and Razavieh, 1996). The minimum sample size for this study with alpha level 0.05 and margin of error of 5 percent using the table developed by Bartlett *et al*. (2001) is 270. The table is shown in Appendix A.

According to the formula developed by Krejcie and Morgan (1970), the minimum number of participants to ensure representativeness of findings with alpha level 0.05 and margin of error of 5 percent or at 95 percent level of confidence is 265. The table is shown in Appendix B. This figure is the about same as that suggested by Bartlett *et al.* (2001).

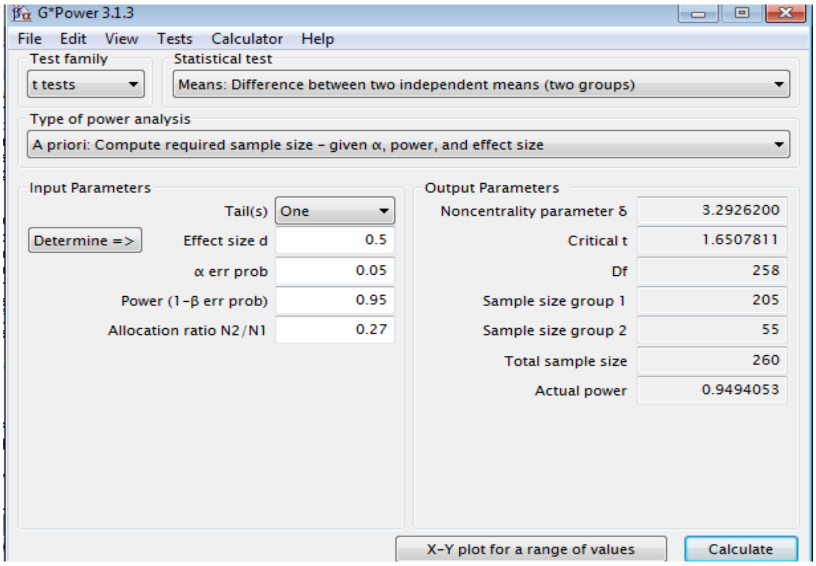


Figure 3.2: Output of GPower3 to determine sample size for t-test

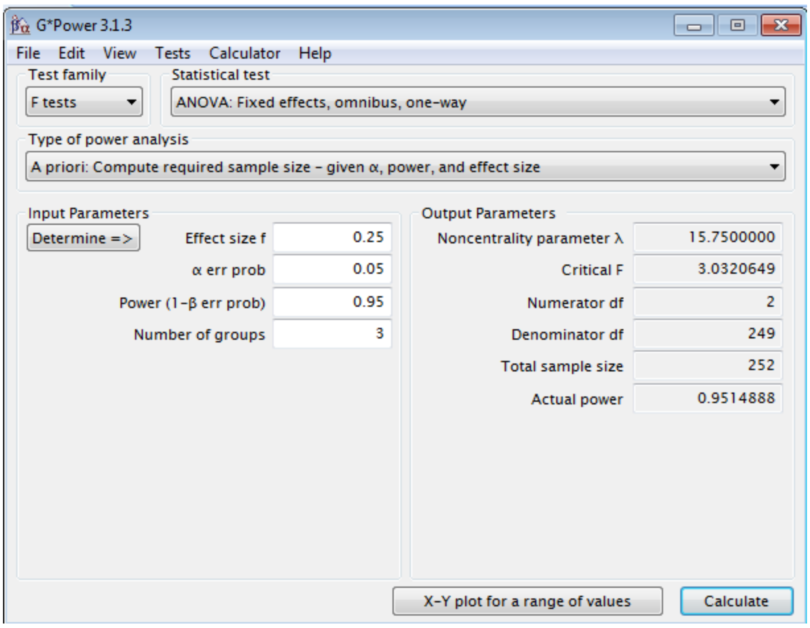


Figure 3.3: Output of GPower3 to determine sample size for ANOVA

ii) Sample Size and Power for Rasch Analyis

In Rasch analysis, sample size determines the stability of item calibration and person measures (Linacre, 1994). According to Linacre (1994), to have 95% confidence that no item calibration is more than 0.5 logit away from its stable value, the minimum sample size for most purposes is between 64 to 144, and to have 99% confidence, the range increases to between 108 to 243, depending on how good the targeting is. The better the targeting, the lesser is the sample size required. For pilot studies, a properly administered sample of size 30 is enough (Wright and Stone, 1979; Wright and Tennant, 1996).

Power of a hypothesis test of a useful model fit in Rasch analysis is the ability to detect departures of the standardized χ^2 fit statistic, which is the mean-square value from 1. Mean-square value of 1.5 or less suggests data are useful for measurement. For sample sizes greater than 30, the certainty as to whether the data are productive for measurement increases. Sample sizes of 100 to 250 are sufficient to test a hypothesis for a perfect data-to-model fit, in which case the mean-square value is 1.0. (Linacre, 2003). Smith *et al.* (2008) showed that for polytomous data, mean square statistics are relatively stable and independent of sample size, and that misfit of data to the model can be identified using published recommended ranges.

In this study, the sample size used was 317, exceeding the minimum size suggested by GPower3, Bartlett's and Krejeie and Morgan's formulae, and more than the minimum size suggested by Linacre (1994) for Rasch analysis.

a) Calculating a Proportionate Stratification

In proportionate stratification, the number of students selected for the sample from each stratum is proportionate to the number of student population in that stratum. Generally, if N is the total population size, N_j is the population size of stratum j, n is the total sample size and n_j is the sample size of stratum j, then $n_j = n \cdot (N_j/N)$. For example, the sample size for first-year civil engineering students = 317 (43/837) = 16. The number of students in each stratum is shown in Table 3.3.

Table 3.3: Distribution of student sample according to year of study, gender and engineering discipline

Course			Gender		
			male	female	Total = 317
Civil	Year of Study	First	9	7	16
		Second	4	6	10
		Third	17	3	20
	Total		30	16	46
Electrical	Year of Study	First	33	12	45
		Second	29	16	45
		Third	51	32	83
	Total		113	60	173
Mechanical	Year of Study	First	25	7	32
		Second	17	9	26
		Third	37	3	40
	Total		79	19	98

b) Using simple random sampling to select the sample for each stratum

After the number of student sample in each stratum has been calculated, the students in each stratum were selected using simple random sampling procedure. This was achieved using the following steps:

i) The filtered list of students was numbered consecutively from 1 to N, where N is the population size of the stratum. For example, there were 26 male first-year civil engineering students, and each of them was assigned a number between 1 to 26 in alphabetical order.

ii) To randomly select the calculated n_j number of students in each stratum, n_j random numbers between 1 and N_j were generated. This was done using a random number generator software, AbleBits Random Number Generator for Excel. This software uses the Mersenne Twister algorithm to produce a sequence of 32-bit integers and has undergone tests on statistical randomness, including the NIST Statistical Test Suite and Diehard tests.

For example, the nine random numbers shown in Figure 3.4 were generated using this software. These numbers were used to select nine out of twenty-six students in the male first-year civil engineering student stratum.

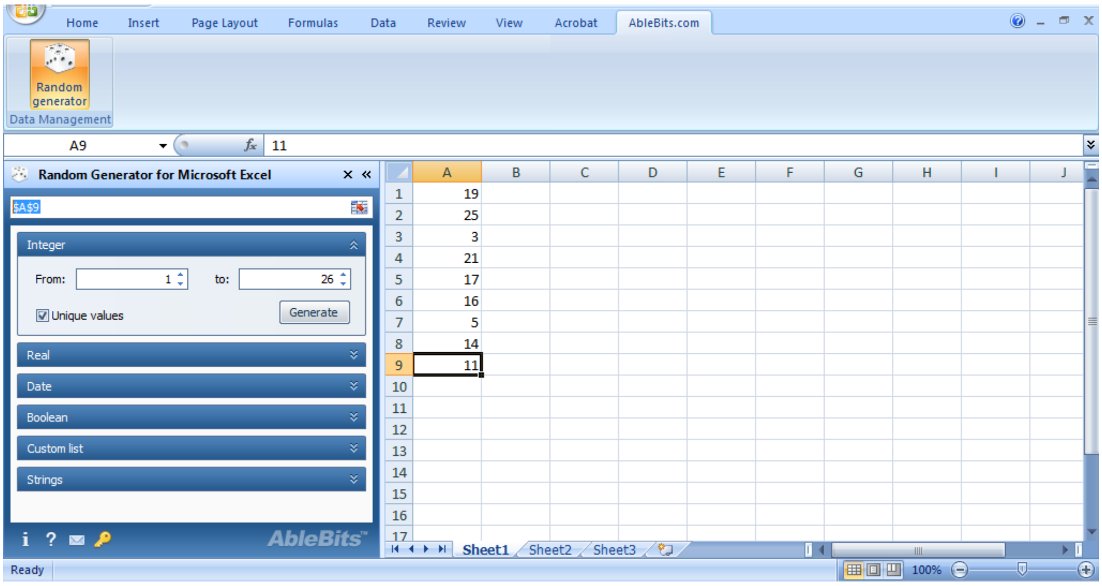


Figure 3.4: Output of random number generator software

3.6.2 Qualitative Data

Qualitative approach was chosen to answer research questions pertaining to students' conception and experience of using ICT skills in engineering courses, the perceived benefits of using ICT skills, the barriers faced in acquiring the skills, and the ICT skills which need to be improved. The main purpose of using qualitative approach in this study was to aid in various stages of instrument development and to obtain a rich contextual description of how ICT skills support their engineering learning experience. Qualitative approach also allows flexibility for the researcher to evoke contextually rich explanatory responses that are meaningful to the participants, and which might be unanticipated by the researcher (Mack *et al*., 2005).

The sampling technique was purposive sampling with the main aim being to gain in-depth insight into these matters. Patton (2002) identifies sixteen varieties of purposive sampling, and for this study, the researcher chose to select stratified purposive sampling. The sample comprised third-year diploma students selected through snowballing from civil, electrical, and mechanical specializations. The reason for selecting third-year students was because they had undergone the first and second years, and could thus make comparisons in terms of their experience in using

ICT in their courses in each year of study. The students in each stratum were also homogeneous in terms of their academic experience since they took the same courses throughout the study program. Homogeneous sampling reduced variation, facilitated group interviewing, and simplified analysis. The sample size for each stratum was not predetermined and would be increased until no more new themes or explanations emerged from the data. This implies a flexible, iterative and cyclical approach to sampling until data saturation is reached (Marshall and Rossman, 2010).

3.7 Instrument Development Process and Instrument Description

This section describes the instrument development process and the resulting instruments for quantitative and qualitative data collection.

3.7.1 Instrument Development for Quantitative Data

Quantitative instrument development and validation followed the guidelines by DeVellis (2003) and Czaja and Blair (2005), and were performed in six phases. Phase 1 involved determining what to measure, a review and assessment of major existing instruments to justify developing a new instrument, and a task inventory to create an item pool. Phase 2 was concerned with drafting the instrument and getting expert reviews and student feedback. Phase 3 comprised pilot testing the instrument, checking the internal consistency and refining the instrument. Phase 4 involved testing the modified instrument and making amendments based on Rasch model fit analysis and interview results. Phase 5 was pilot testing the amended draft. Phase 6, the final phase was the main study using a stratified random sample and testing for reliability and validity of the instrument. Table 3.4 summarizes the phases and the steps taken in the instrument development process of this study.

a) Phase 1: Literature Review and Item Pool Creation

DeVellis (2003) proposes that the first step in survey instrument development is to determine what to measure. In this study, the construct to be measured was engineering students' ICT user-skill ability, which was defined in Section 1.8. However, ability cannot be measured directly. It is a latent variable which can only be estimated by the scores of a set of survey items. Each item score should be an indicator of the strength of the underlying latent variable.

A review of major existing instruments to measure the use of ICT skills in education in Malaysia, Europe, and United States was described in Section 2.13. From this review, demographic variables, dependent and independent research variables, and a pool of candidate items that could represent ICT user-skill ability were identified. Demographics are relevant personal and background information of research participants. Demographic independent variables selected were gender, year of study and engineering discipline. Dependent research variables are the ICT user-skills levels and independent research variables are computer ownership, computer hours of study and recreation, and the frequency of using ICT user-skills during the course of study.

Table 3.4: Phases of instrument development

Phase 1: Literature Review on Previous Studies and Existing Instruments Task Inventory to Include New Items Review and Create Item Pool
Item Pool (86 items)
Phase 2: Instrument Drafting Select, Adapt and Modify Survey Items + New Items
First Draft (67 items)
Phase 3: Pilot Study of the First Draft Student Review (n=11) (Face Validity) Expert Review (n=10) (Content Validity) Post- Phase 3: Amendment (Format, Language, Add 4 Information Skills Items)
Second Draft (71 items)
Phase 4: Pilot Study of the Second Draft Pilot test 1: (n=30): Face Validity, Data Collection Method, Reliability, Fit statistics, Item Polarity, Item Dependency Pilot test 2: (n=60): Reliability, Fit statistics, Item Polarity, Item Dependency Post- Phase 4: Delete 8 Misfitting Items
Final Draft (63 items)
Phase 5: Testing of the Final Draft Pilot test 3: (n=70): Reliability, Fit statistics, Item Polarity, Item Dependency
Phase 6: Main Study (n=317) Reliability, Unified View of Construct Validity Rasch Analysis

Many items from existing instruments related to the general use of ICT skills were identified. However, none of the survey instruments reviewed was tailored for engineering education. Thus, a job analysis based on engineering problem-solving cycle was performed to generate items specifically related to engineering activities. The job analysis was detailed in Section 2.9 and resulted in an additional 16 items. Examination of the item pool yielded three sub-domains of ICT user-skills for engineering education. These are the ability to use of general-purpose application software, the ability to use engineering-specific application, and information skills. A total of 86 items formed the initial pool, the details of which are shown in Table 3.5.

Table 3.5: Initial item pool components

Part	Description	Number of Items	Source
A	Demographic data	7	
B	General ICT information	26	Adapted from: 1. SEUSISS (2003) 2. ECAR (2005)
C	Basic ICT Skills 7 ICT device operations 11 General application 3 Information skills	21	Adapted from the Database of ICT Skills Assessment Tools
D1	16 Engineering applications	16	Newly developed by the researcher based on task inventory
D2	16 Frequency of using engineering applications	16	
	Total	86	

b) Phase 2: Instrument Drafting and Review

Items in the initial pool were examined and some were rewritten several times, first merely to express the idea in different ways. Then the items were checked for clarity while making it as brief as possible, and avoiding double barreled items. For example, the item *I am able to use electronic data collection devices and connect them to the pc to gather and analyze experimental data* was replaced by: *Using engineering packages eg. StarCD to collect data.*

Some items were edited to make the sentences more specific for engineering students. For example, the item: *I am able to use a presentation program eg. MS-Powerpoint to create a presentation* was replaced with: *Making multimedia presentations of engineering projects.* Some were omitted because of being too basic for engineering students. An example is the item: *I am able to operate a personal computer.*

Another important aspect of drafting the instrument is determining the format of measurement. The response format for ICT user-skills items is an ordinal Likert scale with five-response options ranging from "Not at all skilled" to "Expert" as shown in Figure 3.5. The series of numerical values assigned to the response categories indicates a gradation of skill levels. Likert scaling presumes the existence of underlying continuous variable that characterizes the respondents. Likert scale is fairly easy to construct and is widely used in social science research (Ary, *et al.*, 1996; Johnson and Christensen, 2000; Neuman, 2000; Salkind, 1997).

1	2	3	4	5
Not at all skilled	Not very skilled	Moderately skilled	Very skilled	Expert

Figure 3.5: Response scale

The instrument requires students' self-rating of their skill levels, thus a description of the criteria for each performance level would make it easier for the respondents to self-rate themselves (St-Pierre, 2004). Five response categories were used for each item to correspond with the number of skill levels as proposed by Basque, Ruelland and Lavoie (2007). The five skill levels ("Not at all skilled", "Not very skilled", "Moderately skilled", "Very skilled", and "Expert") with the corresponding performance criteria are shown in Table 3.6.

The establishment of Malaysian information literacy standards is part of the National Information Literacy Agenda, but unfortunately to date, there has yet to be an official set of standards for local reference (Edzan, 2008). Thus, the information skills items in this study were based on the information literacy competency standards for higher education (ALA, 2004), and the information literacy competency standards for science and engineering/technology (ALA, 2011). The standards and corresponding items are shown in Table 3.6. To avoid ambiguity and to ensure every respondent understand a terminology in the same way, an explanatory note on the survey items was given as a guide.

Table 3.6: Performance scale

Criteria	Not at all Skilled	Not very skilled	Moderately skilled	Very skilled	Expert
Independence	With help	With help	Without help	Without help	Without help
Frequency	Very rarely	Whenever necessary	Whenever necessary	Whenever necessary	Whenever necessary
Completeness	Partially	Partially	Entirely	Entirely	Entirely
Complexity	Simple tasks	Simple tasks	Simple tasks	Complex tasks	Complex tasks
Familiarity	Usual situations	Usual situations	Usual situations	Usual situations	New situations

Table 3.7: ALA standards and information skills items

Standard	Survey Item	Example
1. The information literate student determines the nature and extent of the information needed.	Defining the required information for an engineering problem.	Identifying key concepts and research issues in a lab exercise or project.
2. The information literate student accesses needed information effectively and efficiently.	Using a computer to access engineering data efficiently.	Constructing search strategy using appropriate commands (AND, OR).
3. The information literate student evaluates information and its sources critically and incorporates selected information into his or her knowledge base and value system.	Evaluating engineering information on websites.	Examining information sources to evaluate authority.
4. The information literate student, either individually or as a group member, uses information effectively to accomplish a specific purpose.	Using information effectively to solve an engineering problem.	Integrating new and prior information to solve an engineering problem.
5. The information literate student understands many of the economic, legal, and social issues surrounding the use of information and accesses and uses information ethically and legally.	Using information ethically and legally.	Recognizing issues related to intellectual property.

The first draft consisted of 4 parts as shown in Table 3.8. Part A consists of five questions on demographics to collect data on students' engineering specialization, gender, age, year of study, and cumulative point average (CPA). There are seven specializations at CST, but they were regrouped into three clusters for analysis purposes: Civil, Mechanical and Electrical. The specializations in each cluster share common foundational courses except for about six specialization courses totaling 16 – 17 credit hours in the final year.

Part B consists of items on general information regarding computer ownership, internet access, computer use, how and where students acquire their ICT skills, the problems they face in acquiring those skills, and their opinion on how ICT help them in their study. These items were common in many ICT surveys such as SEUSISS (2003) and ECAR (2008).

Part C was designed and developed by the researcher based on the engineering problem-solving cycle. Part C has two parts: C1 and C2. Part C1 consists of 18 likert scale items on the frequency of performing engineering-related activities using ICT. The frequency of performing activities is rated using ordered response levels: "Never", "Rarely", "Once a month", "Once a week", "2 – 3 times a week", and "Every day". These items on the frequency of activities are ordered-category items (Uebersax, 2006). Part C2 has 18 likert scale items of self-reported ICT user-skills levels for engineering learning.

Table 3.8: First draft components of the instrument

Part	Description	Number of Items	
A	Demographics	5	
B	General ICT information: 1 Computer ownership 1 Internet access 2 Computer use 5 How skills acquired 4 Barrier to skills acquisition 10 Perceived benefits of ICT for engineering learning 3 Opinion	26	Adapted from SEUSISS and ECAR
C	ICT User-Skills for Engineering Learning 6 ICT device operations 7 General application 5 Information skills	18	Newly developed by the researcher
D	Frequency of Activities in (C)	18	
	Total	67	

c) Phase 3: Expert Review

The first draft was first given to an expert to comment on the suitability of the rating scale, the clarity of instructions, and the format of the validation form. Thereafter the draft instrument was given either by hand or by mail to a panel of ten expert reviewers to check the face and content validity of the instrument. According to Rubio *et al*. (2003), 6 – 20 reviewers are generally adequate. Some of the experts have over twenty years of experience in their respective field. The number of practicing engineers in the panel was more than others to provide important feedback on ICT-related engineering activities based on their on-the-job experience in industries such as oil and gas, and telecommunications. The profile of the experts is shown in Appendix C.

The reviewers were asked to rate the first draft with respect to the appropriateness of the measurement scale type and format, clarity of the instructions to respondents, unambiguousness of survey items, the representativeness of each item with regard to the content domain of ICT user-skills based, and the comprehensiveness of the scale as a whole. Examination of these survey instrument aspects is recommended by Rubio *et al*. (2003).

The rating scale used in the validation form was Likert scale with five response options: Strongly Disagree/Disagree/Somewhat Agree/Agree/Strongly Agree. The reviewers were also asked to give suggestions and comments on the instrument. The validation form is as shown in Appendix D. The expert areas of the reviewers are shown in Table 3.9.

Table 3.9: Panel of reviewers

Profession/Area of Expertise	**Number of Reviewers**
Engineering:	
Education	2
Practising Professionals	5
Education	1
ICT	1
Information Literacy	1
Engineering Students	11

The face validity of the instrument was also checked by a convenience sample of eleven engineering students. This step was important to gauge how prospective respondents would perceive the instrument. The students gave feedback using a form as shown in Appendix E. Students were asked if they could understand the purpose of the survey, the wordings in the questionnaire, the overall logical flow of the items, and if they find the questionnaire of appropriate length. The students took about thirty minutes to complete the survey. Their feedback provided early linguistic flaw detection and an indication of whether students would be willing to spend time on the survey.

Meanwhile, completed validation survey forms were received in stages from the panel of experts. The response rate was 100% and it took about 1 month before all the forms were returned. Based on students' feedback and the panel's comments, the first draft was slightly modified, resulting in the second draft, shown in Appendix F. The composition of the second draft is described in Table 3.10.

Part A and B were unchanged. In Part C, a little modification to the wordings of the items were made. For example, *Using information effectively to accomplish a specific purpose* was changed to *Using information for problem solving.* Two new items on internet search were added to emphasize the new mode of information search. These were C2_19 (*Using the internet to search for contemporary issues in engineering*) and C2_20 (*Using the internet to get information about professional codes of ethics& legal issues*). Even though both items involve the skill of using the internet to search for information, the stress here was on the different purposes of searching to align with the characteristics of engineers described in the Engineering Criteria 2000 (EC 2000). These two items had overlapping content, and redundant items such as these were often purposely chosen because redundancy is the basis of internal consistency (DeVellis, 2003b).

Table 3.10: Components of the second draft

Part	Description	Number of Items
A	Demographic data	5
B	General ICT information: 1 Computer ownership 1 Internet access 2 Computer use 5 How skills acquired 4 Barrier to skills acquisition 10 Perceived benefits of ICT for engineering learning 3 Opinion	26
C	ICT User-Skills for Engineering Learning: 6 General Application 7 Engineering Application 7 Information Skills	
C1	Frequency of Activities in (C)	20
C2	Skills Level of Performing Activities in (C)	20
	Total	71

d) Phase 4: Pilot Testing of the Second Draft

A pilot study is important to assure appropriateness of the survey questionnaire, to check clarity of the questions and to gain insight of potential logistic data collection problems in the actual study. The first pilot study for this research work was conducted at CST in November 2008. Pilot testing of the second draft was done in two stages. The initial stage was to compare the practicality of using paper format survey with a computerized data collection procedure. The same 11 respondents selected to check for face validity in Phase 2 were asked to give feedback on the practicality of using a computerized survey form, and whether it would be more interesting and convenient for them. The big advantage of a computerized form would be time-saving since data need not be keyed again for analysis, thus eliminating potential human error in entering data for analysis. The computerized form, as shown in Figure 3.6, was partially completed. The completed survey part was developed using Visual Basic, and was installed in a computer lab. The researcher took note of the average time taken by the respondents to settle down in the lab, and to eventually use the system. Respondents' verbal feedback on the whole process of taking the survey was obtained. The outcome of this data collection trial, if proven unfavorable could avoid unnecessary development effort and cost.

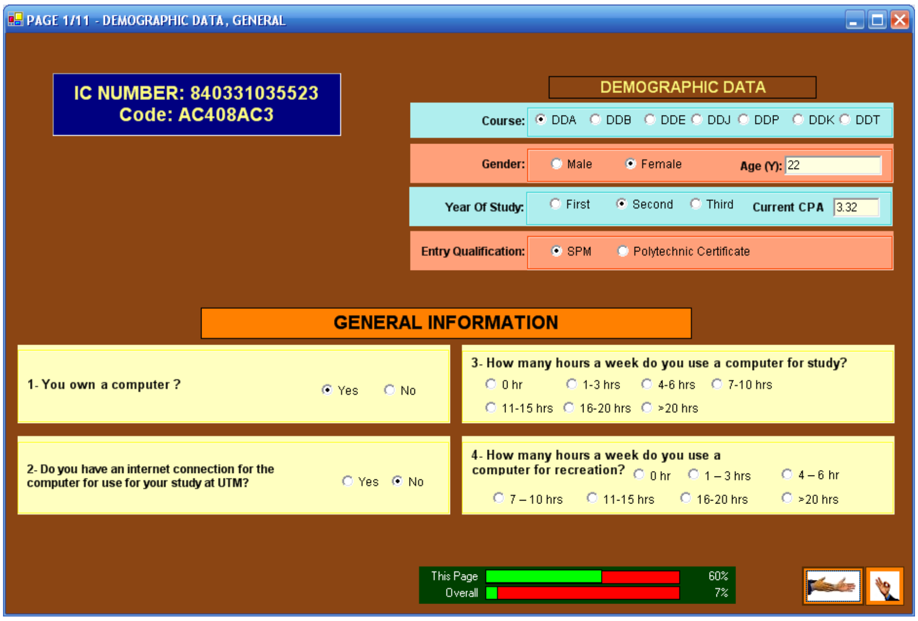


Figure 3.6: A Snapshot of a computerized survey form

After testing for face validity and comparing the mode of survey administration, the researcher decided to use the traditional paper format survey to pilot test the amended ICT user-skills subscale. The second draft was distributed to a larger convenience sample of 30 respondents using a paper format survey form to get an initial indication of the scale's reliability based on the response analysis.

Based on Rasch analysis, the reliability of the ICT user-skills scale indicated by the student reliability index was 0.85. This was equivalent to the Cronbach's alpha (0.89) estimated using raw scores. The WINSTEPS output of reliability indices are shown in Table 3.11.

Table 3.11: Reliability indices of the second draft

INPUT: 30 STUDENT 20 Item REPORTED: 30 STUDENT 20 Item 5 CATS WINSTEPS 3.73

SUMMARY OF 30 MEASURED STUDENT

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	52.8	20.0	-.43	.32	.99	-1.4	1.00	-1.4
S.D.	9.8	.0	1.00	.02	1.39	3.6	1.41	3.6
MAX.	71.0	20.0	1.24	.34	5.67	7.2	5.69	7.2
MIN.	37.0	20.0	-2.13	.26	.08	-5.9	.09	-5.9

REAL RMSE .39 TRUE SD .92 SEPARATION 2.39 STUDEN RELIABILITY .85
MODEL RMSE .32 TRUE SD .95 SEPARATION 2.98 STUDEN RELIABILITY .90
S.E. OF STUDENT MEAN = .19

STUDENT RAW SCORE-TO-MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR-20) STUDENT RAW SCORE "TEST" RELIABILITY = .89

Two items, C2_9 (Using engineering packages eg. StarCD to collect data) and C2_10 (Using project management software eg MS-Project to manage an engineering project) have a very high dependency index of 0.94. Another two items, C2_4 (Using simulation software eg. SIMULINK to experiment with models of engineering systems) and C2_13 (Using E-learning system to support classroom learning of engineering courses) have low point-measure correlations of 0.38 and 0.41 respectively. C2_4 and C2_13 also have infit and outfit MNSQ values out of the acceptable range of (0.7, 1.4). However since the sample size was rather small (n=30), these items would be considered for deletion only if the statistics remain unsatisfactory when a bigger student sample was used.

Before deleting any of the items which did not show good fit to the Rasch model, another test was undertaken. This time, instead of using a convenience sample, the respondents were chosen at random. Sixty respondents were identified using the database in the Students Record office and selection was done using a random number generator to produce 4 digit series to correspond with the last 4 digits of their identity card number.

Reliability of the second draft of the ICT user-skills subscale indicated by the student reliability index was 0.87. This was equivalent to the Cronbach's alpha (0.91) estimated using raw scores. The WINSTEPS of reliability indices are shown in Table 3.12.

Table 3.12: Reliability indices of the second draft

INPUT: 60 STUDENT 20 Item REPORTED: 60 STUDENT 20 Item 5 CATS WINSTEPS 3.73

SUMMARY OF 60 MEASURED STUDENT

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	51.9	20.0	-.56	.37	.98	-1.4	.99	-1.4
S.D.	9.2	.0	1.27	.03	1.54	3.6	1.55	3.6
MAX.	71.0	20.0	1.65	.39	7.85	9.5	7.86	9.5
MIN.	37.0	20.0	-2.70	.27	.07	-5.5	.07	-5.5

REAL RMSE .45 TRUE SD 1.18 SEPARATION 2.64 STUDEN RELIABILITY .87
MODEL RMSE .37 TRUE SD 1.21 SEPARATION 3.30 STUDEN RELIABILITY .92
S.E. OF STUDENT MEAN = .16

STUDENT RAW SCORE-TO-MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR-20) STUDENT RAW SCORE "TEST" RELIABILITY = .91

However, from Table 3.13, the point measure correlations of C2_4 and C2_13 are below 0.5 with infit and outfit MNSQ values above 1. This may indicate that noise due to outliers in the responses overwhelm useful information in the data (Smith, 1996). Thus these items do not contribute to the construct measurement and were hence deleted.

The standardized residual correlation between items C2_9 and C2_10 was still high at 0.82 as seen in Table 3.14. This indicated dependency between the two items, and hence they were deleted from the ICT user-skills scale. Consequently, only 16 items are retained in this subscale. These items were further tested in Phase 5 of the instrument development process to confirm their usefulness in measuring the ICT user-skills construct. The components of the final draft of the survey instrument are shown in Table 3.15.

Table 3.13: Point measure correlations

```
INPUT: 60 STUDENT  20 Item  REPORTED: 60 STUDENT  20 Item  5 CATS WINSTEPS 3.72.2
--------------------------------------------------------------------------------
STUDENT: REAL SEP.: 2.64  REL.: .87 ... Item: REAL SEP.: 1.81  REL.: .77

         Item STATISTICS:  CORRELATION ORDER

-------------------------------------------------------------------------------------------
|ENTRY   TOTAL  TOTAL           MODEL|   INFIT  |  OUTFIT  |PT-MEASURE |EXACT MATCH|        |
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.  EXP.| OBS%  EXP%| Item   |
|------------------------------------+----------+----------+-----------+-----------+--------|
|     4    145     60      .48   .22|1.40   1.8|1.32   1.5|  .43   .59| 60.0  63.0| 4c2_4  |
|    13    161     60     -.25   .21|1.23   1.1|1.29   1.3|  .48   .59| 68.3  62.4| 13c2_13|
|    10    133     60     1.06   .22|1.17    .9|1.15    .8|  .52   .59| 63.3  59.3| 10c2_10|
|     8    146     60      .43   .22|1.07    .4| .99    .0|  .53   .59| 66.7  63.2| 8c2_8  |
```

Table 3.14: Dependency between items

```
INPUT: 60 STUDENT  20 Item  REPORTED: 60 STUDENT  20 Item  5 CATS  WINSTEPS 3.73
--------------------------------------------------------------------------------

     LARGEST STANDARDIZED RESIDUAL CORRELATIONS
     USED TO IDENTIFY DEPENDENT Item
----------------------------------------
|CORREL-| ENTRY          | ENTRY          |
|  ATION|NUMBER Item     |NUMBER Item     |
|-------+----------------+----------------|
|    .82 |      9 9c2_9  |     10 10c2_10 |
```

Table 3.15: Final draft components of instrument

Part	Description	Number of Items
A	Demographic data	5
B	General ICT information: 1 Computer ownership 1 Internet access 2 Computer use 5 How skills acquired 4 Barrier to skills acquisition 10 Perceived benefits of ICT for engineering learning 3 Opinion	26
C	ICT User-Skills for Engineering Learning: 5 General Application 4 Engineering Application 7 Information Skills	16
D	Frequency of Activities in (C)	16
	Total	63

e) Phase 5: Pilot Testing of Final Draft

Based on students' feedback in Phase 3, most preferred a paper format survey to a computerized one because they could fill it up whenever and wherever convenient without having to be in the computer laboratory. Thus a paper-format questionnaire based on the final draft was maintained and administered to a convenience sample of 75 students enrolled in engineering courses. Seventy forms were returned, thus the response rate was 93%.

The final draft was tested for internal consistency using both classical true score and item response approach. The reliability of subscales *frequency of ICT skills use*, and *perceived benefits of using ICT user-skills for engineering learning* were obtained. Unidimensionality of the ICT user-skills subscale was established using CTT statistics and Rasch principal component analysis of residuals.

Important statistics for the final draft are shown in Table 3.16. Both student and item reliability indices are high. Item correlations to the measure are satisfactory. Fit statistics are reasonably good and would improve with a larger sample size. There was less dependency between items compared to the second draft, but with more data in the main study, the relationship between items would be clearer.

Table 3.16: Statistics of the final draft

	Criteria	Statistics
Reliability: i) Student reliability ii) Cronbach's alpha iii) Item Reliability	At least 0.8	i) 0.91 ii) 0.93 iii) 0.80
Item Point-Measure Correlations	High Positive Correlation	> 0.57
Dependency (Absolute Value of Standardized Residual Correlations)	Ideally < 0.30	< 0.45

f) Phase 6: Main study

A total of 400 questionnaires were distributed, and 381 were returned, giving a response rate of 95%. However only 317 were selected based on the completeness of the responses and the predetermined number of respondents for each stratum. Thus the main quantitative study involved 317 respondents from a population of 837 engineering students.

Students were given written information regarding the study and was briefed that their participation was on voluntary basis. They were assured that all data collected were strictly confidential, would be used for academic research and would never be used against them.

Data from the main study were used to confirm the effectiveness of the rating scale. The final instrument was investigated with respect to five types of validity, namely content, substantive, structural, generalizability, and interpretability validity. To ensure valid inferences from Rasch analysis, model assumptions of unidimensionality, item local independence, monotonicity of the latent trait, and nonintersecting item response curves were checked. Measurements of ICT user-skill levels obtained were then used in hypothesis testing relevant to this study. Assumptions for statistical tests, such as normality of the distribution were also investigated. The results of Rasch analysis for the main study and the statistical hypothesis tests were described in Chapter 4.

3.7.2 Instrument for Qualitative Data

In qualitative research, the researcher is essentially the instrument for data collection (Guba and Lincoln, 1981; Janesick, 2003; Patton, 2001). Qualitative study should be conducted in a natural and familiar setting, which in this case is the campus environment. Being a faculty member had enabled the researcher to be in close proximity with the research subjects in their natural learning environment to explore their subjective understanding and conception of the role of ICT skills in engineering learning. All the interviews were conducted by the researcher to minimize interviewer bias and ensure consistency in that questions were asked in the same way in all interview sessions.

3.8 Data Collection

Quantitative and qualitative data were collected to address the research questions and hypotheses. This study used concurrent data collection method based on quantitative and qualitative data collection procedures to fit the mixed method design. Quantitative and qualitative data were collected at the same time and were independent of each other. Qualitative data were used to validate quantitative data in the survey development process.

Data collection process comprises five phases namely, establishing the sampling procedures, obtaining permissions, identifying data sources, method of data recording, and data administration activities (Creswell, 2005). Sampling techniques for quantitative and qualitative data were detailed in Section 3.6.1 and 3.6.2 respectively. Each of the subsequent phases for quantitative and qualitative data is described in the following section.

3.8.1 Obtaining Permission

Research ethics require informed consent of participants. In this study, students were verbally informed that their participation as survey respondents and/or interviewees was voluntary. Generally, people who volunteer, tend to answer truthfully. Prospective participants were told of the expected duration for the survey and interview session. The survey instrument was enclosed with a cover letter describing the research purpose, how their input would contribute to the research, and an assurance of confidentiality. Permission was also sought from faculty members who were willing to distribute the questionnaires to the students to be taken either in class or after class. Interviewees were also told that the conversation and discussion would be recorded, and that they could withdraw if they did not agree with that. All informed consent was in oral form since this research had minimal risk.

To protect the confidentiality of participants, the amount of personal information was kept to the minimum. Demographics data only included those needed as research variables such as gender, engineering major and year of study. The survey form did not require students to write their names. Participants had the option to write their unique identity card number, but only the last four digits were keyed in. Names of interviewees were coded and the identifying list was kept separately from the transcription. Data in digital and hard copy form were only accessible to the researcher and a data entry assistant.

3.8.2 Data Sources

This study used the cross-sectional quantitative data collection strategy because the main emphasis was on the differences between groups based on gender, engineering specialization, and year of study. Quantitative data were gathered using the survey instrument developed for this study.

Qualitative data were obtained through face-to-face semi-structured group and one-on-one interviews. The format for interview design was standardized open-ended interview, in which the wording of the questions was highly structured but would yield open-ended responses (Gall *et al*., 2007). This design allows participants to fully express their opinions and experiences. However, narrative responses in open-ended interviewing would make extraction of similar themes from the transcription rather difficult (Creswell, 2007). The advantage of narrative responses, according to Gall *et al*. (2007) is that it would reduce researcher's biases within the study, especially when many participants were involved.

Three groups consisting of about five to seven third-year engineering students from civil, electrical and mechanical departments were formed. The number of group members selected was in accordance with the norm for group interview to get the advantage of time-saving without making the transcription of interview data too confusing (Daymon and Holloway, 2010).

Group interviews were used to explore the extent to which there was a relatively consistent conception and experience of using ICT skills among participants from the same engineering specialization and to compare the conception with those from other specializations. The advantage of group interview was it enabled more subjects than one-on-one interviews. A group of participants with similar characteristics tend to yield better quality data because there is less tendency for members to censor ideas (Krueger and Casey, 2009). However, group interview is not a reliable technique to assess a student's authentic point of view and there is less opportunity to clarify ambiguities. Thus three sessions of one-on-one interviews were conducted to obtain detailed perceptions and deeper insight of student's experience without the drawbacks of group dynamics such as the influence from other participants.

Both group and one-on-one interviews were semi-structured with an interview guide consisting of a set of standardized questions and topics to be covered during the conversation. However, the order in which questions were asked was not rigid, and was left to the discretion of the interviewer to suit the topics being discussed.

Interview data were used in early stage of the survey item development. After an initial item pool was generated from existing instruments and the literature on engineering problem-solving cycle, the terminology of ICT user-skills used was compared to ensure it would be understood by the study population. Conception of ICT user-skills among interviewees was compared with the pilot test internal consistency results to determine which items to cull in item refinement stage.

3.8.3 Method of Data Recording

Research data were collected and recorded for future reference and analysis purposes. Quantitative data collected via paper format questionnaires were keyed in a digital database of statistical software, SPSS, version 18. The entries were checked for typing error.

For qualitative data, an interview guide as shown in Appendix G was developed to structure the interview. The guide consists of the introduction, the name of the interviewer, date, time and venue of the interview, the semi-structured interview questions, and closing statements. Several checklist tables of main points that would be possibly mentioned were prepared to facilitate note-taking of the interviews. An example of a checklist is shown in Appendix H.

The interview guide lists four topics to be covered during conversations namely, the conception of ICT skills, the use of ICT skills in engineering learning, barriers to using ICT in engineering learning, and the suggestions on how the engineering curriculum can help improve ICT skills. The questions pertaining to each topic and the reasons for asking the questions are shown in Table 3.17. Questions were carefully written to avoid being vague, double-barreled or leading, containing double negatives or unfamiliar jargons or beyond respondents' capability to answer.

The interview was conducted in Bahasa Malaysia because the participants were more fluent in Bahasa Malaysia than English. Using a native language would allow the participants to express their thoughts more easily and reduce misunderstanding of the questions (Slobin, 1996). However many English terms were used as these terms were frequently used in daily conversation and in classes. Examples of these terms are *download, software*, and *install*. For reporting purposes, the conversations were fully translated into English. Probes were used to stimulate the interview and to seek further clarification or when the answer given was not sufficient. An example of a probe used during an interview to get more complete answer was:

Interviewer: *OK, firstly, what do you understand by the term ICT skills?*
Respondent: *Programming skills*
Interviewer: *Programming, OK,* ***what else? (Probe)***

Since discussions may diverge from the interview guide, the interviews were audio-taped and transcribed for analysis. Transcription is a vital aspect of qualitative inquiry because it can affect the way participants are perceived and understood (Oliver *et al.*, 2005). This study used denaturalized approach to transcribing which stresses on the substance of the interview. This means that while attempts were made for a verbatim transcription, more importance was put on the meanings and perceptions created during the conversations than on depicting involuntary vocalization. Denaturalized approached was taken for this study because of the nature of research that requires data on students' understanding and perceptions to answer the research questions. The transcripts were checked against the original audio recordings to ensure accuracy. This process helped the researcher to be familiar with the interview data, which is a key initial phase in the process of thematic analysis (Bird, 2005).

3.8.4 Data Administration Activities

For quantitative data, sets of questionnaires in paper format were distributed through faculty members and student representatives. To obtain convenience samples for pilot tests, questionnaires were distributed through faculty members who had given their consent. However, since stratified sampling method was used for the main study, student representatives were hired to distribute the questionnaires to potential participants. Each set included a cover letter explaining the purpose of the study and took about 15-20 minutes to be completed. Students who were in the pilot study group were excluded from the main study group. Completed questionnaires were returned to the researcher through faculty members or student representatives after about one week. To ensure consistency of understanding, the definition of ICT user-skills under examination was included in the cover letter of the questionnaire. An assistant was hired to key in the data and check against data entry errors before data were analyzed.

According to Creswell (2007), qualitative data administration involves interview preparation, pilot testing, and in-the-field activities of data collection. This includes proper planning for recruiting participants, setting up a comfortable layout with little distraction for the interview, preparing the form to facilitate note-taking, and locating the strategic position for the audio recorder. To recruit potential participants, initially a third-year student from each engineering discipline was selected randomly based on the list at the Student Record office. Upon consent of the selected student to be interviewed, more participants were identified by snowballing. Interview candidates were given the option to participate in a one-on-one or a group interview. Participants were briefed on the purpose of the research and ensured of the confidentiality of any sensitive information given out during the interview. The venue of all interviews was the researcher's office and sitting arrangement was informal circle seating to promote a relaxed conversational ambience.

A pilot test of the interview was conducted to detect flaws and weaknesses in the interview strategy and design. A third year student volunteered for the pilot one-on-one interview, and based on his responses, the clarity of the questions was assessed, the best position for the audio recorder was noted, the interviewee's facial expression and body language were observed to gauge his physical comfort. The interview duration was also noted.

Table 3.17: Interview topics and questions

Topic	Question	Purpose
Conception of ICT skills.	1. What do you understand by the term "ICT skills"?	To aid initial survey item selection and complement statistical fit analysis.
Experience of ICT skills use in engineering learning.	2. Give examples of the engineering courses in which you make significant use of your ICT skills. 3. What are some of the most important advantages of using ICT in engineering learning for you? 4. How does your usage of ICT skills in Year 1, 2 or 3 compare in terms of frequency and type of skills?	To explore in depth the extent of ICT experience during the course of study.
Barriers to using ICT in engineering learning	5. What are the major barriers you face in using ICT skills in engineering courses?	To complement and compare with survey data on the barriers to using ICT in engineering learning.
Suggestions on how the engineering curriculum can help improve ICT skills.	6. Which ICT skills do you feel you need to improve? Why? 7. Please give some suggestions on how the engineering curriculum can help improve ICT skills so that you can use those skills better in learning engineering.	To obtain suggestions based on students' experience.

3.9 Data Analysis

This study used both quantitative and qualitative data analysis methods to investigate and address the issues stated in the research questions.

3.9.1 Quantitative Data Analysis

Quantitative data were analyzed using statistical methods and Rasch analysis. Statistical analysis was done using the PASW Statistics Version 18, while Rasch analysis was performed using WINSTEPS 3.72. Analysis was performed on research variables to answer the research questions. Independent variables were student variables: engineering specialization, gender, year of study, and the frequency of performing engineering activities. Dependent variables were perceived ICT skill levels. The steps in statistical and Rasch analysis were described according to the research questions addressed.

3.9.1.1 Statictical Analysis

Generally, statistical analysis involves the steps shown in Table 3.18:

Table 3.18: Steps in statistical analysis

Step 1: Prepare the data for analysis by performing data cleaning: a) Detect errors, missing data, outliers b) Check for normality Step 2: Identify the research question to address. Step 3: Decide which variables in data set can be analyzed to answer the research question. Step 4: Decide what statistical analysis technique is appropriate. This depends on a number of factors: a) The number of variables involved: i) one variable – univariate analysis ii) two variables – bivariate analysis iii) more than two variables – multivariate analysis b) The measurement level of variables involved (nominal, ordinal, interval, ratio). c) Check the assumptions for the technique to determine appropriateness of the technique. d) Determine how to conduct the analysis using a statistical package. e) Perform the analysis. f) Interpret the results. g) Draw conclusion from the results. h) Relate the conclusions with the research question.

The statistical analyses done were to seek answers to the following research questions (RQs) detailed in Chapter 1:

RQ 3a): What are the characteristics of the study sample with respect to each of the following variables?

i) gender
ii) year of study
iii) engineering specialization
iv) computer ownership
v) internet access

vi) hours of computer use for

- study
- recreational activities

vii) where and how students acquire ICT skills.

viii) students' perceptions of the role of ICT skills in helping them learn in engineering courses.

Prior to conducting any statistical test, descriptive statistics were used to explore and clean the data for analysis. Missing values, outlying values, and data entry errors were identified. After ensuring the data were clean, univariate analyses were performed to describe the characteristics of variables such as frequency and percentages. Large amount of quantitative data were summarized using frequency and graphical representation to address RQ 1a.

RQ 3b): Is there an association between gender, year of study, and engineering specialization with each of the following variables?

i) computer ownership

ii) internet access

iii) hours of computer use for study

iv) hours of computer use for recreational activities

Crosstabulations of the variables were performed to determine the relationship between pairs of the categorical (gender, year of study, engineering specialization, computer ownership, and internet access) and ordinal variables (hours of computer use for study and recreational activities). If significant relationship exists, the strength of the relationship is indicated by several measures such as the contingency coefficient, phi and Cramers's V. Phi and Cramer's V can take on a value between -1 and +1. By convention, cut-off phi values of 0.1, 0.3 and 0.5 indicate small, medium and large effect size respectively (Cohen, 1988, 1992).

RQ 1): What are the components of the construct and the associated ICT user-skills for engineering learning used in the survey instrument?

Based on the review of various definitions of ICT user-skills including a description by UNESCO (2008a) described in Chapter 2, the components of the construct and the associated ICT user-skills for engineering learning were proposed. Based on the empirical data collected, principal component analysis (PCA) was performed to identify components of the scale by reducing the 16 scale variables into a small number of underlying components. PCA accounts for the total variance of the variables. Total variance is made up of variance explained by the components plus error variance not explained by the components. Prior to PCA, three tests were used to check whether the study data was suitable for principal component analysis (Gavin, 2008):

i) Kaiser-Meyer-Olkin measure of sampling adequacy (KMO-test: KMO > 0.5)
ii) Bartlett's test of spherity ($p < 0.05$)
iii) The determinant of the correlation matrix (Determinant > 0.00001)

KMO index indicates the adequacy of correlation matrices for PCA or factor analysis. KMO index is between 0 and 1, and measures the proportion of common variance among the variables. The higher the index, the more common variance is shared, indicating latent common factors, thus making PCA amenable. Bartlett's test of sphericity tests the hypothesis that the variables are independent. If the test is significant with alpha value < 0.05, then the variables are deemed to be independent, making PCA suitable. The problem of multicollinearity exists when it becomes difficult to separate the effects of significantly alike variables. This is indicated by the determinant of the correlation matrix being more than 0.00001 (Garson, 2008).

3.9.1.2 Rasch Analysis

The steps in Rasch analysis are shown in Table 3.19.

Table 3.19: Steps in Rasch analysis

Step 1: Identify the research question to address.
Step 2: Check the functioning of the rating scale.
Step 3: Select the appropriate Rasch model.
Step 4: Check data requirements for the model.
Step 5: Checking psychometric properties of the instrument:
i) Reliability
ii)Validity

Step 1: Identify the research questions to address.
The questions were RQ2, RQ 2a), RQ2b), RQ2c), RQ2d), and RQ2e).

RQ 2: What are the psychometric properties of the measurement instrument?
RQ 2a): To what extent is the rating scale effective in supporting the construction of measures?

Step 2: Check the functioning of the rating scale.

To determine the effectiveness of the rating scale, the following statistics (Linacre, 2002) were examined:

i) Item-measure correlations
ii) Number of observations in every response category
iii) Distribution of observations
iv) Order of category probability curves
v) Outfit MNSQ < 2.0
vi) 1.0 < threshold advance < 5.0

Step 3: Rasch model selection

Section 2.14.8 describes some of the more commonly used Rasch models. Each model has different assumptions regarding the scale structure of response options. A rating scale model consists of items with the same rating scale structure. A partial credit model has items with different rating scale structures, which would increase the parameter estimates since each item would have a separate parameterization for the rating scale. In practice, a simpler model with the same rating scale for all items and thus fewer parameters is usually preferred especially if the items use the same response format because it is easier to explain and can be understood better (Linacre, 2000).

The decision on which Rasch model to use in this study was made based on the criteria proposed by Van der Linden and Hambleton (1997) and Linacre (2000). Consequently, Andrich's rating scale model was chosen. The decision process is shown in Figure 3.7.

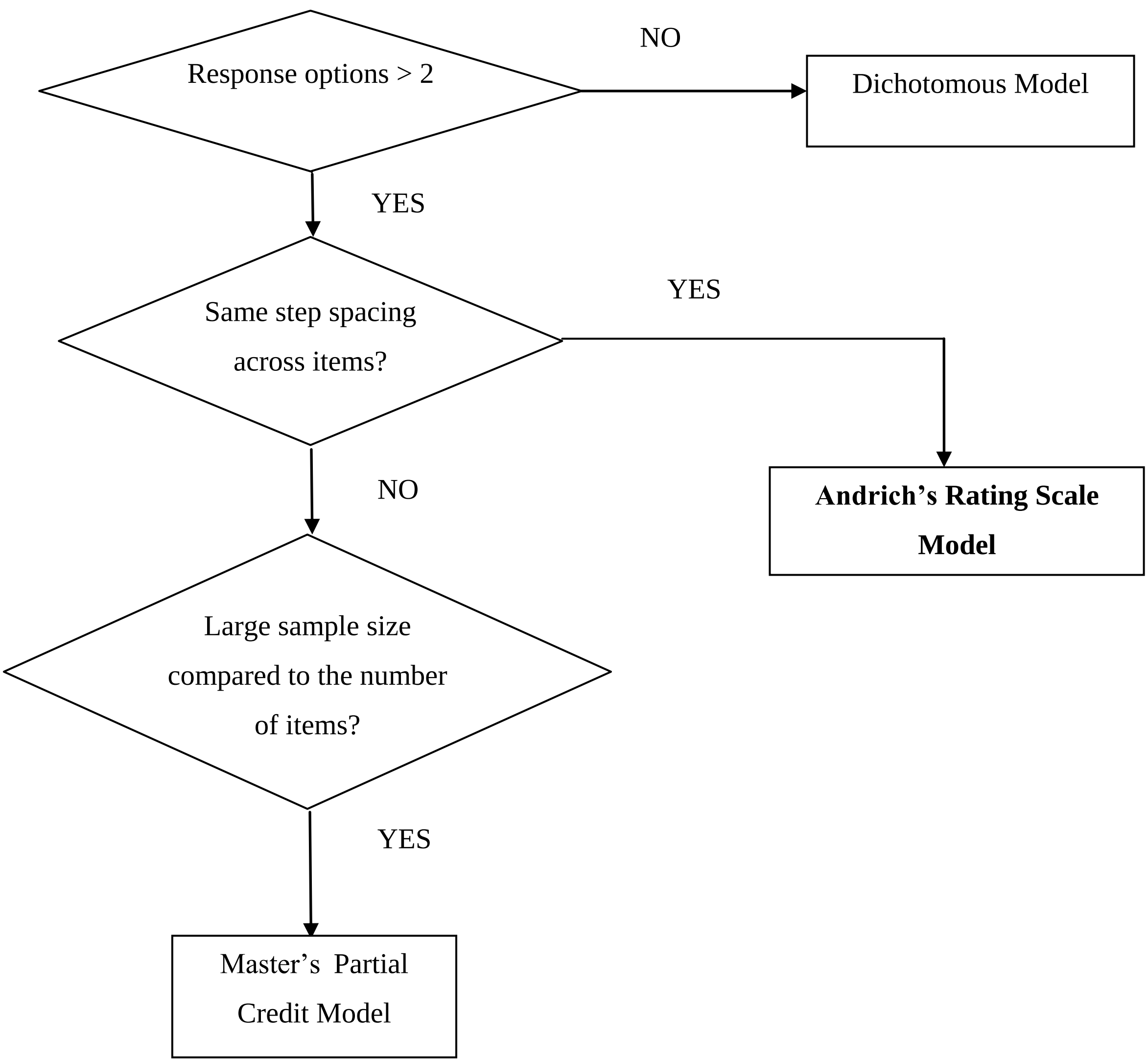


Figure 3.7: The decision chart to select the most appropriate Rasch model

The assumptions and specifications that must be satisfied before the benefits of the Rasch model can be realized are: i) unidimensionality, ii) local independence, iii) monotonicity of the latent trait, iv) nonintersecting item response curves, v) sample-free measurement, and vi) test-free measurement.

The procedures used to test each of the assumptions are as follows:

Unidimensionality

The measurement scale was examined for unidimensionality using the following criteria:

a) Not more than 5% of survey items misfit the Rasch model. Individual item fit was examined using the goodness-of-fit statistics, MNSQ and ZSTD Acceptable fit ranges are $0.7 < MNSQ < 1.3$, and $-2 < ZSTD < +2$ (Bond and Fox, 2007).

b) Based on the tentative guidelines in the Winstep manual (Linacre, 2009):

i) At least 50% of the variance should be accounted for by the first component after applying principal component analysis to the residuals of the model.

ii) The unexplained variance in the first contrast as indicated by the eigenvalue size, should be less than 2. This would indicate the variance is due to random noise. According to Fisher (2007), if unexplained variance in each of the five contrasts is between 5 and 10% then there is good evidence of unidimensionality.

iii) Simulation of the research data should show consistent results. Several sets of simulated data equivalent to the raw data were produced using Winsteps to investigate the stability of measures.

Local Independence

Items are locally independent if the items do not have significant covariance after accounting for the latent variable, and thus the residuals from model-based expectations should be uncorrelated or weakly correlated with correlation coefficient < 0.3 (Smith, 2002).

Monotonicity of the Latent Trait

In a Rasch measurement model, observations in higher categories must be produced by higher measures (Linacre, 2002). Thus, the average measures by category must advance monotonically up the rating scale. This means a person with a higher ability has a greater probability to respond correctly to a more difficult item than a person with a lower ability. Junker and Sijtsma (2000) showed that monotonicity holds for one parameter logistic models, which is quite similar to Rasch dichotomous model. To verify monotonicity of item characteristic curves (ICC), the graphs can be produced using Winsteps to depict the non-decreasing property.

RQ 2c): Does the instrument fulfill the criteria for face validity?

To establish face validity, the instrument was administered to a pilot study group of eleven engineering students and an information literacy expert who gave feedback on whether they perceive the questionnaire as a valid instrument to measure ICT user-skills for engineering learning.

RQ 2d): Does the instrument fulfill the criteria for construct validity?

Construct validity of the survey instrument was examined within the Rasch framework. Evidence of construct validity for this study was based on content, substantive, structural, generalizability, and interpretability aspects.

i) What are the evidences for the content aspect of validity?

To establish the content aspect of validity, ten experts in related fields such as instrument development, information literacy, ICT, engineering education, and engineering practice were consulted to give feedback on the relevance and representativeness of the content. The expert reviewers were asked to evaluate the relevance of individual items and the overall representativeness of the survey items of the full domain of ICT user-skills ability.

Reviewers filled up a validation form described in Section 3.6.1, and their feedback was analyzed quantitatively using content validity index (CVI). The experts rated the relevance of each item based on a 5-point Likert scale: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4(agree) and 5 (strongly agree). CVI was calculated at item and scale level. Item level CVI was calculated by the dividing the total number of experts who gave a 4 or 5 for an item, by the number of experts . To get an overall CVI for the scale, the item-level CVIs were averaged across all items.

In Rasch analysis, relevance is also indicated by item fit indices. Misfitting items may be measuring an irrelevant construct. To examine how well survey items represent ICT user-skills domain for engineering learning, item strata and person-item map (Wright map) were examined. The minimum number of item strata required to interpret the latent variable should be two (Smith, 2001).

The Wright map is a pictorial representation of the relationship between the difficulty of items and the ability of students. The Wright map has two vertical histograms placed side by side. Histogram on the left represents students, and the one on the right represents items. Students are ordered from the most able at the top to the least able at the bottom. Items are ordered from the rarest to be endorsed at the top to the most frequently endorsed at the bottom. Calibration of the logit ruler on the left is for student ability, where M denotes the mean ability, S is one standard deviation from the mean, and T is two standard deviations from the mean. Similarly, calibration on the right is for item difficulty. Each “X” on the left denotes a specified number of students and each “X” on the right denotes an item. Items which lie opposite students have a 50:50 chance of being endorsed by the students. Items located higher than students have less than 50:50 chance of being endorsed, and items located below the students have more than 50:50 chance of being endorsed.

Obvious gaps along the item difficulty axis in the Wright map indicate areas of the construct domain which have not been covered. Targeting of persons' ability by the survey items can be determined by examining three main parts of the Wright map: the tail of the distribution of persons, the tail of the distribution of items, and the location of the bulk of the persons relative to the location of the bulk of the items (Bond and Fox, 2007).

Technical quality of the instrument can be assessed by item fit estimates that demonstrate how well observed values match those predicted by the Rasch model. Graphical evidence of the fit is displayed by the item characteristic curves which relate the expected values for an item and the student ability measures. Observed values are plotted on the same graph. The closer the observed values are to the item characteristic curve (ICC), the better is the fit.

ii) What are the evidences for the substantive aspect of validity?

Substantive aspect of validity is indicated by student fit statistics which show to what extent a student's response pattern to the items conforms to model prediction and how similar the pattern is to the majority of responses. Misfitting persons do not show responses consistent with the item difficulties. However, only misfitting persons whose removal would make the fit statistics noticeably better should be removed (Linacre, 2010). Graphs of student frequency distributions between different groups can be used to compare the response patterns.

Another graphical evidence of substantive validity is the shape and ordering of the category probability curves for each item. The category probability curve relates student ability level with the probability of endorsing a response category for a particular item. The threshold order must concur with the theorized order of student ability levels to verify that responses were not made idiosyncratically.

iii) What are the evidences for the structural aspect of validity?

Structural aspect of validity of scale dimensionality can be ascertained by examining the item fit statistics and the distribution of the total variance across principal components.

iv) What are the evidences for the generalizability aspect of validity?

Generalizability aspect of validity is determined by checking the specific objectivity property of Rasch measures. This means item measures are independent of the samples used or across different populations, and student ability measures are invariant across different sets of items. Item measures that depend on the group of students are said to display differential item functioning (DIF). DIF can be depicted graphically by comparing the item characteristic curves of different groups. Significant differences in observed scores between the groups of students indicate DIF, in which case the scale does not have generalizabilty validity. DIF if significant if DIF size > 0.5 logit and if t-statistic > 2.0.

Invariance of item difficulty measures could be verified by dividing the students into two subgroups according to their ability. Then item calibrations could be produced using WINSTEPS for each subgroup. t-test could be performed to examine if there is a significant difference between the mean of the two sets of item calibrations.

Likewise, to verify the invariance of student ability measure, items could be divided into different subgroups according to the difficulty level. Then student abilities could be estimated using each subgroup of items. . t-test could be performed to examine if there is a significant difference between the mean of the two sets of student measures.

Another indicator of generalizability is the consistency of student measures across items given by the student separation index or the internal consistency reliability coefficient. A high value of student separation index indicates high consistency of student measure across items, and supports generalizability validity.

v) What are the evidences for the interpretability aspect of validity?

Another validity aspect assessed in this study is interpretability of measures. This means the extent to which item and student measures can be communicated clearly, both individually and as a group. Item map for students and items can be used to compare individual student ability and item difficulty by locating the respective position on the logit scale. The range of ability and difficulty can be observed easily from the map. The number of student skill levels and how well the item difficulty matched student ability can be affirmed in the map. A summary of the indicators or statistics used to inform each of the validity aspect above is presented in Table 3.20.

Table 3.20: Indicators of validity

Aspect of Construct Validity	**Indicators/ Statistics**
Content	Expert review: Content Validity Index (CVI > 0.8) Representativeness: Item Strata > 2 Technical quality: Fit statistics (0.7 < MNSQ < 1.3) (-2.0 < ZSTD < +2) Item-Measure Correlations > 0
Response process	Student frequency distribution (check if consistent with theory/hypothesis) Category probability curve Person fit statistics
Structural	Item fit statistics PCA of residuals Insignificant DIF for item and student measures (< 0.5 logit) Student separation index (internal consistency) > 0.8 DIF > 0.5 logit with t-statistic > 2.0
Interpretability	Interpretation of item map

RQ 2e): Does the instrument exhibit differential item functioning (DIF) with respect to:

i) gender

ii) year of study

iii) engineering specialization

To examine DIF, DIF analysis was performed with respect to the student variables: gender, year of study, and engineering specialization. According to (Bond and Fox, 2007), DIF Contrast < 0.5 is insignificant.

The evidences of construct validity of the instrument are presented in Chapter 4.

RQ 4a): Is there a significant difference of ICT user-skills ability between male and female students?

RQ 4b): Is there a significant difference of ICT user-skills ability between students in different engineering specializations?

RQ 4c): Is there a significant difference of ICT user-skills ability between students in different year of study?

RQ 5: What is the correlation between the perceived usefulness of ICT user-skills for learning and the frequency of performing engineering learning activities?

RQ 6: What is the correlation between the frequency of performing engineering learning activities and students' ICT user-skills ability?

RQ 7a): Are there significant differences in the frequency of performing engineering learning activities between male and female students?
RQ 7b): Are there significant differences in the frequency of performing engineering learning activities between students in different engineering specialization?
RQ 7c): Are there significant differences in the frequency of performing engineering learning activities between students in different year of study?

To answer research questions 3a) – 3i), 4a) – 4c), 5, 6, 7a) - 7c), statistical tests listed in Table 3.21 were performed.

RQ 9): What is the frequency distribution of students according to their ICT user-skills levels?

To obtain the frequency distribution of students according to their ICT user-skills levels, cut scores that separate the students into different ability categories must be determined. In this study, the cut scores were determined using the Bookmark method proposed by Wang (2003). This method uses item difficulty estimates produced by the Rasch model as the cut scores. For Andrich's rating scale model, the item difficulty estimates corresponding to the thresholds could be used as the cut scores. This method was selected because it utilized the Rasch estimates and as such did not require different concepts for standard setting.

Table 3.21: Statistical tests to answer research questions

Measurement	Independent Variable	Dependent Variable	Statistical Test
General Profile Information RQ 3a) 3b) 3c) : Frequency Distribution			
RQ 3d) Computer Ownership: Cross tabulation			
	Gender (nominal)	Computer Ownership (nominal)	Chi-square
	Year of study (ordinal)	Computer Ownership	Chi-square
RQ 3e) Internet access: Cross tabulation			
	Gender (nominal)	Internet access (nominal)	Chi-square
	Year of study	Internet access	Chi-square
RQ 3f) i) Hours of computer use for study RQ 3f) ii) Hours of computer use for recreation			
Test for Significant Difference	Gender (nominal)	Hours of computer use for study (ordinal)	Wilcoxon-Mann Whitney test
Test for Significant Difference	Year of study (ordinal)	Hours of computer use for study) (ordinal)	Kruskal Wallis
Test for Significant Difference	Eng. Discipline (nominal)	Hours of computer use for study (ordinal)	Wilcoxon-Mann Whitney test
Frequency: RQ 3g) where and how students acquire ICT skills RQ 3h) students' perceptions of the role of ICT skills in engineering learning. RQ 3i) the problems faced in improving ICT skills.			

t-test and Kolmogorov-Smirnov test: RQ 4a): Is there a significant difference of ICT user-skills ability between male and female students?
Kruskal Wallis/ANOVA: RQ 4b): Is there a significant difference of ICT user-skills ability between students in different engineering specialization? RQ 4c): Is there a significant difference of ICT user-skills ability between students in different years of study?
Spearman's rank correlation: RQ 5**:** What is the correlation between the perceived usefulness of ICT user-skills for learning and the frequency of performing engineering learning activities? RQ 6: What is the correlation between the frequency of performing engineering learning activities and students' ICT user-skills ability?
Cross tabulation /Chi-square/Kruskal Wallis test: RQ 7a): Are there significant differences in the frequency of performing engineering learning activities between male and female students? RQ 7b): Are there significant differences in the frequency of performing engineering learning activities between students in different engineering specializations? RQ 7c): Are there significant differences in the frequency of performing engineering learning activities between students in different years of study?

3.9.2 Qualitative Data Analysis

Qualitative approach was chosen to explore and gain insight into students' conception and experience of using ICT skills in engineering courses, the perceived benefits of using ICT skills, the barriers faced in acquiring the skills, and the ICT skills which need to be improved. The main purpose of using qualitative approach in this study was to aid in various stages of instrument development and to obtain a rich contextual description of how ICT skills support their engineering learning experience. Qualitative approach also allows flexibility for the researcher to evoke contextually rich explanatory responses that are meaningful to the participants, and which might be unanticipated by the researcher (Mack *et al*., 2005).

This section details the steps taken to address the research questions that require qualitative data. Qualitative data for this study were obtained using a series of semi-structured interviews. Interview data were collected and analyzed concurrently with the quantitative data.

RQ 7a): What is engineering students' conception of ICT skills?

RQ 7b): What are the benefits of using ICT for engineering learning?

RQ 7c): What are the problems encountered in using ICT for engineering learning?

To answer RQs 7a), b), and c), a thematic analysis of interview transcriptions was carried out. Thematic analysis is a method of producing explicit structures and meanings that a participant embodies in an interview transcription (Gavin, 2008). It involves the process of identifying, analyzing, and reporting themes within data (Braun and Clarke, 2006). A theme is a group of linked categories with similar meanings that emerge through a recursive process of reading through text. Themes are identified and are progressively integrated into higher order themes.

Thematic analysis was selected to describe the patterns of qualitative data in this study to generate a plausible theory of a phenomenon that is grounded in the data. This is achieved through re-reading the data to identify recurring themes, which will be grouped into relevant and meaningful categories to arrive at the core concepts that link them together (Goulding, 1999; Strauss and Corbin, 1998). In this study, thematic analysis was used to examine students' conception of ICT literacy and to describe their experience of using ICT skills in engineering learning.

Some important pre-analysis decisions were made with regard to the key issues in thematic analysis. These included the definition of what counts as a theme, whether the analysis would produce a rich description of the entire data set or a detailed account of one particular aspect, whether to perform inductive or theoretical analysis, whether the themes would be identified at semantic or latent level (Boyatzis, 1998a), and which paradigm would be used for the analysis.

In this study, what constitutes a theme depends on whether the data relate to the research question, and the number of instances of data that display evidence of the theme does not necessarily mean the theme is more important, and vice-versa. Prevalence of a theme was counted in terms of the number of interviewees who mentioned the theme across the whole data set.

Thematic analysis was used in this study to provide detailed account of the themes across the entire data set related to the research question, specifically students' conceptual understanding of ICT literacy and their experience of utilizing ICT skills in engineering courses. The approach taken to identify the themes depended on the purposes of the research questions. To examine students' conception of ICT literacy, the theoretical approach was taken. Using this approach, data coding was guided by a coding template developed a priori based on the definition of ICT literacy. A coding template served as a data management tool to organize similar and related text for analysis (Crabtree and Miller, 1999). However the template was flexible enough to include other themes.

To describe students' experience, the inductive or data-driven approach was taken. In this approach, themes were identified based on the data collected without referring to any pre-determined coding template or researcher's preconceptions. In both cases, themes were identified at the semantic level within the explicit meanings of the data that convey ideas, assumptions and conceptualization of ICT literacy. Data patterns were examined and interpreted in terms of their significance and implications in relation to the literature.

Braun and Clarke (2006) proposed a recursive six-phase process of thematic analysis described in Table 3.22. The process starts with identifying patterns of meaning and issues of potential interest in the data, generating codes, sorting the codes into overarching themes, and ends with the reporting of the meanings of the themes in the data. Codes refer to the most basic meaningful element of the raw data and can be induced from the data (Boyatzis, 1998b). Crabtree and Miller (1999) outlined the deductive a priori template of codes approach. In this study, a hybrid approach which combines data-driven codes and a priori template of codes was used. This was because it could incorporate the concept of ICT literacy while allowing new themes to emerge based on the data.

According to Boyatzis (1998b), the coding process involves recognizing an important instance and encoding it for interpretation and analysis. A template of codes or a code manual based on the UNESCO definition of ICT literacy was set up to organize instances or segments of text which provided the evidence for the credibility of the study. Each code had two attributes: The code name and the description of the theme.

Table 3.22: Phases of thematic analysis

Phase	Description of the Process
1. Become familiar with the data.	Transcribe interview data and read it repeatedly before coding to get initial ideas. Identify interesting points and possible patterns of the data.
2. Generate initial codes.	Develop the code manual. Reread text line by line. Identify the most basic meaningful elements of data to produce more codes. Use the code manual to collate data relevant to each code.
3. Search for themes.	Connect and organize the codes into broader groups or themes.
4. Review themes.	Check the different themes. Data within themes have coherence in meaning. Data between themes have distinct distinguishing features. Draw a thematic map.
5. Define and label themes.	Give clear definition of themes and identify the interesting essence of each theme in relation to the research question. Name the theme to reflect its gist.
6. Corroborate and legitimize coded themes.	Highlight the merit and credibility of analysis through sufficient evidence of themes within the data to confirm the findings.

Analysis and interpretation of the interview data would go beyond the surface of the data and would discuss important issues related to the research questions. Issues include the meaning of each theme, the assumptions underlying each theme, the implications of the theme, what learning environment and conditions are likely to have given rise to the theme, and the overall account the different themes reveal about students’ conceptualization and experience of using ICT user-skills in engineering learning.

RQ 1: What are the components of the ICT user-skills construct and the associated ICT user-skills for engineering learning?

To answer RQ 1, several steps were taken. First, an extensive literature review on the concept of ICT literacy and the various definitions of ICT user-skills was performed. The review was presented in Section 2.2. This was followed by a review of the engineering disciplines, the skills that engineering graduates should possess, and the engineering learning outcomes recommended by MEEM and ABET as described in Section 2.4, 2.6, and 2.7. Then the ICT skills incorporated in existing instruments related to the general use of ICT skills among university students were identified, as detailed in Section 2.13. The combination of these steps yielded the list of ICT user-skills for engineering learning used in this study.

A job analysis using task inventory approach based on engineering problem-solving cycle was performed to generate survey items specifically related to engineering activities. This was detailed in Section 2.8 and 2.9. How these items relate to engineering learning outcomes was discussed in Section 2.11. These items were later verified by practicing engineers and the validation process was described in Section 3.7.1.

Peer debriefing is one of several ways that can be used to evaluate the trustworthiness of qualitative findings (Braun and Clarke, 2006). In this study, peer debriefing was used to provide an independent analysis of the interview data from the perspective of a peer who could give input on how well the themes cover data, and to compare the way data were labeled and sorted. The peer debriefer selected for this study had an engineering background with over twenty-years of experience working in ICT industry and was familiar with qualitative research.

3.10 Operational Framework

Research activities for this study are depicted in an operational framework as shown in Figure 3.8. This framework is an integration of the major phases in the study using the mixed methods research design described in Figure 3.1. The relevant figures and tables are put together in the operational framework to convey a complete overview of the phases, steps and activities involved.

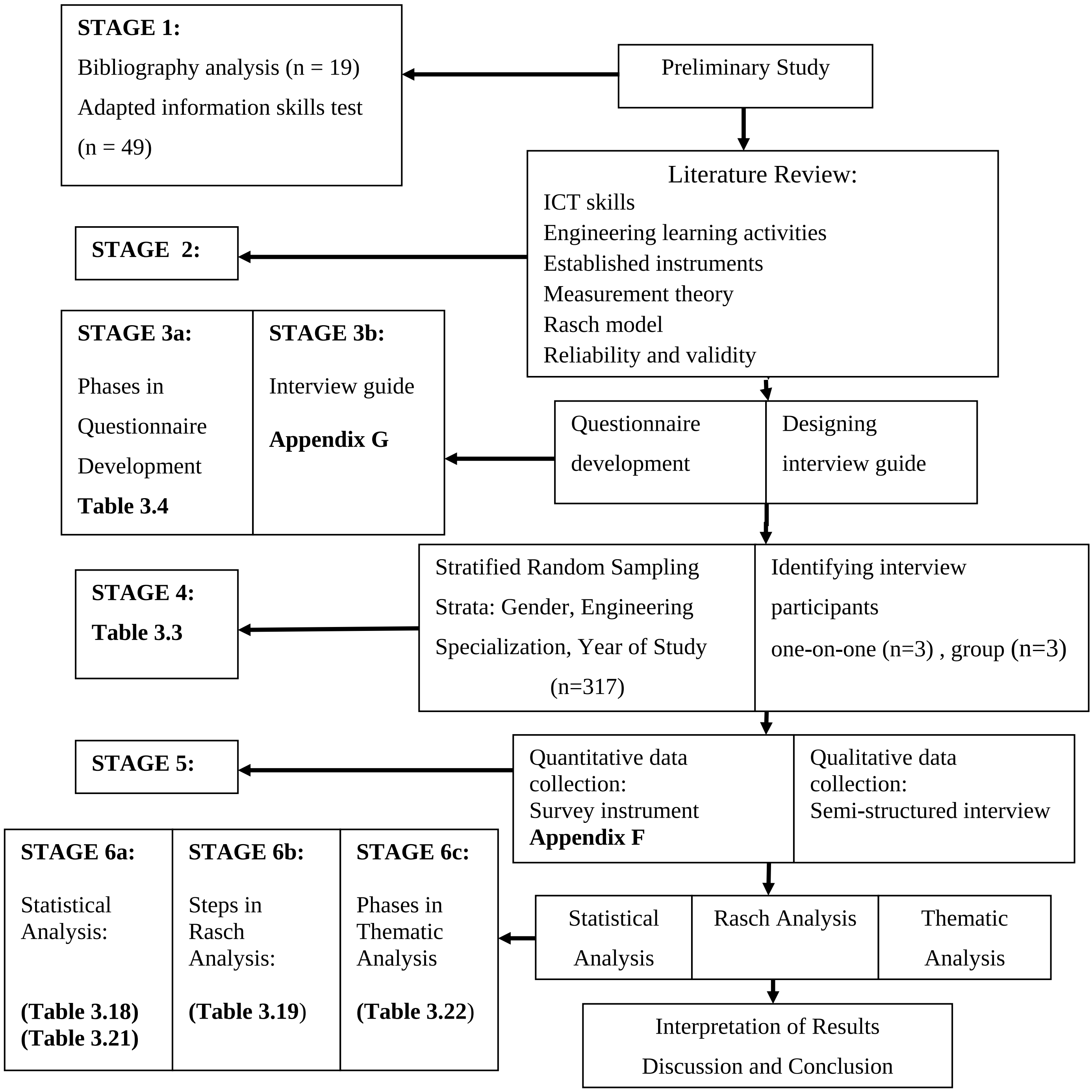


Figure 3.8: Operational framework of the study

3.11 Summary of the Chapter

This chapter details the methodology which comprises the research design, description of the study setting, research participants, sampling techniques and sample size selection, instrument development and validation process, quantitative and qualitative data collection methods, and methods of data analysis for the study. The operational framework details the research activities undertaken to address the specific research questions posed in Chapter 1 pertaining to the profiling of students' ICT user-skills and the development and validation of the psychometric properties of survey instrument.

CHAPTER 4

RESULTS

4.1 Introduction

This chapter presents the findings from the main study data. It also presents the results of the examination on data requirements and test assumptions prior to conducting various analyses using the main study data. The results of quantitative analysis comprising both descriptive and inferential statistics are described, followed by the results of qualitative analysis based on student interviews. Results of the main study analyses conducted in every stage of the research process are presented sequentially according to the research questions.

4.2 Main Study Data Preparation

Prior to performing statistical analysis, the main study data (N = 317) were explored to detect data entry errors and missing values. To check against data entry errors, every entry was checked at least twice. Only questionnaires with minimal missing data were selected to allow comparison of results using a common base, and to reduce the problem of biased estimates and distortion of statistical power which could lead to invalid conclusions (Von Hippel, 2004; Little and Rubin, 2002). Table 4.1 and Table 4.2 show the partial results of exploring the data to check for missing values and to test for normality.

From Table 4.1, it can be seen that the variables have 100% valid responses with no missing values. In CTT analysis, missing values must be taken care of using one of several methods before data analysis can be performed to avoid biased estimates. One method is by doing listwise deletion whereby incomplete cases are deleted from analysis.

Table 4.1: Case processing summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
IC No	317	100.0%	0	.0%	317	100.0%
Course	317	100.0%	0	.0%	317	100.0%
Gender	317	100.0%	0	.0%	317	100.0%
Age	317	100.0%	0	.0%	317	100.0%
Year of Study	317	100.0%	0	.0%	317	100.0%
Own a computer	317	100.0%	0	.0%	317	100.0%

Normality tests are important to determine whether parametric or non-parametric data analysis methods are more appropriate. An example of the hypotheses for testing for normality:

Null hypothesis, H_0: The distribution of C2_1 is normal.

Alternative hypothesis, H_1: The distribution of C2_1 is not normal.

From Table 4.2, since the p-value is 0.00, H_0 is rejected. Thus the distribution of C2_1 varies significantly from normal distribution.

Normality tests for other variables were conducted in the same manner.

Table 4.2: Tests of normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
C2_1_defining req info for eng problem	.212	317	.000	.892	317	.000
C2_2_using a comp to access eng data efficiently	.199	317	.000	.904	317	.000
C2_3_using info effectively to solve eng prob	.205	317	.000	.900	317	.000
C2_5_using graphics&charting tools in Excel,MATLAB or SPSS to perform statistical analysis	.209	317	.000	.889	317	.000
C2_6_using programming languages to dev s/ware to solve eng probs	.233	317	.000	.879	317	.000

a. Lilliefors Significance Correction

4.3 Findings of Quantitative Analysis

Research findings related to the research questions are described accordingly.

4.3.1 Characteristics of Study Sample

RQ 3a): What are the characteristics of the study sample with respect to each of the following variables?

i) gender
ii) year of study
iii) engineering specialization

iv) computer ownership

v) internet access

vi) hours of computer use for

- study
- recreational activities

vii) where and how students acquire ICT skills.

viii) students' perceptions of the role of ICT skills in helping them learn in engineering courses.

The study sample of 317 students selected by stratified random sampling based on gender, year of study and engineering specialization represented about 38% of the student population at CST in 2009. Exploration of the data yielded the statistics on the characteristics of the study sample as shown in Table 4.3.

The majority of the students are male, which is common in engineering programmes. The mean age is 19.3 years because these are full-time students who joined the college right after finishing high school. About 45% of the students in the study sample were in the third year, while about 29% and 26% were in the first and second year respectively. Most of the students specialize in electrical/electronic engineering. Over 80% of the student sample owned a personal computer or laptop, and most of them have internet access at all times. About 50% of the students spent less than 3 hours per week using the computer for study. Most students spent more hours on the computer for recreation than for study. The number of hours used for study and recreation using the computer is shown in Figure 4.1 and Figure 4.2.

Table 4.3: Study sample characteristics

Demographic Variables	Count (Percentage)
Age Mean = 19.3, Standard deviation = 1.09 Minimum = 18; Maximum = 24	
Year of Study	
Year 1	93 (29.3)
Year 2	81 (25.6)

Year 3	143 (45.1)
Engineering Specialization	
Civil	46 (14.5)
Electrical	173 (54.6)
Mechanical	98 (30.9)
Computer Ownership	
Yes	257 (81.1)
No	60 (18.9)
Internet Access	
Yes	220 (69.4)
No	97 (30.6)
Hours of Computer Use for Study	
< 1 hr	35 (11.0)
1– 3 hrs	128 (40.4)
4 – 6 hrs	72 (22.7)
7 – 10 hrs	37 (11.7)
11 - 15 hrs	13 (4.1)
16 - 20 hrs	13 (4.1)
> 20 hrs	19 (6.0)
Hours of Computer Use for Recreation	
< 1 hr	10 (3.2)
1– 3 hrs	75 (23.7)
4 – 6 hrs	77 (24.3)
7 – 10 hrs	53 (16.7)
11 - 15 hrs	33 (10.4)
16 - 20 hrs	25 (7.9)
> 20 hrs	44 (13.9)
Where and How Students Acquire ICT Skills:	
Information skills class conducted by UTM PSZ	64 (20.2)
ICT courses in UTM other than by PSZ	68 (21.5)
ICT courses/workshops/seminars outside UTM	78 (24.5)
Self-learning using manuals and handbooks	239 (75.4)
Taught by friends and family	283 (89.3)

Problems Faced in Acquiring ICT Skills:	
Finding the right time	273 (86.1)
Courses are expensive	230 (72.6)
No suitable ICT courses	148 (46.7)
No credit given for the optional ICT courses	173 (54.6)

Most students acquire ICT skills through self-learning (75.4%) and learning from friends and family (89.3%) rather than from formal courses. Many faced the problems of finding the right time (86.1%) and costly courses (72.6%) in acquiring ICT skills.

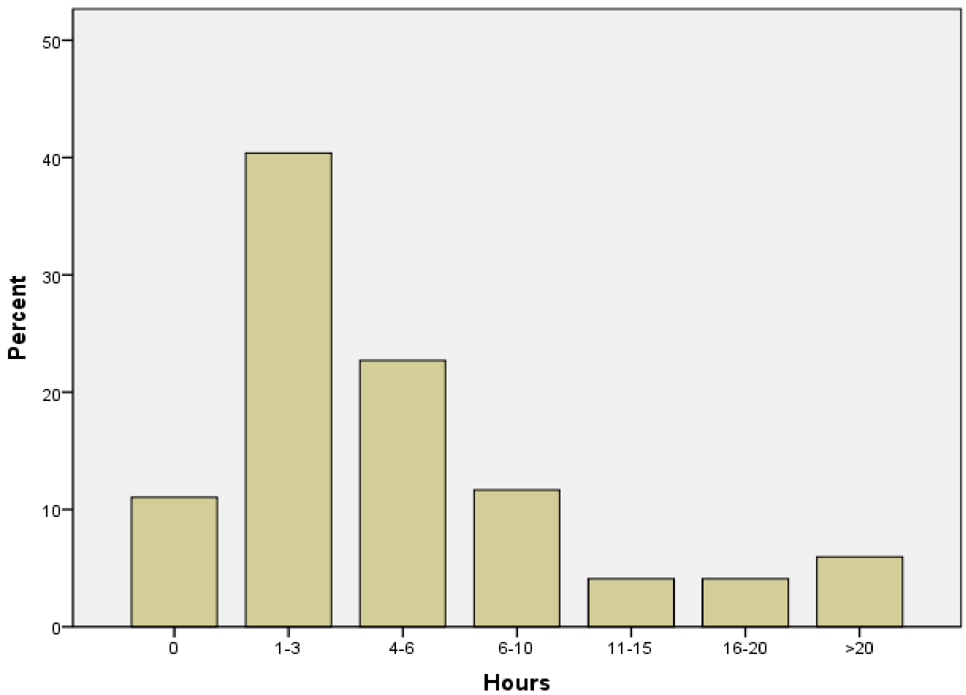


Figure 4.1: Hours of study using a computer

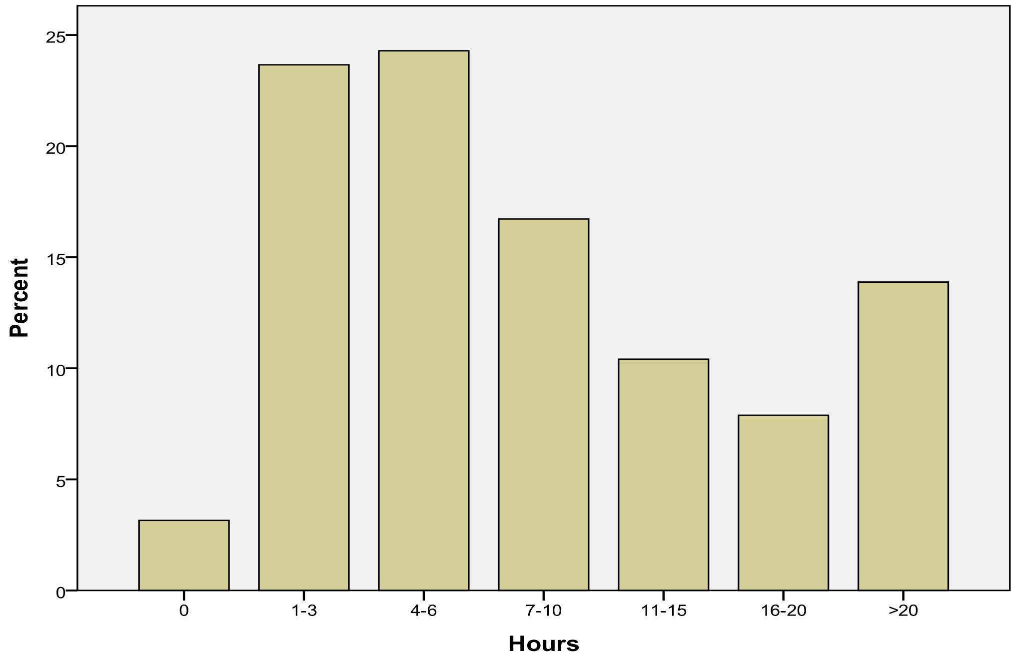


Figure 4.2: Hours of recreation using a computer

Table 4.4 summarizes students' perceptions on how ICT skills support engineering learning. More than 50% of students agree or strongly agree that ICT makes learning more interesting, helps in conducting better research, facilitates communication with course mates, encourages independent learning, and creates awareness of professional ethics and legal issues.

Table 4.4: Perceptions on the role of ICT in engineering learning

	How ICT Skills Support Engineering Learning	Strongly Disagree	Disgree	Somewhat Agree	Agree	Strongly Agree
1.	Understand engineering concepts better.	7 (2.2)	44 (13.9)	126 (39.7)	119 (37.5)	21 (6.6)
2.	Makes the courses more interesting.	6 (1.9)	29 (9.1)	79 (24.9)	159 (50.2)	44 (13.9)
3.	More active participation in courses	7 (2.2)	48 (15.1)	137 (43.2)	110 (34.7)	15 (4.7)
4.	Makes learning more convenient.	18 (5.7)	52 (16.4)	113 (35.6)	121 (38.2)	13 (4.1)
5.	Can manage course activities better.	7 (2.2)	56 (17.7)	122 (38.5)	113 (35.6)	19 (6.0)
6.	Can do better research work in courses.	8 (2.5)	17 (5.4)	73 (23.0)	152 (47.9)	67 (21.1)
7.	Get prompt feedback on my course performance.	11 (3.5)	39 (12.3)	124 (39.1)	127 (40.1)	16 (5.0)
8.	Communicate better with course mates.	8 (2.5)	17 (5.4)	73 (23.0)	152 (47.9)	67 (21.1)
9.	Encourage independent learning.	14 (4.4)	18 (5.7)	105 (33.1)	140 (44.2)	40 (12.6)
10.	Awareness of professional ethics and legal issues.	9 (2.8)	24 (7.6)	118 (37.2)	124 (39.1)	42 (13.2)

4.3.2 Association between Student Variables

RQ 3b): Is there an association between gender, year of study, and engineering specialization with each of the following variables?

i) computer ownership
ii) internet access
iii) hours of computer use for study
iv) hours of computer use for recreational activities

To examine if association exists among categorical and ordinal variables, crosstabulations were performed. But prior to that, the assumptions required for the analysis were examined:

1. Unbiased sample. This assumption was met because of the random sampling design of the study.
2. The observations are independent of each other. This was met because the sampling of one observation was not dependent on the sampling of another observation. This can be proven objectively using test for independence.
3. Row and column variable categories are mutually exclusive and include all observations.
4. No expected frequency should be less than 1 and no more than 20% of the expected frequencies should is less than 5. This assumption was met because all expected frequencies were > 5.

A two-way contingency table analyses were done to answer RQ 3b i), ii) and iii). Null hypotheses state that there is no association between every pair of the variables above, while the alternative hypotheses state the contrary. An example of null and alternative hypotheses:

Null hypothesis (H_0): There is no association between gender and computer ownership.
Alternative hypothesis (H_1): There is an association between gender and computer ownership.

Cross-tabulation between gender and computer ownership produced the results shown in Table 4.5 and Table 4.6.

Table 4.5: Gender * computer ownership cross tabulation

			Own Computer		Total
			yes	no	
Gender	male	Count	173	49	222
		Expected Count	180.0	42.0	222.0
		% within Gender	77.9%	22.1%	100.0%
	female	Count	84	11	95
		Expected Count	77.0	18.0	95.0
		% within Gender	88.4%	11.6%	100.0%
Total		Count	257	60	317
		Expected Count	257.0	60.0	317.0
		% within Gender	81.1%	18.9%	100.0%

Table 4.6: Effect size measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.123	.029
	Cramer's V	.123	.029
N of Valid Cases		317	

The result a of chi-square test on the association between gender and computer ownership yields a Pearson chi-square test statistic of 4.77 with 1 degree of freedom and p-value = 0.029 < 0.05. The strength of the association is 0.123. Thus, there is a significant association between gender and computer ownership with a small effect size.

A summary of crosstabulation results between pairs of variables in RQ 3a) is given in Table 4.7.

Table 4.7: Summary of cross tabulation results

Crosstabulation	χ^2	Degree of Freedom	p-value	phi	Conclusion
Gender * Computer Ownership	4.774	1	0.029	-0.123	Reject H_0
Gender * Internet Access	4.609	1	0.032	-0.121	Reject H_0
Gender * Hours of Computer Use for Study	16.292	6	0.012	0.227	Reject H_0
Gender * Hours of Computer Use for Recreation	14.567	6	0.024	0.214	Reject H_0
Year of Study * Computer Ownership	8.159	2	0.017	0.16	Reject H_0
Year of Study * Internet Access	5.238	2	0.073	0.129	Do not reject H_0
Year of Study * Hours of Computer Use for Study	40.614	12	0.000	0.358	Reject H_0
Year of Study * Hours of Computer Use for Recreation	23.741	12	0.022	0.274	Reject H_0
Engineering Specialization * Computer Ownership	4.724	2	0.094	0.122	Do not reject H_0
Engineering Specialization * Internet Access	5.761	2	0.056	0.135	Do not reject H_0
Engineering Specialization * Hours of Computer Use for Study	7.346	12	0.834	0.152	Do not reject H_0
Engineering Specialization * Hours of Computer Use for Recreation	12.559	12	0.402	0.199	Do not reject H_0

Based on the crosstabulation output, association exists between:

i) Gender and Computer Ownership
ii) Gender and Internet Access
iii) Gender and Hours of Computer Use for Study
iv) Gender and Hours of Computer Use for Recreation
v) Year of Study and Computer Ownership
vi) Year of Study and Hours of Computer Use for Study
vii) Year of Study and Hours of Computer Use for Recreation

4.3.3 Components of ICT User-Skills Construct and Related Learning Activities

RQ 1: What are the components of the construct and the associated ICT user-skills for engineering learning?

Based on the review of various definitions of ICT user-skills including a description by UNESCO (2008a) described in Chapter 2, the components of the construct and the associated ICT user-skills for engineering learning were proposed in Table 4.12. The components are:

i) The ability to use general-purpose software for engineering learning (8 items).
ii) The ability to use engineering software (7 items).
iii) The ability to use information skills for engineering learning (5 items).

However, the results of two pilot tests showed four activity items might have to be deleted to improve the internal consistency reliability of the proposed scale. These were:

i) Using E-learning system to support classroom learning of engineering courses.
ii) Using simulation software eg. Electronics Workbench, SIMULINK to experiment with models of engineering systems.
iii) Using engineering packages eg. StarCD to collect data.
iv) Using project management software eg MS Project to manage an engineering project.

However, items should not be dropped only because they do not fit the Rasch model (Bohlig *et al.*, 1998). Further investigation is required to determine whether the remaining items represent the domain of ICT user-skills for engineering learning in context of the population under study. First, the frequency of performing each the four activities was analyzed. Then thematic analysis of student interview transcriptions was done to explore their conception of ICT skills and the extent to which learning of the skills have been constructed through their experience of using those skills. The convergence of the quantitative and qualitative findings would be discussed in Chapter 5.

The frequency of each of the four activities above is shown in Table 4.8, Table 4.9, Table 4.10, and Table 4.11.

Table 4.8: Frequency of using e-learning system

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	never	26	8.2	8.2	8.2
	rarely	88	27.8	27.8	36.0
	once per month	71	22.4	22.4	58.4
	once per week	82	25.9	25.9	84.2
	2-3 times per week	43	13.6	13.6	97.8
	everyday	7	2.2	2.2	100.0
	Total	317	100.0	100.0	

Table 4.9: Frequency of using simulation software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	never	79	24.9	24.9	24.9
	rarely	83	26.2	26.2	51.1
	once per month	65	20.5	20.5	71.6
	once per week	50	15.8	15.8	87.4
	2-3 times per week	32	10.1	10.1	97.5
	everyday	8	2.5	2.5	100.0
	Total	317	100.0	100.0	

Table 4.10: Frequency of using engineering data collection packages

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	never	141	44.5	44.5	44.5
	rarely	72	22.7	22.7	67.2
	once per month	46	14.5	14.5	81.7
	once per week	33	10.4	10.4	92.1
	2-3 times per week	20	6.3	6.3	98.4
	everyday	5	1.6	1.6	100.0
	Total	317	100.0	100.0	

Table 4.11: Frequency of using project management software

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	never	134	42.3	42.3	42.3
	rarely	71	22.4	22.4	64.7
	once per month	47	14.8	14.8	79.5
	once per week	41	12.9	12.9	92.4
	2-3 times per week	17	5.4	5.4	97.8
	everyday	7	2.2	2.2	100.0
	Total	317	100.0	100.0	

Table 4.12: Proposed components of ICT user-skills ability construct and related activities

Construct	Activities using User-Skills
Ability to use general-purpose software for engineering learning.	Using E-learning system to support classroom learning of engineering courses.
	Using software eg. MS-Word to write a well-formatted engineering project report.
	Using video technology to record engineering projects, field trips, demonstrations etc.
	Making multimedia presentations of engineering projects.
	Using files to share information between project teams.
	Communicating through the Internet eg email, chat, forum with project members.
	Using the internet to gain knowledge of contemporary issues in an engineering discipline.
	Using the internet to gain knowledge of engineering professional codes of ethics and legal issues.
Ability to use engineering software.	Using simulation software eg. Electronics Workbench, SIMULINK to experiment with models of engineering systems eg. to replicate the behavior of an electronic device.
	Using graphics and charting tools in Excel, MATLAB or SPSS to perform statistical analysis of engineering systems.
	Using programming languages to develop software to solve engineering problems.
	Using application software eg AutoCAD and

	MATLAB to design engineering systems.
	Using software eg Excel, Maple, MathCAD to solve engineering mathematical problems.
	Using engineering packages eg. StarCD to collect data.
	Using project management software eg MS-Project to manage an engineering project.
Ability to use information skills for engineering learning.	Defining the required information for an engineering problem.
	Using a computer to access engineering data.
	Using information in problem solving.
	Evaluating engineering information on the websites.
	Using information ethically and legally.

The four items comprising the activities of using e-learning, simulation software, data collection software, and project management software are likely candidates to be dropped because of their poor item fit indices. However, the decision would also depend on the analysis results of the interview data regarding students' conception of ICT user-skills and actual experience and practice of those skills. The corroboration of the quantitative and qualitative results would be discussed in Chapter 5.

Using data of the remaining 16 ICT user-skills items, principal component analysis was conducted to identify the components of the ICT user-skills construct and to compare the resulting components with those suggested by the literature. However, since the data used for PCA analysis were raw category self-reported scores which were not measures of ability, this analysis was done only as a comparison of the structure of the scale between the CTT approach and the Rasch model , and not to be used in subsequent analysis.

Prior to conducting PCA, these assumptions (Gavin, 2008) were checked and found to be satisfied:

i) Kaiser-Meyer-Olkin measure of sampling adequacy (KMO-test: KMO = 0.939 > 0.5)
ii) Bartlett's test of spherity ($p = 0.00 < 0.05$)
iii) The determinant of the correlation matrix (Determinant = 0.0000542 > 0.00001)

PCA extracted two components, and the component on which the item loadings were higher is shown in Table 4.13. The rotation method used was Varimax with Kaiser Normalization. The rotation converged in 3 iterations. The structure of a small number of components compared to the number of individual items makes the construct easier to understand. Based on the PCA results, the two components of ICT user-skills construct are:

i) Ability to use general-purpose software and information skills (12 items).
ii) Ability to use engineering software (4 items).

PCA combined the component *Ability to use general-purpose software for engineering learning* with the component *Ability to use information skills* into one. These two components explained 60.4% of the total variance. However, since it could be proven that the items form a unidimensional scale, the items were grouped in accordance with the UNESCO (2008a) definition to differentiate between the ability to use general-purpose software such as Microsoft Word and information skills such as evaluating the authority of a website.

Table 4.13: Components of the ICT user-skills construct

Item Number		Component 1	Component 2
1	C2_1_defining required information for an engineering problem	.541	
2	C2_2_using a computer to access engineering data efficiently	.622	
3	C2_3_using info effectively to solve engineering problem	.581	
4	C2_5_using graphics & charting tools in Excel,MATLAB or SPSS to perform statistical analysis		.769
5	C2_6_using programming languages to develop software to solve engineering problems		.778
6	C2_7_using application software eg AutoCAD to design eng systems		.716
7	C2_8_using software eg Excel, Maple, MathCAD to solve mathematical problems		.785
8	C2_11_evaluating engineering information on websites	.709	
9	C2_12_using information ethically and legally	.589	
10	C2_14_using software eg MS-Word to write a well-formatted engineering project reports	.621	
11	C2_15_using video technology to record,field trips and demonstrations	.557	
12	C2_16_making multimedia presentations	.665	
13	C2_17_using files to share info between project team members	.796	
14	C2_18_communicating via Internet eg email,chat, forum	.820	
15	C2_19_using internet to search for contemporary issues in engineering	.759	
16	C2_20_using internet get information about professional codes of ethics& legal issues	.632	

4.3.4 Psychometric Properties of ICT User-Skills Measurement Instrument

RQ 2: What are the psychometric properties of the measurement instrument?

a) To what extent is the rating scale effective in supporting the construction of measures?

4.3.4.1 Rating Scale Effectiveness

There were five response categories for the ICT user-skills scale: 1(Not at all skilled), 2 (Not very skilled), 3 (Moderately skilled), 4 (Very skilled) and 5 (Expert). The statistics that indicate the effectiveness of the rating scale were examined (Linacre, 2002). These were:

i) Item-Measure Correlations

All item-correlations were in the range (0.61, 0.75) which indicates that the items are oriented in the same way and positively correlated with the underlying construct.

ii) Number of Observations in Every Response Category

All items have observation frequency > 10 in response categories 1, 2, 3, and 4. However, items 1, 2, 3, 4, 5, 6, and 9 have less than 10 observations in category 5 (Expert). Thus, to avoid potentially unstable calibrations, category 4 was combined with category 5.

iii) Distribution of Observations

Based on the bar charts for students and items in Figure 4.3, student distribution is unimodal at the center, while item distribution is less spread-out, indicating that the items target students around the mean better than at either ends of the distribution. The mean student measure is 0.3 logit and the mean standard error is 0.43 logit, thus by Fisher's criterion that when the mean student measure is less than one error of measurement from the item mean which is set to 0 by convention, the rating scale has a good targeting.

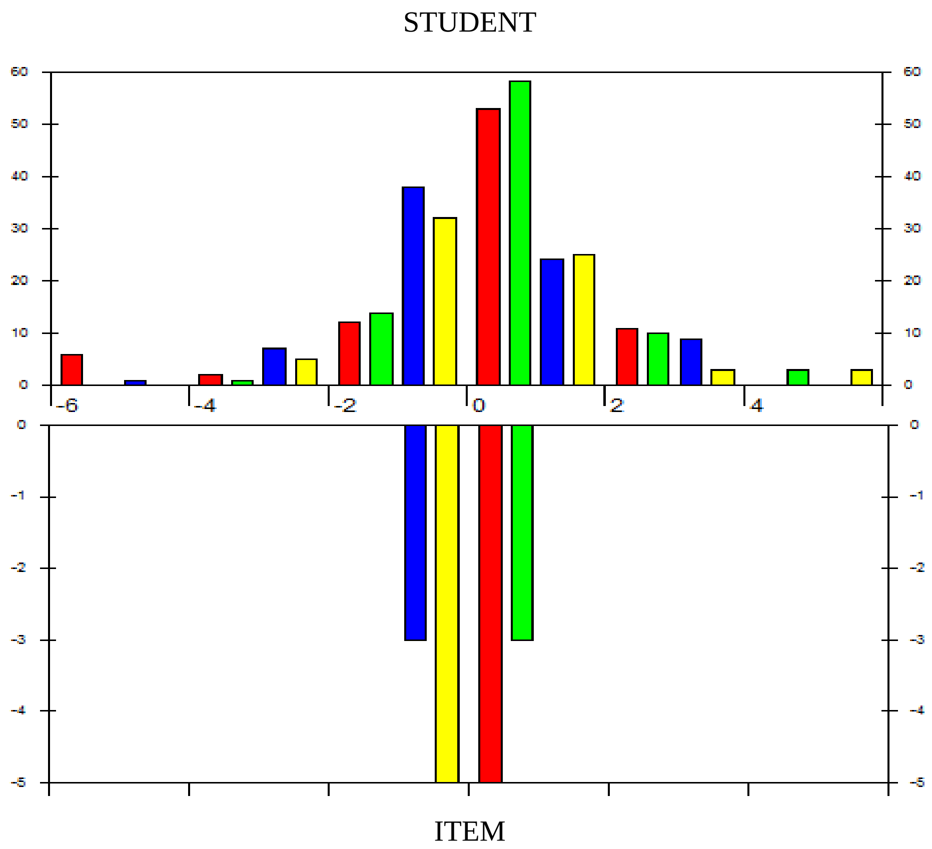


Figure 4.3: Bar charts of students and items

iv) Order of Category Probability Curves

The category probability curves of all items in the scale have similar shapes and order as the category probability curve for item 1 shown in Figure 4.4. The curves must be in logical order to justify the use of successive integer scores as a basis for measurement. Higher scores represent higher level of the latent trait. A score of x on a given item implies that a person has surpassed x thresholds but failed to surpass the remaining $m - x$ thresholds, where m is the number of categories.

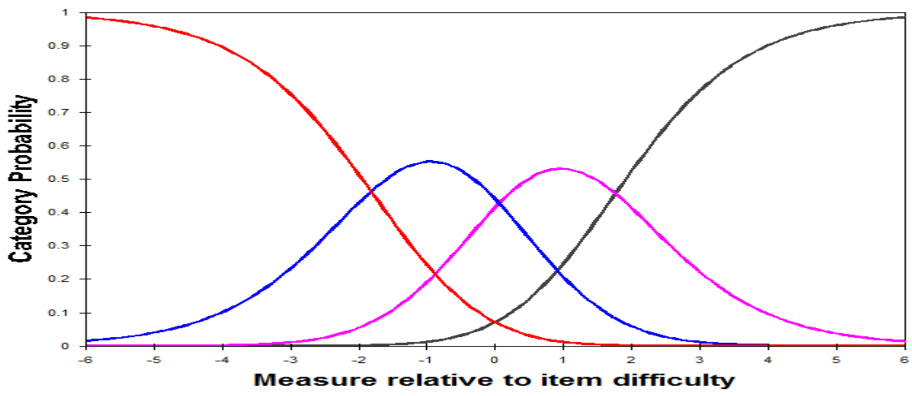


Figure 4.4: Category probability curve for item 1

v) Outfit MNSQ < 2.0

Outfit MNSQ which is sensitive to extreme responses or outliers has values in the range of (0.77, 1.24), less than < 2.0, indicating the items do not have too much noise, and thus are useful for measurement.

vi) 1.0 < Threshold Advance < 5.0

The location of the threshold for each category is shown in Table 4.14. The threshold advance from Category 2 to Category 3, and from Category 3 to Category 4 is more than 1.0 and less than 5.0.

Table 4.14: Threshold advance

Category	**Threshold (Measure at intersection)**	**Threshold advance**
1	None	-
2	-1.82	-
3	0.06	0.06 – (-1.82) = 1.88
4	1.76	1.76 - 0.06 = 1.70

vii) Item Model Fit MNSQ:

0.76 < Infit MNSQ < 1.19

0.74 < Outfit MNSQ < 1.24

Since both infit and outfit MNSQ lie within the range (0.71, 1.4), according to Fisher's guidelines, the item model fit is very good.

viii) Student and Item Measurement Reliability (Fisher, 2007)

Student Reliability = 0.91 (Very Good)

Item Reliability = 0.97 (Excellent)

Instrument reliability is indicated by student reliability index in Rasch model (Linacre, 2002), which is 0.91. This index is equivalent to Cronbach's alpha in Classical Test Theory. The value of Cronbach's alpha using raw scores to estimate internal consistency reliability is 0.94. Thus the instrument is shown to be reliable using both Rasch model and CTT.

ix) Student and Item Separation (Fisher, 2007)

Student Separation = 3.16 (Good)

Item Separation = 5.54 (Excellent)

x) Ceiling Effect (Fisher, 2007)

There are 3 maximum scores out of 317. Thus the percentage is 0.95% < 1%, which indicates a very good ceiling effect.

xi) Floor Effect (Fisher, 2007)

There are 6 maximum scores out of 317. Thus the percentage is 1.89% < 2%, which indicates a good floor effect.

xii) Variance in Data Explained by Measures

The percentage of data variance explained by the measures is 50.2%, which is considered good (Fisher, 2007; Linacre, 2002).

xiii) Unexplained Variance in Contrasts 1 – 5 of PCA of Residuals

The percentage of unexplained variance of PCA of residuals is between 11% – 15% for contrasts 1 and 2, and between 7 – 10% for contrasts 3, 4, and 5. According to the criterion described by Fisher (2007), the quality of the instrument with respect to this criterion is fair.

4.3.4.2 Checking the Assumptions of Rasch Measurement

RQ 2b) Are the assumptions of Rasch measurement met?

To ensure valid inferences from Rasch analysis, the data must meet the assumptions of unidimensionality, local independence, monotonicity of the latent trait, and having non-intersecting item response curves (Sijtsma and Molenaar, 2002).

i) Unidimensionality

Principal Component Analysis of the residuals was performed on the study data and the result is shown in Figure 4.5.

```
   Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                              -- Empirical --    Modeled
Total raw variance in observations     =      32.2 100.0%         100.0%
  Raw variance explained by measures   =      16.2  50.3%          50.2%
    Raw variance explained by persons  =       9.1  28.2%          28.2%
    Raw Variance explained by items    =       7.1  22.1%          22.1%
  Raw unexplained variance (total)     =      16.0  49.7% 100.0%   49.8%
    Unexplned variance in 1st contrast =       2.5   7.6%  15.4%
    Unexplned variance in 2nd contrast =       1.9   5.8%  11.6%
    Unexplned variance in 3rd contrast =       1.7   5.2%  10.4%
    Unexplned variance in 4th contrast =       1.4   4.3%   8.6%
    Unexplned variance in 5th contrast =       1.1   3.5%   7.0%
```

Figure 4.5: Result of PCA of residuals

Simulated data were used to examine the consistency of the statistics as suggested by Linacre (2007). The criteria for unidimensionality and the results of analysis of five sets of simulated data are shown in Table 4.15.

Table 4.15: Criteria and statistics for unidimensionality

Criteria	< 5% misfitting items ***	infit MNSQ: (0.70, 1.30) outfit MNSQ: (0.70, 1.30) infit ZSTD: (-2.0, 2.0) outfit ZSTD: (-2.0, 2.0)	Percentage of the variance accounted for by the first component > 50%	Percentage of unexplained variance in each of the five contrasts < 10%
Study Data (n=317)	No misfitting items	infit MNSQ: (0.76, 1.19) outfit MNSQ: (0.74, 1.24) infit ZSTD: (-3.4, 2.4) outfit ZSTD: (-3.5, 2.7)	50.3%	Contrast 1: 15.4% Contrast 2: 11.6% Contrast 3: 10.4% Contrast 4: 8.6% Contrast 5: 7.0%

Simulated Dataset 1 (n= 317)	No misfitting items	nfit MNSQ: (0.88, 1.17) outfit MNSQ: (0.87, 1.24) infit ZSTD: (-1.6, 2.1) outfit ZSTD: (-1.3, 2.5)	51.9%	Contrast 1: 9.4% Contrast 2: 9.1% Contrast 3: 7.8%
Simulated Dataset 2 (n= 317)	No misfitting items	infit MNSQ: (0.89, 1.12) outfit MNSQ: (0.86, 1.23) infit ZSTD: (-1.4, 1.6) outfit ZSTD: (-1.6, 2.5)	53.6%	Contrast 1: 9.1% Contrast 2: 8.4% Contrast 3: 8.1% Contrast 4: 7.7% Contrast 5: 7.3%
Simulated Dataset 3 (n= 317)	No misfitting items	infit MNSQ: (0.90, 1.12) outfit MNSQ: (0.87, 1.11) infit ZSTD: (-1.4, 1.5) outfit ZSTD: (-1.3, 1.3)	53.5%	Contrast 1: 9.4% Contrast 2: 8.6% Contrast 3: 8.3% Contrast 4: 7.7% Contrast 5: 7.6%
Simulated Dataset 4 (n= 317)	No misfitting items	infit MNSQ: (0.85, 1.14) outfit MNSQ: (0.84, 1.11) infit ZSTD: (-2.0, 1.8) outfit ZSTD: (-1.9, 1.2)	53.5%	Contrast 1: 9.0% Contrast 2: 8.6%
Simulated Dataset 5 (n= 317)	No misfitting items	infit MNSQ: (0.86, 1.08) outfit MNSQ: (0.86, 1.10) infit ZSTD: (-1.8, 1.1) outfit ZSTD: (-1.7, 1.2)	52.4%	Contrast 1: 9.4% Contrast 2: 8.5% Contrast 3: 8.1% Contrast 4: 8.0% Contrast 5: 7.7%

*** An item is considered misfitting if all three fit statistics are violated

The percentage of the total variance accounted for across the contrasts in the simulated datasets is rather evenly distributed, suggesting a unidimensional structure.

Based on the criteria and the statistics of the study and simulated data which show consistency, the scale is unidimensional (Fisher, 2007).

ii) Local independence

Items are considered locally independent if the residuals of a pair of items are uncorrelated or weakly correlated with correlation coefficient < 0.3 after the underlying construct has been accounted for (Sijtsma and Molenaar, 2002). The correlation coefficients of the residuals in the study data is shown in Table 4.16.

Table 4.16: Correlation coefficients of standardized residuals

Item	Item	Correlation
15	16	0.30
4	7	0.28
1	3	0.27
1	2	0.27
14	15	0.26
4	5	0.25
7	13	- 0.29
5	14	- 0.28
4	8	- 0.27
7	14	- 0.27

The maximum magnitude of the correlation coefficients is 0.30, signifying a weak relationship, thus indicating local independence between the items (Sijtsma and Molenaar, 2002).

iii) Monotonicity of the Latent Trait

The non-decreasing item characteristic curve for every item can be seen from the respective ICC graph as in Figure 4.6. This means that as ability increases, the probability to endorse an item also increases.

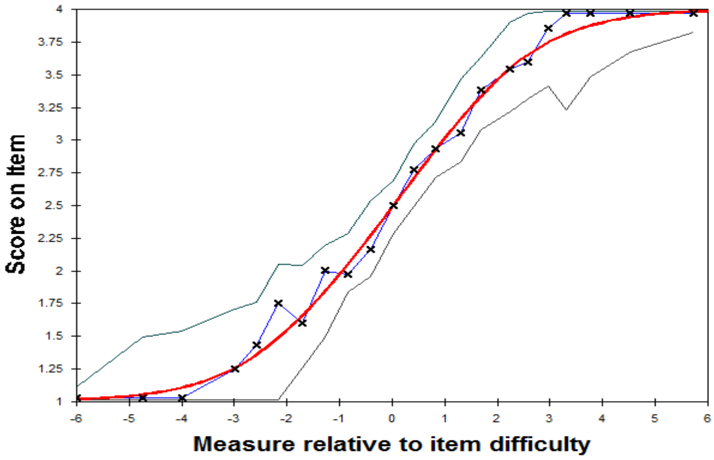


Figure 4.6: Item characteristic curve for item 3

iv) Non-intersecting item response curves

Figure 4.7 shows the non-intersecting curves for the response categories of the scale. Easier items have higher probability of being endorsed, and the order of the probabilities of a correct response for all items is the same for all ability levels. This means that the item ordering is reliable. Thus, an estimate of the scale score reliability equivalent to Cronbach's alpha can be calculated.

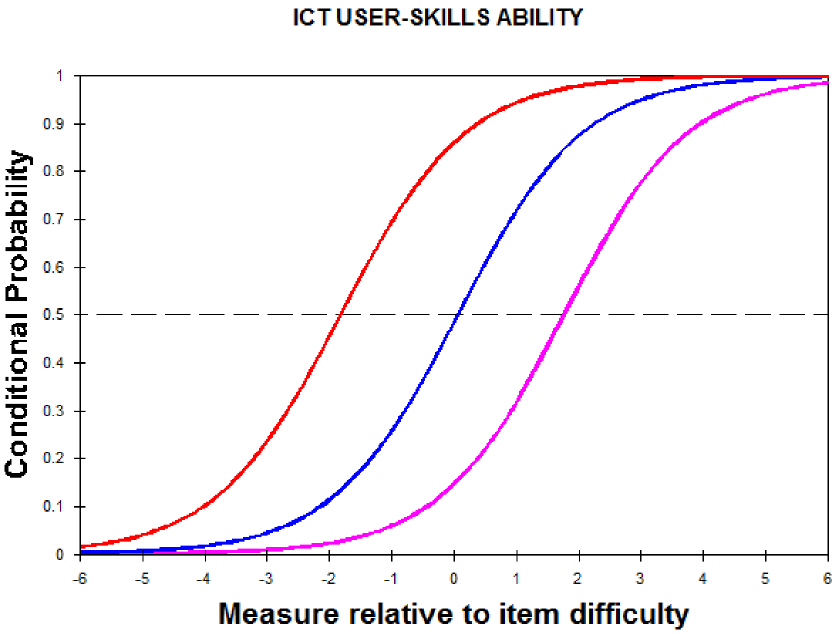


Figure 4.7: Nonintersecting item response curves for the categories

4.3.4.3 Checking the Validity of Survey Instrument

RQ 2c): Does the instrument fulfill the criteria for face validity?

A group of 11 students gave feedback on the clarity of the survey items and how far they agreed that the survey items were about their ICT skills. They responded to the following questions on a 5-point rating scale - 1 (strongly disagree), 2 (disagree), 3 (neutral), 4(agree) and 5 (strongly agree):

1. The wording of the questions is easy to understand.
2. The flow of the questionnaire is easy to follow.
3. The survey seems to be about students' ICT skills.

Students were also asked to write comments about the survey. About 73% (n=8) of the students responded favorably to questions 1 and 2, by choosing option 4(Agree) and 5(Strongly Agree). Over 90% (n=10) of the students chose the option 4(Agree) and 5(Strongly Agree) on Question 3.

An expert on information literacy was consulted to check on the face validity of the instrument. He agreed that the items were about students' self-reported ICT skills for engineering learning, and gave input on how to improve the format of the questionnaire to make it more easily understood.

Based on the feedback obtained, the format for Part C was made simpler by separating the items on the use of ICT skills in engineering education (Part C1) from the frequency of use (Part C2). The items in Part C1 and C2 were then categorized into three sub-domains: General Application Software, Engineering Application Software, and Information Skills. Two new items on internet use were added: *Using the internet to gain knowledge of contemporary issues in an engineering discipline* and *Using the internet to gain knowledge of engineering professional codes of ethics and legal issues.*

RQ 2d) Does the instrument fulfill the criteria for construct validity?

The aspects of construct validity relevant to this study are content, substantive, structural, generalizability, and interpretability. Table 3.13 was used as a guide to determine whether the instrument had construct validity based on the different types of evidence.

a) Evidence of the Content Aspect

i) Expert Review

Experts were asked to rate the relevance of each of the ICT user-skills items, and the comprehensiveness of entire ICT user-skills scale as a whole. The CVI of each item and of the overall scale are shown in Table 4.17. The evidence of the representativeness of the survey items was the high CVI value of 1.00.

The ratings on the comprehensiveness of the entire ICT user-skills scale, the clarity of the purpose of the questionnaire, the clarity of instructions to participants, the clarity of meaning of survey items, the format and layout of the questionnaire, and the appropriateness of the measurement scale are summarized in Table 4.18. The high percentage of agreement (at least 80%) on the comprehensiveness of the scale, the clarity of survey purpose, the clarity of meaning, the appropriateness of the measurement scale, and the questionnaire format supported content validity of the instrument.

Table 4.17: Content validity index of survey items

Item No.	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	Item CVI
General-purpose Software											
10 - Word	X	X	X	X	X	X	X	X	X	X	1.00
11 - Video	X	X	X	X	X	X	X	X	X	X	1.00
12 - Present	X	X	X	X	X	X	X	X	X	X	1.00
13 – Files	X	X	X	X	X	X	X	X	X	X	1.00
14 - Comm	X	X	X	X	X	X	X	X	X	X	1.00
* Elearn	X	X	X	X	X	X	X	X	X	X	1.00
Engineering Software											
4 – Stats	X	X	X	X	X	X	X	X	X	X	1.00
5 - Prog	X	X	X	X	X	X	X	X	X	X	1.00
6 - Design	X	X	X	X	X	X	X	X	X	X	1.00
7 – Math	X	X	X	X	X	X	X	X	X	X	1.00
* ColData	X	X	X	X	X	X	X	X	X	X	1.00
* Simulate	X	X	X	X	X	X	X	X	X	X	1.00
* ProjMgt	X	X	X	X	X	X	X	X	X	X	1.00
Information Skills											
1 - Define	X	X	X	X	X	X	X	X	X	X	1.00
2 - Access	X	X	X	X	X	X	X	X	X	X	1.00
3 – Use	X	X	X	X	X	X	X	X	X	X	1.00
8 - Evaluate	X	X	X	X	X	X	X	X	X	X	1.00
9 – Ethics	X	X	X	X	X	X	X	X	X	X	1.00
Overall CVI											1.00

‘X’: A rating of 4 (Agree) or 5 (Strongly Agree)

Table 4.18: Expert rating of overall questionnaire

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	% (rating 4 or 5)
The entire ICT user-skills scale is comprehensive	5	5	5	5	4	5	5	5	4	4	100%
The purpose of the survey is clear	4	5	4	5	3	4	4	4	4	4	90%
The meaning of the survey items is clear	5	5	4	5	3	5	4	5	4	3	80%
The format of the questionnaire is suitable	4	4	4	5	4	5	4	4	4	3	90%
The measurement scale is appropriate	5	5	5	5	4	5	4	5	4	4	100%

Some of the comments written by the reviewers regarding the questionnaire are shown in Table 4.19.

Table 4.19: Commentary by experts

Expert	Comments
1	*The questions posed in the survey instrument will gradually help the students to retrieve and access information during their tenure as students. The four parts of the survey are integral areas of library information skills which will assist students in basic searching skills and the most advanced research needs for information.*
2	*The questions are suitable and relevant.*
4	*I believe the questionnaire meet the intended objectives as it covers various aspects on ICT.*
6	*A very good and comprehensive questionnaire.*
7	*The questions are comprehensive. From the survey output, we can analyze and recommend solutions to close any gaps and thus, improve the system.*
8	*A questionnaire that digs deep inside the practical aspects of ICT use in engineering.*
10	*Please change the format in the last part to make the survey look simpler.*

** Numbering of the experts follows the order in Appendix C

ii) Technical Quality of Items

Another aspect of content validity is the technical quality of items. Technical quality refers to i) how close the observed values are to the predicted values produced by the measurement model and ii) the correlation of items to the measure. The residual-based fit statistics, the weighted (infit) and unweighted (outfit) mean-squares and t-statistics for each item, and the item-measure correlations are as in Table 4.20. All of the infit and outfit mean squares are between 0.7 and 1.3. This means all of the items fit the Rasch model (Bond and Fox, 2007).

The fit for each item can be displayed by the item characteristic curve which shows the relationship between the expected score on an item and the student ability measure in logits. Figure 4.8 and Figure 4.9 show ICC for item 1 and item 2 respectively.

Table 4.20: Fit statistics

Item STATISTICS: CORRELATION ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
6	774	317	.45	.08	1.19	2.4	1.24	2.7	.61	.69	49.0	53.0	6c2_7
5	728	317	.78	.08	1.17	2.2	1.14	1.6	.63	.68	52.9	53.6	5c2_6
7	728	317	.78	.08	1.16	2.0	1.11	1.3	.66	.68	53.9	53.6	7c2_8
14	968	317	-.97	.09	1.12	1.5	1.08	.9	.67	.69	55.2	56.1	14c2_18
15	917	317	-.57	.09	1.09	1.2	1.05	.6	.67	.69	52.3	54.9	15c2_19
4	757	317	.57	.08	1.06	.8	1.02	.3	.68	.69	53.2	53.2	4c2_5
16	896	317	-.42	.09	1.13	1.7	1.07	.8	.68	.69	54.9	54.4	16c2_20
1	785	317	.37	.08	.91	-1.2	.98	-.2	.69	.69	58.1	53.3	1c2_1
12	871	317	-.24	.09	1.02	.3	1.02	.3	.70	.69	56.2	54.2	12c2_16
8	849	317	-.08	.08	.92	-1.1	.97	-.3	.71	.69	58.4	53.8	8c2_11
13	925	317	-.63	.09	.96	-.5	.92	-.8	.71	.69	59.4	55.1	13c2_17
9	852	317	-.10	.08	.83	-2.4	.81	-2.5	.73	.69	58.8	53.9	9c2_12
10	873	317	-.25	.09	.99	-.1	.95	-.5	.73	.69	53.2	54.0	10c2_14
11	826	317	.08	.08	.93	-.9	.90	-1.3	.73	.69	56.2	53.7	11c2_15
3	825	317	.09	.08	.76	-3.4	.74	-3.5	.74	.69	58.4	53.7	3c2_3
2	820	317	.13	.08	.76	-3.4	.77	-3.0	.75	.69	59.1	53.7	2c2_2
MEAN	837.1	317.0	.00	.09	1.00	-.1	.99	-.2			55.6	54.0	
S.D.	68.5	.0	.49	.00	.14	1.8	.13	1.6			2.9	.8	

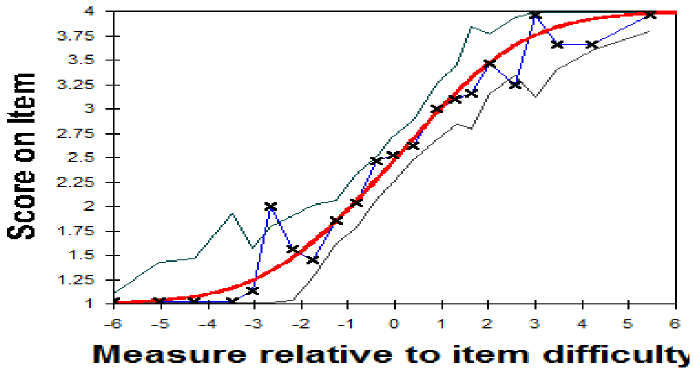


Figure 4.8: ICC for item 1

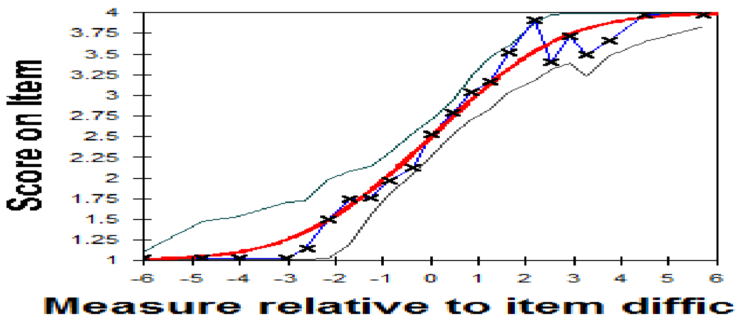


Figure 4.9 : ICC for item 2

a) Evidence of the Internal Structure Aspect

Internal structure of an instrument is defined by the dimensionality of the construct being measured and the scoring method used (Bond and Fox, 2007). The unidimensionality of the instrument was established by examining the fit statistics and the PCA of residuals, which was done in Section 4.3.4.2 to check that the requirements of a unidimensional measurement model were met before employing the Rasch model.

In a Rasch model, total raw scores are sufficient statistics for the parameters of the model (Smith and Smith, 2004). This means that the sample used to estimate the model parameters gives no additional information about the value of the parameters. The score obtained by a student on a particular item is defined as the number of threshold locations on the latent trait surpassed by the student. This score is estimated using an estimation procedure such as the Extra-Conditional Maximum Likelihood Estimation (XMLE), which was implemented in the WINSTEPS software (Smith and Smith, 2004).

b) Evidence of the Substantive Aspect

Graphical evidence of the substantive aspect includes the shape and order of the category probability curve and the frequency distribution graphs of different groups of students (Cavanagh and Waugh, 2011). The category probability curve is a probability density function for a response to an item. It shows the probability for an item response to be in each of the four response categories for a particular measure on the horizontal axis. The category probability curve for the study sample is shown in Figure 4.10.

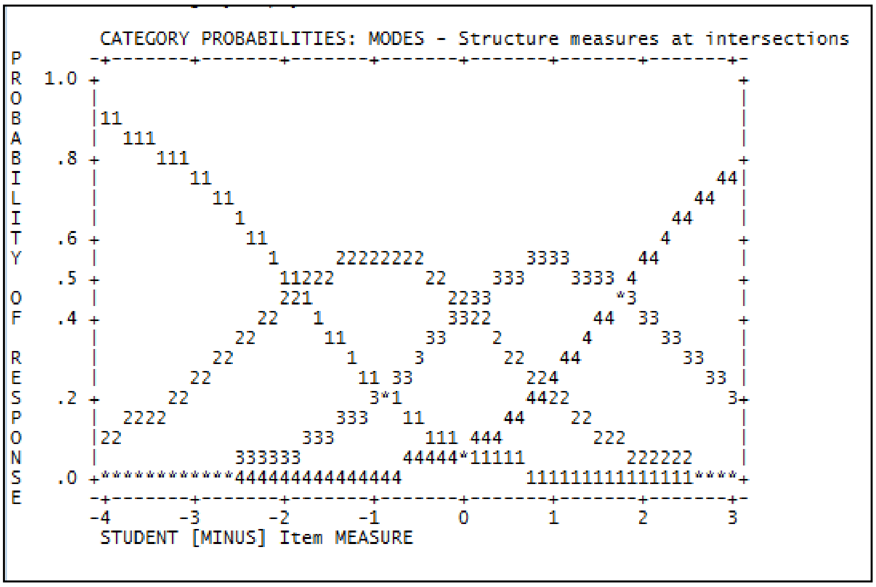


Figure 4.10: Category probability curve

According to Cavanagh and Waugh (2011), the probability of a response in a given category is dependent on the location on the horizontal axis (student – item measure). There are four ordered categories for each item, scored from 1 to 4. There are three thresholds which correspond with the location on the latent continuum (student – item measure) where the probability of endorsing two adjacent categories is the same. For example, a person with (student – item measure) equals to 0.06 is equally like to endorse category 2 and 3. From Figure 4.11, the three thresholds are located at -1.82, 0.06, and 1.76 logits respectively. It can be seen that as threshold values advance, the probability to endorse a higher category increases.

SUMMARY OF CATEGORY STRUCTURE. Model="R"

CATEGORY LABEL	SCORE	OBSERVED COUNT	%	OBSVD AVRGE	SAMPLE EXPECT	INFIT MNSQ	OUTFIT MNSQ	ANDRICH THRESHOLD	CATEGORY MEASURE	
1	1	698	14	-1.46	-1.56	1.13	1.14	NONE	(-3.02)	1
2	2	1532	30	-.39	-.31	.93	.93	-1.82	-.94	2
3	3	1736	34	.71	.68	.90	.87	.06	.97	3
4	4	1106	22	1.95	1.94	1.02	1.01	1.76	(2.98)	4

OBSERVED AVERAGE is mean of measures in category. It is not a parameter estimate.

Figure 4.11: Category structure

Another evidence of the substantive aspect is the extent to which students' response strings match the item ordering. Student fit statistics were examined to obtain the percentage of students within the acceptable infit and outfit mean-square range. From Table 4.21, more than 80% of the students have responses with acceptable infit and outfit values between 0.4 and 1.6.

Table 4.21: Student fit statistics frequency distribution

Mean-Square Value	Infit MNSQ		Outfit MNSQ	
	Frequency	Percent	Frequency	Percent
Below 0.4	23	7.3	23	7.3
0.4 – 1.6	260	**82.0**	261	**82.3**
Above 1.6	34	10.7	33	10.4
Total	317	100.0	317	100.0
Mean	1.03		1.03	
Std Deviation	0.42		0.42	

Comparison of ability measures between different student subgroups such as between gender can be an evidence of substantive validity if it supports existing theory or hypothesis. Gender studies on various aspects of ICT ability are quite extensive and have produced different conclusions. The frequency distributions of ICT user-skills ability (measured in logits) for male and female students are shown in Figure 4.12 and Figure 4.13 respectively.

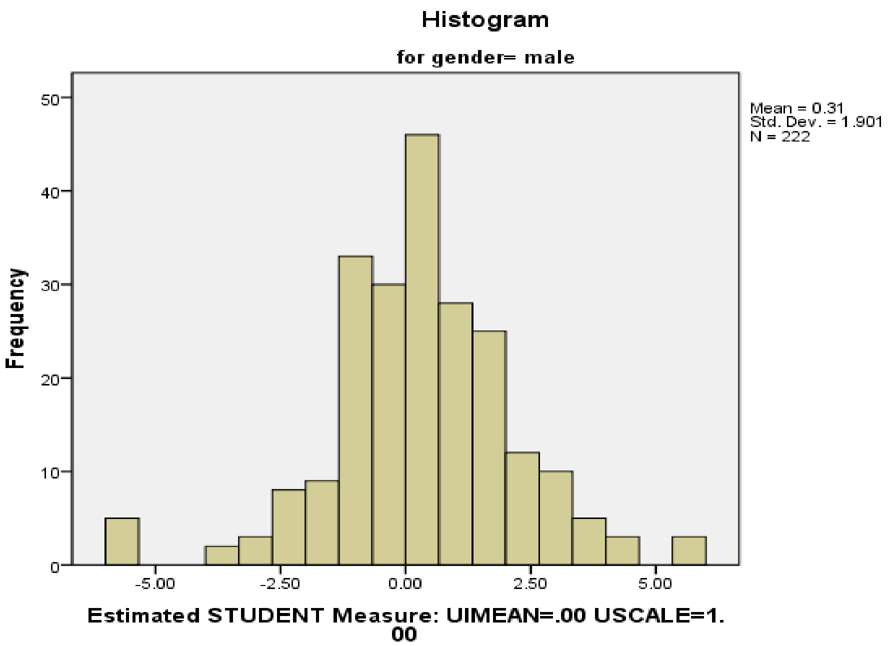


Figure 4. 12: Frequency distribution of male students' ICT user-skills ability

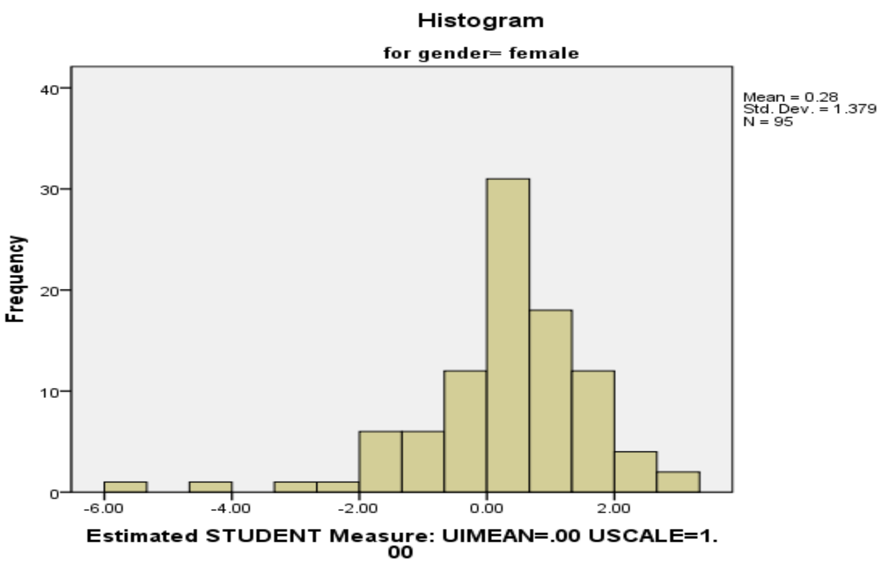


Figure 4.13: Frequency distribution of female students' ICT user-skills ability

Kolmogorov-Smirnov (K-S) test was chosen to test for significant gender difference in ICT user-skills ability because both distributions are non-normal (Gavin, 2008). The result is shown in Table 4.22. Since $p = 0.178 > 0.05$, there is no significant difference in the means of the two groups. This finding would be discussed in Chapter 5 in relation to the literature review. Similar comparisons based on other student variables such as the year of study and engineering specialization could be performed.

Table 4.22: Result of K-S test on gender difference

		Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00
Most Extreme Differences	Absolute	.135
	Positive	.135
	Negative	-.085
Kolmogorov-Smirnov Z		1.099
Asymp. Sig. (2-tailed)		.178
Grouping Variable: Gender		

Alternatively, t-test could also be used to test for significant difference even though the distribution of measures is non-normal because for large sample sizes (> 15 cases per group), the test can yield fairly accurate p values (Wilcox, 2001). The result of t-test on equality of means between the two groups produced the result: $t(241.2) = 0.177$, $p = 0.86$. Since $p > 0.05$, there is no significant difference in the means of the two groups. This result was similar to the one produced by the Kolmogorov-Smirnov test.

c) Evidence of the Generalizability Aspect

Generalizability of item and student measures are indicated by differential item functioning (DIF) and differential person functioning (DPF) values (Cavanagh and Waugh, 2011). DIF and DPF size between - 0.5 and + 0.5 are considered insignificant, indicating that the measures are relatively invariant (Tennant and Pallant, 2007). An instrument should consist of items with difficulty measures which are independent of any group of respondents who use the instrument. For example, items with the same success rate among male and female students would support the generalizability aspect of validity.

A DIF plot that compares ICT user-skills ability between male and female students is shown in Figure 4.14. Since the magnitude of DIF < 0.5, it can be concluded that the items do not exhibit DIF with respect to gender. Examination of DIF plots as shown in Figure 4.15 and Figure 4.16 to compare ICT user-skills ability between students in different engineering specialization and year of study produced similar results. Thus it can be concluded that the ICT user-skills items do not exhibit DIF with respect to students' gender, engineering specialization and year of study. This means that the items are not biased with respect to those student characteristics and as such can produce comparable ability measures (Tennant and Pallant, 2007).

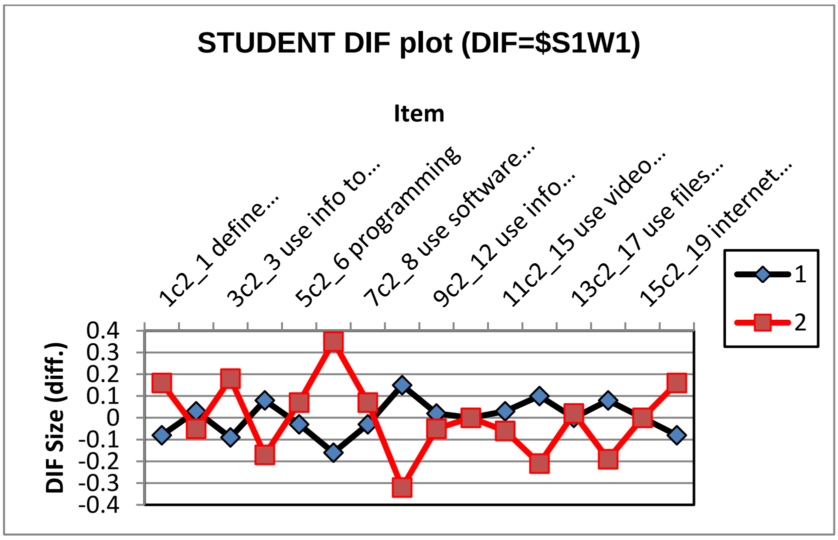


Figure 4.14: DIF size based on gender

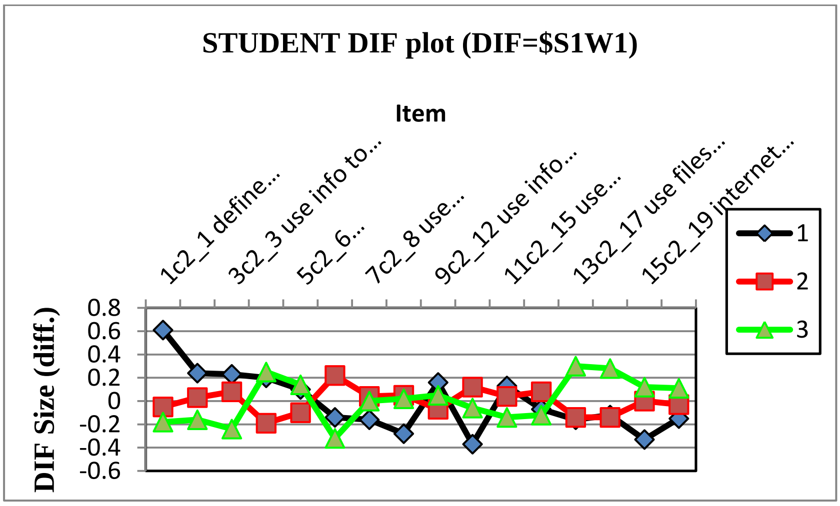


Figure 4.15: DIF size based on engineering specialization

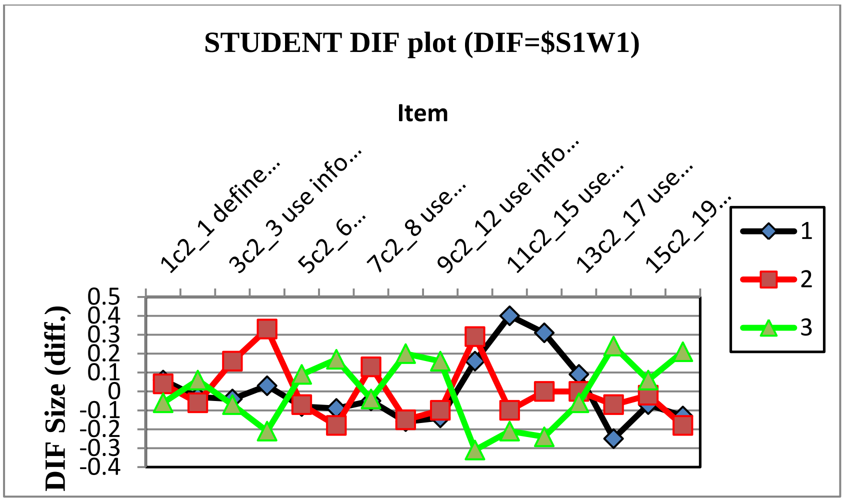


Figure 4.16: DIF size based on year of study

Invariance of item difficulty measures were verified by dividing the students into two subgroups according to their ability. One subgroup consisted of students with ability measures less than the mean value (0.30), and the other subgroup consisted of students with measures higher than the mean. Then item calibrations were produced using WINSTEPS for each subgroup. Paired t-test was then performed to examine if there is a significant difference between the mean of the two sets of item difficulty measures shown in Table 4.23.

Table 4.23: Two sets of item difficulty measures

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Set 1	.49	-.02	.07	.64	.92	.68	.91	-.10	-.13	-.61	-.18	-.34	-.79	-.79	-.43	-.33
Set 2	.28	.28	.12	.53	.64	.24	.65	-.06	-.07	.02	.34	-.15	-.55	-1.09	-.69	-.49

Wilcoxon signed rank test was chosen to test if there is significant difference between the two sets of item difficulty measures. The result is shown in Table 4.24. Since p = 0.816 > 0.05, there is no significant difference between the two sets of item difficulty measures.

Table 4.24: Result of Wilcoxon signed rank test

	Estimated Item Measure: UIMEAN=.00 USCALE=1.00
Asymp. Sig. (2-tailed)	.816

Likewise, to verify the invariance of student ability measure, two subgroups of items with similar targeting were formed. One subgroup (Set 1) consisted of items (2, 3, 6, 7, 8, 9, 14, 16) and the other subgroup (Set 2) consisted of items (1, 4, 5, 10, 11, 12, 13, 15). Student abilities were then estimated using each subgroup of items. The frequency distributions of student measures using items in Set 1 and Set 2 are shown in Figure 4.17 and Figure 4.18 respectively.

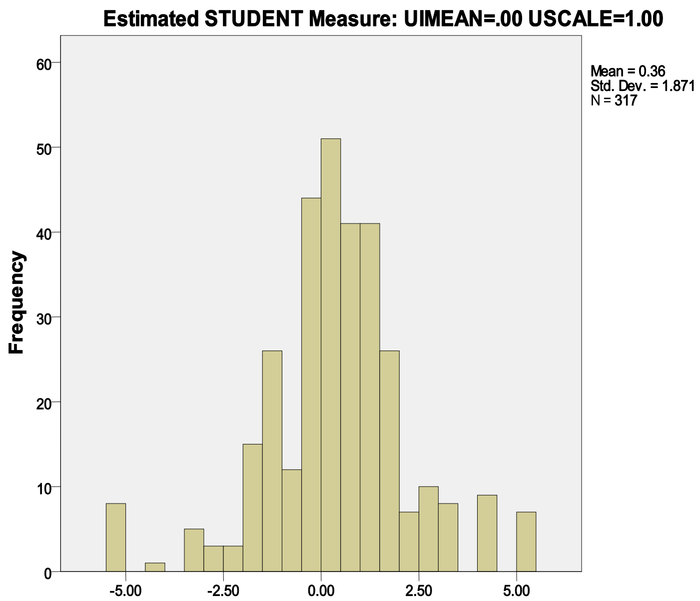


Figure 4.17: Student measure distribution using set 1

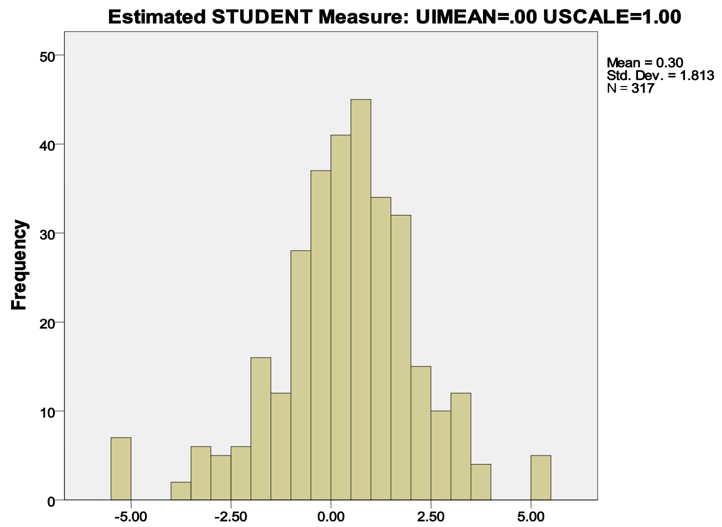


Figure 4.18: Student measure distribution using set 2

Checking for normality using Kolmogorov-Smirnov test yields the results shown in Table 4.25 and Table 4.26:

Table 4.25: K-S test of normality for male student measure distribution

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Estimated MALE STUDENT Measure: UIMEAN=.00 USCALE=1.00	.093	317	.000	.956	317	.000

a. Lilliefors Significance Correction

Table 4.26: K-S test of normality for female student measure distribution

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Estimated FEMALE STUDENT Measure: UIMEAN=.00 USCALE=1.00	.077	317	.000	.971	317	.000

a. Lilliefors Significance Correction

Since in both cases, the p-value = 0.0, it can be concluded that both distributions are non-normal. Wilcoxon Signed Ranks Test was then chosen to test for significant difference between the two distributions (Wilcox, 2001). The result is shown in Table 4.27.

Table 4.27: Wilcoxon signed ranks test result

	Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00
Asymp. Sig. (2-tailed)	.377

Since $p = 0.377 > 0.05$, it can be concluded that there is no significant difference between the distribution of the two groups.

Alternatively, since the distributions do not depart from normal distribution substantively, paired t-test could be performed to examine if there is a significant difference between the mean of the two sets of student measures. The result of paired t-test: $t(316) = 1.169$, $p = 0.243$. Since $p > 0.05$, there is no significant difference between the two sets of student ability measures.

Another evidence for the generalizability aspect of validity for the ICT user-skills scale is the student reliability index which is equivalent to Cronbach's alpha internal consistency reliability. For this study sample, the student reliability index = 0.91 as shown in Table 4.28. Thus there is a high probability that the same relative student measures could be reproduced.

Table 4.28: Student reliability

SUMMARY OF 317 MEASURED (EXTREME AND NON-EXTREME) STUDENT

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	42.3	16.0	.30	.43				
S.D.	10.8	.0	1.76	.26				
MAX.	64.0	16.0	5.84	1.84				
MIN.	16.0	16.0	-5.89	.34	.12	-4.6	.12	-4.6

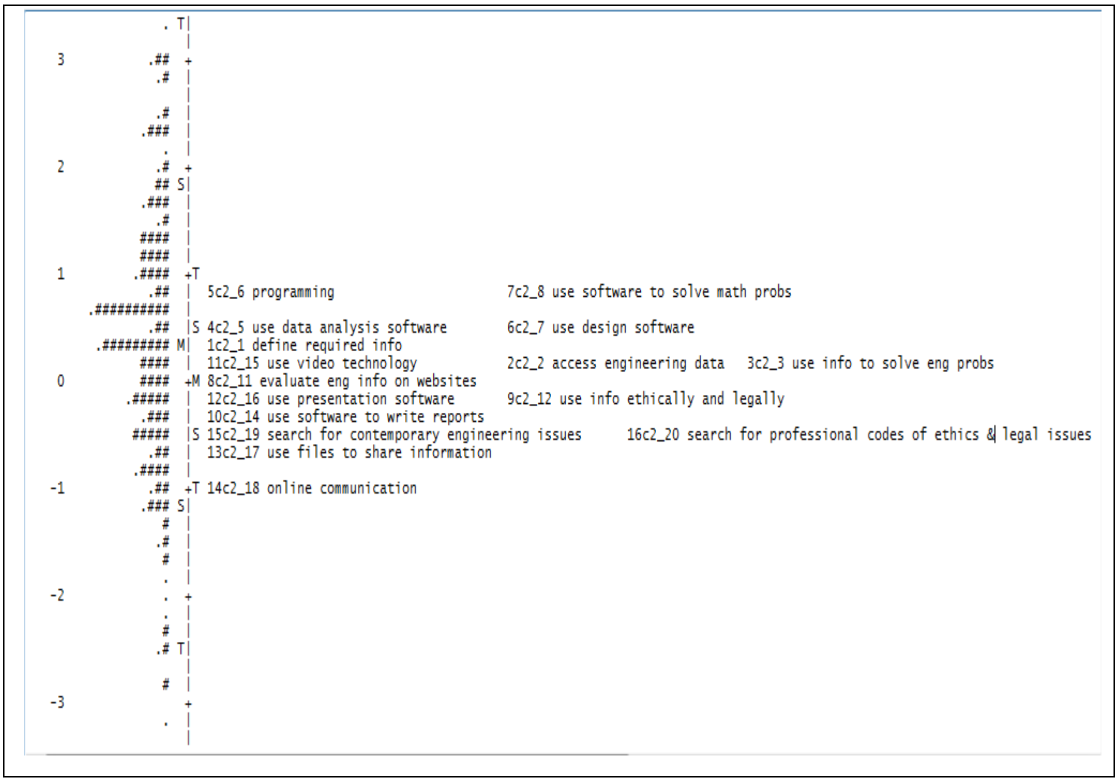
REAL RMSE .53 TRUE SD 1.67 SEPARATION 3.16 STUDEN RELIABILITY .91
MODEL RMSE .50 TRUE SD 1.68 SEPARATION 3.34 STUDEN RELIABILITY .92
S.E. OF STUDENT MEAN = .10

STUDENT RAW SCORE-TO-MEASURE CORRELATION = .97
CRONBACH ALPHA (KR-20) STUDENT RAW SCORE "TEST" RELIABILITY = .94

d) Evidence of the Interpretability Aspect

Comparison of item and student measures is based on the item map shown in Figure 4.19. Student ICT user-skills ability and item difficulty are plotted on the logit scale within the range of (-5.89, 5.84). Item difficulty levels are in the range of (-0.97, 0.78). The map orders the level of ICT user-skills ability for engineering learning on the left side and the difficulty level of ICT-related engineering learning activities on the right side. Students at the top of the scale have higher level of ICT user-skills ability and those further down the scale have lower level of ICT user-skills ability. Activities at the top of the scale such as programming and using mathematical software require higher ability level compared to activities further down the scale such as online communication.

From the map, it can be observed that the mean student ability (0.30) is higher than the mean item difficulty (0.0). A test has good targeting when the bulk of the items and the persons are opposite each other. For this study sample, the targeting of items is better for students with moderate ability than those who with high or low ICT user-skills ability since all of the items are located within one standard deviation of the mean student ability. About 77% of the students are located within one standard deviation away from the mean.



Each # represents 3 students, each . represents 1 or 2 students
M: Mean; S= 1 std deviation from the mean; T = 2 std deviations from the mean

Figure 4.19: Item-student map

The reliability of other subscales of the instrument was examined using Rasch Model. The reliability indices for subscale *Perceived Benefits of Using ICT for Engineering Learning* and subscale *Frequency of Using ICT Skills for Engineering Learning* are shown in Table 4.29 and Table 4.30 respectively. The summary of reliability indices are shown in Table 4.31.

Table 4.29: Reliability indices of the *Perceived Benefits of ICT Use for Engineering Learning* subscale

```
     SUMMARY OF 317 MEASURED (EXTREME AND NON-EXTREME) STUDENT
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT         OUTFIT    |
|          SCORE      COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      33.1       10.0       1.86     .65                                 |
| S.D.       5.2         .0       1.51     .38                                 |
| MAX.      40.0       10.0       5.20    1.84                                 |
| MIN.      12.0       10.0      -3.02     .41        .09   -3.9    .10   -4.0 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .78 TRUE SD    1.30  SEPARATION  1.67  STUDEN RELIABILITY  .73 |
|MODEL RMSE    .75 TRUE SD    1.31  SEPARATION  1.74  STUDEN RELIABILITY  .75 |
| S.E. OF STUDENT MEAN = .09                                                  |
-------------------------------------------------------------------------------
STUDENT RAW SCORE-TO-MEASURE CORRELATION = .94
CRONBACH ALPHA (KR-20) STUDENT RAW SCORE "TEST" RELIABILITY = .85

     SUMMARY OF 10 MEASURED (NON-EXTREME) Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT         OUTFIT    |
|          SCORE      COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN    1050.5      317.0        .00     .09       1.01     .1    .97    -.2 |
| S.D.      46.3         .0        .43     .01        .07     .8    .09     .9 |
| MAX.    1137.0      317.0        .47     .11       1.13    1.5   1.11    1.2 |
| MIN.     997.0      317.0       -.85     .09        .88   -1.5    .86   -1.6 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .10 TRUE SD     .42  SEPARATION  4.34  Item   RELIABILITY  .95 |
|MODEL RMSE    .10 TRUE SD     .42  SEPARATION  4.41  Item   RELIABILITY  .95 |
| S.E. OF Item MEAN = .14                                                     |
-------------------------------------------------------------------------------
UMEAN=.0000 USCALE=1.0000
Item RAW SCORE-TO-MEASURE CORRELATION = -1.00
2920 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 5038.96 with 2617 d.f. p=.0000
Global Root-Mean-Square Residual (excluding extreme scores): .6226
```

Table 4.30: Reliability indices of the *Frequency of ICT Use for Engineering Learning* subscale

```
     SUMMARY OF 317 MEASURED (EXTREME AND NON-EXTREME) STUDENT
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT         OUTFIT    |
|          SCORE      COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      32.8       14.0       -.40     .42                                 |
| S.D.      13.8        3.0       1.25     .37                                 |
| MAX.      64.0       16.0       4.44    1.82                                 |
| MIN.       3.0        3.0      -4.41     .25        .06   -6.1    .07   -5.7 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .58 TRUE SD    1.10  SEPARATION  1.89  STUDEN RELIABILITY  .78 |
|MODEL RMSE    .57 TRUE SD    1.11  SEPARATION  1.96  STUDEN RELIABILITY  .79 |
| S.E. OF STUDENT MEAN = .07                                                  |
-------------------------------------------------------------------------------
STUDENT RAW SCORE-TO-MEASURE CORRELATION = .88 (approximate due to missing data)
CRONBACH ALPHA (KR-20) STUDENT RAW SCORE "TEST" RELIABILITY = .95 (approximate due to missing data)

     SUMMARY OF 16 MEASURED (NON-EXTREME) Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT         OUTFIT    |
|          SCORE      COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN     649.2      278.0        .00     .07       1.00    -.1   1.00    -.2 |
| S.D.      83.4       16.5        .28     .00        .16    2.1    .17    1.8 |
| MAX.     819.0      295.0        .45     .08       1.33    4.0   1.34    3.2 |
| MIN.     506.0      246.0       -.66     .07        .75   -3.7    .73   -3.2 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .07 TRUE SD     .27  SEPARATION  3.72  Item   RELIABILITY  .93 |
|MODEL RMSE    .07 TRUE SD     .27  SEPARATION  3.85  Item   RELIABILITY  .94 |
| S.E. OF Item MEAN = .07                                                     |
-------------------------------------------------------------------------------
               DELETED:       4 Item
UMEAN=.0000 USCALE=1.0000
Item RAW SCORE-TO-MEASURE CORRELATION = -.97 (approximate due to missing data)
4259 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 9692.89 with 3944 d.f. p=.0000
Global Root-Mean-Square Residual (excluding extreme scores): .8820
```

Table 4.31: Summary of reliability indices of part B and C1

Subscale	Reliability
Part B: *Perceived Benefits of Using ICT for Engineering Learning*	Student Reliability = 0.73 Item Reliability = 0.95 Cronbach's alpha = 0.85
Part C1: *Frequency of Using ICT skills for Engineering Learning*	Student Reliability = 0.79 Item Reliability = 0.93 Cronbach's alpha = 0.95

Since the evidences support the reliability and validity of the instrument, the measures produced can be used to examine relationships between students' ability measures with respect to their characteristics. Before applying appropriate statistical tests, the assumption of normality of the distribution of ability measures was checked. The frequency distribution of ability measures is shown in Figure 4.20.

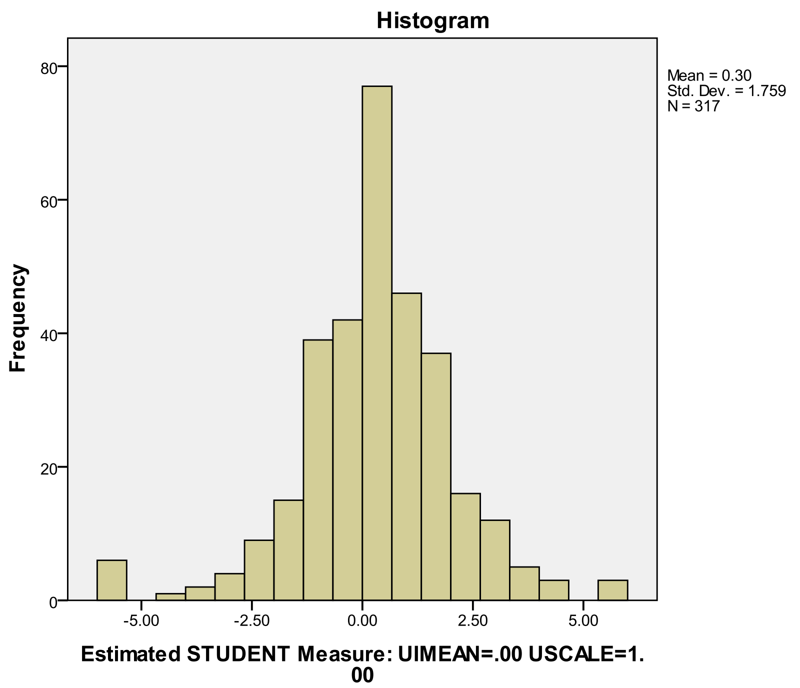


Figure 4.20: Histogram of student ability measures

The results of Kolmogorov-Smirnov test is shown in Table 4.32. Since $p < 0.05$, the test is significant. Thus the distribution of student measures differs significantly from the normal distribution.

Table 4.32: Test of normality of student ability measure distribution

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00	.088	317	.000	.948	317	.000

a. Lilliefors Significance Correction

The following research questions were addressed to describe and compare students' ICT user-skills ability:

RQ 4a): Is there a significant difference in ICT user-skills ability between male and female students?

The result of 2-sample K-S test is shown in Table 4.33.

Table 4.33: Result of K-S test for gender difference in ability

		Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00
Most Extreme Differences	Absolute	.135
	Positive	.135
	Negative	-.085
Kolmogorov-Smirnov Z		1.099
Asymp. Sig. (2-tailed)		.178

Grouping Variable: Gender

Hypothesis for RQ 4a):

H_0: There is no significant gender difference in ICT user-skills ability.

H_1: There is significant gender difference in ICT user-skills ability.

Since $p = 0.178 > 0.05$, H_0 is accepted. It can be concluded that there is no significant gender difference in ICT user-skills ability.

RQ 4b): Is there a significant difference in ICT user-skills ability between students in different engineering specializations?

Hypothesis for RQ 4b):

H_0: There is no significant difference in ICT user-skills ability between students in different engineering specializations.

H_2: There is significant difference in ICT user-skills ability between students in different engineering specializations.

The result of Kruskal Wallis test is shown in Table 4.34 and Table 4.35.

Table 4.34: Mean ranks of measures for different engineering specializations

	Course	N	Mean Rank
Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00	Civil	46	164.54
	Electrical	173	159.99
	Mechanical	98	154.65
	Total	317	

Table 4.35: Result of test for student ability differences between engineering specializations

	Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00
Chi-square	.410
df	2
Asymp. Sig.	.815
Kruskal Wallis Test	

Grouping Variable: Course

Since $p = 0.815 > 0.05$, H_0 is accepted. It can be concluded that there is no significant difference in ICT user-skills ability between engineering specializations.

RQ 4c): Is there significant difference in ICT user-skills ability between students in different year of study?

Hypothesis for RQ 4c):

H_0: There is no significant difference in ICT user-skills ability between students in Year 1, 2, and 3.

H_3: There is a significant difference in ICT user-skills ability between students in Year 1, 2, and 3.

The result of Kruskal Wallis test is shown in Table 4.36 and Table 4.37.

Table 4.36 Mean ranks of measures for year 1, 2 and 3

	Year of Study		N	Mean Rank
Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00		First	93	129.40
		Second	81	131.73
		Third	143	193.69
		Total	317	

Table 4.37: Result of test for student ability differences between year 1, 2 and 3

	Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00
Chi-square	37.394
df	2
Asymp. Sig.	.000
Kruskal Wallis Test	
Grouping Variable: Year of Study	

Since p= 0.00 < 0.05, H_0 is not accepted. It can be concluded that there is significant difference in ICT user-skills ability between students in Year 1, 2 and 3.

Since there is a significant difference between student ability measures in different years, the next step is to perform tests between those in:

i) Year 1 and 2
ii) Year 1 and 3
iii) Year 2 and 3.

i) Year 1 and 2

H_0: There is no significant difference in ICT user-skills ability between students in Year 1 and 2.
H_3: There is a significant difference in ICT user-skills ability between students in Year 1 and 2.

The result of 2-sample K-S test is shown in Table 4.38.

Table 4.38: Result of test for student ability differences between year 1 and 2

		Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00
Most Extreme Differences	Absolute	.110
	Positive	.110
	Negative	-.080
Kolmogorov-Smirnov Z		.723
Asymp. Sig. (2-tailed)		.672
a. Grouping Variable: Year of Study		

Since p= 0.672 > 0.05, H_0 is accepted. It can be concluded that there is no significant difference in ICT user-skills ability between students in Year 1 and 2.

ii) Year 1 and 3
H_0: There is no significant difference in ICT user-skills ability between students in Year 1 and 3.
H_3: There is a significant difference in ICT user-skills ability between students in Year 1 and 3.

The result of 2-sample K-S test is shown in Table 4.39.

Table 4.39: Result of test for student ability differences between year 1 and 3

		Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00
Most Extreme Differences	Absolute	.355
	Positive	.000
	Negative	-.355
Kolmogorov-Smirnov Z		2.663
Asymp. Sig. (2-tailed)		.000

a. Grouping Variable: Year of Study

Since p= 0.00 < 0.05, H_0 is not accepted. It can be concluded that there is a significant difference in ICT user-skills ability between students in Year 1 and 3.

iii)Year 2 and 3

H_0: There is no significant difference in ICT user-skills ability between students in Year 2 and 3.

H_3: There is a significant difference in ICT user-skills ability between students in Year 2 and 3.

The result of 2-sample K-S test is shown in Table 4.40.

Table 4.40: Result of test for student ability differences between year 2 and 3

		Estimated STUDENT Measure: UIMEAN=.00 USCALE=1.00
Most Extreme Differences	Absolute	.291
	Positive	.000
	Negative	-.291
Kolmogorov-Smirnov Z		2.091
Asymp. Sig. (2-tailed)		.000
Grouping Variable: Year of Study		

Since p= 0.00 < 0.05, H_0 is not accepted. It can be concluded that there is a significant difference in ICT user-skills ability between students in Year 2 and 3.

RQ 5: What is the correlation between the frequency of performing engineering learning activities and the perceived usefulness of ICT user-skills?

To find the correlation between the frequency of performing engineering learning activities (ordinal) and the perceived usefulness of ICT user-skills (ordinal) and Spearman's rho bivariate correlation coefficients were calculated (Vogt, 2007). The significant level used was 0.01. The results are shown in Table 4.41.

Table 4.41: Spearman's rho correlation coefficient between the frequency of performing engineering learning activities and students' perception of the usefulness of ICT user-skills

Item Number	Activity Description	Correlation
1	C2_1_defining required information for an engineering problem	0.31
2	C2_2_using a computer to access engineering data efficiently	0.33
3	C2_3_using info effectively to solve engineering problem	0.32
4	C2_5_using graphics & charting tools in Excel,MATLAB or SPSS to perform statistical analysis	0.24
5	C2_6_using programming languages to develop software to solve engineering problems	0.20
6	C2_7_using application software eg AutoCAD to design eng systems	0.19
7	C2_8_using software eg Excel, Maple, MathCAD to solve mathematical problems	0.13
8	C2_11_evaluating engineering information on websites	0.28
9	C2_12_using information ethically and legally	0.32
10	C2_14_using software eg MS-Word to write a well-formatted engineering project reports	0.22
11	C2_15_using video technology to record,field trips and demonstrations	0.12
12	C2_16_making multimedia presentations	0.17
13	C2_17_using files to share info between project team members	0.26
14	C2_18_communicating via Internet eg email,chat, forum	0.26

15	C2_19_using internet to search for contemporary issues in engineering	0.23
16	C2_20_using internet get information about professional codes of ethics& legal issues	0.17

The correlation coefficients are within the range of (0.12, 0.33) which indicates a significant but rather weak positive correlation. This means that the more an activity is perceived as useful, the higher is the frequency of doing the activity.

RQ 6: What is the correlation between the frequency of performing engineering learning activities and students' ICT user-skills ability?

To find the correlation between the frequency of performing engineering learning activities (ordinal) in the ICT user-skills subscale and students' ICT user-skills ability (interval), Spearman's rho bivariate correlation coefficients were calculated (Vogt, 2007). The significant level used was 0.01. The results are shown in Table 4.42.

Table 4.42: Spearman's rho correlation coefficient between the frequency of performing engineering learning activities and students' ICT user-skills ability

Item Number	Activity Description	Correlation
1	C2_1_defining required information for an engineering problem	0.47
2	C2_2_using a computer to access engineering data efficiently	0.48
3	C2_3_using info effectively to solve engineering problem	0.44
4	C2_5_using graphics & charting tools in Excel,MATLAB or SPSS to perform statistical analysis	0.38
5	C2_6_using programming languages to develop software to solve engineering problems	0.32
6	C2_7_using application software eg AutoCAD to design eng systems	0.30
7	C2_8_using software eg Excel, Maple, MathCAD to solve mathematical problems	0.37

8	C2_11_evaluating engineering information on websites	0.56
9	C2_12_using information ethically and legally	0.50
10	C2_14_using software eg MS-Word to write a well-formatted engineering project reports	0.53
11	C2_15_using video technology to record,field trips and demonstrations	0.50
12	C2_16_making multimedia presentations	0.55
13	C2_17_using files to share info between project team members	0.56
14	C2_18_communicating via Internet eg email,chat, forum	0.38
15	C2_19_using internet to search for contemporary issues in engineering	0.47
16	C2_20_using internet get information about professional codes of ethics& legal issues	0.41

All the correlation coefficients are within the range of (0.30, 0.56) which indicates moderate positive correlation. This means that the higher the frequency of performing an ICT user-skills activity, the higher is the student ability in doing the activity.

RQ 6a): Are there significant differences in the frequency of performing engineering learning activities between male and female students?

Mann-Whitney tests were conducted to test for significant difference in the frequency of performing engineering learning activities between male and female students. The significant level used was 0.05. The results are shown in Table 4.43.

Table 4.43: Test for significant difference in frequency of activities between male and female

	defining req info for eng problem	using a comp to access eng data	using info in prob solving	using Excel, MATLAB or SPSS to perform statistical analysis
Mann-Whitney U	9853.500	10286.000	9765.000	10316.000
Asymp. Sig. (2-tailed)	.338	.721	.285	.753
	using programming languages to dev s/ware to solve eng problems	using app s/ware eg AutoCAD to design eng systems	using s/ware Excel,Maple,MathCAD to solve math probs	evaluating eng info on the w/sites
Mann-Whitney U	1036400	8863.000	9422.500	1036400
Asymp. Sig. (2-tailed)	.803	.020	.122	.803
	using info ethically and legally	using s/ware eg MS-Word to write a well format eng proj report	using video technology to record,field trips, demo etc	making m/media presentations
Mann-Whitney U	10119.500	9858.000	9089.000	8770.000
Asymp. Sig. (2-tailed)	.560	.349	.046	.015
	using files to share info between proj teams	communicating through Internet eg email,chat, forum	using internet of comptemporary issues in eng discipline	using internet of eng prof codes of ethics& legal issues
Mann-Whitney U	10316.500	10282.500	963400	9273.000
Asymp. Sig. (2-tailed)	.755	.721	.214	.082

a. Grouping Variable: Gender

There are significant differences in the frequency of performing engineering learning activities between male and female students in the following activities:

i) using design software

ii) using video technology

iii)making multimedia presentation

In each of the three activities above, the frequency of performing the activities by male students is significantly higher than female as indicated by the mean ranks as shown in Table 4.44.

Table 4.44: The frequency of performing the activities according to gender

Ranks					
		Gender	N	Mean Rank	Sum of Ranks
using app s/ware eg AutoCAD to design eng systems		male	222	166.58	36980.00
		female	95	141.29	13423.00
		Total	317		
using video technology to record,field trips, demo etc		male	222	165.56	36754.00
		female	95	143.67	13649.00
		Total	317		
making m/media presentations		male	222	167.00	37073.00
		female	95	140.32	13330.00
		Total	317		

RQ 6b): Are there significant differences in the frequency of performing engineering learning activities between students in different engineering specialization?

Kruskall Wallis tests were conducted to test for significant difference in the frequency of performing engineering learning activities between students in different engineering specializations. The significant level used was 0.05. The results are shown in Table 4.45.

Table 4.45: Test for significant difference in frequency of activities between different engineering specialization

	defining req info for eng problem	using a comp to access eng data	using info in prob solving	Using statistical software	Programming to solve eng problems
Chi-square	.553	1.796	1.074	6.199	6.188
Df	2	2	2	2	2
Asymp. Sig.	.759	.407	.585	.045	.045

	using design software	using s/ware to solve math probs	evaluating eng info on the w/sites	using info ethically and legally	using s/ware to write a well format eng proj report
Chi-square	438	2.924	2.436	.403	.287
Df	2	2	2	2	2
Asymp. Sig.	.133	.232	.296	.818	.866

	using vid technology to record,field trips, demo etc	making m/media presentations	using files to share info between proj teams	communicating through Internet eg email,chat, forum
Chi-square	1.971	.078	1.964	.316
Df	2	2	2	2
Asymp. Sig.	.373	.962	.375	.854

	internet search comtemporary issues in eng discipline	internet search prof codes of ethics& legal issues
Chi-square	2.403	1.039
Df	2	2
Asymp. Sig.	.301	.595

a. Kruskal Wallis Test

b. Grouping Variable: Course

There are significant differences in the frequency of performing engineering learning between students in different engineering specializations in the following activities:

i) using statistical software

ii) programming

Further investigation using Mann-Whitney tests showed significant differences in the frequency of using statistical software between electrical and mechanical engineering students (p = 0.016), and in the frequency of programming activity between electrical and civil engineering students (p = 0.014). The result is shown in Table 4.46.

Comparing the mean ranks between the groups, the results show that electrical engineering students do programming significantly more frequently than civil engineering students. They also use statistical software significantly more than mechanical engineering students. The results are shown in Table 4.47 and Table 4.48.

Table 4.46: Test for significant difference in the frequency of programming between civil and electrical students

	programming
Mann-Whitney U	3067.000
Asymp. Sig. (2-tailed)	.014

Table 4.47: Test for significant difference in the frequency of programming between civil and electrical engineering students

	Course	N	Mean Rank	Sum of Ranks
programming	Civil	46	90.17	4148.00
	Electrical	173	115.27	19942.00
	Total	219		

Table 4.48: Test for significant difference in the frequency of using statistical software between electrical and mechanical engineering students

	Perform Statistical Analysis
Mann-Whitney U	7015.500
Asymp. Sig. (2-tailed)	.016

a. Grouping Variable: Course

RQ 6c): Are there significant differences in the frequency of performing engineering learning activities between students in different years of study?

Kruskall Wallis tests were conducted to test for significant differences in the frequency of performing engineering learning activities between students in different years of study. The significant level used was 0.05. The results are shown in Table 4.49.

Table 4.49: Test for significant difference in frequency of activities between different years of study

	defining req info for eng problem	access eng data	using info in prob solving	perform statistical analysis	programming
Chi-square	11.147	15.170	19.371	16.991	6.277
df	2	2	2	2	2
Asymp. Sig.	.004	.001	.000	.000	.043

	using design software	using s/ware to solve math probs	evaluating eng info on the w/sites	using info ethically and legally	using s/ware to write a well format eng proj report
Chi-square	5.903	14.892	13.873	4.801	15.858
df	2	2	2	2	2
Asymp. Sig.	.052	.001	.001	.091	.000

	using video technology	making m/media presentations	using files to share info between proj teams	comm
Chi-square	18.595	43.486	7.746	4.709
df	2	2	2	2
Asymp. Sig.	.000	.000	.021	.095

	Internet search of contemporary issues in eng	Internet search of eng prof codes of ethics& legal issues
Chi-square	9.267	7.270
df	2	2
Asymp. Sig.	.010	.026

a. Kruskal Wallis Test

b. Grouping Variable: Year of Study

There are significant differences in the frequency of using ICT skills between students in different years of study with regard to the activities listed in Table 4.50.

However, there is no significant difference in the frequency of using ICT skills for engineering learning between students in Year 1 and Year 2.

Table 4.50: Testing for significant difference in frequency of activities between year 1 and year 3 and between year 2 and year 3

Item		Year 1 vs Year 3	Year 2 vs Year 3
1	C2_1_defining required information for an engineering problem	0.001	-
2	C2_2_using a computer to access engineering data	0.001	0.004
3	C2_3_using info to solve engineering problem	.0.000	0.002
4	C2_5_using Excel,MATLAB or SPSS to perform statistical analysis	0.002	0.000
5	C2_6_using programming languages to develop software to solve engineering problems	-	0.027
6	C2_8_using software eg Excel, Maple, MathCAD to solve mathematical problems	0.008	.0.000
7	C2_11_evaluating engineering information on websites	0.003	0.001
8	C2_14_using software eg MS-Word to write a well-formatted engineering project reports	0.000	0.005
9	C2_15_using video technology to record,field trips and demonstrations	0.000	0.011
10	C2_16_making multimedia presentations	0.000	0.000
11	C2_17_using files to share info between project team members	0.046	0.011
12	C2_19_using internet to search for contemporary issues in engineering	0.004	0.043
13	C2_20_using internet get information about professional codes of ethics& legal issues	0.006	-

Activities which have no significant difference in terms of frequency between Year 1, Year 2, and Year 3 are:

i) Using design software (p = 0.052)
ii) Using information ethically and legally (p = 0.091)
iii) Communication (p= 0.095)

RQ 8): What is the frequency distribution of students according to their ICT user-skills levels?

The item difficulty estimates corresponding to the three thresholds were used to separate the students into four ability groups. These estimates were -1.82, 0.06, and 1.76. The frequency of students in each ability group is shown in Table 4.51.

Table 4.51: Student frequency distribution

Category	Frequency	Percentage
Not at all skilled	24	7.6
Not very skilled	106	33.4
Moderately skilled	137	43.2
Very skilled	50	15.6

Majority of the students were either not very skilled or moderately skilled, comprising a total percentage of 76.6%. The *Very Skilled* group was a combination of the last two categories of *Very Skilled* and *Expert*. The categories were combined because the number of students in *Expert* category for many items was less than 10.

4.4 Findings of Qualitative Analysis

Qualitative analysis was performed to address the following research questions:

RQ 8a): What is engineering students' conception of ICT skills?
RQ 8b): What are the benefits of using ICT for engineering learning?
RQ 8c): What are the problems encountered in using ICT for engineering learning?

Three one-on-one interviews and three group semi-structured interviews were conducted. In total, eighteen students were interviewed. The interviews sought to explore students' conception of ICT skills and their experience of using those skills in their study. Experience of using ICT skills were discussed with respect to the frequency of using those skills, the benefits and the problems associated to usage of the ICT skills.

A thematic analysis was conducted on students' interview transcription. The analysis was a hybrid of inductive and theoretical analysis, in which a code manual was prepared before the analysis, and additional codes were added during data analysis whenever necessary. Any data related to the research question was considered a theme, and the number of instances of data supporting a theme was recorded to indicate the theme prevalence (Braun and Clarke, 2006). The themes were identified at semantic level based on the recorded words.

The phases of thematic analysis followed the steps in Table 3.22. The code manual was developed a priori based on the definition of ICT user-skills by UNESCO and the benefits of using ICT as a tool in learning. Based on the definition of ICT skills, three classifications of ICT skills were used: ICT Device Operations (DO), General-purpose Application Software (GS), and Engineering Software (ES). Usage of ICT as a tool can be categorized into four different types: Informative Tool (IT), Situative Tool (ST), Constructive Tool (CT1), and

Communicative Tool (CT2). Transription data were collated for each code. The codes used for the categories and the code description are shown in Table 4.52.

Table 4.52: The code manual

Code Category	Code Label	Code Name	Definition
Types of ICT User-Skills	DO	ICT Device Operations	Managing and operating ICT hardware.
	GS	General-Purpose Software	Software that provide specific capabilities, but not for a specific purpose.
	ES	Engineering Software	Software designed to solve specific engineering problems.
	IS	Information Skills	Skills to recognize when information is needed and the ability to locate, evaluate and use effectively the needed information.
Benefits of using ICT as Tools	IT	Informative Tool	Provides abundant data in various formats. An example is the internet.
	ST	Situative Tool	Creates learning situations eg learner-centered approach, e-learning, simulated learning environment.
	CT1	Constructive Tool	Manipulate data and aids in analysis to produce tangible or intangible output. Example of tangible output: Project report.

			Example of intangible output: Conceptual understanding.
	CT2	Communicative Tool	Facilitate communication and remove time and space barriers. New ways of interaction.
Problems Associated with using ICT Skills	CONN	Connectivity	Limited wireless connection. Unstable internet connection.
	RESOURCE	Resource	Limited availability of software and hardware outside class/lab/library hours.
	EXP	Exposure	Lack exposure to the latest software/technology in industry.
	PRAC	Practice	Lack of practical skills in using software and hardware.
	BASIC	Basic Skills	Lack of basic computer and information skills.
	MTNCE	Maintenance	Maintenance of equipment and computer.

4.4.1 Students' Conception of ICT Skills

RQ 8a): What are students'conceptions of ICT skills?

The questions asked by the interviewer with respect to RQ7a) took several forms, but essentially had the same meaning. On ICT skills, the questions were:

1. What do you understand by the term "ICT skills"?
2. What do you understand by the term "being ICT literate"?
3. What kind of skills do you think an ICT literate person should have?

A synthesis and examples of the transcripted interview data related to each code were given in the following section.

4.4.1.1 Operating ICT Devices (DO)

Almost all of those interviewed included the skill to operate ICT hardware as part of being ICT literate. These skills included basic operating skills such as booting the computer, using presentation hardware, and using digital communication gadgets. Basic knowledge of computer configuration and systems were also mentioned. Examples of the relevant interview data:

> We learn about LAN, WAN… how to use hardware, and so on.
>
> (Student DDA2)

> Able to boot a computer without help, and able to diagnose computer problems and perform computer maintenance.
>
> (Student DDE6)

4.4.1.2 General-Purpose Software (GS)

Most students mentioned the ability to use application software as part of being ICT literate. These software were used in engineering and non-engineering courses. Some of the common software mentioned were word processor, web browser, and data manipulating software. Examples of the comments related to using general-purpose software were:

> What I know about ICT is it concerns our understanding and knowledge about the usage of current technology such as the internet and software such as Word and Excel.
>
> (Student DDA1)

> We have to know how to use related software like Word or Office.
>
> (Student DDA6)

4.4.1.3 Engineering Software (ES)

Most students mentioned the ability to use engineering software as part of being ICT literate. Some of the software mentioned were PLC, MATLAB, and Micro-P program. Sample comments were:

> I used MATLAB to solve mathematical equations. Wrote C, C++ programs to solve problems.
>
> (Student DDE6)

> I used Gantt Chart in Project Management class. For Engineering Drawing class in the first year, I used AUTOCAD. During my second year, for the subject Engineering Survey, I used Excel to calculate road curves.
>
> (Student DDA4)

4.4.1.4 Information Skills (IS)

A majority of the interviewees mentioned several information skills. Most described it as the skills to search information using the internet. Some of the comments were as follows:

> Using computer technology and internet, because most of the times, to do an assignment I need to go and search for the necessary information.
>
> (Student DDA7)

> Besides using Google and Wikipedia, I can use SCRIBD to search for information.
>
> (Student DDA7)

4.4.2 Benefits of using ICT in Engineering Learning

RQ 8b): What are the benefits of using ICT skills in engineering learning?

To explore students' experience related to the benefits of using ICT in engineering learning, the question asked was one of the following:

1. From your experience, what do you consider the main advantages of using ICT skills in engineering learning?
2. What do you consider as the main benefits of using ICT skills in your study?
3. In your opinion, what are the most important advantages of using ICT skills in your study?

From the literature, there are four main categories of ICT tools. These categories might overlap because of the multiple functions a tool can serve. However for a particular tool, some functions may be more efficient than others. For example, a mobile phone can serve a communicative and an informative tool, but is less efficient as a constructive tool because of its size. In this study, the benefits of using ICT in engineering learning were classified under the most efficient function served by the related ICT tool. The benefits of using ICT mentioned by the students were as follows:

4.4.2.1 Informative Tool

Using ICT as an informative tool was mentioned by most interviewees. Students used information search software such as LESTARI to access and store information. Sample comments were:

> I can use the software and hardware to search for information in an efficient way.
>
> (Student DDJ5)

4.4.2.2 Situative Tool

Some students commented on using ICT as a situative tool that can provide a convenient and conducive learning environment. Some of the comments were:

> Can understand a subject in greater detail because students are motivated to look for new information in a short time and at anytime they wish, and not deterred by say the hot weather or rain.
>
> (Student DDJ1)

> ICT makes learning more interesting. If we use a pc, we seldom feel sleepy compared to reading books - we have to turn the pages.
>
> (Student DDE4)

4.4.2.3 Constructive Tool

Using ICT as a constructive tool was mentioned by most interviewees. They could see how simulation software could be used to demonstrate some basic engineering principles such as the flow of current in a circuit. Examples of comments were:

> My lecturer used a simulation software to demonstrate an electronic system. That enhanced my understanding.
>
> (Student DDJ4)

> Using Microsoft Project to manage projects, say, to estimate the duration of a project, I can use the Gantt chart. I can visualize certain aspects of the project using the chart, instead of just imagining it…I can also see the interdependency between the activities, which activities must be completed before the next ones can proceed.
>
> (Student DDA3)

> If we draw using AUTOCAD, we can see it in 3D.
>
> (Student DDA4)

4.4.2.4 Communication Tool

Since communication is one of the most popular uses of ICT today, most students mentioned it explicitly. They could communicate and exchange information with ease. Some sample comments were:

> Can share information through emails or the elearning system or using hardware like pendrive.
>
> (Student DDA5)

> Exchange of information is very fast. In the past we mostly used paper, photocopy, so the information transfer was very minimal. Using the current computer system, we use soft copy, much easier and faster to send information. And the output is of better quality.
>
> (Student DDE5)

The themes that emerged from the interview data related to students' conceptions of ICT skills are depicted in Figure 4.21. The major themes consisted of three types of ICT user-skills and four categories of ICT tools. These themes were the same as those in the literature. No new themes emerged from the data. Instances of data for each theme were described in Section 4.4.1 and Section 4.4.2. Based on the interview data, the students' conception of ICT user-skills were mainly as tools that can be used in four ways, as informative, constructive, communicative or situative tool.

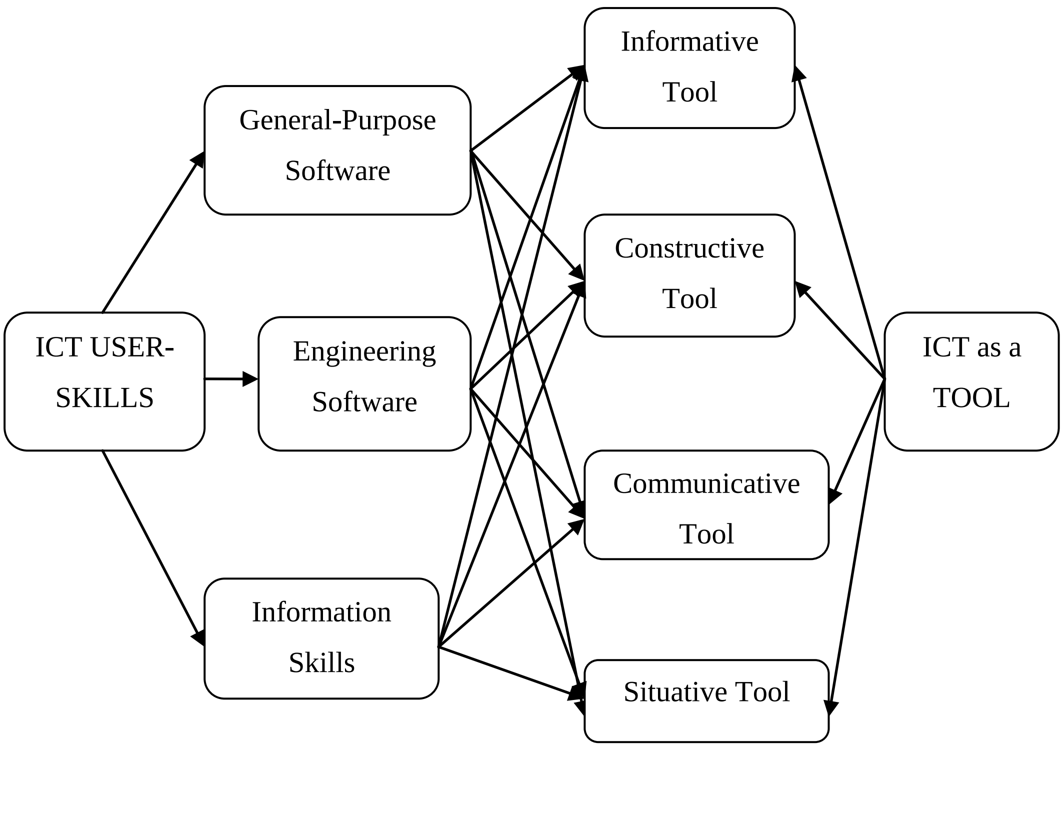


Figure 4.21: The thematic map of students' ICT user-skills conception

To establish the credibility of the researcher's qualitative findings, a peer debriefer was engaged to go through the audio recording and interview transcription independently. He obtained similar main theme for the respondents' ICT skill conception, that ICT was regarded a tool to do learning tasks. He specifically mentioned ICT as an information and communication tool. His report is shown in Appendix I.

4.4.3 Problems Associated with using ICT in Engineering Learning

RQ 8c): What are the problems encountered in using ICT for engineering learning?

Most of the problems mentioned by students were related to internet connectivity, availability of software and hardware resources, lack of practical skills, lack of industrial exposure, lack of information search skills, and poor computer maintenance. The prevalence of each subtheme was stated to indicate whether the problem was common across interviewees or only mentioned by a few.

4.4.3.1 Connectivity

Many students mentioned the problem of internet connectivity at the residential college. The wireless connection was reported to be very slow and unstable. Some of the comments given were:

> Anybody would say the same thing – the internet connectivity is terrible. Unstable – causing delayed assignments because we can't look for information. Many students use their own broadband, but still inconvenient if the campus WIFI is not available. And if the campus server is down, cannot do anything, have to come back another day.
>
> (Student DDA2)

4.4.3.2 Availability of Resources

More than half of the interviewees raised the problem of inadequate software and hardware. They had to download trial software version for use outside official laboratory hours. This would take time and the software could only be used for limited time.

> Software is not freely available. We get free CDs when we buy textbooks, but for those who can't afford to buy a book, would have to borrow the CD from friends.
>
> (Student DDA5)

4.4.3.3 Practice

Another common problem faced by students was the lack of practical skills during their study. This factor did not help them to be skillful or confident in handling engineering equipment.

> Lack of exposure on actual uses of software. My knowledge of engineering software is very basic, I don't understand the details.
>
> (Student DDE1)

> I only use the computer to do my assignments, not to actually design a structure. I don't even know how to design a structure using the software. I used AUTOCAD to learn to draw very basic objects like a round object or an oblong object of different sizes. We were not taught how to calculate, say the height of a structure. Only to draw very basic designs. Too basic.
> Not enough class time to study AUTOCAD because the class is combined with Engineering Drawing class. So class hours have to be divided between learning manual drawing and using AUTOCAD.
>
> (Student DDA4)

4.4.3.4 Exposure

Some students mentioned the lack of exposure to up-to-date software and databases.

> I don't know the latest software for designing structures. Even though we invite engineers from the industry to tell about the latest development, it's like…ooooo great, but we only know about it. We don't do it. We're not taught to design, or to calculate using the software. So, it's very unfortunate that we're being left behind in this aspect.
>
> (Student DDJ1)

4.4.3.5 Basic Skills

Some students talked about the lack of basic computer and information search skills. Even though they have IT classes, they opined that the approach used was more theoretical than practical. Thus, most students had to learn ICT skills from other resources, such as friends and family.

> We have many computers but some students don't know how to use the software. Some of my friends are ICT illiterate, don't know how to use the computer much, only the basic functions but they don't know how to go about searching for information. What we learn in IT class is mostly theoretical. We have to learn the practical aspect elsewhere. Like me, my father taught me how to type equations in Word.
>
> (Student DDA3)

> Lack of exposure on information search. For example, I don't know how to use the VPN service.
>
> (Student DDJ3)

4.4.3.6 Maintenance

Several students mentioned the lack of computer maintenance, especially the computer virus infection problem.

> Poor computer maintenance. The computers usually have virus problems that have caused data loss. Sometimes I even have to reformat my drive.
>
> (Student DDJ5)

The themes that emerged from the interview data with respect to the problems associated with using ICT are shown in Figure 4.22.

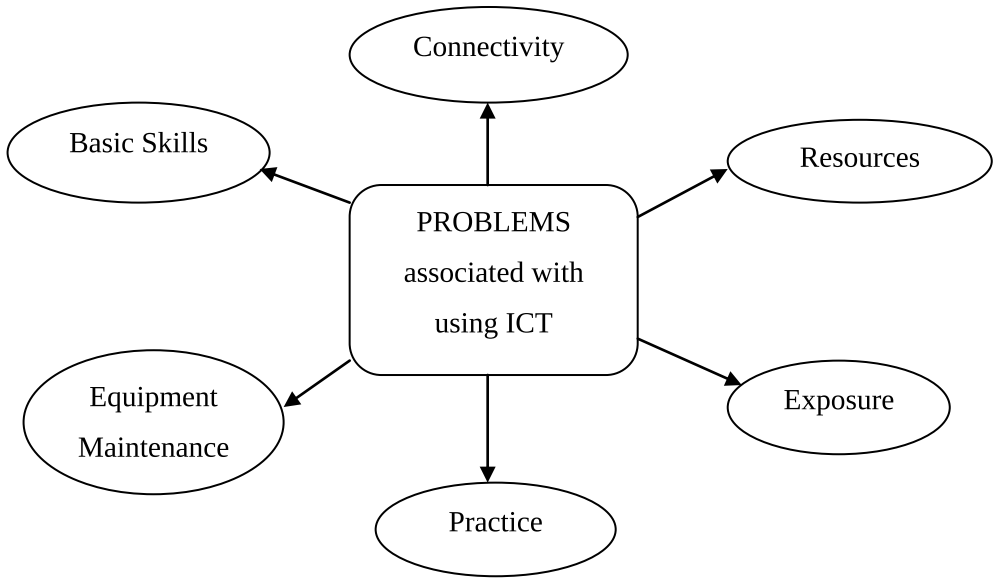


Figure 4.22: The thematic map of the problems associated with using ICT

4.5 Summary of the Chapter

This chapter has presented the results of quantitative and qualitative data analyses which followed the methodology detailed in Chapter 3. Demographic profile and characteristics of the respondents with respect to ICT user-skills were described. Psychometric properties such as the reliability and validity of the ICT user-skills sub-scale were evaluated. Evidences of construct validity based on Rasch data analysis were presented. Associations between student variables were analyzed using the student ability measures produced in Rasch analysis. Hypothesis testing was conducted to detect significant differences among different strata of students. Interview data were analyzed to describe students' conceptions of ICT skills as well as the benefits and problems associated with using ICT skills for engineering learning. The results obtained would be discussed in Chapter 5.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 Introduction

This chapter discusses the results obtained in Chapter 4 in relation to the study objectives and the literature. The main objectives of the study were to develop a survey instrument to measure students' ability to use ICT skills for engineering learning, to describe engineering students' ICT user-skills profile, , and to examine the relationships between students' demographic characteristics, frequency of activities, and their ICT ability. First, the summary of the results are presented. This is followed by a discussion on instrument development in which quantitative findings are corroborated with the qualitative findings and compared with existing literature. Then the findings on students' ICT user-skills profile and the relationships with other variables are explained and discussed with respect to the literature. The chapter proceeds to describe the theoretical and practical contribution of the study, the implications of the study, and proposes recommendations for future research. Finally, conclusions for the study are presented.

5.2 Summary of the Results

The quantitative and qualitative results produced in answering the research questions related to the respective research objectives are summarized in the following subsections. The summary of the results is as follows:

5.2.1 Sample Characteristics

Out of 317 respondents, 70% are male. The mean student age is 19.3 years. Over 80% of the student sample owned a personal computer or laptop, and most have internet access at all times. About 50% of the students spent less than 3 hours per week using the computer for study but more than 70% of the students spend more than 4 hours per week on recreation using the computer. The majority of the students felt that ICT courses were costly and could not find time to take ICT courses on their own. Most students learned their ICT skills from family and relatives. Most students felt that ICT makes learning more interesting, helped them do better research, facilitates communication with course mates, encourage independent learning, and creates awareness of professional ethics and legal issues.

5.2.2 Development of the ICT User-Skills Subscale

The ICT User-Skills subscale comprises 16 items as shown in Table 5.1. The 16 items were selected as a result of the corroboration between quantitative and qualitative findings. Based on the misfit of the four items with respect to the Rasch model, and considering the minimal extent of learning believed to have taken place with regards to the corresponding activities, namely using e-learning, simulation software, data collection software, and project management software as indicated by the interview data, the researcher decided to drop the four items.

Table 5.1: Items in the ICT User-Skills subscale

No.	Items
1.	Using software eg. MS-Word to write a well-formatted engineering project report.
2.	Using video technology to record engineering projects, field trips, demonstrations etc.
3.	Making multimedia presentations of engineering projects.
4.	Using files to share information between project teams.
5.	Communicating through the Internet eg email, chat, forum with project members.
6.	Using the internet to gain knowledge of contemporary issues in an engineering discipline.
7.	Using the internet to gain knowledge of engineering professional codes of ethics and legal issues.
8.	Using graphics and charting tools in Excel, MATLAB or SPSS to perform statistical analysis of engineering systems.
9.	Using programming languages to develop software to solve engineering problems.
10.	Using application software eg AutoCAD and MATLAB to design engineering systems.
11.	Using software eg Excel, Maple, MathCAD to solve engineering mathematical problems.
12.	Defining the required information for an engineering problem.
13.	Using a computer to access engineering data.
14.	Using information in problem solving.
15.	Evaluating engineering information on the websites.
16.	Using information ethically and legally.

5.2.3 Psychometric Properties of ICT User-Skills Subscale

1) The rating scale for the ICT User-Skills subscale was: 1(Not at all skilled), 2 (Not very skilled), 3 (Moderately skilled), 4 (Very skilled) and 5 (Expert). This scale has been proven effective to measure students' ICT skills ability.

2) The study data have been shown to meet the assumptions of Rasch analysis: unidimensionality, local independence, monotonicity of the latent trait, and having non-intersecting item response curves.

3) The study has established the reliability of the ICT User-Skills subscale. The reliability index is 0.91.

4) The study has established the construct validity of the ICT User-Skills subscale. Aspects of construct validity relevant in this study are: content, substantive, structural, generalizability, and interpretability.

5.2.4 Association between Student Variables

There is a significant association between the following student variables:

1) Gender and Computer Ownership
2) Gender and Internet Access
3) Gender and Hours of Computer Use for Study
4) Gender and Hours of Computer Use for Recreation
5) Year of Study and Computer Ownership
6) Year of Study and Hours of Computer Use for Study
7) Year of Study and Hours of Computer Use for Recreation

5.2.5 Significant Differences in ICT User-Skills Ability across Gender, Engineering Specialization, and Year of Study

1) The study has shown that there is no significant difference in ICT user-skills ability across gender and engineering specialization.

2) The study has shown that there is significant difference in ICT user-skills ability between students in Year 1 and 3, and between students in Year 2 and 3.

5.2.6 Correlation between the frequency of performing engineering learning activities and the perceived usefulness of ICT user-skills

The study results indicated a significant albeit weak positive correlation between the frequency of performing engineering learning activities and the perceived usefulness of ICT user-skills. This means that the more an activity is perceived as useful, the higher is the frequency of doing the activity. This was in accordance with the Technology Acceptance Model (TAM) which has identified perceived usefulness of technology as a factor that influences technology acceptance Davis (1989).

5.2.7 Correlation between ICT user-skills ability and frequency of activities

The study results showed a moderate positive correlation between ICT user-skills ability and the frequency of ICT activities. This was an empirical evidence of the behaviorist Law of Exercise (Hergenhahn and Olson, 2005).

5.2.8 Significant Differences in the Frequency of Performing Engineering Learning Activities with Respect to Gender, Engineering Specialization and Year of Study.

1) There are significant differences in the frequency of performing engineering learning activities between male and female students in the following activities:
   a) using design software
   b) using video technology
   c) making multimedia presentation

2) There are significant differences in the frequency of performing engineering learning between students in different engineering specializations in the following activities:
   a) using statistical software
   b) programming

3) There are significant differences in terms of the frequency of all ICT user-skills activities between Year 1, Year 2, and Year 3 except in:
   a) Using design software ($p = 0.052$)
   b) Using information ethically and legally ($p = 0.091$)
   c) Communication ($p = 0.095$)

5.2.9 Engineering Students' Conception of ICT Skills and their Experience in using ICT Skills for Learning

Students' conception of ICT skills is that of a tool to help them achieve learning objectives. The tool functions in four different but overlapping ways: as an informative tool, situative tool, constructive tool, and communicative tool. Some tools were used more than others, and their skill levels in using the tools differed. Students self-reported ICT skill levels showed that the lowest levels were for advanced engineering applications as evidenced from the item map output of Rasch analysis.

5.3 Discussion of the Results

This section first presents a discussion on the ICT user-skills instrument development process in which the quantitative and qualitative findings were converged. Then, possible explanations for the main study results were proposed to relate the findings to the literature and the learning theories underpinning the study. The demographic findings on the study sample characteristics were discussed. Relationships between demographic variables and ICT were compared to the findings in similar studies.

5.3.1 Development of the ICT User-Skills Instrument

Existing instruments to measure ICT skills among students in higher education are not tailored for engineering education. Even though there are many general-purpose ICT skills which are similar across fields of study, engineering education requires the use of specialized software to support engineering learning tasks. Hence, a new instrument incorporating specific ICT skills for engineering applications is required to examine students' ICT skills for engineering learning. In this study, the instrument was developed specifically to measure the ICT user-skills ability of a population of diploma of engineering students at a Malaysian college.

One of the first decisions in creating a new instrument was the choice of the rating scale to use. In many polytomous cases, Likert scale was used with categories such as "Strongly Agree" and "Agree". The disadvantage of such a scale is it is subjected to each respondent's interpretation of what the categories mean, and how different one category is compared to adjacent categories. This subjectivity may cause much variance in respondents' choices of options. To overcome this problem, categories with more precise meaning as recommended by Basque, Ruelland and Lavoie (2007) were used in this study. Thus, five response categories, ("Not at all skilled", "Not very skilled", "Moderately skilled", "Very skilled", and "Expert") with the corresponding performance criteria were given as item response options.

The items included in the new instrument that represented the different types of ICT skills were generated from a task analysis based on the engineering problem-solving cycle. However, to ensure that the instrument was suitable for the target student population, which in this study comprised the students enrolled in the diploma of engineering programs at a Malaysian college, it was important to take into account the students' conception of ICT skills and their experience in utilizing the skills in engineering courses, both of which would affect the extent of internalized learning.

Final year students who have gone through six semesters of study were purposely selected for interviews to get a whole view of the diploma study experience. Many of these students described their experience in using ICT skills for engineering design, simulation, project management, and data collection as very shallow and basic. Students seemed to watch the simulation of an event more, rather than doing the simulation themselves as evidenced by this comment*: My lecturer used a simulation software to demonstrate an electronic system. That enhanced my understanding.*

Quantitative findings on the frequency of these activities show a high percentage of students giving a rating of "Never" or "Rarely for using the software for engineering design, simulation, project management, and data collection. Specifically, the percentages were respectively 47%, 51%, 65%, and 67%. The effect of infrequency of activities was probably worsened by the fact that the diploma students did not undergo practical training during their study since practical training was not part of the curriculum. Practical training is vital to give students hands-on experience of the actual engineering tasks and to internalize learning. Thus, from the perspective of constructivist learning theory and cognitive development, this may mean that learning has not been effective in these areas because:

> Learning is defined as the construction of knowledge as sensory data are given meaning in terms of prior knowledge. Learning always is an interpretive process and always involves construction of knowledge.... Constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of what they are learning.
>
> (Tobin, 1990:122)

The decision on which items to drop from the proposed instrument was based on two factors. The first was the empirical data on how well an item fit the Rasch model. The second was the belief on the extent of learning that has taken place, judged from students' feedback and the activity frequency data. Furthermore, according to Biggs (2003) and Pelligrino *et al.* (2001), alignment of assessment tasks and learning activities are pre-requisites for making judgment on what students know and how much they learn. Thus, if an item has a poor fit, and the extent of learning was believed to be minimal because of insufficient learning activities, then the item would be dropped. Based on these two factors, the researcher decided to drop four items: *Using E-learning, Using Simulation Software, Using Data Collection Packages,* and *Using Project Management Software*. At this stage, the quantitative findings of item fit and frequency of activities were converged with the researcher's interpretation of the qualitative findings of students' learning experience based on thematic analysis of interview transcriptions.

5.3.2 Psychometric Evaluation of the Instrument

Psychometric evaluation of an instrument is important to assure quality in testing. Aspects of an instrument that need to be ascertained to assure quality measures include the functioning of the rating scale employed, whether the assumptions underlying the measurement model are met, and the accuracy and precision of the instrument (Fisher, 2007).

The functioning of the rating scale was examined using the criteria by Linacre (2002) and Fisher (2007). All the criteria were met, except for the minimum number of responses in the "Expert" category for some items which were less than 10. To overcome the problem of instability of parameter estimates, category "Very Skilled" were combined with category "Expert" during data analysis.

The assumptions of unidimensionality, local independence, monotonicity of the latent trait, and having non-intersecting item response curves were checked to ensure valid inferences based on the Rasch model output. Unidimensionality of the construct represented by the 16 survey items were verified using simulated datasets.

The concepts of accuracy and precision in measurement are called validity and reliability. The results of a test are only useful if there is control over measurement error (Stone, 2002). This means the instrument must be proven valid and reliable before being put to use. Determination of validity and reliability should be based on two entities of measurement, namely items and persons.

In this study, internal consistency reliability of the instrument was checked using both CTT and the Rasch model approach. In CTT, reliability is usually calculated for items, but rarely for persons. For this study, the reliability of the instrument indicated by Cronbach's alpha was high at 0.94. The Cronbach's alpha was calculated using raw scores. Internal consistency reliability in the Rasch model using item and student measures in logit was represented by the student reliability index (0.91) and the item reliability index (0.97). This indicated that the ICT user-skills subscale was reliable and the item difficulty calibrations and student ability measures were reproducible.

Validity of an instrument is conditional on the time of administration, the setting where the instrument is administered, and the people who participate in the survey (De Vellis, 2003). Thus an instrument that is valid in one circumstance may not be valid in another. Evidences of content and construct validity of the ICT user-skills subscale administered in the main study are summarized in Table 5.2.

Table 5.2: Empirical evidence of validity

Aspect of Construct Validity	Criteria of Validity	Empirical Evidence
Content	Expert review: Content Validity Index (CVI > 0.8)	CVI = 1.00
	Representativeness: Item Strata > 2	Item Strata = 5.54 > 2
	Technical quality: Fit statistics (0.7 < MNSQ < 1.3)	Fit statistics: (0.74 < MNSQ < 1.24)
	Item-Measure Correlations > 0.5	Item-Measure Correlations > 0.61
Substantive	Student frequency distribution (consistent with theory/hypothesis)	Based on t-test: No gender difference in ICT user-skills ability.
	Category probability curve	In correct order with thresholds at -1.82, 0.06, 1.76
	Person fit statistics	> 80% of MNSQ within (0.4, 1.6)
Structural	Item fit statistics	Fit statistics: (0.74 < MNSQ < 1.24)
	PCA of residuals	Percentage of the total variance accounted for by the first component > 50%
		Percentage of unexplained variance in each of the five contrasts < 10%

Generalizability	Insignificant DIF for item and student measures (< 0.5 logit) Student separation index (internal consistency) > 0.8	DIF = 0 Student reliability index = 0.92
Interpretability	Item map	Targeting of items and students was good according to Fisher's criteria i.e. the mean student measure is less than one error of measurement from the mean item measure.

The student separation statistic of 3.16 indicates that the ICT user-skills subscale effectively discriminates between students with varied ability levels. The item separation statistic of 5.54 indicates that the items are well spread out across the difficulty continuum (Linacre, 2009).

One of the most useful output of Rasch analysis to evaluate an instrument is the item map, also known as the Wright map (Bond and Fox, 2007). On the map, student ability is lined up with item difficulty on the same metric. Thus by examining the map, one can evaluate how well the items are matched up with the students. The Wright map for this study is shown in Figure 5.1. It can be seen that although there are some gaps between items along the measured ability continuum, the range of the items covers the bulk of the students in the study. Students located opposite the gaps could not be measured with precision because of the lack of items. Most of these students were at the top and bottom ends of the scale. However, most of students within one standard deviation from the mean could be measured quite reliably using the instrument.

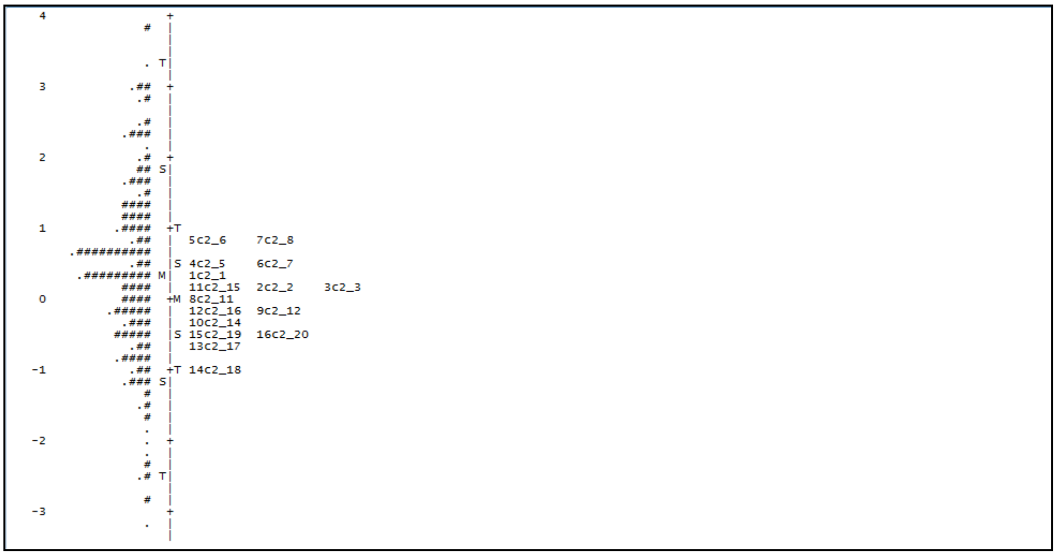


Figure 5.1: Wright map

Since items in a Rasch rating scale model have the same discrimination levels, item difficulty can be compared solely based on item location on the map (Bond and Fox, 2007). Items can be selected to measure students in certain ability group, and some items on the same levels can be omitted to make the instrument shorter and less time-consuming for the respondents without affecting student ability measures. Figure 5.2 shows the ICT user-skill item statistics in measure order. Comparing Figure 5.1 and Figure 5.2, it can be seen that the measure order corresponds with the location of the items on the Wright map.

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
5	728	317	.78	.08	1.17	2.2	1.14	1.6	.63	.68	52.9	53.6	5c2_6 programming
7	728	317	.78	.08	1.16	2.0	1.11	1.3	.66	.68	53.9	53.6	7c2_8 use software to solve math problems
4	757	317	.57	.08	1.06	.8	1.02	.3	.68	.69	53.2	53.2	4c2_5 use data analysis software
6	774	317	.45	.08	1.19	2.4	1.24	2.7	.61	.69	49.0	53.0	6c2_7 use design software
1	785	317	.37	.08	.91	-1.2	.98	-.2	.69	.69	58.1	53.3	1c2_1 define required information
2	820	317	.13	.08	.76	-3.4	.77	-3.0	.75	.69	59.1	53.7	2c2_2 access engineering data
3	825	317	.09	.08	.76	-3.4	.74	-3.5	.74	.69	58.4	53.7	3c2_3 use information
11	826	317	.08	.08	.93	-.9	.90	-1.3	.73	.69	56.2	53.7	11c2_15 use video technology
8	849	317	-.08	.08	.92	-1.1	.97	-.3	.71	.69	58.4	53.8	8c2_11 evaluate engineering information on websites
9	852	317	-.10	.08	.83	-2.4	.81	-2.5	.73	.69	58.8	53.9	9c2_12 use information ethically and legally
12	871	317	-.24	.09	1.02	.3	1.02	.3	.70	.69	56.2	54.2	12c2_16 use presentation software
10	873	317	-.25	.09	.99	-.1	.95	-.5	.73	.69	53.2	54.0	10c2_14 use software to write reports
16	896	317	-.42	.09	1.13	1.7	1.07	.8	.68	.69	54.9	54.4	16c2_20 internet search for professional codes of ethics a
15	917	317	-.57	.09	1.09	1.2	1.05	.6	.67	.69	52.3	54.9	15c2_19 internet search for contemporary engineering issue
13	925	317	-.63	.09	.96	-.5	.92	-.8	.71	.69	59.4	55.1	13c2_17 use files to share information
14	968	317	-.97	.09	1.12	1.5	1.08	.9	.67	.69	55.2	56.1	14c2_18 online communication
MEAN	837.1	317.0	.00	.09	1.00	-.1	.99	-.2			55.6	54.0	
S.D.	68.5	.0	.49	.00	.14	1.8	.13	1.6			2.9	.8	

Figure 5.2: Item measure order

Based on the summary statistics shown in Figure 5.3, the mean of student ability was 0.30 logit, which was slightly higher than the mean item difficulty, which was set by default at 0.0. The standard deviation of student ability measures was 1.76 logit, more than 3 times the standard deviation of item difficulty measures, which was 0.49. This means student ability measures are three times more spread out compared to item difficulty measures. The relative location of the means and the different spread between students and items can be observed from the Wright map shown in Figure 5.2.

```
     SUMMARY OF 317 MEASURED (EXTREME AND NON-EXTREME) STUDENT
-------------------------------------------------------------------------------
|           TOTAL                         MODEL         INFIT        OUTFIT    |
|           SCORE      COUNT     MEASURE  ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|------------------------------------------------------------------------------|
| MEAN       42.3       16.0         .30    .43                                |
| S.D.       10.8         .0        1.76    .26                                |
| REAL RMSE    .53 TRUE SD    1.67  SEPARATION  3.16  STUDENT RELIABILITY  .91|
|                                                                              |
| S.E. OF STUDENT MEAN = .10                                                   |
-------------------------------------------------------------------------------

     SUMMARY OF 16 MEASURED (NON-EXTREME) Item
-------------------------------------------------------------------------------
|           TOTAL                         MODEL         INFIT        OUTFIT    |
|           SCORE      COUNT     MEASURE  ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|------------------------------------------------------------------------------|
| MEAN      837.1      317.0         .00    .09      1.00    -.1    .99    -.2 ||
| S.D.       68.5         .0         .49    .00       .14    1.8    .13    1.6 |
|                                                                              |
|------------------------------------------------------------------------------|
| REAL RMSE    .09 TRUE SD     .49  SEPARATION  5.54  Item   RELIABILITY  .97 |
|                                                                              |
| S.E. OF Item MEAN = .13                                                      |
-------------------------------------------------------------------------------
```

Figure 5.3: Summary statistics

The distribution of students within different ability groups can be visualized by drawing lines corresponding to the cut scores as shown in Figure 5.4. For this study, lines can be drawn on the Wright map at cut score points of -1.82, 0.06, and 1.76 to identify the items that differentiate students within each ability group. Those below the cut score -1.82 belong to the *Not At All Skilled* group. Those between -1.82 and 0.06 belong to the *Not Very Skilled* group. Those between 0,06 and 1.76 are *Moderatey Skilled*, and those above 1.76 are *Very Skilled.*

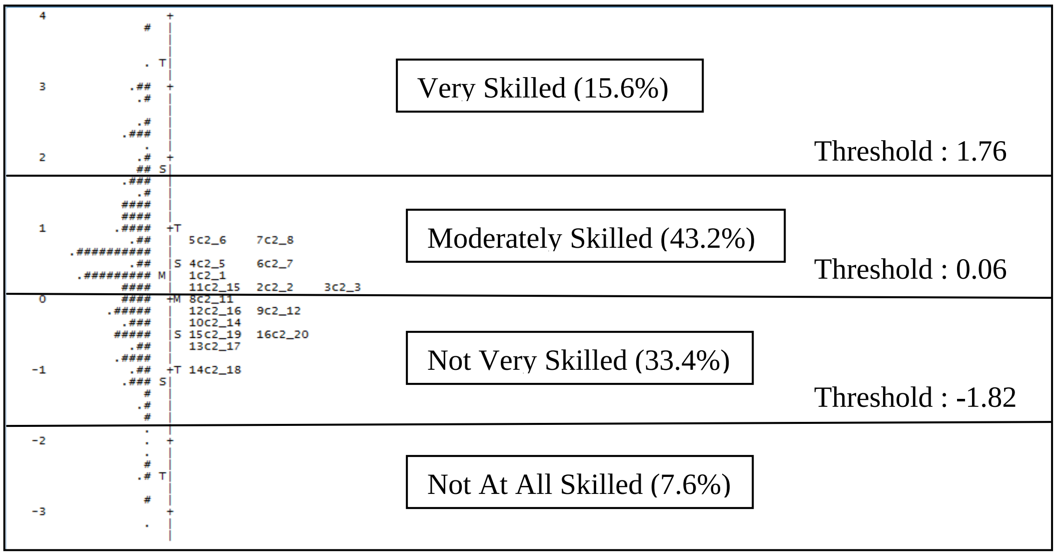


Figure 5.4 : Student ability groups

From the map, it can be seen that the items perceived as the most difficult were those at the top of the scale: c2_6 (programming), c2_8 (using Math software), c2_7 (using design software), and c2_5 (using data analysis software). According to Bloom's Taxonomy of Cognitive Development, these activities require higher-order thinking skills and conceptual understanding, and without sufficient practice would be difficult to excel at (Biggs, 2003). From Figure 5.4, it can be seen that these four activities were the least frequently performed.

Similarly, it can be seen from the Wright map that students perceived themselves to be most able in activities that require lower thinking skills such as c2_18 (online communication), c2_17 (using file to exchange information), c2_19 (internet search for contemporary issues), and C2_20 (internet search for professional codes of ethics and legal issues). From Figure 5.2, these activities were also the most frequently performed. On the whole, Figures 5.1 and 5.2 illustrate the positive association between student ability and frequency of activities found in Section 4.3.4.2.

The Wright map can also be used to compare the frequency of the ICT activities used for study as shown in Figure 5.5. The activities at the top are the least frequently performed, and those at the bottom are the most frequently performed. It can be clearly seen that students perform activities using general-purpose applications such as the Internet, word processor, and presentation software more often than specialized engineering application software.

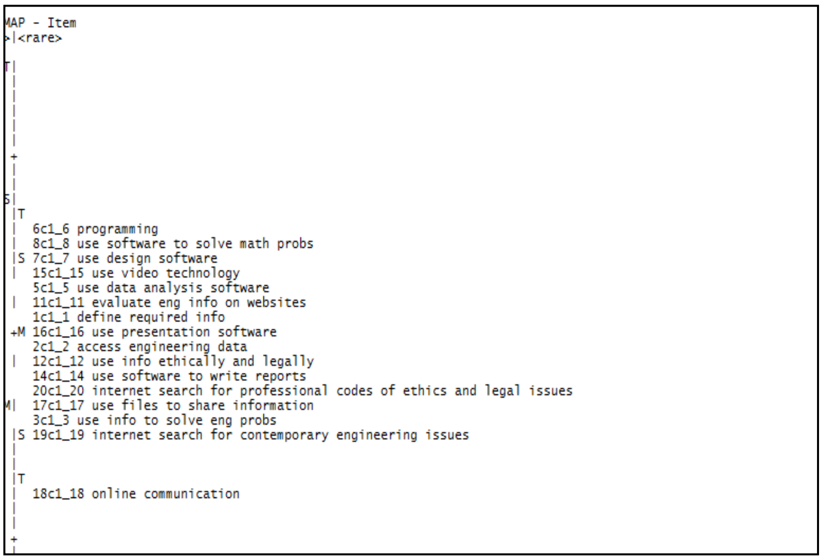


Figure 5.5: Order of the frequency of ICT activities

5.3.3 Sample Characteristics

The large percentage of male students in the sample (70%) compared to female indicates gender imbalance in engineering studies, very much similar to the trend in other parts of the world since the past decades as shown in the studies by Nosek *et al*. (2009), Bailyn (2003) and Turner and Bowen (1999). The mean age was 19.3 because these were full-time students who joined the college right after finishing high school.

In terms of computer ownership and internet access, most students owned a computer and had good internet access, similar to the findings in SEUISS (2003). However, considering the SEUISS study was done six years earlier, the findings might be an example of the lag of ICT infusion in education between developing and developed countries. The fact that the percentage of computer ownership and internet access among Malaysian students in the 2009 study sample were lower than in the

2008 ECAR study seems to affirm the notion of the global digital divide in terms of computer ownership and internet accessibility. This might also be due to the relatively cheaper computer prices and affordable internet services in the United States compared to Malaysia.

Most students in the study sample spent about 1 – 3 hours per week for study and about 4 – 6 hours per week for recreation. This was a lot less than the computer hours spent on study and recreation by students in the ECAR study, most of whom spent more than 20 hours per week. This could be due to the lower percentage of computer ownership and internet accessibility among the 2009 Malaysian student sample compared to those in the 2008 ECAR study. But this could also be a case of the disparity of ICT use between people with different media culture (Norris, 2001). Like the students in the SEUSISS study, most students in this study also learned their ICT skills from family and relatives, and by self-learning. This might be because that was the most convenient and economical way to learn ICT skills.

On the benefits of using ICT, most (64%) students in this study felt that ICT made learning more interesting. However, only about 42% felt that ICT made learning more convenient. In comparison, about 66% of students in the ECAR survey agreed that ICT makes their course activities more convenient. The endorsement order of the benefits of using ICT in their study can be discerned from the map in Figure 5.2. The benefits at the top of the scale were the least frequently endorsed. The benefits at the bottom of the scale were the most frequently endorsed. The low percentage among the Malaysian students in the study sample who felt ICT makes learning convenient could be due to the internet connectivity problem mentioned by many in the interview. This internet connectivity problem was also reflected in the survey findings in which only 31% of the students agree or strongly agree that the ICT services at the college were available for study purposes.

Figure 5.6: Endorsement order of the benefits of ICT

5.3.4 Relationships between ICT User-Skills Ability and Student Variables

Research findings show significant gender difference in computer ownership, internet accessibility, and the hours spent on study and recreation. Higher percentage of female students owns a computer and has internet access than male students. Female students also spend more time using the computer for study and recreation. From the literature, gender difference in ICT use and access has existed since over a decade ago. For example, Looker and Thiessen (2003) found gender difference among Canadian youths with regard to computer use and access. Despite the significant gender differences in computer use and internet access, this study found no significant difference in the ICT user-skills ability between male and female engineering students. This finding was generally similar to the one found by Teck and Lai (2011) who only found significant gender difference in the ability to perform computer maintenance among pre-university students.

This study found that engineering specialization has no association with computer ownership, internet access, study and recreational hours using the computers. There was also no significant difference in the ICT user-skills ability between Civil, Electrical and Mechanical engineering students. This may mean that the subjects taken by these students or the extent of ICT integration in the subjects do not make significant differences in the students' ICT skills levels, or that the subjects do not require significantly different level of ICT user-skills ability.

Year of study represents the extent of knowledge, skills and experience that students acquire during their study. The first year in the diploma of engineering programs consists of general education courses, foundational studies in mathematics and science, and some introductory engineering courses such as Engineering Drawing, Statics, and Dynamics. During the second and third years, students would take more engineering courses, which normally demand more study time. As expected, this study found significant differences in the study hours using the computer across different years of study. Third year students spent the most study hours, followed by second year students.

The mean ICT user-skills ability for students in Year 1, 2, and 3 were -1.60, - 0.26, and 0.92 logit respectively. This might indicate the extent to which the diploma of engineering curriculum was effective in improving students' ICT user-skills. The differences in ICT ability means between Year 1 and Year 3 and between Year 2 and Year 3 were significant, but between Year 1 and Year 2 were not significant. A study of the relationship between ICT skill levels and the frequency of ICT-related activities indicated a positive correlation across all items. This positive correlation concurs with the Behaviorism law of exercise, which implies that increasing the frequency of an action would tend to increase the mastery level of performing that action. This means that to enhance students' ICT skills, students' use of ICT skills in learning activities especially during the first two years of the program should be intensified.

The study results showed significant differences in the frequency of performing engineering learning activities between male and female students in using design software, using video technology, and making multimedia presentation. This finding agreed with the recent finding by the ECAR (2009) study on gender difference in technology adoption preferences. The ECAR study found that males do more audio and video creation than females. Similar results on adoption were found in studies by (Fenwick, 2004; Liff and Shepherd, 2004).

5.3.5 Evaluation of Qualitative Research Findings

The worth of a qualitative research study depends on the trustworthiness of the findings and should be evaluated with respect to the procedures used to produce the findings (Graneheim and Lundman, 2004). Lincoln and Guba (1985b) posit four interrelated criteria to establish the trustworthiness of the findings. These are the credibility, transferability, dependability, and confirmability of the findings.

Credibility refers to the confidence in the "truth" of the findings. The "truth" depends on how well data and analysis procedures address the research focus. In this study, to get input from a variety of aspects such as gender and engineering specialization, interviewees were selected from both gender and all three engineering specializations. One of the techniques that can be applied to establish credibility as suggested by Lincoln and Guba (1985c) is peer debriefing. The analysis results produced by the peer debriefer were consistent with those produced by the researcher, and hence was an evidence of the credibility of the findings.

Transferability refers to the applicability of the findings in other contexts. In this study, the research setting, the selection and characteristics of participants were described in Section 3.3 and 3.4. Data collection procedures and analysis techniques have been detailed out in Section 3.6 through 3.9. This information would facilitate transferability of the findings to another context if the reader decides to do so.

Dependability relates to the extent data change over time during the data collection and analysis process. Changes in the curriculum, for example can affect the consistency of data. Data collection in this study took place within one semester during which no changes were made to the curriculum. The learning infrastructure and environment had remained about the same during the data collection and analysis stages. Thus the data remained consistent within the period of the study and met the dependability criteria.

Confirmability refers to the extent to which the findings represent the interviewees' perspective and not influenced by the researcher's bias or interest. In this study, confirmability of the findings was established using methods triangulation. The quantitative findings on students' skill levels as shown by the Wright map confirmed the qualitative findings that students were more skilled in using general ICT applications such as word processor than in using engineering-specific applications such as AUTOCAD. The two methods also confirmed the internet connectivity problem faced by the students.

5.4 Conclusions

ICT user-skills are essential for future engineers in the increasingly digital world to keep pace with fast scientific and technological advances in the borderless world of information. The gap between required ICT skills and the ICT skills of engineering graduates might continue to exist and become wider if proactive intervention steps are not taken. One of the first steps towards improvement is a regular monitoring of student skill levels. Key to skills assessment is a reliable and valid measuring instrument.

The main objectives of this study were a) to develop a reliable and valid instrument to measure students' ability in using ICT skills for engineering learning, b) to examine engineering students' ICT user-skills profile, and c) to ascertain the relationships between student ICT skill levels and relevant independent variables. These objectives were set as the first steps in the process to achieve the most important goal of measurement, which is to improve student learning by informing curricular and educational policy planning and decision-making.

The ICT user-skills instrument was developed through a literature review of major existing instruments, task inventory of engineering problem-solving cycle, and semi-structured student interviews. The accuracy and precision of the instrument were established through psychometric evaluation of validity and reliability using the

Rasch model on the data of 317 engineering students. Thus, the instrument may be suitable for future use to measure ICT user-skills of the students at the college of study.

Some of the findings on the relationships between ICT skill levels and research variables were i) A positive correlation between frequency of activities and ICT user-skills levels, ii) Significant differences in ICT user-skills levels across the year of study, and iii) Non-significant differences in ICT user-skills levels across gender and engineering specializations. For findings such as these to be meaningful for planning improvement strategies, the measurement of student attributes such as their ICT skill levels must be context and focus-specific with respect to the purpose of measurement. And most of all, the measurement instrument employed must be proven reliable and valid for the target population, as has been done in this study.

5.4.1 Theoretical Contribution of the Study

The theoretical contribution of this study is the creation of an empirically validated measurement instrument based on the learning theories, measurement theory and engineering learning objectives. Learning theories that underpin the study are constructivist learning theory, behavorist law of exercise, transformative learning theory and the concept of zone of proximal development within social development theory. Measurement theory that forms the basis of instrument development is Rasch measurement. Engineering learning objectives are based on ABET and MEEM criteria which incorporate Bloom’s taxonomy of educational outcomes.

5.4.2 Practical Contribution of the Study

This study has developed an instrument to measure ICT user-skills for engineering learning. Measures of student ability can be used for program diagnosis and formative assessment of students. Levels of performance can be interpreted as the progression on a developmental scale, which can guide the teaching and learning strategy. Appropriate intervention plan or method of scaffolding to enhance the ability to use ICT skills for engineering learning can be identified for students at each skill developmental stage.

Profiles of student ICT user-skills can provide empirical evidence of their skills and illuminate on the factors associated with those skills. Knowing the relationship between demographic variables such as the year of study and skill levels can indicate the need to revise certain aspects of the curriculum such as the course content and learning objectives. Positive correlations between the frequency of activities and skill levels could be the basis for increasing the frequency of activities to enhance the skills. Profiles of students' existing ICT skills would also serve as a testimonial on the effectiveness of the curriculum as a whole.

5.4.3 Implications of the Study

The instrument consists of a set of tasks or items with difficulty levels calibrated using the Rasch model. The items on which students have 50% chance of success can be identified from the Wright map. These items can be used to determine each student's Zone of Proximal Development, the conceptual zone where each student can achieve more with external assistance or scaffolding compared to what he can achieve independently. The ZPD is the state of readiness for further development in the domain of skills to be acquired. The relative locations of students and items would indicate the type of learning activities that should be planned so that the activities are not so easy that they become bored, or so difficult that students become frustrated. Incorporating the ZPD with criterion-referenced interpretation of measurement would shift the emphasis from focusing on performance scores to informing teaching and learning practice.

As an illustration of how the ZPD can be identified using the item and student measures to inform on the mode of intervention, consider the students in the *Not Very Skilled* group with ability measures between -1.0 and 0 logit in Figure 5.4. The corresponding group of items (c2_11, c2_12, c2_14, c2_16, c2_17, c2_18, c2_19, c2_20) was related to the use of general purpose software, and none of the engineering application software. The intervention plan for this group of students could start by developing the skill of accessing engineering data, which has the lowest difficulty level in the next group of items. This could be achieved through class assignments and hands-on library skills class. The fact that most students did not acquire their ICT skills from formal university or library courses might indicate under-utilization of the university expertise to scaffold student learning. Moreover, the positive correlation between frequency of activities and ICT user-skills levels indicated by this study could be a motivation to promote more frequent ICT-related engineering learning activities across the years of study (Hergenhahn and Olson, 2005).

5.4.4 Recommendations for Future Work

Even though the instrument has been proven reliable and valid in the study context, there is always room for improvement. For example, the instrument can be further improved by providing more items to fill up the gaps shown in the Wright map to correspond to student measures especially those at the bottom and top portion of the scale. Results showed that some students were located very low on the ability continuum, indicating that they might not have even the very basic ICT skills often presumed of the digital natives.

An instrument is always initially developed for a specific purpose within a certain context. Adoption or adaptation of an instrument must meet the criteria of reliability and validity for the context within which the instrument will be used. Thus, additional research with a more diverse sample across study settings, curriculum, and cultures may improve the generalizability of the ICT user-skills for engineering learning measurement instrument.

Each of the survey items can be further detailed depending on the purpose of the measurement. For example, one aspect of information skills is the ability to evaluate information which could be broken down into several tasks such as making judgment regarding the quality, authority, relevance, usefulness, and accuracy of information.

The use of other models such as the Multidimensional Random Coefficients Multinomial Logit Model can be explored as more items are added to the instrument. This is because in practice, more often than not, the assumption of unidimensionality does not hold, and the application of a multidimensional measurement model might produce richer descriptions of student ability.

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APPENDIX A

Table for determining sample size from a given population

by Bartlet *et al.*

	Sample size					
	Continuous data (margin of error=.03)			Categorical data (margin of error=.05)		
Population size	alpha=.10 t=1.65	alpha=.05 t=1.96	alpha=.01 t=2.58	p=.50 t=1.65	p=.50 t=1.96	p=.50 t=2.58
100	46	55	68	74	80	87
200	59	75	102	116	132	154
300	65	85	123	143	169	207
400	69	92	137	162	196	250
500	72	96	147	176	218	286
600	73	100	155	187	235	316
700	75	102	161	196	249	341
800	76	104	166	203	260	363
900	76	105	170	209	270	382
1,000	77	106	173	213	278	399
1,500	79	110	183	230	306	461
2,000	83	112	189	239	323	499
4,000	83	119	198	254	351	570
6,000	83	119	209	259	362	598
8,000	83	119	209	262	367	613
10,000	83	119	209	264	370	623

NOTE: The margins of error used in the table were .03 for continuous data and .05 for categorical data. Researchers may use this table if the margin of error shown is appropriate for their study; however, the appropriate sample size must be calculated if these error rates are not appropriate. Table developed by Bartlett, Kotrlik, & Higgins.

APPENDIX B

Table for determining sample size from a given population

by Krejcie and Morgan

N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260
15	14	110	86	290	165	850	**265**
20	19	120	92	300	169	900	269
25	24	130	97	320	175	950	274
30	28	140	103	340	181	1000	278
35	32	150	108	360	186	1100	285
40	36	160	113	380	181	1200	291
45	40	180	118	400	196	1300	297
50	44	190	123	420	201	1400	302
55	48	200	127	440	205	1500	306
60	52	210	132	460	210	1600	310
65	56	220	136	480	214	1700	313
70	59	230	140	500	217	1800	317
75	63	240	144	550	225	1900	320
80	66	250	148	600	234	2000	322
85	70	260	152	650	242	2200	327
90	73	270	155	700	248	2400	331
95	76	270	159	750	256	2600	335

Note: “N” is population size
“S” is sample size.

APPENDIX C

Profile of reviewers

No.	Area of Expertise	Years of Experience	Name and Designation
1.	Information Research	20	Nazruddin bin Mohd Sarif Librarian Universiti Teknologi Malaysia
2.	Education (Workshop Facilitator on Instrument Development)	25	Prof. Dr Rio Sumarni bt Sharifuddin Head of Department (External Programme) Faculty of Education Universiti Teknologi Malaysia
3.	Mechanical Engineering	8	Rozaimee bin Ahamad Zakaria Inspection Section PETRONAS Gas Berhad
4.	Inspection	13	Ir. Mohammad Baki bin Mansor Section Head Inspection Section PETRONAS Gas Berhad
5.	Mechanical Engineering	Not Stated	M Faizul bin M Ruhani Executive Technical Services Department PETRONAS Gas Berhad
6.	Plant Inspection	11	Mohd Kamah bin Md Nor Plant Inspector Technical Services Department PETRONAS Gas Berhad
7.	Inspection	7	Ir. Hj Khairil Nizam bin Khirudin Senior Engineer Technical Services Department PETRONAS Gas Berhad
8.	System Enabler	27	Rusli bin Alias Assistant General Manager Centre of Excellence Technology Telekom Malaysia Berhad

9.	Lecturer	20	Dr Aminuddin bin Abu Head of Department Department of Mechanical Engineering Universiti Teknologi Malaysia
10.	Information and Communication Technology	42	Musa bin Mohd Lazim Senior Manager Teliti Computers Sdn Bhd

APPENDIX D

Survey instrument validation form

Title of Survey Instrument: **The Use of Information and Communication Technology Skills in Engineering Learning (Part A, B, and C)**

I hereby acknowledge that the above mentioned survey instrument developed by Rosmah Binti Ali from College of Science and Technology, Universiti Teknologi Malaysia has been checked. The outcome is as follows: (Please tick your answer).

		Strongly Disagree	Disagree	Somewhat Agree	Agree	Strongly Agree
1.	The objective of the instrument is stated clearly.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.	The instrument format is appropriate.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.	The font size is appropriate.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
4.	The meaning of every item is clear.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5.	The instructions are clear.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.	The measurement scale is appropriate.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

The item is representative of the ICT user-skills content domain for engineering applications.		Strongly Disagree	Disagree	Somewhat Agree	Agree	Strongly Agree
		1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
1.	Defining the required information for an engineering problem.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.	Using a computer to access engineering data efficiently.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.	Evaluating engineering information on the websites.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
4.	Using information effectively to accomplish a specific purpose.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
5.	Using information ethically and legally.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.	Using E-learning system or the Internet to support classroom learning of engineering courses.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
7.	Using software eg. MS-Word to write a well-formatted engineering project report.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
8.	Using software eg Excel, Maple, MathCAD to solve engineering mathematical problems.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
9.	Using engineering packages eg. StarCD to collect data.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
10.	Using graphics and charting tools in Excel, Matlab or SPSS to perform statistical analysis of engineering systems.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
11.	Using programming languages to develop software to solve engineering problems.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
12.	Using application software eg AutoCAD and Matlab to design engineering systems.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13.	Using simulation software eg. Electronics Workbench, SIMULINK to experiment with models of engineering systems eg. to replicate the behavior of an electronic device.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
14.	Using video technology to record engineering projects, field trips, demonstrations etc.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

15.	Making multimedia presentations of engineering projects.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
16.	Using project management software eg MS-Project to manage an engineering project.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
17.	Using files to share information between project teams.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
18.	Communicating through the Internet eg email, chat, forum with project members.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Please evaluate the comprehensiveness of the entire scale by indicating items that should be added, deleted or modified.

The entire scale is comprehensive.	Strongly Disagree	Disagree	Somewhat Agree	Agree	Strongly Agree
	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Items to be added:

____

____

____

Items to be deleted:

____

____

____

Items to be modified:

____

____

____

Comments:

____
____
____
____
____
____

Thank you.

Signature: ______________________________

Full Name: ______________________________

Experience in Engineering
Profession (Years): _________________________

Designation: ______________________________

Name and Address of Employer:

____
____
____
____
____

Stamp of Employer: ________________ Date: ____________

APPENDIX E

Student feedback form

Please give your feedback on the survey questionnaire.

1. The wording of the questions is easy to understand.
   1 ☐ strongly disagree 2 ☐ disagree 3 ☐ neutral 4 ☐ agree
   5 ☐ strongly agree

Please indicate in the questionnaire form which questions you find confusing or hard to understand, if any.

2. The flow of the questionnaire is easy to follow.
   1 ☐ strongly disagree 2 ☐ disagree 3 ☐ neutral 4 ☐ agree
   5 ☐ strongly agree

3. The questionnaire is too time-consuming.
   1 ☐ strongly disagree 2 ☐ disagree 3 ☐ neutral 4 ☐ agree
   5 ☐ strongly agree

4. What token of appreciation would you most welcome for participating in the survey?
   1 ☐ pen 2 ☐ key chain 3 ☐ bookmark 4 ☐ ruler
   5 ☐ Other (Please specify______)

5. How long did it actually take you to complete the survey? ________ minutes
   1 ☐ < 15 mins 2 ☐ 16 – 30 mins 3 ☐ 31 - 45 mins 4 ☐ > 45 mins

6. The survey seems to be about students' ICT skills.
   1 ☐ strongly disagree 2 ☐ disagree 3 ☐ neutral 4 ☐ agree
   5 ☐ strongly agree

Other comments/suggestions:

____

____

____

____

APPENDIX F

An Instrument to Measure ICT User-Skills Ability for Engineering Learning

PART A DEMOGRAPHIC DATA

INSTRUCTIONS
Please tick the appropriate box: ☑

1. Course: 1 ☐ DDA 2 ☐ DDB 3 ☐ DDE 4 ☐ DDJ
   5 ☐ DDP 6 ☐ DDK 7 ☐ DDT

2. Gender: 1 ☐ Male 2 ☐ Female

3. Age: ______ years

4. Year of Study: 1 ☐ First 2 ☐ Second 3 ☐ Third

5. Current CPA: _________

PART B

1. Do you own a computer? 1 ☐ Yes 2 ☐ No

2. Do you have an internet connection for the computer you use for your study at UTM?
   1 ☐ Yes2 ☐ No

3. How many hours a week do you use a computer for study?
   1 ☐ 0 hr 2 ☐ 1– 3 hrs 3 ☐ 4 – 6 hrs 4 ☐ 6 – 10 hrs 5 ☐ 11 - 15 hrs
   6 ☐ 16 - 20 hrs7 ☐ > 20 hrs

4. How many hours a week do you use a computer for recreation (chatting, games etc)?
   1 ☐ 0 hr 2 ☐ 1– 3 hrs 3 ☐ 4 – 6 hrs 4 ☐ 7 – 10 hrs 5 ☐ 11 - 15 hrs
   6 ☐ 16 - 20 hrs 7 ☐ > 20 hrs

5. Where did you learn your current ICT skills (eg. Word, Excel, Powerpoint, Electronic information search)?

   (You can tick more than one box):

		1 Yes	**2 No**
a.	I took the information skills class conducted by UTM PSZ		
b.	I took ICT courses in UTM other than (a)		
c.	I attended ICT		

	courses/workshops/seminars outside UTM		
d.	I learnt it on my own using manuals and handbooks		
e.	I was taught by friends and family		

6. Main issues you face in acquiring ICT skills:
(You can tick more than one box)

		1 Yes	**2 No**
a.	Finding the right time		
b.	Courses are expensive		
c.	No suitable ICT courses		
d.	No credit given for the optional ICT courses		

7. What is your opinion about the following statements? Please select one box only: ☑

		Strongly Disagree	Disagree	Somewhat Agree	Agree	Strongly Agree
a.	ICT is integrated into my engineering courses.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
b.	My engineering lecturers use ICT well in the courses I take.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
c.	UTM's ICT services are always available when I need to use them for study.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

8. How does ICT help you learn in engineering courses? Please select one box only: ☑

		Strongly Disagree	Disagree	Somewhat Agree	Agree	Strongly Agree
a.	ICT use in my engineering courses helps me understand engineering concepts better.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
b.	ICT makes the courses more interesting.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
c.	I take part more actively in courses that use ICT because the courses are more student-centered.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
d.	ICT makes learning more convenient because I can use the e-learning system whenever I cannot attend the classes.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

e.	ICT helps me manage my course activities better. (plan, control, and perform activities).	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
f.	ICT helps me do better research work in my courses.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
g.	ICT helps me get prompt feedback on my course performance from my lecturers.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
h.	ICT helps me communicate and work better with my course mates.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
i.	ICT helps me become an independent learner.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
j.	ICT helps me become aware of professional ethics and legal issues.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

PART C1 ICT SKILLS RELATED TO ENGINEERING ACTIVITIES

1. How often do you use your ICT skills to perform the following activities during your study?

Please select one box only: ☑

	Activities	Type of ICT skills	Never	Rarely	Once per month	Once per week	2 – 3 times per week	Every day
1.	Defining the required information for an engineering problem.	IL	0☐	1☐	2 ☐	3☐	4☐	5☐
2.	Using a computer to access engineering data efficiently.	IL	0☐	1☐	2 ☐	3☐	4☐	5☐
3.	Using information effectively in problem solving.	IL	0☐	1☐	2 ☐	3☐	4☐	5☐
4.	Using simulation software eg. Electronics Workbench, SIMULINK to experiment with models of engineering systems eg. to replicate the behavior of an electronic device.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
5.	Using graphics and charting tools in Excel, Matlab or SPSS to perform statistical analysis of engineering systems.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
6.	Using programming languages to develop software to solve engineering problems.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
7.	Using application software eg AutoCAD and Matlab to design engineering systems.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
8.	Using software eg Excel, Maple, MathCAD to solve engineering mathematical problems.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
9.	Using engineering packages eg. StarCD to collect data.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
10.	Using project management software eg MS-Project to manage an engineering project.	A	0☐	1☐	2 ☐	3☐	4☐	5☐

** IL = Information Literacy
** A = Application software/hardware

** IL = Information Literacy
** A = Application software/hardware

	Activities	Type pf ICT skills	Never	Rarely	Once per month	Once per week	2 – 3 times per week	Every day
11.	Evaluating engineering information on the websites.	IL	0☐	1☐	2 ☐	3☐	4☐	5☐
12.	Using information ethically and legally.	IL	0☐	1☐	2 ☐	3☐	4☐	5☐
13.	Using E-learning system or the Internet to support classroom learning of engineering courses.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
14.	Using software eg. MS-Word to write a well-formatted engineering project report.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
15.	Using video technology to record engineering projects, field trips, demonstrations etc.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
16.	Making multimedia presentations of engineering projects.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
17.	Using files to share information between project teams.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
18.	Communicating through the Internet eg email, chat, forum with project members.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
19.	Using the internet to gain knowledge of contemporary issues in an engineering discipline.	A	0☐	1☐	2 ☐	3☐	4☐	5☐
20.	Using the internet to gain knowledge of engineering professional codes of ethics and legal issues.	A	0☐	1☐	2 ☐	3☐	4☐	5☐

Please refer to the following description to answer Part C2.

Criteria	Not at all Skilled	Not very skilled	Moderately skilled	Very skilled	Expert
Independence	With help	With help	Without help	Without help	Without help
Frequency	Very rarely	Whenever necessary	Whenever necessary	Whenever necessary	Whenever necessary
Completeness	Partially	Partially	Entirely	Entirely	Entirely
Complexity	Simple tasks	Simple tasks	Simple tasks	Complex tasks	Complex tasks
Familiarity	Usual situations	Usual situations	Usual situations	Usual situations	New situations

C2. How competent are you in performing the following activities?
Please select one box only: ☑

	Activities	Type pf ICT skills	Not at all skilled	Not very skilled	Moderately skilled	Very skilled	Expert
1.	Defining the required information for an engineering problem.	IL	1☐	2 ☐	3☐	4☐	5☐
2.	Using a computer to access engineering data efficiently.	IL	1☐	2 ☐	3☐	4☐	5☐
3.	Using information effectively to solve an engineering problem.	IL	1☐	2 ☐	3☐	4☐	5☐
4.	Using simulation software eg. Electronics Workbench, SIMULINK to experiment with models of engineering systems eg. to replicate the behavior of an electronic device.	A	1☐	2 ☐	3☐	4☐	5☐
5.	Using graphics and charting tools in Excel, Matlab or SPSS to perform statistical analysis of engineering systems.	A	1☐	2 ☐	3☐	4☐	5☐
6.	Using programming languages to develop software to solve engineering problems.	A	1☐	2 ☐	3☐	4☐	5☐
7.	Using application software eg AutoCAD and Matlab to design engineering systems.	A	1☐	2 ☐	3☐	4☐	5☐
8.	Using software eg Excel, Maple, MathCAD to solve engineering mathematical problems.	A	1☐	2 ☐	3☐	4☐	5☐
9.	Using engineering packages eg. StarCD to collect data.	A	1☐	2 ☐	3☐	4☐	5☐
10.	Using project management software eg MS-Project to manage an engineering project.	A	1☐	2 ☐	3☐	4☐	5☐

** IL = Information Literacy
** A = Application software/hardware

	Activities	Type pf ICT skills	Not at all skilled	Not very skilled	Moderately skilled	Very skilled	Expert
11.	Evaluating engineering information on the websites.	IL	1☐	2 ☐	3☐	4☐	5☐
12.	Using information ethically and legally.	IL	1☐	2 ☐	3☐	4☐	5☐
13.	Using E-learning system to support classroom learning of engineering courses.	A	1☐	2 ☐	3☐	4☐	5☐
14.	Using software eg. MS-Word to write a well-formatted engineering project report.	A	1☐	2 ☐	3☐	4☐	5☐
15.	Using video technology to record engineering projects, field trips, demonstrations etc.	A	1☐	2 ☐	3☐	4☐	5☐
16.	Making multimedia presentations of engineering projects.	A	1☐	2 ☐	3☐	4☐	5☐
17.	Using files to share information between project teams.	A	1☐	2 ☐	3☐	4☐	5☐
18.	Communicating through the Internet eg email, chat, forum with project members.	A	1☐	2 ☐	3☐	4☐	5☐
19.	Using the internet to gain knowledge of contemporary issues in an engineering discipline.	A	1☐	2 ☐	3☐	4☐	5☐
20.	Using the internet to gain knowledge of engineering professional codes of ethics and legal issues.	A	1☐	2 ☐	3☐	4☐	5☐

** For this study, items no. 4, 9, 10, and 13 are omitted from Section C1 and C2.

APPENDIX G

Interview guide

INTRODUCTION:	
Thank you	Thank you for coming to this interview.
Purpose	The purpose for this interview is to collect data on your experience in using ICT during your study here as part of a research to improve the university ICT literacy program.
Duration	The interview will take about 30 minutes (one-on-one) / 1 hour 30 minutes (group)
Recording	This interview will be recorded because I don't want to miss any of your comments. I will also do some note-taking to jot down your main points.
Confidentiality	Your identity will be kept confidential. Your input will only be used for academic purposes.
Opportunity for questions	Is there anything you would like to ask?
Consent	Are you willing to participate in this interview?
INTERVIEW QUESTIONS: • Not more than 15 open-ended questions • Use probes as needed	Q1. What do you understand by the term "ICT skills"? Q2. Give examples of the engineering courses in which you make significant use of your ICT skills. Q3. What are some of the most important advantages of using ICT in engineering learning for you? Q4. How does your usage of ICT skills in Year 1, 2 or 3 compare in terms of **frequency** and **type of skills**? Q5. What are the major barriers you face in using ICT skills in engineering courses? Q6. Which ICT skills do you feel you need to improve? Why? Q7. Please give some suggestions on how the engineering curriculum can help improve ICT skills so that you can use those skills better in learning engineering.
CLOSING REMARKS:	
Additional comments	Is there anything else you would like to add?
Next steps	I will compile and analyze your comments and suggest recommendations to the university.
Thank you	Thank you for your time.

APPENDIX H

Example of interview checklist table

Q1: What do you understand by the term "ICT skills"?

Code	**Name of Interviewee**	**Definition of ICT Skills**							
		Use ICT devices/ hardware	Use s/ware	Use Internet services	Define Info	Access Info	Select Info	Eval Info	Use of Info

APPENDIX I

Peer debriefer's report

From the audio files and textual transcription of the interviews, my general conclusions with regards to the ICT skill levels and ICT conception of the interviewees are as follows:

1. The ICT skills that they have are mostly self-acquired, driven by their own motivation. It looks like most respondents were not aware of their ICT skill levels.

2. No doubt, they have to have some skills as necessitated by some formal subjects in their courses, without which they might not have had the motivation as mentioned above.

3. It seems that they are not properly guided to acquire the most relevant skills in the wide scope of ICT, so as to prepare them for the purpose of their formal course and future profession.

4. Some participants display a sound knowledge in ICT, while some try to impress the interviewer with ICT topics that they do not really know.

5. The main theme for their conception of ICT skills is as a learning tool with a variety of functions such as to access information and to communicate with others.

6. A well guided acquisition of ICT skills is highly recommended for these students, not only to facilitate them in their formal courses, but more importantly for their future professions when ICT skills are the things that they cannot live without.

APPENDIX J

List of publications

1. Ali, R., Abu-Hassan, N., and Md Daud, M. Y. (2010). Information Literacy Skills of Engineering Students. *International Journal of Research and Reviews in Applied Science,* 5(3), 264-270.

2. Ali, R., Abu-Hassan, N., and Md Daud, M. Y. (2009). Information Literacy of Engineering Students: A Case Study. *International Conference on Engineering Education* (ICEED). 7-8 Dec 2009. Kuala Lumpur. 143-147.

3. Ali, R., Abu-Hassan, N., and Md Daud, M. Y. (2009). Information and Communication technology Skills in Engineering Education. *International Conference on Engineering and Education (ICEE) in the 21st Century*. 23-25 Mac 2009. Kuching, Sarawak.

4. Basiron, S., Ali, R., Salim, K. R., Hussain N. H., and Haron, H. N. (2008). A Review of Engineering Education in Malaysia. *International Conference on Engineering Education (ICEE)*. New Challenges in Engineering Education and Research in the 21st Century. 27-31 July 2008. Pécs-Budapest, Hungary.