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

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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.

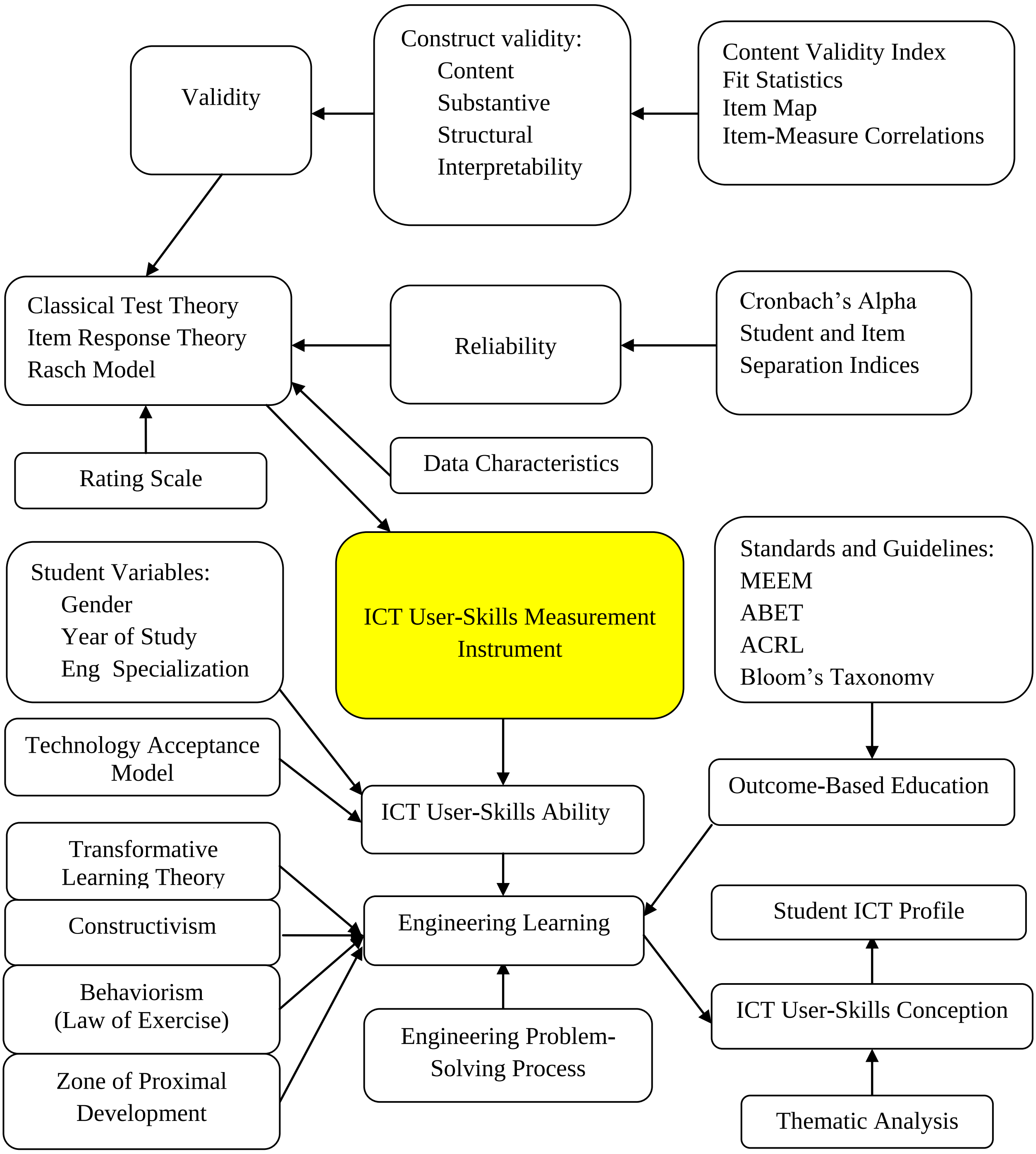

Figure 1.1: Conceptual framework for the study

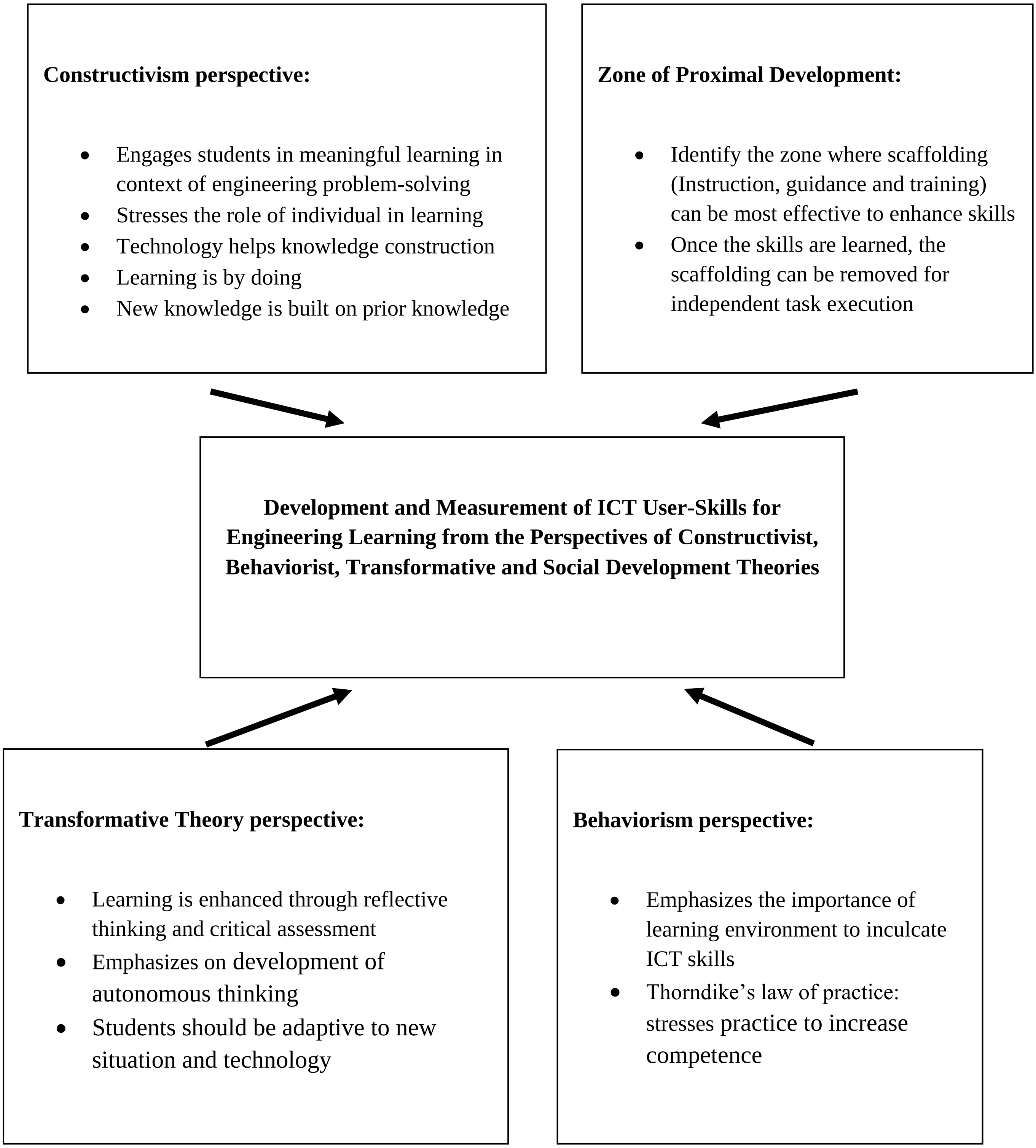

Figure 1.2: Theories underlying the development and measurement of ICT skills for engineering learning

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.

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