AN INSTRUMENT TO MEASURE STUDENTS' READINESS FOR EMBEDDED SYSTEM DESIGN COURSE

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DEDICATION

My Family

My Late Supervisor

My Supervisors

My Teachers

My Friends

My Neighbours

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ABSTRACT

Embedded Systems Design has emerged as one of the fastest growing areas in the world. In this regard, higher education institutions acknowledge the significance for offering Embedded Systems Design course to fulfil the needs of skilled human resources in the field. Unfortunately, being a highly difficult and specialized course, it requires students to have sufficient body of knowledge courses in both theory and practice. To address this issue, this study proposed an instrument to measure students' readiness for Embedded Systems Design course. The study was conducted using a sequential exploratory mixed method design. First, a survey instrument named MeSRESD which consisted of 10 scales and 89 items was developed. MeSRESD assessed students' cognitive, affective, and psychomotor skills through holistic assessment by taking into account the domains of technical skills, critical thinking skills, communication skills, team working skills, entrepreneurship skills, lifelong learning skills, level of interest, attitude, and prior experience. Content validity of MeSRESD was verified using content validity index (CVI) and content validity ratio (CVR). All MeSRESD scales showed CVI and CVR ranging from 0.92 to 1.00 and from 0.88 to 1.00 respectively, establishing an excellent content validity. A pilot study on 40 students was performed to assess the Cronbach's alpha scale reliability. The results obtained were from 0.73 to 0.92 using Statistical Package for Social Sciences (SPSS 23.0) and from 0.70 to 0.99 using WINSTEPS 3.92.1, indicating an excellent internal consistency reliability. MeSRESD construct validity was established using Rasch Analysis and WINSTEPS 3.92.1. The results showed that all scales fitted the Rasch measurement model with acceptable fit index from 0.6 to 1.4 and demonstrated excellent consistency, with a reliability index from 0.97 to 0.99 for items and from 0.70 to 0.88 for persons. The unidimensionality of each MeSRESD scales was evaluated using principal component analysis. Based on these results, we concluded that the survey instrument was valid and reliable. MeSRESD was administered in nine universities in Malaysia, Sudan, and Saudi Arabia. A total of 415 questionnaires with a response rate of 97.4% were analysed. Based on the literature review, the readiness threshold of 3.40 was selected. However, the students' mean scores of MeSRESD scales were from 2.47 to 2.89, which were lower than the threshold. In light of these results, the study revealed strong evidence that students lack prior knowledge and had poor understanding of Embedded Systems Design course. They possessed poor proficiency in critical thinking, communication, team working, entrepreneurship, and lifelong learning skills. In addition, they had low level of interest, lack of prior experience and had negative attitude towards learning Embedded Systems Design course. Therefore, there is a need for universities to address this issue and take remedial action to improve the chance of academic success for the students not only in Embedded Systems Design course, but also in other related courses.

ABSTRAK

Rekabentuk Sistem Terbenam muncul sebagai salah satu bidang yang paling pesat membangun di dunia. Berdasarkan keadaan ini, institusi pengajian tinggi mengakui kepentingan untuk menawarkan kursus Rekabentuk Sistem Terbenam untuk memenuhi keperluan pekerja mahir dalam bidang ini. Walaubagaimanapun, disebabkan tahap kesukaran yang tinggi dan merupakan kursus pengkhususan, kursus ini memerlukan pengetahuan asas yang merangkumi aspek teori dan praktikal. Bagi menangani isu ini, kajian ini mencadangkan satu instrumen untuk mengukur kesediaan pelajar untuk kursus Rekabentuk Sistem Terbenam. Kajian dijalankan menggunakan kaedah gabungan penjelajahan berurutan. Pertama, instrumen kajiselidik MeSRESD yang terdiri dari 10 skala dan 89 item dibangunkan. MeSRESD menilai kemahiran kognitif, afektif dan psikomotor pelajar melalui penilaian holistik dengan mengambil kira kemahiran teknikal, pemikiran kritikal, kemahiran komunikasi, kerja berpasukan, keusahawanan, pembelajaran sepanjang hayat, tahap minat, sikap dan pengalaman terdahulu. Kesahan kandungan instrumen disahkan menggunakan Indek Kesahan Kandungan (CVI) dan Kadar Kesahan Kandungan (CVR). Kesemua skala MeSRESD menunjukkan CVI dan CVR dengan julat dari 0.92 hingga 1.00 dan dari 0.88 hingga 1.00, menunjukkan tahap kesahan yang sangat memuaskan. Satu kajian rintis melibatkan 40 pelajar dijalankan untuk menilai skala kebolehpercayaan Cronbach's alpha. Keputusan yang diperolehi adalah dari 0.73 hingga 0.92 menggunakan Statistical Package for Social Sciences (SPSS 23.0) dan dari 0.70 hingga 0.99 menggunakan WINSTEPS 3.92.1, yang menunjukkan kebolehpercayaan konsisten dalaman yang sangat memuaskan. Kesahan konstruk MeSRESD diperolehi dengan menggunakan Analisis Rasch dan WINSTEPS 3.92.1. Keputusan menunjukkan semua skala memenuhi model pengukuran Rasch dengan indeks terimapakai 0.6 hingga 1.4 dan menunjukkan tahap konsisten yang sangat memuaskan dengan indeks kebolehpercayaan 0.97 hingga 0.99 bagi item dan 0.70 hingga 0.88 bagi individu. Skala unidimensi setiap skala MeSRESD dinilai menggunakan analisis komponen utama. Berdasarkan kepada keputusan ini, dapat dirumuskan bahawa instrumen kajiselidik ini adalah sah dan boleh dipercayai. MeSRESD telah diedarkan ke sembilan universiti di Malaysia, Sudan dan Arab Saudi. Sejumlah 415 soalan kajiselidik dengan kadar respon 97.4% telah dianalisis. Berdasarkan kajian literatur, tahap ambang kesediaan 3.40 telah dipilih. Walaubagaimanapun, skor purata pelajar bagi skala MeSRESD adalah dari 2.47 hingga 2.89, lebih rendah dari nilai ambang yang dipilih. Berdasarkan keputusan ini, kajian ini mendedahkan bukti jelas tentang kekurangan pengetahuan asas dan kekurangan tahap pemahaman di kalangan pelajar dalam kursus Rekabentuk Sistem Terbenam. Mereka memiliki tahap kemahiran berfikir kritikal, komunikasi, kerja berpasukan, keusahawanan dan pembelajaran sepanjang hayat yang lemah. Tambahan lagi, minat mereka adalah rendah, kurang pengalaman terdahulu dan mempunyai sikap negatif terhadap kursus Rekabentuk Sistem Terbenam. Oleh itu, universiti perlu mengambil langkah-langkah pembetulan bagi menangani masalah ini untuk memastikan kemampuan pelajar ditingkatkan untuk menguasai kursus Rekabentuk Sistem Terbenam dan kursus lain yang berkaitan.

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LIST OF ABBREVIATIONS

ABET	-	Accreditation Board for Engineering and Technology
BEM	-	Board of Engineers Malaysia
BOK	-	Body of Knowledge
CCT	-	Classical Test Theory
CO	-	Program Outcome
CVI	-	Content Validity Index
CVR	-	Content Validity Ratio
DIF	-	Differential Item Functioning
EAC	-	Engineering Accreditation Council
ETAC	-	Engineering Technology Accreditation Council
FBSU	-	Fahad Bin Sultan University
ICL	-	Imperial College London
I-CVI	-	Item- Content Validity Index
I-CVR	-	Item- Content Validity Ratio
INFIT	-	Inlier-sensitive or Information-weighted Fit
IRT	-	Item Response Theory
KFUPM	-	King Fahad University of Petroleum and Minerals
MeSRESD	-	Measuring Student Readiness for Embedded System Design
MIT	-	Massachusetts Institute of Technology
MNSQ	-	Mean-Square
MQA	-	Malaysian Qualifications Agency
MQF	-	Malaysian Qualifications Framework
NTU	-	Nanyang Technological University
OBE	-	Outcome Based Education
OUTFIT	-	Outlier-sensitive Fit
PO	-	Program Outcome
S-CVI	-	Scale-Content Validity Index
S-CVR	-	Scale-Content Validity Ration
SU	-	Stanford University
SUST	-	Sudan University of Science and Technology

UMP	-	Universiti Malaysia Pahang
UMST	-	University of Medical Sciences and Technology
Uofk	-	University of Khartoum
UTM	-	Universiti Teknologi Malaysia
UTP	-	Universiti Teknologi Petronas
ZSTD	-	Z-Standardized

LIST OF SYMBOLS

e	-	error
δ	-	Standard Deviation
n	-	number of experts who has chosen Strongly Relevant (5) and Relevant (4)
N	-	Total number of experts
Ni	-	Corresponding Respondents' Response
Wi	-	Weighted Categories
z	-	Z Score

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CHAPTER 1

INTRODUCTION

1.1 Importance of Readiness for Learning

In early 20th, Thorndike formulated the three laws of learning: The law of readiness, the law of exercise, and the law of effect (Thomas, 2007). Law of readiness is the main law of learning, which means that learning takes place when an action is stimulated by preparatory adjustment, set or attitude. Readiness means a preparation of action. If the students is not prepared to learn, learning cannot be automatically instilled to them. Readiness indicates a degree of concentration and eagerness; the students must be ready to learn the topic presented to them and must acquire the requisite knowledge and skills. Readiness law stated that to keep students ready to learn the topic must be introduced to them in a logical order and a well-designed curriculum will realize this goal (Gillan *et al*., 2015; Nihat *et al*., 2017). Therefore, education institutions must determine students' readiness to learn a specific subject, or to execute required tasks. Students need to be well prepared before starting learning new courses. Measuring student readiness prior to start learning a new course can help the lecturers prepare the skills and strategies they need to better prepare their students for success (Atousa *et al.,* 2016; Wafaa, 2016). Students are considered ready for learning when they acquired the knowledge and skills needed to succeed in the course.

1.2 Importance of Embedded Systems

In recent years, Embedded Systems have emerged as increasingly important systems in the manufacturing sector due to their wide applications in digital electronics and smart devices. Advances in digital design technology result in an incredible surge in computational power in appliances. Billions of chips could be produced at low cost and with ever increasing functional capabilities (Choi *et al*., 2016). Yet, the

exponential scaling also made the design of these chips much more difficult, requiring a step up into the hierarchy of abstraction levels in order for designers to be able to cope with the increased complexity. At the same time, integration of software and hardware aspects has resulted in Embedded Systems (Crystal, 2016; Mora *et al.*, 2015; Weirich, 2014; Tennina *et al.*, 2014; Andersson, 2014).

Embedded Systems are everywhere. In our daily lives, ranging in complexity from a single device such as Personal Data Assistant (PDA) to large weather prediction systems. They have an enormous diversity of applications, which varies from low cost and big market to very high cost and few markets, from daily life consumer electronics to industry automation equipment, from entertainment devices to academic equipment's, from medical instruments to aerospace and weapon control systems. They span all aspects of our life as shown in Figure 1.1. (Crystal, 2016; Zhuo *et al*., 2014; Corral, 2014; Fan *et al*., 2013).

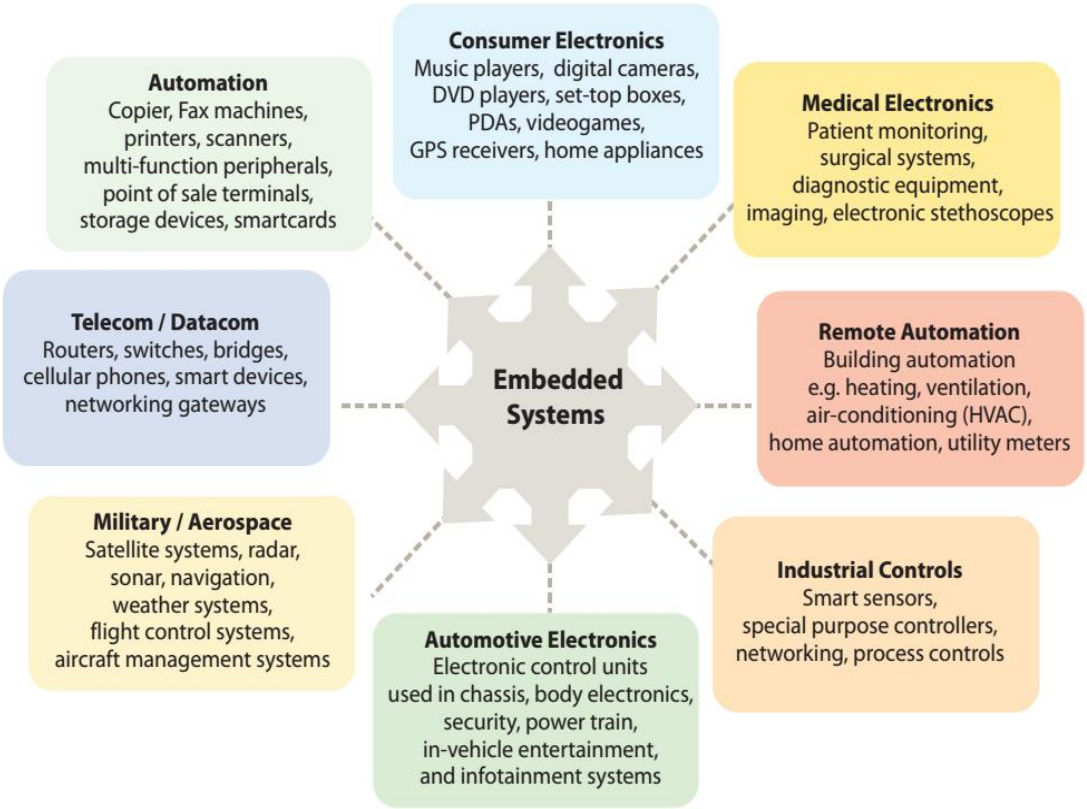

Figure 1.1 Major Applications of Embedded Systems
(Source: TATA Consultancy Services-http://feeds2.feedburner.com/tcswhitepapers)

As a hybrid system, they draw from a variety of sources such as computer engineering, computer science, electrical, electronic or communication engineering and other disciplines that utilize computer programming. This diversity contributes to a variety of embedded systems concepts, definitions, and applications in the technology. Due to its widespread usage, many of the brightest students no longer aim to become computer scientists, but rather plan to enter directly into the life sciences or Nano-engineering disciplines (Henzinger and Sifakis, 2007). Thus, there is a confluence high demand for Embedded System programmers, multivariate curricula offered by differing university programmers and a multiplicity of student backgrounds who are attracted to the burgeoning opportunities for programmers. Globally, Embedded System market set for rapid growth. According to the report, global demand for Embedded Systems market was valued at USD 159.00 billion in 2015, and is expected to generate revenue of USD 225.34 billion by end of 2021, which require a steady supply of skilled talent to meet the present and future needs (Joel, 2016).

1.3 Motivation

This section presents the factors that motivate for this study and why Embedded Systems is an important topic. Firstly, there are needs for talented graduates. The Embedded Systems market is booming right now. This growth is driven by the continued development of technological trends, such as adoption of the Internet of things and smart devices as well as increasing demand for Embedded Systems with multi-core technologies and Embedded System graphics and escalating demand for Embedded Systems in the automobile industry. Also, widespread application of these systems in application areas such as aeronautics, space, rail, mobile communication, and electronic payment solutions is set to bolster the growth of the global Embedded System market globally (Hideto, 2018). Consequently, anyone with a Computer Science (CS) degree may end up programming for these devices at some point in their career (Joel, 2016). Secondly, there is a need to bridge the knowledge gap. Based on the systematic literature review, prior research emphasized on Embedded Systems teaching and learning and there is a dearth of research to examine the students' readiness to learn Embedded Systems Design course (Lukman *et al*., 2016; Belal *et*

al., 2016; Ilakkiya *et al*., 2016). This study addressed this issue by developing an instrument to measure students' readiness to learn Embedded System Design course.

Finally, the potential benefits of measuring the students' readiness prior starting learning Embedded Systems Design course provide threefold benefits. First, this study will contribute to the literature on the sources of Embedded Systems Design readiness by measuring the student's skills required to succeed in Embedded System Design course using a valid assessment instrument. Second, help the universities to become attuned to the full extent of the Embedded System Design course problem as it affects undergraduate students teaching and learning. Finally, the universities can revisit their curriculum to identify the strengths and the weaknesses and develop a new one that is able to expose students to industrial and commercial quality implementations and bridge the gap between conceptual understanding and concrete implementations

1.4 Background of the Problem

Learning is an active process of knowledge construction that requires perception, thinking, and problem solving, memory (Ormrod, 2012). While all of these processes are essential to learning, individuals' readiness to engage in learning has been relatively under-studied. However, the concept of readiness has a lengthy history in psychology-going back as early as the work of Edward L. Thorndike, a founder of educational psychology at the turn of the 20th century, who described the readiness as a fundamental of learning (Smith *et al.,* 2015). Readiness is a variable relevant to learning which is consist of prior knowledge and skills (Smith *et al.,* 2015). Prior knowledge and skills defined as the preinstructional knowledge and skills that students have learned from the previous courses. That is, prior knowledge and skills are the foundation for subsequent learning that should be mastered before new information is to be taught (Claudia *et al*., 2016). Therefore, if students don't have appropriate prior knowledge and skills, intended learning cannot take place. This kind of learning impediments is labelled a 'null learning impediments'. This 'null' means that students

don’t have prior knowledge and skills that is assumed to be what they have learned from the prior courses.

Higher education institutions acknowledge the significance of embedded systems and offering embedded system design course to electrical, electronics, and computer engineering students in order to produce a steady supply of skilled talent, both in numbers and in the appropriate skills sets, to meet the present and future needs of the sector. Design and implementation of embedded systems requires a broad prior knowledge in a multidisciplinary areas (Bezdek, *et al*., 2006). These areas include Computer Science, Electrical and Electronics Engineering and Computer Engineering and aspects of control and signal processing, computing theory, real-time processing, distributed systems, optimization and evaluation, and systems architecture and engineering (Stelios, 2016). However, a very dynamic progress of technologies used in Embedded System Design adds a requirement of constantly updating the knowledge (Lucena, 2007). Hence, embedded systems engineers must acquire the ability to solve complex open and undefined problems, which involves synthesizing broad perspectives in an interdisciplinary way knowledge, skills, approaches and tools from various areas. Thus, there is a need for engineers to develop competency both, in knowledge (hard skills and soft skills) to be able to deal with this complexity of integrating multicultural teams in big projects involved multiple profiles. (Lima and Rocha, 2013; Lima and Flores, 2014). Therefore, several researchers have suggested reform of engineering education in higher education institutions in order to keep pace with industry since it is a mean of producing engineers, in order to reduce the gap between academic perceptions and industry expectations or employability skills for entry-level engineers (Mona *et al*., 2016; Domal and Trevelyan 2009; Srour *et al*., 2013; AUB, 2013; Baytiyeh 2012; Yoder, 2011)

Before starting learning the Embedded System design course, students need to be well prepared. Knowledge and skills are dependent on prior knowledge and skill, knowing what students know and can do when they come into the classroom or before they begin a new topic of study, can help the lecturer create instructional activities that build off of student strengths and acknowledge and address their weaknesses to better prepare their students for success, especially for those students with computer science

background who are not aware of the requirements of Embedded Systems Design course.

To learn effectively, students need to integrate new material into their existing knowledge base, construct new understanding, and adapt existing conceptions and beliefs as needed Ghanat *et al*., (2017). Therefore, students who lack sufficient prior knowledge are unable to may struggle to progress in their study (Nicette *et al*., 2015). Since the prior knowledge has a large influence on student performance, the students need to take many prior courses to have a complete coverage of contemporary embedded system design concepts. Furthermore, students studying this course often have diverse backgrounds in engineering and computer science disciplines, thus making classroom delivery. However, despite the variety of educational approaches used to integrate these courses into their curricula, higher learning institutions face several difficulties and challenges seems to be universal when it comes to addressing the Embedded Systems such as cognitive mindset (Lukman *et al*., 2016; Marcelo, 2015). People learn by connecting different ideas together. Cognitive scientists verified that learning is a process of drawing connections on what people have already known. Hence, students with different backgrounds will associate the new knowledge differently. As students from different disciplines have different ground courses, they would have the different cognitive mindset. (Bertels *et al*., 2009). A student from different disciplines might have a different description for the same term. For example, the word "model" for Computer Science student can mean a software model, while it means a hardware model for the Electronics students (Balid *et al*., 2014).

Several studies have been conducted and instruments have been developed to measure student readiness for e-Learning (Atousa *et al*., 2016; Wafaa, 2016; Anchalee and Jonathan, 2016; Nasiri *et al*., 2014; Coopasami, 2014). These studies assessed students' readiness for entering e-Learning courses in their investigation. Additional, many instruments have been developed to measure students' college and career readiness (Annamaria and Alessio, 2016; Di Fabio and Bucci O., 2016; Alessandri *et al*., 2015). Moreover, several instruments have been developed to measure organization readiness for change as the employees' readiness is represented an essential factor the change initiatives (George *et al.,* 2016; Belias *et al*., 2015; Mdletye

et al., 2014; Katsaros *et al*., 2014). However, despite the fact, there are many instruments that can assess student's readiness for career, colleges, and research (Cuellar and Lucido, 2012, Belias *et al*., 2014), there is yet to be an instrument specifically designed for measuring students readiness for an Embedded System Design course and, if there were one, it would need to be a valid and reliable assessment instrument. This study is intended to fill that gap.

1.5 Problem Statement

Engineering learning, like all learning, occurs against the backdrop of prior knowledge that students bring to the learning experience. Several researchers from numerous fields of education agreed that one of the factors affecting students' learning is their existing knowledge before starting learning a new subject and indicated the great importance of subject-specific prior knowledge for the development of competencies. In studies, which investigated the relation between learners' prior knowledge, and training success, the high predictive power of the prior knowledge furthermore becomes obvious (Abele, 2015). In addition, studies performed by Hailikari *et al*. (2012), Kelly (2006) and Batchelor (2004) highlighted the problems faced by lecturers in higher education is that students lack important prior body of knowledge (BOK) courses and skills needed when they enter the more advanced courses in their curriculum. This is not only a challenge for students and lecturers, but also an important issue in curriculum design.

Early studies on Embedded Systems unveiled that the requirements for talents in Embedded System area are quite high. Those who devote themselves to the development of Embedded Systems not only have basic knowledge of hardware but also have knowledge of the underlying operating systems, such as task scheduling and others. In addition to the field of Embedded System applications, they should have basic software development capabilities and specific expertise. Most of the previous works have focused on Embedded System teaching and learning methods and Embedded System curriculum design. However, studies from across the globe suggested that students of all ages understanding of the Embedded System function

concept revealed misconceptions and difficulties that students encounter when learning Embedded Systems Design course and have extensive knowledge gaps (Jiang, 2011).

Over the years, several surveys have been developed to assess student readiness for career, colleges, and research (Siti, 2017; Fazilat, 2016; Cuellar and Lucido, 2012). Furthermore, several studies have been conducted and instrument designed to measure students' readiness to learn the Chemistry course in higher education institutions as shown in Table I2 (Appendix I). Kelli and Stacey (2015) developed an instrument to measure the students prior knowledge readiness to the Chemistry laboratory course while Villafañe (2015) developed an instrument to measure the students prior knowledge and attitude to learn biochemistry course and Ryan (2012) developed and instrument to measure the precollege Arabic speaking students' attitudes toward Science course. Also, Luajean (2016), King (2013) and Bidya and Randy (2016) developed an instrument to measure the student prior knowledge for Mathematics while, Benjamin *et al*. (2016) develoled an instrument to measure the student prior knowledge and their attitude towards the Science, Technology, Engineering, and Mathematics (STEM). Nine (9) of these studies developed an instruments to measure the students' prior knowledge only, while three (3) of the studies assess the students prior knowledge as well as their attitude as shown in Table I5 (Appendix I). However, this study developed and validate and instrument MeSRESD to assess students' cognitive, affective, and psychomotor skills through holistic assessment by taking into account the domains of technical skills, critical thinking skills, communication skills, team working skills, entrepreneurship skills, lifelong learning skills, level of interest, attitude, and prior experience

However, there is no instrument specially designed for measuring students' readiness to learn Embedded System Design course for undergraduate students based on the findings of systematic literature review in Section 2.4. To the best of the researcher's knowledge, this work is the first of its kind, which aims to generate information that can be used to bridge the gaps in Embedded Systems learning by developing an instrument based on the learning theory and measurement theory to measure students' readiness to learn Embedded Systems Design course, named

MeSRESD (Measuring students' readiness to learn Embedded Systems Design course).

1.6 Research Objectives

In order to solve the problem identified, the following research objectives are formulated.

(a) RO1: To identify the important body of knowledge courses (BOK) for Embedded System Design course

(b) RO2: To identify the cognitive, affective, and psychomotor skills required to learn Embedded Systems Design course

(c) RO3: To determine the validity and reliability of the instrument to measure students' readiness for the Embedded Systems Design course

(d) RO4: To assess the students' readiness to learn Embedded System Design course using MeSRESD

1.7 Research Questions

Four (4) research questions (RQ) were formulated to guide this research and address the research objectives. These are:

(a) RQ1: What are the important body of knowledge (BOK) courses for undergraduate students to learn Embedded System Design course?

(b) RQ2: What are the cognitive, affective, and psychomotor skills required to learn Embedded System Design course?

(c) RQ3: How can the instrument's validity and reliability be evaluated?

(d) RQ4: Are students ready to learn Embedded System Design course?

The answers to these research questions will help clarify and delineate the essential learning sequence that can lead to curriculum changes and a smoother transition for students taking an initial Embedded Systems Design course. It is also, expected that the development of a systematic assessment protocol for determining readiness will enable students to better prepare for Embedded System Design course and assist course designers to tailor learning processes to build on existing student's competencies.

1.8 Scope of the Study

This study is implemented using a sequential exploratory hybrid development of qualitative and quantitative methods. The first version of a 5-point Likert type format scale format MeSRESD instrument contain 91 items. The item are generated based on course outcomes (CO) and program outcomes (PO) of the curriculum from selected universities. The content validity of the first version of MeSRESD instrument is measured by CVI and CVR using data collected from validation form, which contain of 101 items. Two items A13 and A14 scores are 0.54 for I-CVI (lower than 0.78 suggested by Lynn, 1986) and 0.08 for I-CVR (lower than 0.54 as suggested by Lawshe, 1975). Therefore, these two items are considered not relevant and are deleted resulting in a second version of MeSRESD of 89 items. The consensus of the panel that first version of MeSRESD instrument is well structured, clear, complete, comprehensive, and could adequately measure the students' readiness to learn the Embedded Systems Design course. The questionnaire survey was administered in nine universities in three countries. Three universities in Malaysia, four universities in Sudan and two university in Saudi Arabia were involved in the study as shown in Chapter 3 (Table 3.22). The target group of this research were undergraduate in these universities. The data analysis performed for the four selected universities since MeSRESD instrument items are generated from the CO of the BOK courses of these four universities. In addition, the curriculums of the selected universities and the world

top four ranking universities are analysed to determine the body of knowledge courses shown in Table 2.1 (Rudolph, 2005) that the students' have learned in each university before taking the embedded system design course.

1.9 Conceptual Framework

This study is implemented using a sequential exploratory hybrid development The conceptual framework shown in Figure 1.3 provides the context for developing and validating an instrument to measure students' readiness to learn Embedded Systems Design course and be successful in their study. The challenges to learn Embedded Systems Design faced by the learners, both at undergraduates and postgraduates serve as the basis of the proposed conceptual framework. Challenges either with respect to knowledge (hard skills and soft skills) are drawn from the constructivist learning theory (Piaget, 2013; Koh *et al*., 2014; Duke *et al*., 2013; Joseph *et al*., 2016) and Kolb's learning theory (Kolb, 2007; Schultz *et al*., 2016; Botelho *et al*., 2016), and Behaviourism learning theory (Denise and Jonathan, 2016; Kirshner, 2016; Dale and Schunk, 2012).

The conceptual framework is constructed based on the results of the literature review and students' interviews feedback. It is in line with the current and future human resource needs of graduates who need to be equipped with variety of skills. Student must be able to demonstrate transferable skills, such as interpersonal skills, communication skills, problem-solving skills, teamwork and decision-making skills (Lips and Wright, 2012; Vitouladiti, 2014) in addition to their basic academic knowledge (Terresa, 2013; Vitouladiti, 2013). The conceptual framework consists of six (6) themes as shown in Figure 1.2 and the details of the themes are shown in Figure 1.3.

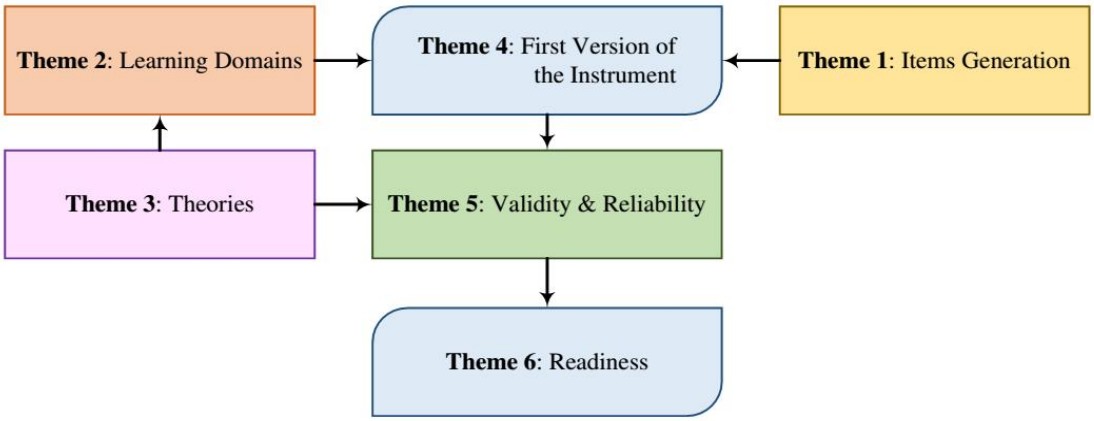

Figure 1.2 Themes of conceptual framework

1.9.1 Theme 1: Item Generation

In this theme, interviews were conducted with students to determine the knowledge and skills they required as well as to capture their feedback for Embedded Systems Design course readiness. Then, pool of items are generated based on feedback from students, literature review and the course outcomes (CO) of the BOK courses from selected universities.

1.9.2 Theme 2: Learning Domains

The generated items are classified into ten (10) scales based on the cognitive, psychomotor and affective learning domains of the Bloom's Taxonomy. The items were categorized with reference to the Malaysian Qualifications Agency (MQA, 2016) learning outcomes, Accreditation Board for Engineering and Technology (ABET, 2017), and Kolb's constructivism and behaviorism learning theories.

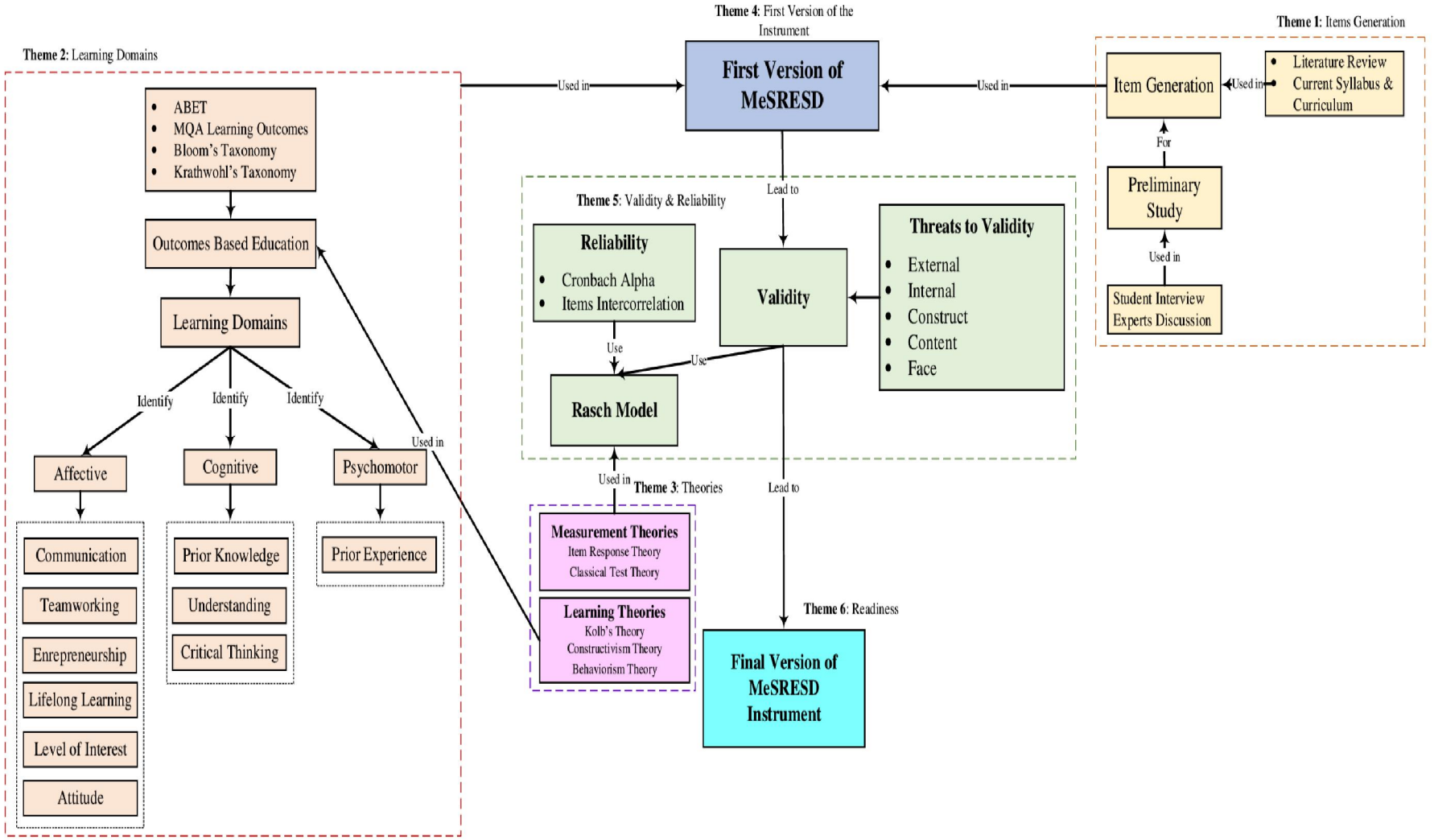

Figure 1.3 Conceptual framework

1.9.3 Theme 3: Theories

This theme present the theories that represent the backbone of the study. Learning theories such as, constructivism theory (Piaget, 2013; Koh *et al*., 2014; Duke *et al*., 2013; Joseph *et al*., 2016), behaviourism theory (Denise and Jonathan, 2016; Kirshner, 2016; Dale, 2012) and Kolb's theory (Kolb, 2007; Schultz *et al*., 2016; Botelho *et al*., 2016) have been used to develop the outcomes based learning models. These models are widely used for curriculum design in higher education institutions in Malaysia, Sudan and Saudi Arabia. Meanwhile, Rasch model of the Item Response Theory (IRT) is used for measuring the construct validity of second version of MeSRESD. The construct validity was measured in terms of statistical analysis (MNSQ, ZSTD, item reliability, person reliability and item and person separation), item fit analysis, unidimensionality and item local independence, the Wright map as well as the differential item functioning (DIF) using WINSTEPS 3.92.1 (Raykov *et al.*, 2017; Cai and Thissen, 2015). In addition, the Classical Test Theory (CCT) used to measure the person Cronbach's alpha reliability using WINSTEPS 3.92.1 (Raykov *et al*., 2016; Kohli *et al*., 2015).

1.9.4 Theme 4: First Version of the Instrument

The first version of the instrument was prepared using a 5-point Likert-type scale format to each item's options. The items were organized and graded as "Strongly Agree (5), "Agree (4), "Somewhat Agree" (3), "Disagree" (2) and "Strongly Disagree". The instrument was divided into two parts; the first part aims to identify the respondents' demographic information, while the second part contains the items to measure the students' readiness. Also, a validation form was developed to evaluate the instrument face and content validity by a panel of experts.

1.9.5 Theme 5: Validity and Reliability

Validity and reliability are vital attributes of instrument development. They are used to indicate the quality of the instrument and can help to assure the research findings as credible and trustworthy. This is particularly vital in a qualitative research, where the researcher's subjectivity can readily cloud the interpretation of the data, and where study findings are often questioned or viewed with skepticism by the scientific community. Validity is defined as the extent to which an instrument measures what it is supposed to measure and performs as it is designed to perform (Bolarinwa, 2015; Rumble and Leal, 2013). Validity in research is concerned with accuracy and trustfulness of the scientific findings (Bolarinwa, 2015). Several varieties of validity have been performed including face validity, content validity, internal validity, external validity and construct validity.

In this study, both the face and content validity were used to measures the degree to which the instrument fully assesses or measures the construct of interest through the evaluation by a panel of experts in the field of electrical engineering, electronics engineering, computer engineering, and engineering education. Particularly, experts reviewed all of the questionnaire items for readability, clarity, and comprehensiveness and come to some level of agreement as to which items should be included in the final instrument. Face validity is established via a panel of experts reviewing the instrument items and agreeing that each of the instrument items matches to its given conceptual domain and that the construct is a valid measure of the concept which is being measured just on the face of it. Content validity index (CVI) suggested by Lynn (1986) and content validity ratio (CVR) suggested by Lawshe (1975) were used to assess the content validity quantitatively (Azwan *et. al*., 2016). CVI was used to measure both the items level (I-CVI) and the scale-level (S-CVI), whereas CVR was used to measure both the items level (I-CVR) and the scale-level (S-CVI). Also, the internal validity is conducted to ensure that the essential conclusions made from this MeSRESD instrument is valid and acceptable. A number of threats to internal validity were present in this work such as history, instrument threat, selection bias, and contamination. Meanwhile, external validity was performed to ensure that this study outcome can be generalized to other populations (Bolarinwa, 2015).

Additionally, construct validity was performed to ensure the validity of the instrument. Rasch model using WINSTEPS version 3.92.1 software is used to analyze the data as well as to test the construct validity of the instrument. The Rasch model construct validity is conducted by measuring instrument statistical analysis, item fit analysis and Wright map. To ensure that the collected data fit the Rasch model, unidimensionality test and local independence tests are performed. Using Rasch model to perform fit and unidimensionality analysis as part of the instrument development process will enhance the quality of the instrument. In addition, differential item function was performed using WINSTEPS 3.92.1 to ensure that they are no gender differences in the MeSRESD instrument validity to measure students' readiness to learn Embedded System Design course.

The detection and removal of the misfit data as part of the analysis process is a strong statistical justification for this study, which improved the reliability of the items and indirectly served the purpose of instrument calibration to ensure a more accurate measurement. Reliability is the extent to which an instrument consistently measures what it is intended to measure. Instrument reliability analysis was performed by measuring reliability alpha coefficient to examine the scale consistency and internal consistency of scaled items by examining the average inter-item correlation (Le *et al.,* 2008). This is considered to be a fundamental measure of the reliability of research instruments (Pallant, 2007). Measuring of reliability alpha coefficients provides the researcher with information on which questionnaire items are related to each other and which items should be removed or changed accordingly. In this study, the relevant reliability which is test/retest reliability is used to measure the internal consistency reliability to assess the consistency of results across items measured with Cronbach's Alpha.

1.9.6 Theme 6: Readiness

The students' readiness measured based on the results obtained from respondent' to MeSRESD instrument. Students' readiness to learn Embedded System Design course is evaluated using Statistical Package for the Social Sciences (SPSS)

version 23.0 and Rasch analysis using WINSTEPS 3.92.1. To provide better insights on readiness, this study applied the assessment model by Akaslan and Law (2011) since it was coded as 1, 2, 3, 4 and 5, as in a five-point Likert scale format similar to the MeSRESD instrument format. The result is interpreted as Not-Ready if the mean score is less than required threshold and as Ready if the mean score is equal to or greater than 3.40. The numbers of five-point Likert scale (ranged from 1 to 5) which were used in this study, was transformed to means to articulate the weights of the study variables. The weighted mean for each number in Likert scale was calculated then the readiness for each item was also determined. The critical level: 4 intervals/5 categories = 0.8 is identified. Therefore, the strongly disagree level (1.0 – 1.79), disagree level (1.8 – 2.59), somewhat agree level (2.60 – 3.39), agree level (3.40 – 4.19) and strongly agree level (4.2 – 5.0) resulting in the threshold readiness level of 3.40 as the agree level is stated from 3.40.

1.10 Significance of the Study

Although Embedded Systems teaching and learning challenges have been broadly researched over the past 20 years (Milosh *et al*., 2011), little research has been performed on the measurement of student readiness to learn Embedded Systems Design course. This study contributes to BOK by producing a valid and reliable measurement instrument for evaluating student's prior knowledge and skills for Embedded Systems Design course. Electrical, Electronics, and Computer engineering programs can use this instrument to evaluate their students' readiness to learn Embedded Systems Design course as well as to review their curriculum structure. Findings of this study will help the universities to become attuned to the full extent of the Embedded Systems Design course problem as it affects undergraduate and postgraduate teaching and learning. Moreover, the universities can review their curriculum to identify the strengths and the weaknesses and improve it to better prepare the students for Embedded Systems Design course and reduce the gap between conceptual understanding and concrete implementations. Furthermore, this work serves as a solid base for other researchers interested in Embedded Systems Design course curriculum development.

1.11 Importance of the Study in Engineering Education

In the engineering education, learning outcomes are usually focused on the knowledge, underrating and skills, which are designed to develop the students. Hence, this study contributes to the engineering education by assessing the student prior knowledge and skills required to learn the Embedded System Design course. The findings of the study could be used to improve the students' competences, teaching and learning process as well as educational practice in higher engineering. The study importance is highlighted by relating the research question (RQ) and the research objective (RO) with the course and program outcomes of the BOK courses with respective to engineering education research area and strands of inquiry as shown in Table 1.1.

Table 1.1 Importance of engineering education context

Research Objective	Research Question	Engineering Education Research Area	Strand of Inquiry
RO1: To identify the important body of knowledge courses (BOK) for Embedded System Design course.	RQ1. What are the important body of knowledge courses for undergraduate students to learn Embedded Systems Design Course?	Engineering learning	Knowing the BOK courses the students required to learn the Embedded System Design course
RO2: To identify the cognitive, affective, and psychomotor skills required to learn Embedded Systems Design course	RQ2: What are the cognitive, affective, and psychomotor skills required to learn Embedded Systems Design Course?	Engineering learning	Knowing the soft skill, attitude, prior experience the students required to learn the Embedded System Design course
RO3: To determine the validity and reliability of the instrument to measure students' readiness for the Embedded Systems Design course	RQ3: How can the instrument's validity and reliability be evaluated?	Engineering learning	Knowing the course and program outcome (CO/PO) of the BOK course and related them the MeSRESD instrument items
RO2: To assess the students' readiness to learn Embedded Systems Design Course using MeSRESD	RQ4: Are students ready to learn Embedded System Design Course?	Engineering learning	Knowing the effect of the insufficient BOK courses and lack of soft skills, attitude and prior experience on the student readiness for the Embedded System Design course

1.12 Operational Definition

Following are operational definitions of main terms used in this thesis. These definitions can assist in understanding, the instrument development process to measure students' readiness to learn Embedded System Design course.

(a) **Readiness**: Readiness is the level of preparation a student needs in order to enroll and succeed in their study (White and Leah, 2015).

(b) **Validity**: Extent to which a test measures what it is designed to measure (Lukman *et al*., 2016; Bolarinwa, 2015; Rumble and Leal, 2013). In research, validity concerns with accuracy and trustfulness of the scientific findings (Bolarinwa, 2015; Rumble and Leal, 2013). In this study, the relevant validity is content validity and construct validity.

(c) **Reliability**: Ability of the scale to create reproducible results. An instrument is said to be reliable if we get same/similar answers repeatedly (Karol *et al*., 2016). In this study, the relevant reliability is test/retest reliability to measure the consistency of a measure evaluated over time and the internal consistency reliability to assess the consistency of results across items, often measured with Cronbach's Alpha (Le *et al.,* 2008)

(d) **Preliminary Study**: An initial exploration of issues related to a proposed quality review or evaluation. It provides the groundwork for the study. It covers, in particular, statements regarding the initial situation, the research questions, the problem statement, the objectives to be achieved and the methodology and the research design (ElHassan, 2017; Saunders, 2012; Metzger, 2010).

(e) **Dichotomous Response**: A response format of two categories such as correct-incorrect, yes-no, agree-disagree (Linacre, 2016).

(f) **Polytomous Response**: Responses in more than two ordered categories, such as Likert rating-scales (Linacre, 2016).

(g) **Body of knowledge (BOK)**: The core knowledge, skills, and abilities generally the students required to succeed in the study (Alice *et al*., 2011).

(h) **Curriculum**: The set of courses, and their content, offered at a school or university. (Marilyn and Bert, 2017).

1.13 Thesis Organization

This thesis is organized into five chapters. In Chapter 1, the problem statement, research questions, research objectives and the scope of the study are clearly defined. Firstly, an introduction of Embedded Systems Design course is presented. This is followed by a brief discussion of the problem statement. Subsequently, the research questions and objectives are stated. The scope of this study is defined, importance of the research in engineering education and the operational definition are stated.

Chapter 2 presents the background of Embedded Systems and the fundamental concept of the outcome-based education (OBE). Next, several learning and measurements theories that lay the foundation for this research are presented and finally, a systematic literature review on an Embedded Systems Design course readiness and instrument development and validation, are presented.

Chapter 3 discusses the methodology used in this research. The MeSRESD instrument development and validation to measure student readiness for Embedded System Design course is described. The data collection and data analysis methods are presented. Finally, the students' readiness are explained.

Chapter 4 presents the result and discussion of this study. The instrument content validity was presented. Qualitative analysis, Quantitative analysis, and construct validity using Rasch analysis results and findings stemmed from questionnaire that was distributed to 415 respondents and group interviews' using SPSS 23, NVivo 11 and WINSTEPS 3.92.1 are presented. Chapter 5 presents the discussion and the conclusion of this study regarding the research aim and objectives

based on the results presented in the chapter 4. The implication of the study and theoretical contribution are presented. Finally, the conclusion, limitations, recommendations, and the future work of the Study are presented.

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