THE ROLE OF RESEARCH LABORATORY IN DEVELOPING SKILLED HUMAN CAPITAL: LESSONS LEARNED FROM MALAYSIAN AND JAPANESE UNIVERSITIES

ATIQURRAHMAN BIN ROSDI

FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
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THE ROLE OF RESEARCH LABORATORY IN DEVELOPING SKILLED HUMAN CAPITAL: LESSONS LEARNED FROM MALAYSIAN AND JAPANESE UNIVERSITIES

ABSTRACT

Rapid advancement of the economic trend nowadays requires multi-skilled graduates to fulfil the labour market demands. This scenario denotes high quality graduates in the field of Science, Technology, Engineering and Mathematics (STEM) that could satisfy the needs for quality trained researchers and graduates in Malaysia. Looking at the developed eastern country, Japan is renowned as one of the worlds' fastest developing technological inventors even though it had been devastated with an atomic bomb in 1945. Strong research capacity in the Japanese laboratory has been recognized as an indicator for the advanced development in Japan. Concerning the significant role of research laboratory, it could contribute towards the development of new knowledge, human values, research skills, management settings, and social networks. Hence, this study examines the practices of research laboratory in university to develop skilled human capital in science and technology in Malaysia and Japan. It provides an overview of capacity building of research laboratory in producing practical skills, transferable skills and intellectual simulation especially in the context of 21st century learning in Malaysia and Japan. This study was completed through an original case study, interviews and short visit that were conducted in Malaysia, i.e. University of Malaya (UM), University of Putra Malaysia (UPM), National University of Malaysia (UKM), UCSI University and Japan, i.e. Kyoto University, Tsukuba University, Kyushu University, and Japan Advanced Institute of Science and Technology (JAIST). The analysis presents key findings of historical development, science and technology strength in research and development, support for research, research culture, positioning student to a research group, mentor-apprenticeship, monitoring students' development, and networks and output. In order to adopt the best practice in research laboratory for human capital growth, laboratory research universities must function in a supportive physical and intellectual infrastructure. This study also suggests that research design should expose students to the real research world in parallel to the global interest to develop the life-long skills and provide collaborative interaction between different institutions like the university, industry, and government. The analysis would be helpful to improve the performance of research laboratories in universities.

Keywords: research laboratory, human capital, human skill, university.

PERANAN MAKMAL PENYELIDIKAN DALAM PEMBANGUNAN MODAL INSAN BERKEMAHIRAN: IKTIBAR DARI UNIVERSITI MALAYSIA DAN JEPUN

ABSTRAK

Seiring dengan kemajuan ekonomi yang pesat pada hari ini, para graduan yang mempunyai pelbagai kepakaran adalah sangat diperlukan bagi memenuhi permintaan dalam pasaran tenaga kerja. Hal ini melibatkan para graduan berkualiti tinggi dan terlatih daripada bidang Sains, Teknologi, Kejuruteraan dan Matematik (STEM) yang sangat diperlukan di Malaysia. Merujuk kepada negara-negara timur yang maju, Jepun sering dianggap sebagai salah satu negara pereka teknologi di dunia yang paling pantas berkembang walaupun ia pernah dihancurkan dengan bom atom pada tahun 1945. Keupayaan penyelidikan makmal Jepun yang kukuh dikatakan sebagai suatu penanda bagi kemajuan pembangunan di Jepun. Berhubung dengan peranan penting makmal penyelidikan, ia dapat menyumbang kepada perkembangan pengetahuan baru, nilai insaniah, kemahiran penyelidikan, latar pengurusan, dan rangkaian sosial. Maka, kajian ini meninjau amalan makmal penyelidikan di universiti dalam membangunkan modal insan yang berkemahiran dalam bidang Sains dan Teknologi di Malaysia dan Jepun. Ia menyediakan gambaran pembinaan keupayaan makmal penyelidikan dalam menghasilkan kemahiran praktikal, kemahiran boleh pindah dan simulasi intelek terutamanya dalam konteks pembelajaran abad ke-21 di Malaysia dan Jepun. Kajian ini dilengkapkan melalui suatu kajian kes asal, temubual dan lawatan singkat yang dikendalikan di Malaysia, iaitu di Universiti Malaya (UM), Universiti Putra Malaysia (UPM), Universiti Kebangsaan Malaysia (UKM), dan Universiti UCSI, serta di Jepun, bertempat di Universiti Kyoto, Universiti Tsukuba, Universiti Kyushu, dan Institut Kajian

Tinggi Sains dan Teknologi Jepun (JAIST). Analisis ini menunjukkan penemuan penting dalam perkembangan sejarah, kekuatan sains dan teknologi dalam penyelidikan dan pembangunan, sokongan penyelidikan, budaya penyelidikan, penyertaan suatu kumpulan penyelidik, bimbingan-perantisan, pemantauan perkembangan para pelajar, serta rangkaian dan hasilan. Bagi mengambil amalan terbaik dalam makmal penyelidikan untuk pembangunan modal insan, universiti penyelidikan Malaysia haruslah berfungsi dengan sokongan suatu infrastruktur fizikal dan intelektual. Kajian ini juga mencadangkan bentuk penyelidikan harus memberi pendedahan kepada pelajar mengenai dunia penyelidikan sebenar yang selari dengan kepentingan menyeluruh pendidikan bagi membangunkan kemahiran sepanjang hayat dan menyediakan interaksi kerjasama antara berbagai institusi, seperti pihak universiti, industri dan kerajaan. Analisis ini akan membantu dalam menambah baik prestasi makmal-makmal penyelidikan di universiti.

Kata kunci: makmal penyelidikan, modal insan, kemahiran insan, universiti.

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LIST OF SYMBOLS AND ABBREVIATIONS

AMPI	:	Advanced Materials Processing and Integrity
AR	:	Augmented Reality
AUN	:	ASEAN University Network
CERVIE	:	Centre of Excellence for Research, Value, Innovation and Entrepreneurship
ChECA	:	Chemical Energy Conversions and Applications
CPS	:	Creative Problem Solving
CTRM	:	Centre for Excellence in Composites and Aerospace
GERD	:	Gross Expenditure on Research and Development
GDP	:	Gross Domestic Performance
GII	:	Global Innovation Index
GOT	:	Graduated-on-Time
GRIs	:	Government Research Institutions
HIR	:	High Impact Research
HLI	:	Higher Learning Institution
HOT	:	Higher Order Thinking
HPWP	:	High-Performance Work Practices
ICT	:	Information, Communication and Technology
IIUM	:	International Islamic University of Malaysia
ISTECC	:	International Sustainability Technology, Environment and Civilization Conference
IT	:	Information Technology
JAIST	:	Japan Advanced Institute of Science and Technology
KIC	:	Knowledge Integration Community

KLEC	:	Kuala Lumpur Education City
KSAVE	:	Knowledge, Skills, Attitude, Values and Ethics
MARDI	:	Malaysian Agriculture Research and Development Institute
MASTIC	:	Malaysian Science, Technology and Innovation Center
MEB	:	Malaysian Education Blueprint
MEXT	:	Ministry of Education, Culture, Sports, Science and Technology
MJII	:	Mara-Japan Industrial Institute
MOHE	:	Ministry of Higher Education
MOSTI	:	Ministry of Science, Technology and Innovation Malaysia
NEB	:	National Education Blueprint
NHEAP	:	National Higher Education Action Plan
NHESP	:	National Higher Education Strategic Plan
NIE	:	Newly Industrialised Economy
NISTEP	:	National Institute of Science and Technology Policy
NSRC	:	National Science and Research Council
OSHA	:	Occupational Safety and Health Administration
PBE	:	Problem Based-Engineering
PCT	:	Patent Cooperation Treaty (PCT)
PI	:	Principal Investigator
PORIM	:	Palm Oil Research Institute of Malaysia
PSL	:	Problem Solving Laboratory
PY	:	Publication Year
QS	:	Quacquarelli Symonds
ROA	:	Return on Asset
ROI	:	Return on Investment
RSE	:	Research, Science and Engineering

R&D	:	Research and Development
R&D&C	:	Research, Development and Commercialization
SAMM	:	Malaysian Laboratory Accreditation Scheme
SEED	:	Southeast Asia Engineering Education Development Network
SIRIM	:	Standards and Industrial Research Institute of Malaysia
SOP	:	Standard Operating Procedure
STEM	:	Science, Technology, Engineering and Mathematics
STI	:	Science, Technology and Innovation
S&T	:	Science and Technology
TIMSS	:	Trends in International Mathematics and Science Study
TM	:	Telekom Malaysia Berhad
UIHCC	:	University-Industry-Higher Education Collaboration Council
UIL	:	UNESCO Institute for Lifelong Learning
UKM	:	University of National Malaysia
UM	:	University of Malaya
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
UPM	:	University of Putra Malaysia
USA	:	United States of America
USM	:	University of Science Malaysia
UTM	:	University of Technology Malaysia

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Introduction

The knowledge-based economic trend worldwide requires multi-skilled graduates to fulfil the current labour market demands. In this paradigm, the success of economic growth heavily depends upon the production of ideas and human capital, instead of only the technological invention (Faggian & McCann, 2008). According to Cunningham and Villaseñor (2016), the global demands put pressure on the field of Science, Technology, Engineering and Mathematics (STEM) to produce more workforces with proactive generic skills, emotional intelligence, logic, and teamwork skills. These broader socio-emotional, higher-order cognitive, basic cognitive, and technical skill sets are formed through the complexity of non-routine job analytical tasks. In the study, it is found that when the socio-emotional skill set is the employer's priority, it particularly emphasizes on teamwork, honesty, punctuality, work ethics, interpersonal skills, work attitude, integrity, life skills (negotiation, cultural diversity), and responsibility, followed by the higher-order cognitive skill set, which includes communications, problem-solving, and critical thinking skills. Furthermore, a study conducted in Australia relates job demands to graduates' attributes that are considered important to employers, which are identified as personal abilities, interpersonal abilities, intellectual abilities and specific skills, and knowledge (communication, management and information technology (IT) literacy) (Herok, Chuck, & Millar, 2013).

Interestingly, most of the criteria illustrate the congruent elements that are being cultivated in university research laboratories; seeing that university is the final platform for students' skills training before going into the realm of a profession (Kavanagh & Drennan, 2008). The laboratory course was first established formally by

Liebig at Giessin and Eton at the Rensselaer Polytechnic Institute 185 years ago. Since then, the laboratory has been appraised as one of the fascinating features in science education (Psillos & Niedderer, 2003). Numerous studies have shown that laboratory learning offers higher order thinking (HOT) skills (Malik & Setiawan, 2015), social skills (Falk, Fischbacher, & Gächter, 2013), and practical and transferable skills (Carnduff & Reid, 2003). Indeed, research laboratory-based science contributes to the development of new knowledge, human values, research skills, management settings, and social networks (Toole & Czarnitzki, 2009). Furthermore, it was found that business firms with academic scientists perform better in generating their outcome compared to others (Murray, 2004; Toole & Czarnitzki, 2009). In addition, it was observed that most of the science graduates possess the values of 'management ability' as required by employers to be the potential leaders in a company (Herok et al., 2013).

1.2 Problem Statement

Laboratories play a significant role in producing skilled scientists in the research and development (R&D) sector (Murray, 2004; Toole & Czarnitzki, 2009). In this respect, these scientists develop their implicit and explicit knowledge through "bench-level" experience and interaction within a research group (Zucker, Darby, & Brewer, 1998; Zucker, Darby, & Armstrong, 2002). They collaborate with their laboratory head to write proposals, recruitments, managing post-docs, writing articles, serving on review panels, and so on (Etzkowitz, 2003, 2006). Through social interaction, Murray (2004) pointed out that social interaction can be broadened through the "local laboratory network" with other laboratory groups. Moreover, many research laboratories, especially in universities, compete to get funding from limited grants. This orientation progressively hones their skills to identify, evaluate, and utilize scientific opportunities in academic professions.

In Malaysia, the number of qualified science and engineering graduates from universities is not encouraging, as some of them could not apply what they learnt in university to their jobs (Hanapi & Nordin, 2014). This scenario infuses concern among the academicians regarding the quality of graduates that was reported not to be up to the employer's expectations or even worse, unemployable (Cheong, Hill, Fernandez-Chung, & Leong, 2016). It was recorded that 38.17% of the local science and engineering students do not have good communication skills, 16.13% lack of self-confident and 12.91% did not possess critical and analytical thinking to work competitively, hence giving dissatisfaction to their employers (Kementerian Pengajian Tinggi Malaysia, 2012). The data are coherent to the surveys made by the World Bank and TalentCorp Malaysia in 2014 for fresh graduate's employability (Tan & Neo, 2015). In terms of human capital quality, which constitutes of employability, this condition does not appear as successfully striving towards achieving the national vision to be one of the leading countries in Research, Development and Commercialization (R&D&C). A prior study has identified that research institutions in Malaysian universities are still lacking in terms of producing quality and trained researchers despite tremendous efforts made (Azman, Sirat, & Pang, 2016). The low number of talent workforce in science and technology (S&T) will undermine the ability of R&D&C centre to innovate and be competitive at the international level (MOSTI, 2016). Since research laboratory is an education and training institution, the laboratory activities to develop talented human capital should be made organized and meaningful.

Meanwhile, Japan is renowned as one of the worlds' fastest developing technological inventor even though it had been devastated with an atomic bomb in 1945 (Allen, 2012). Scientific production in research universities, especially in the field of science and engineering, is a vital component in contributing towards the Japanese R&D sector (Shibayama, Baba, & Walsh, 2015). It was recorded that Japan has high rates of researchers per 1,000 workforces and is striving to increase even further (Heitor, Horta, & Mendonça, 2014). In addition, the Japanese researchers are also able to build and innovate foreign technologies in a short time frame, with lower cost, and high quality products (Bakri, 2008). As mentioned by Serah and Noor (2012), the motivation for self-improvement among the Japanese researchers is the factor of less or no defect products produced from the Japanese firm. Among others, group work practice in Japan is also a factor that contributes towards fast, innovative, and scientific production (Serah & Noor, 2012). Teamwork and communication skills between manufacturing, production, and marketing teams are coordinated well to support the Japanese economic growth (Bess, 1988; Yamaguchi, 2013). On the other hand, looking at the current situation in Malaysia, a prior study found that sufficient labour skills in R&D sectors among workforces are also crucial even though importing technology is a much faster solution in accessing new technologies (Azizan, 2004). In addition, the number of skilled human capital is relatively important due to the recent shift from a production-based economy to a knowledge-based economy (Fleming & Søborg, 2010; Azman et al., 2016).

Therefore, this study takes a further step by investigating the role and practices of research laboratory in Malaysian and Japanese universities to foster skilled human capital.

1.3 Research Questions

From the problem statement above, there are a few question that arose and need to be taken into consideration such as the following:

i. What is the contribution of laboratory activities in universities towards the R&D performance in Malaysia and Japan?

ii. What are the differences and similarities of the S&T situation and laboratory practices in Malaysian and Japanese universities?

iii. What could be learnt from the best practices that are being adapted in Malaysian and Japanese university laboratories?

1.4 Research Objectives

There are two objectives deemed to achieve throughout this study based on the problem statements above:

i. To study the contribution of laboratory activities in universities towards the R&D performance in Malaysia and Japan.

ii. To examine the S&T and laboratory culture practiced in Malaysian and Japanese universities.

iii. To learn the best practices in developing skilled human capital in Japanese and Malaysian university research laboratories.

1.5 Significance of Study

This study covers a part of the topic related to research laboratories in Malaysian and Japanese universities. It is hoped that this study could give significant contributions in the following sectors:

i. As an academic study that covers practices of research laboratories in universities.

ii. Present findings that are helpful in setting up and planning to improve the performance of research laboratories in universities.

iii. To improve the quality of education especially in S&T for the better graduate outcomes and institutional excellence. This effort is also to support the fourth pillar of the Mid Term Review of the 11th Malaysia plan "Accelerating human capital development for an advanced nation":

> *"Human capital development will continue to be a key priority to empower the workforce in supporting economic growth. Focus will be given to create skilful, knowledgeable and innovative human capital to meet the requirements of the industry. Human capital development initiatives will provide opportunities for quality employment as well as ensure access to quality education and training towards building a more inclusive, equitable and prosperous nation. These will be implemented through four priority areas, namely reforming the labour market, improving labour efficiency and productivity, enhancing access to quality education and training as well as fostering stronger industry-academia linkages."*
>
> (Ministry of Economic Affairs, 2018, Chapter 4, p. 1-9)

1.6 Research Scope

Since the title of this study can be interpreted into a broader area, hence, some borders are inevitable to comply during the study in order to give maximum research output. The scope of this study is related to the aspect of best practices could be learnt from Malaysian and Japanese research laboratories. This study will only focus on the research laboratories operated in selected universities in Malaysia and Japan.

1.7 Outline of Chapters

A full discussion of this study is divided into seven chapters. As seen in this chapter, the idea for this study is elaborated through the introduction, problem statement, purposes and the research questions arisen from the problem statement. In addition, this chapter provides the significance of this study for reasons of the 5W 1H (why, what, when, where, who and how) and the scope for this study to be carried out.

The second chapter begins with basic concepts, features, strategies and importance relied upon the human capital and skills in the 21st century. The second part relates the practices implemented in research laboratories and the way they assist in human capital formation and skills growth. While the third part reviews the practices in the universities research laboratories. A theoretical and conceptual framework is discussed in this chapter to identify the possible gaps for continuous chain of knowledge.

The third chapter presents a methodological flow of present studies based on relevant prior literature. This chapter, justifies the qualitative methodology used, its participants and the rational of the sample for the qualitative-case study approaches. To sum up, it comprehensively defines the methodological framework used in this study. This chapter also addresses some of the limitations in this study.

Chapter four and five discuss findings from documents review, in-depth interviews and informal discussions through the short-visits to research laboratories in Malaysian and Japanese universities. Eight interview findings from universities are discussed prominently by using thematic analyses and triangulation of overall findings.

Then, chapter six elaborates further on the comparison between practices of research laboratories between Malaysia and Japan. The comparison looks at the similarities and differences between practices of research laboratory to develop skilled human capital in both countries.

Chapter seven responds to the third research question critically on the best practices in Japanese research laboratories that could be learnt by Malaysia considering the local situation. The best practices learnt to aid the quality of the management in laboratories, in order to generate actual competent graduates. Finally, the last section summarizes and gives suggestions to further study in this research field.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter is organized to review relevant literatures on the relationship between practices of research laboratory in universities toward the skilled human capital performance in science and technology. The discussion of this chapter is divided into three bodies of literatures. The first part provides an overview of prior studies that have been carried out which convey the concept and importance relied upon the human capital. The second part focuses on the relationship of research laboratories in assisting towards the growth and formation of skilled human capital. In parallel to the objectives of this study, the third part discusses the research capacity building and practices adopted in the context of university research laboratories.

2.2 Human Capital and Skills Development

This section explores the concept of human capital, the importance of skilled human capital to the socio-culture and economic growth of the country, the skills needed in the 21st century and "Knowledge, Skills, Attitude, Values and Ethics" (KSAVE) Model which aims to measure the 21st century skills.

2.2.1 The Concept of Human Capital

An economy scholar, Theodore Schultz pioneered the term "human capital" in 1961. Human capital, according to him, is an input to the productivity developed through education and training (Becker, 1994; Azizan, 2004). The human capital theory postulates the knowledge and skills in an individual (stock of human capital) created, developed, accumulated, retained, managed, and manipulated through experience and personal attributes (Becker, 1994; Struminger, 2013; Azman et al., 2016). Briefly, the basis of this theory has presented the central role of education as a knowledgeable and skilled activity in developing the human capital.

Additionally, this concept was discussed extensively by multi-disciplined scholars. While economists view human capital as productive skills and technical knowledge embodied in labour for economical production, social psychologists define human capital as the intellectual, moral capabilities, and individual expertise that can be improved through education, training, and investments (Hashi & Xareed, 2009). For psychologists, human capital is far more than economic production skills of an individual. To sum up, both definitions imply that the collective power of economic and human skills could be developed through investments in education and training. According to Azman et al. (2016), the conventional method to measure human capital is through education and training, simply because those are viewed as important investments in human capital. Moreover, Lai Wan (2007) argued that education could enhance productivity if it is complemented with training and good management practices. Indeed, knowledge culture, sense of belonging, and innovative activities could be nurtured in an organization through good management practices (Azizan, 2011). In addition, the understanding of both factors were already explained by Smith (1998) earlier, that properly planned training is a process to improve attitudes, knowledge, and skills through learning experience in order to satisfy the future manpower needed; further, education according to him is defined as a set of activities to develop knowledge, skills, moral values, and understanding required in all aspects of life. Besides that, it is also important to understand the way knowledge, culture, and values are formed from their historical timeline. As history suggests, the changes in its economic and political aspects drive human in adapting to a new technology accordingly by assimilating with new cultural values for their positive growth from time to time (Murad, 2004; Bakri, 2008). Continuous changes in the national policy would affect culture and values towards the development of science and technology.

While the above studies look into what the human capital is, the most comprehensive (and expensive) studies would be able to evaluate, over time, the ways education or schools are able to impact the graduates' human capital development at work (with controlled group of participants). This is not easy and may require years of research and would consume a lot of time to go through the students' academic performance and careers (Struminger, 2013). However, it is plausible to study the ways and quality of education or schools' influence on human capital and skill development. Furthermore, Hanushek (2013) meaningfully inferred that quality of tertiary education strongly affects human capital growth, especially in the developing countries. The focus on quality measures the determinants of cognitive skills that bridges the gap between developed and developing countries. To be more specific, Azizan (2011) and Porter (1990) conceived the idea that the university's quality, research activities, and skills training are equally important in projecting high-quality workers. This opens an investigation on two aspects of discussion. First is the focus of research in universities in affecting graduates' knowledge, skills, and values at work, whereas the second is the supply side of graduates who have completed S&T field of education formally or informally at the university level and worked in qualified S&T occupation or rather known as S&T human capital (Auriol & Sexton, 2002). This aspect reflects the necessity of S&T production in the academic field of tertiary education as one of the key factors to the modern economic today (Shibayama et al., 2015).

2.2.2 The Importance of Skilled Human Capital

Awareness on the importance of human capital is not recent (Solow, 1956; Lucas, 1990; Quiggin, 1999). Solow (1956) in his economic growth model describes that the innovation process could be done through a productive supply of human capital. The continual supply of human capital will enhance the firm's productivity and subsequently the innovation process in the country, whereas a model of using human capital gives positive attribution in an economic growth; in contrast, the model of using only physical capital is poorly performed in the same sector (Quiggin, 1999). An example of the situation is, firm A employs workers who are experts in inventing a certain type of machine that is more profitable as compared to firm B that relies on imported machines from outside to operate. Based on the Lusacian model too, the skilled human capital could affect the productivity of labour and thereafter determine the success of national growth (Lucas, 1990; Azizan, 2004). Moreover, shifting the economic trend nowadays from a production-based economy to a knowledge-based economy requires a dynamic shift in focus to generate wealth. The principal argument in a knowledge-based economy indicates that economic growth does not solely depend upon the production of things and physical capital, but also on the production of new idea and human capital (Strulik, 2005; Faggian & McCann, 2008).

The expanding knowledge based-economy has increasingly forced public and private firms to go faster in stimulating the national economic growth. Hence, this situation has urged firms to recruit high quality graduates instead of investing a lot to train new workers. In addition, most firms embrace that the impulse of human capital has a good competitive advantage to achieve cost-effectiveness and better firm performances (Marimuthu, Arokiasamy, & Ismail, 2009). This interpretation is consistent with the queuing theory (Di Stasio & Van de Werfhorst, 2016). The theory explains that education level is served as a signal to help employers identify candidates who are trainable in the future. This theory adds up another point that employers while hiring tend, to reduce training costs by looking at the potential and easily trainable candidates at the job-relevant skills upon joining the organization. Investing in higher education is important for the initial career stages of fresh graduates, even though empirical data from Lovaglio, Vacca, and Verzillo (2016) showed that investment through higher education in Italy contributes for only a marginal proportion to the economic performance. To highlight, higher education quality remarks greater graduates' capability for future employment as proposed by the signaling theory (Chevalier, 2014). These investments are not simply just costs, but the valuable return (graduate output) is the object to be calculated. In fact, firm performance is particularly measured by three components, namely profitability, capital employed, and return on assets (ROA) (Marimuthu et al., 2009). The output of high quality graduates must not only be equipped with knowledge and skills, but also positive human values (Hashi & Xareed, 2009). As discussed by Bakri (2008) and Murad (2004), the inculcation of cultural values such as cleanliness, punctuality, and attitude towards technology lead to further additional value towards S&T human capital. In the study, the historical aspect has been discussed primarily for its important role towards formation of the cultural values. Thus, the investment to develop human capital must be well-focused on the political, economic, and material benefits in the future.

The incorporation view of human capital consists of collective human values, working skill, and knowledge through daily experience, formal training, non-formal training, and education. Human capital is not only related to the knowledge and skills, but also cultivated them with good attitude, values, and ethics. Failure to complement each of the human capital components might defect the process of integrating the holistic approach (Hashi & Xareed, 2009).

Figure 2.1 represents a model of human capital theory (Swanson & Holton, 2001; Marimuthu et al., 2009). The key assumption to be highlighted in this relationship is through the investment in education and training as well as the recruitment of quality graduates that could increase their knowledge and skills for the firm's performance. Then, further learning after employment will be driven through on-job training organized by the firm.

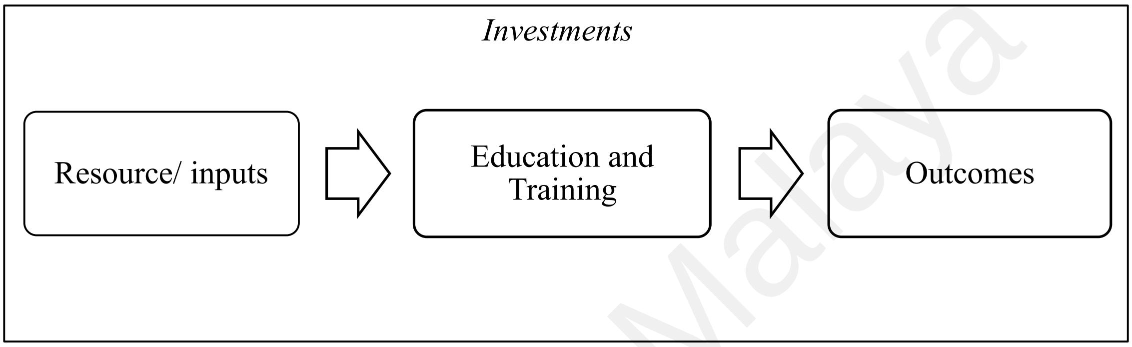


Figure 2.1: A Model of Human Capital Theory
(Source: Marimuthu et al., 2009 and Swanson, 2011: 110)

2.2.3 Skills in 21st Century and KSAVE Model

The previous sub-chapter points out that education and training management are the paramount tool for investment to improve human capital quality. This sub-chapter discusses the skills required in this 21st century. Generally, a skill is defined as an ability to perform a task (Azizan, 2011). In the 21st century, it is important to equip graduates with the necessary skills that are adaptable to the technological innovation. The 21st century differs primarily from the 20th century in terms of the skills needed due to the advancement of information and communication technologies (ICTs) (Dede, 2010). In addition, more skills like complex problem solving, critical thinking, creativity, people management, emotional intelligence, and negotiation skills are necessary for the 4th industrial revolution in this century.

If graduates have limited skills, then it would be hard for them to adapt to the advancement of technology even if they were certificate qualified. Moreover, a shift from product-based economy to the knowledge-based economy remarks the greater importance of skilled workforce rather than solely investment on technology (Azizan, 2011). Employers need to recruit graduates who are knowledgeable, critical and higher order skills, and good workers' attitude. In that sense, higher education carries out a huge responsibility in preparing graduates with multi-skills needed to succeed in a world of ever-changing and emerging technologies. Hence, Binkley et al. (2012) introduced a KSAVE model in explaining both concepts of basic and advanced skills to measure the skills needed in developing human capital. The KSAVE stands for Knowledge, Skills, Attitudes, Values, and Ethics such as follows:

i. *Knowledge* refers to a certain understanding required for each of these skills (knowledge may apply to many or single jobs).
ii. *Skills* are the abilities and competencies experienced by students for the focus of learning.
iii. *Attitudes, Values, and Ethics* refer to the behaviours and aptitudes practiced in responding to each of these skills.

The KSAVE model is used to measure ten important skills needed in the 21st-century. The ten skills are creativity and innovation, critical thinking and problem solving, learning to learn, communication, teamwork, tools for work consisting of information literacy and ICT literacy, local and global citizenship, life and career, personal, and social responsibility. These ten skills could be refined further into five transferable skills that are creative and critical thinking skills, problem solving skills, communication skills, academic writing skills, and teamwork skills (Malik & Setiawan, 2015). These skills were found to commensurate with what had been elaborated by Marion (2015) and Wagner (2008) for their seven survival skills. The first survival skill is critical thinking and problem-solving skills, in which students should be able to understand and tackle the source of the problem. The second survival skill is collaboration and leadership skills, in which students possess strategic thinking of global awareness and create international interaction. The third survival skill is agility and adaptability to become lifelong learners who are capable of overcoming any resistance. The fourth skill is initiative and entrepreneurialism; good at looking for new ideas, opportunities and improvements. The fifth skill is communication and oral skills in presenting global views and ideas. Next is the ability to access and analyze information. This means students must be ICT literate to synthesize, evaluate, and filtrate data. The last survival skill is curiosity and motivation to venture into the 21st-century learning atmosphere.

This model has been extensively applied in several groups of literature such as "The development of Higher Order Thinking Laboratory to Improve Transferable Skills of Students", "Collaborative Problem Solving: A 21st-Century Skill", and "Preparing education for the information society: the need for new knowledge and skills" (Care & Griffin, 2010; Plomp, 2013; Malik & Setiawan, 2015). Some terms used to refer to the 21st century skills are also known as research fluency, employability, lifelong learning, or transferable skill in accordance with certain countries (Malik & Setiawan, 2015; Marion, 2015). Above all, the model covers both trainable soft and hard skills. Referring to Azizan (2011), hard skill is the technical skills acquired through training and knowledge transference specified to a certain job whereas soft skill is the generic or non-technical skills acquired through daily experience and social interaction in a community. The employer will look at potential graduates who do not only excel in their studies, but also in terms of their interpersonal skills. A study carried out by Ooi and Ting (2017) in Malaysia found that the most frequent skills mentioned in the job advertisement are communication skills, followed by teamwork skills, leadership skills, critical thinking and problem solving, lifelong learning and information management, entrepreneurship, ethics, and professional morals. This is the basis of the skills criteria specified by the Malaysian employers recently. Then, through on-job-training after being recruited, they will hone these skills further for better competency in technological innovation. Therefore, it is important to form these skills through education and training at higher educational institution to equip graduates with all the skills needed.

2.3 The Laboratory-Based Learning towards Skills Production

This section reviews the practices of research laboratories from formal, informal and non-formal education aspects. This study also explores the skills obtained through the practices of laboratory learning. In the last sub-section, the contribution of the skills towards human capital development is critically discussed.

2.3.1 Linking Formal, Informal and Non-Formal Education

Human capital theory suggests that education is a promising productive source in absorbing the market demand. However, signaling theory (Spence, 1973) and filtering theory (Arrow, 1973) appear to be against the human capital theory since they argue that education is only meant to provide individual expectation with any qualification for employment. Di Stasio and Van de Werfhorst (2016) pointed out three theoretical perspectives: human capital, queuing, and closure theories. According to the human capital theory, education provides marketable skills that make employees to be more productive (Becker, 1994). Investment in human capital is to impart the skills that the employers find valuable. Queuing theory then views education as a machine to identify those who have the potential to develop valuable skills in the future, while social closure theory emphasizes the role of education in reproducing processes of inclusion and exclusion between social groups. To sum up, despite arguments of the above theories, all present the importance of education on skilled human capital formation. All in all, it is important to discuss and review education from the perspectives of formal, informal, and non-formal learning.

Formal education is the knowledge and skills acquisitioned through controlled grading systems such as certificates, diplomas, or degrees (Azizan, 2011). On the other hand, informal learning refers to the learning outside of the formal learning that is unstructured and does not follow a specific curriculum and activities occur in everyday daily life, whilst non-formal learning is the knowledge and skills acquired outside the formal learning but it has a specific structure and is connected to a particular syllabus or curriculum (OECD, 2012). To recap, informal learning is usually a voluntary basis and takes place during the student's leisure time, for instance science exhibition whereas non-formal learning is connected to the various activities available for broad learning. It is a structure associated with formal learning in educational and training settings with higher flexibility and it occurs mainly in a community-based workplace and activities of civil society organizations (UNESCO Institute for Lifelong Learning (UIL), 2012).

According to Affeldt, Tolppanen, Aksela, and Eilks (2017), the differences between formal, informal, and non-formal learning are neither easily traceable nor straight forward. For example, non-formal and informal education are not coherently applied, even though both are widely defined as a whole (Garner, Hayes, & Eilks, 2014). Learning experiences out-of-school could be argued whether it should be defined as a non-formal or informal education since it could be considered as part of the formal learning. Furthermore, considering the elective courses provided in university, whether it should be labelled as formal or non-formal education is debatable because it is not always structured within the specific curriculum. Regardless, considering limited research has been done in this area (Affeldt et al., 2017); this study deliberates on all formal, informal, and non-formal learning experience in research laboratory referring to science research capacity building in a research organization. Reviewing prior studies, knowledge and skills in laboratories has been presented through three-ways of education: formal, informal, and non-formal education (Coen, Bottorff, Johnson, & Ratner, 2010; Affeldt et al., 2017). For example, mentoring programs with external research communities could be done formally through workshops and informally through meetings, email, and telephone (Langille, Crowell, & Lyons, 2009). The existing network creates a joint educational platform such as science club for any out-of-school non-formal learning environments particularly for primary and secondary school students. The research laboratory aims at enriching students' opportunities for practical skills and achieving higher credentials in education.

Biao (2015) in his study emphasized on the combination of formal and non-formal systems of education to deliver lifelong learning for human capital development. Increasing world complexities day by day is no longer irrelevant for formal or non-formal education alone, despite how well it is delivered to face the 21st-century challenges nowadays. In the study, lifelong learning skills for human capital development usually connect between formal and non-formal education and are more easily planned for practical purposes. On top of that, research students always keep updated with the latest development in all aspects of human living and technology because quality research taken is parallel to a lifelong learning principal. Researchers must be able to manipulate the current technology and equipment to facilitate and accelerate their research production. For example, an augmented reality (AR) technology has been widely used from K-12 to higher education to improve laboratory skills and attitude towards science laboratory (Akçayır, Akçayır, Pektaş, & Ocak, 2016).

2.3.2 Skills Acquisition through Research Laboratory

Over the past 30 years, many works of literature highlighted the role of laboratory as a medium for attitude development and practical work (Kerber, 1988; Carnduff & Reid, 2003; Raj & Devi, 2014). According to Kerber (1988), students will develop confidence and curiosity levels in reflecting themselves as scientists and enthusiasm to increase contribution towards the industry and environment. Carnduff and Reid (2003) viewed laboratory activities as serving the purpose to provide students with practical skills, transferable skills, and intellectual simulations as presented in **Table 2.1**.

Table 2.1: Three Broad Skills through Practices in Laboratory

Skills	Practices
Research skills	Safety, experimental procedure, manipulating instrument
Transferable skills	Teamwork, organization, time management, communication, presentation, information retrieval, data processing, numeracy, designing strategies, problem-solving
Intellectual Simulation	Connected to the 'real world' through publication, patents and paper conference

Source: Carnduff and Reid, 2003

Scientific inquiry requires students to master research skills. Lack of research skills could lead to failure in experimentation and thwart the process of cultivating positive attitude towards science (Raj & Devi, 2014). In addition, the scientific nature of science students to hone their research skills capabilities are inherently equivalent to the nature of university-based discoveries. Students in universities deliberately consider task in their laboratory as a beneficial experience to gain appropriate research techniques continuously for their future employment. Besides that, research design is composed of several stages which are designing research objectives, making hypotheses, demonstrations, conducting experiments, analyzing results, discussion, and deducing a conclusion. This practical learning offers students with rich learning experience, conceptual understanding, and research skills (Malik & Setiawan, 2015).

Laboratory-based learning also develops cognitive abilities. Cognitive is derived from the word-cognition. According to the fourth edition of Oxford dictionary, cognition is defined as the process of acquiring knowledge and understanding through thought, experience, and senses (Oxford University Press, 2009). As laboratory tasks could undoubtedly quantify the cognitive performance, the development of conceptual thinking could evoke the imagination and determine the attitude of students towards science (Sharpe, 2012). In this context, positive attitude is an important factor to develop both soft and hard skills among students. The thinking activity through laboratory learning increases their confidence level to view themselves as scientists. In fact, Brookhart (2010) introduced 'Higher Order Thinking Practicum Laboratory' (HOT Lab) model in order to explain the processes of thinking skills. HOT Lab consists of eight stages integrated with Creative Problem Solving (CPS) and Problem Solving Laboratory (PSL) as tabulated in **Table 2.2.**

Table 2.2: Stages of Laboratory Model of Higher Order Thinking

Process	Stage	Divergent abilities	Logical and critical abilities
Understand the challenges	1st stage: Identify opportunities	Find experiences, roles and context for the object of interest; To explore experience and opportunities	Accept the challenge and start systematic efforts in response to the challenge
	2nd Stage: Exploring data	Collect data from different perspectives and impressions	Filter the most important facts and analyze them
	3rd Stage: Identify the research problem	Formulate a problem statement	Choose a realistic and reliable problem statement
Generate idea	4th Stage: Generating idea	Refine as much possibilities to solve the problem statement	Refine the most reliable idea
Prepare laboratory work	5th Stage: Developing Solutions	Generate, evaluate and confirm idea	Choose the important idea satisfying the criteria to evaluate, strengthen and improve ideas
	6th Stage: Establish the base of acceptance	List all the potential objectives for the solution and confirm potential methodology	Focus on the most realistic solutions and prepare research plan to run the solution
Conduct laboratory work	7th Stage: Doing laboratory work	Work fast and provide a variety of interpretations and apply concept in different ways	Skilled in the use of technology, application to the theory and complete criteria to make the solution
Communicate and evaluate results	8th Stage: Communicate and evaluate results	Critically analyze and develop idea to solve them in the discussion section	Present the output in verbal and academic writing; critical to wrong concepts, generalization and conclusion

Source: Brookhart, 2010

Besides research skills, competitiveness in gaining large grant scales to support science laboratory has developed human capital further in academic research. This orientation progressively fosters individuals’ skills to identify, evaluate, and exploit scientific opportunities for them to increase their laboratory funding. The scientists who successfully gain research grants will develop their self-confidence and research competencies, build professional qualification and networks, gain managerial experience, and strive towards scientific opportunities (Toole & Czarnitzki, 2009). This management skill is not only acquired and practiced by the laboratory head, but also students who are hired as research assistants and post-doctoral. These students could have an opportunity to learn on managing research funding, deal with suppliers or tenders, and engage in e-procurement in the laboratory. There are two prominent factors to support the conducive research and scholarly activities. The first factor is the availability of sufficient laboratory space and equipment and the second one is the availability of human resources and intellectual/scholarly resources for the support of research mentors and active-peers (Mullen, Murthy, & Teague, 2008). This support for research could facilitate the stages of research based on the HOT Lab Model, whilst gaining research and management skills.

In a laboratory, a research team is organized to design research activities. Historically, the structure of research organization is adopted from the practices of Germany University's model in the 19th century with a full professor who specialized in a certain discipline and was assisted with several staffs (Etzkowitz, 2003). In research laboratory group, a professor acts as a supervisor or principal investigator and is assisted with graduate and undergraduate students. At the same time, the students are trained to work together and hone their management and teamwork skills through proposal writing for research grants, recruitments, managing post-docs and publishing full data, and writing article journals (Toole & Czarnitzki, 2009). The cooperation and interaction within the team forges communication skills to develop implicit and explicit knowledge through the "bench-level" experience (Zucker et al., 1998; Zucker et al., 2002).

Linn, Palmer, Baranger, Gerard, and Stone (2015) claimed that mentoring is one of the essential elements in universities' laboratory practices. Mentoring participation deals with many previous perceptions such as *"I'm used to following the procedure to do this, to do that"* and *"I am very frustrated with everything failing as I thought of it coming as magic"*. Thus, senior mentors guide students who are juniors to link their research experience in order to solve the research investigation and lead them towards the correct path. Normally, mentoring is shared among professors, postdocs, graduate students, and undergraduate students. A study showed that mentoring relationships occur more often between graduates, postdocs, and undergraduate students or peer-mentor relationships and yet less with professors. The trend occurs because more time is spent on the technical aspects with postgraduates when compared with professors who advise on theoretical knowledge and professional skills growth (Strawn & Livelybrooks, 2012; Feldman, Divoll, & Rogan-Klyve, 2013). The professional skills are not only applied in the context of research such as problem-solving skills, knowledge, writing skills, designing experiments, and identifying research gaps, but also for their personality growth and emotional support. Therefore, it is important for closed monitoring between professor or principal investigator and students to occur in the laboratory. In addition to the studies, peer mentoring also offers professional supports, mutual respect as well as and enhancing communication skills, teaching skills, and self-esteem through a conducive open-spaced office (Tyler et al., 2016). Given these points, the laboratory environment maximizes daily interaction within the social group in the sense of teamwork to ease workload and for better generated ideas. It is also noted that the availability of larger numbers of seniors and active research peers could form an interaction of effective teamwork to ease workload and build academic research community in laboratory.

Finally, the output of laboratory work is usually documented, published, and sometimes patented to ensure effective intellectual simulation occurs, either among the academic or non-academic community. The practice aims to promote innovative research and enable beneficial ideas returned to serve the wider community. For Louis, Blumenthal, Gluck, and Stoto (1989), patenting is a common entrepreneurial culture among the science faculty in a university. This practice exposes academic scientists to develop human capital not only in terms of research skills but also invention skills as practiced by them. Similarly, Toole and Czarnitzki (2009) perceived that academic scientists should be oriented towards both scientific and commercial opportunities. This reason is due to observing the economic availability today; gaining both opportunities is much profitable at a certain degree, for instance, in a research portfolio. A key study referring to scientist who joined a firm as an entrepreneur is that of Stuart and Ding (2006), in which those who are good at both scientific and commercial skills are most likely to be selected in profit-science. This fact is also supported by the hazard model that both publication counts and patenting counts could give positive attribution to the firms joined. The research output has commonly been published in the academic journal articles, books, theses, and paper proceedings. In fact, academic writing is far more than just a mechanical process of summarizing all the experimental results, but it is to critically evaluate beneath the results and posit them to fill debatable contexts among the academicians (Shibayama et al., 2015). These tasks prepare quality graduates with academic writing skills and are ethically responsible for every writing they made.

Several studies also linked a number of important relationships between firms, particularly in publication across boundaries and alliances of university laboratories (Powell, Koput, & Smith-Doerr, 1996; Zucker et al., 1998; Salleh & Omar, 2013). There was also a study on an entrepreneurial firm that advocated the social capital (or social network) and could be broadened through laboratory network, either through local networks between seniors, juniors, and supervisors or cosmopolitan network between firms and universities (Murray, 2004; Toole & Czarnitzki, 2009). Social networks are originated from social interactions. Through laboratory network, the presence of social interaction among the laboratory members is common. A broader perspective has been studied by Falk et al. (2013) who argued that people who belong to the same group often imitate their laboratory members or mentors and professors, and this is what we refer to as social interaction effects.

In the research laboratory, social interaction effect always occurs due to high tendency of laboratory members in cooperating and communicating effectively in the same area of research topic. They collaborate to produce papers together and assign tasks to collect raw data. The basis for this interaction has established a consortium of local social networks and even continues after graduation. According to Linn et al. (2015), it is reported that research experience helps to expand their academic and social science networks beyond the international relationship. They get to learn acting like professionals in designing research as well as feeling ownership and commitment on research projects and groups (Linn et al., 2015; Stroth, 2015).

To conclude, laboratory-based learning refers to various sets of activities that require students to perform tasks adequately, ranging from research skills, transferable skills, and intellectual simulation. Experience obtained from the laboratory works generate technical and cognitive skills from personalizing research topic/problem, designing, and writing whereas the informal and non-formal workplaces in the research laboratory environment improve teamwork, communication, mentoring and management skills in the research organization. It is also highlighted that laboratory experience will be likely to achieve its higher objectives if students are involved into the intellectual simulation (Carnduff & Reid, 2003; Carayol & Matt, 2004). Researchers would be able to develop invention and entreprenurship skills for commercial opportunities. In addition, exposure in the wider scientific community could increase social skills and confidence level in their respective research areas.

2.3.3 Contribution of Skills in Laboratory towards Human Capital Development

Besides government research institutions and private R&D's, university research laboratories have also become the government's agenda to produce high-performance work practices (HPWP) (Asmawi & Chew, 2016). Under the situation of market compensation, researchers have to take risks on their R&D projects. Hence, the HPWP training since universities could help to overcome this situation via early training in university research laboratories. Even though 'bundles' of skills training from university laboratories might only be applicable under certain firms or types of work, the values of knowledge, skills, and attitude in human capital are the most valuable and non-substitutable for innovation as compared to tangible resources (land and money). This is because, in reality, graduates might not work in the same area they studied, but the transferable skills and abilities could be adopted to enhance respective organizational performance (Hanapi & Nordin, 2014).

On the other hand, Wantchekon, Klašnja, and Novta (2015) argued human capital as the fundamental factor that differentiates the economic growth among developing countries. Therefore, many countries nowadays compete with each other to build research identities and the capacity of R&D must be continued even in resource-limited settings in order to produce adequate number of researchers or scientists. Starting from university research laboratories, the collaboration between young researchers could be made and it gradually expands the networks to an international level. Research education and training have been marked to underpin this challenge. The policy to strengthen this research laboratory is not only to produce output, but also to attract more students to pursue science, technical, and engineering disciplines through various incentives such as research assistant schemes, postgraduate funds, and so on.

Besides that, Renzulli (2012) in his study entitled "Re-examining the role of gifted education and talent development for the 21st-century a four-part theoretical approach" had pointed out The Enrichment Triad Model in developing youth towards the 21st century skills. One of the points presented is an inductive model of learning as an important continuum element to experience youth with skills for their future job. The inductive model of learning refers to activities that occur outside the classroom learning such as research laboratory. There are three conditions required in order to acquire skills from this learning. Firstly, it is the personalization of topic or problem, where students do work because they want to. Secondly, the students use methods of creative production from practicing professionals. Thirdly, work is always geared towards production intended on particular audience. Hence, involving students in effective coordinated research could engage them towards achieving human skills personalization.

2.4 Activities of Research Laboratory in University

The earlier subtopics discussed the skills obtained via research laboratory education and training. Having positive relationship between both topics, the first sub-section reviews the research laboratory in university and the way it could be differentiated from teaching laboratory. This study then explores the research capacity building in the laboratory. The final sub-section looks at the purpose of research laboratory activities in universities.

2.4.1 Overview of Research Laboratory in University

Laboratory is one of the fascinating medium of science learning in university. Since experimental work is a fundamental part of science, it would be rare to find any high institutional without a substantial component of laboratory activity. If practical skills are to be developed, then the laboratory course must be included in the curriculum. Moreover, the expectation towards laboratory is that it is a place not only for skills development but also attitude towards scientific investigation and culture.

It is argued that laboratory activities are less constrained than lectures in terms of contents and demands and they lead to excellent opportunities for staff and students to meet informally (lboud, Dunn, & Hegarty-Hazel, 1989). Laboratory activities become the medium for social interaction to occur in the research group and work. In universities, there are two types of laboratory, namely teaching laboratory and research laboratory. The teaching laboratory is an experimental or practical course that is usually associated with the undergraduate course for the practical application of theoretical science in the class and mainly focusing on basic research (Beck, Butler, & Da Silva, 2014). Normally, undergraduate students start to learn in this laboratory from the first year of university to the third year of their studies. Over the past 15 years, there were many literatures that tried to bridge laboratory courses with the Science Technology Engineering and Mathematics (STEM) field in order to attract more students in this field through several directives. Mentoring, independent, and collaborative research are the elements, where students work together in the laboratory field on certain projects to fulfil the course requirement (Spell, Guinan, Miller, & Beck, 2014). Meanwhile, research laboratories are a place where more advanced research comprising of both basic and applied research are carried out by a certain research group.

Usually, final year undergraduate students would start to participate in this research laboratory after completing fundamental project in the teaching laboratory. The students involved in this laboratory usually work on a particular research individually and are supervised under their lecturer(s) to fulfil graduation purpose, publish papers, attend conferences, and make patents. The core purpose of exposing students in the research laboratory is to venture extensive knowledge for what the department cannot do to fulfil the social needs. The research executed would be able to fill the knowledge gaps albeit their unpredictable results. In brief, it could be simply inferred that teaching laboratory is a subset of the research laboratory in terms of soaring towards research goals. While it would be worthwhile to evaluate the skills cultivated throughout the practices of research laboratory, this study is not intended to elaborate deeper on the differences between these two laboratories.

2.4.2 Capacity Building in Research Laboratory

In a knowledge-based economy, knowledge development has grown up rapidly and is required for every complex mode of research activity for a laboratory to operate. Hence, research laboratory needs to leverage its key resources with potentially great output, minimal risk, and cost-effective. To do so, the activities must be operated not only through the in-house practices but also outside. Situating both activities that involve intertwined international and domestic interaction as well as in-house practices expounds the definition of capacity building in ensuring the flow of new knowledge and skills (Hulcombe, Sturgess, Souvlis, & Fitzgerald, 2014). The reason behind this is to ensure that the research laboratory is continuously up-to-date in terms of every new knowledge for its particular research area because even successful organization struggles to maintain its competitiveness through only in-house practices (Numprasertchai & Igel, 2005). According to Spronken-Smith, Mirosa, and Darrou (2014), there are four-point approaches to engage students in the research culture of their universities: (1) research-led (focus), (2) research-oriented (cognitive process), (3) research-based (hands-on learning), and (4) research-tutored (publication). Therefore, this study explores both internal and external research capacity building by viewing models underpinning the philosophical aspect structuring the practices of research laboratory.

Drawing a case analysis at the NEXUS multidisciplinary health research center at University of Colombia, Coen et al. (2010) introduced a relational model underlying both tangible and intangible structures. This model changed the notion of contextual discussion that was introduced by Langille et al. (2009) into the synergistic structure, cumulative structure, and operational base. The research center integrates the field of nursing, medicine, psychology, history, statistics, sociology, geography, epidemiology, population and public health, and educational psychology. Based on the diverse field of research, capacities for building of research laboratory were discussed under the synergistic structure (will be discussed further), namely conceptual models (Coen et al., 2010; Hulcombe et al., 2014), mentorship and training (Heitkemper et al., 2008; Tyler et al., 2016), communication (Hulcombe et al., 2014), learning opportunities program (Coen et al., 2010), partnership and networks (Numprasertchai & Igel, 2005), and knowledge translation and public outreach (Langille et al., 2009).

A conceptual model is an initial research set up before going for experimentation and communicating results (Malik & Setiawan, 2015; Shibayama et al., 2015). To highlight, this is an important mechanism to ensure that the research is guided along the right track in order to develop graduates with adequate skills and rich learning experience. However, certain models implemented may be readjusted and refined over time and situation. The conceptual lens acts as the main element that leads to other practices such as communication, collaboration, facilitation of research networks, support or mentoring, and contextualization of the research capacity development (Hulcombe et al., 2014). In turn, failure to set up the well-structured capacity building models will thwart the overall process of cultivating research culture among graduates.

Sequence sets of training and mentoring program play an important role to generate next scholar generations and subsequently build a solid community in their respective discipline (Azman et al., 2016). Notably, a previous case study at the University of Washington has found that closed mentoring by means of grantsmanship allows them to enculturate science based on their model for almost 20 years in research center at the university (Heitkemper et al., 2008). Moreover, at the health research center (NEXUS), University of British Columbia was able to develop its prosperity through a vibrant research culture in the learning communities (Coen et al., 2010). There was also a study conducted by Tyler et al. (2016) that showed the elements of mentorship, independence, team-building, creativity, and collaboration, while enhancing knowledge, skills, and attitude for the implementation of cooperative group from supervisor-students or mentor-protégé that reformed the Hunterian Neurosurgical Laboratory in 1984 after being dormant for about 20 years from 1960s to the early of 1980s through training and mentoring.

Shibayama et al. (2015), Hulcombe et al. (2014) and Etzkowitz (2003) are among the scholars who discussed practices in research laboratory. From anecdotal evidence in university, an operational base in laboratory is naturally organized by the laboratory head and some members under his/her supervision. The laboratory head appointed is usually a professor or an associate professor and the following members are assistant professors or senior lecturers, postdoctoral researchers, technician, and junior faculty members such as PhD, Master's, and a few final year undergraduate students. The research group is characterized as a sequential teamwork with multiple roles to allow the laboratory head aiming for long-term goals. In the presence of physical infrastructure, they carry out a certain portfolio of research projects that may either be challenging with potentially great impact or less novelty with minimal risk for the expected output (Shibayama et al., 2015). In fact, research laboratory in university is regarded as a "quasi-firm" and operates like a small firm-based entity; it is just lacking of direct profit motive to be described as a company (Etzkowitz, 2003). Effective communication that occurs between students,

students-principal investigator, and supportive staff or relevant organization enculturate positive and collaborative research culture. Furthermore, leadership, collaboration, and supportive networks that also address an effective communication with allied partners may enable the translation of evidence into practice (Hulcombe et al., 2014). At this stage, communication and partnership are intertwined to sustain the research capacity building strategies.

A lot of learning programs introduced by the faculty and laboratory to provide research students with creativity and connectivity. Activities such as seminars, retreats, journal clubs, institutes, and other symposia could be a platform for research exchanges, refining new models of research direction, evolving management and social skills, and through local networks (Coen et al., 2010). The program creates research culture and connection between laboratory members for both formal and informal connection, in contrast to the knowledge translation and public outreach that are intended for the wider audience (Brew, Boud, & Malfroy, 2017). The consortium local laboratory networks that exist during the research training program could build some common interest shared among the laboratory members and their collaborators from other campus departments (Heitkemper et al., 2008). Even though it might be difficult to manage the long term mutual interest, the strategy is however worth the limited resource setting.

Partnership and networking in R&D field play pivotal roles to facilitate the research taken, create valuable channels for collaboration, and formulate other synergistic components (Huba, Fagin, Franklin, & Regenstreif, 2006). This strategy will provide access and flow of knowledge across other synergistic structure such as knowledge translation to communicate with wider public audiences. Additionally, the cosmopolitan network exists between research laboratories in universities, industries, and government to ease and enhance the commercialization of R&D (Toole & Czarnitzki, 2009).

Commercializing new innovative products by universities can also be used for the country's additional sources of income (Ahmad, Farley, & Naidoo, 2012). Through partnership and networking, research laboratory may also obtain funding from the industry for their alternative assets. The triple helix model between university-industry-government, Knowledge Integration Community (KIC) model, and University-Industry-Higher Education Collaboration Council (UIHCC) are the examples of globally established models (Leydesdorff, 2013; Salleh & Omar, 2013). This model is used to facilitate the collaboration as it is hard for strategic alliance in R&D to occur if there is no mutual interest and knowledge exchange (Numprasertchai & Igel, 2005; Ponomariov & Boardman, 2010).

The ultimate goal to carry out research is to translate research problem into knowledge and solution (Ponomariov & Boardman, 2010). There are many prior works of literature that have discussed a wide range of strategies such as disseminating knowledge through publication and patent for academicians, organizing a program to share knowledge with the target audience, and engaging with media for non-academicians (Heitkemper et al., 2008; Langille et al., 2009). Patenting is a common entrepreneurial culture among life science faculty in university (Toole & Czarnitzki, 2009), whilst publication is a research output translated into peer-reviewed article journals, books, theses and proceedings. Normally, both are only limited and accessible for academicians and subscribers. While knowledge translation goes beyond the communication with external audiences, the approaches can be done through consultation, newsletter articles, newspaper, radio and, television interviews and exhibitions at public events (Langille et al., 2009).

2.4.3 The Purpose of Research Laboratory Activities in Universities

R&D activity in universities is one of the imperative factors soaring towards the human capital and technological development (Azman et al., 2016). For example, in the United States of America (USA), research in universities plays a significant role towards their national economic growth (Amran, Rahman, Salleh, Ahmad, & Haron, 2014). In light of the event, the capacity of research in laboratory has been evolving over the years and become a dynamic institution for experts to share their knowledge and establish a vibrant culture of research (Langille et al., 2009; Azman et al., 2016).

To date, prior works of literature discussed the focus of university's research laboratories from various perspectives (Feller, Ailes, & Roessner, 2002; Heitkemper et al., 2008; Langille et al., 2009; Malik & Setiawan, 2015; Kumar, 2017). For example, the university's laboratory is focusing on the industrial technology innovation (Feller et al., 2002). In the study, it is reported that since the university's research laboratory is not a stable and long-term organization, the program-based public sector is essential to sustain their strategically planned and fundamental portfolios of R&D as stated below:

> *"The absence of program-based public sector support for this cluster of attributes—strategically planned, fundamental engineering research; organizational and administrative infrastructure; graduate and undergraduate education in an interdisciplinary, project-based, and industrially-relevant context—evidently removes a major lever that private firms use to justify support for generic, pre-competitive research."* (Feller et al., 2002, p. 473)

To adapt to the complex mode of 21st-century knowledge, laboratory also functions to foster multidisciplinary research (Heitkemper et al., 2008). The trans-disciplinary collaboration as well as mentoring at the individual and organizational levels in terms of grantsmanship (e.g. writing clear objectives, literature, and organizing backgrounds to support the study hypotheses) satisfy the mutual interest among researchers and continuous investments in infrastructure (e.g. investigator and technician training and equipment) are the approaches to sustain multidisciplinary research. The study also stresses the impact that can be seen not only in the advancement of science within a certain field, but also in knowledge translation towards communities, cross-institutional collaboration, and policy change in the long run.

Based on the case study conducted by Langille et al. (2009) at Atlantic health promotion research center, the laboratory operates to promote their models and advances university goals. The models of health promotion center provide places for training and overcome all challenges in generating new outcomes of knowledge. The research laboratory also adds unique value to universities by obtaining external funds as potential investments that are not fully realized and subsequently attracts talented human resources interested in research.

In addition, laboratory practical could enhance student's skills and offer rich learning experience (Malik & Setiawan, 2015). Based on an inductive theory of learning, informal learning that occurs in research laboratory could organize creative and investigative activities for young researchers through three processes as explained below:

> *"First, there is a personalization of the topic or problem—students are doing the work because they want to. Second, students are using methods of investigation or creative production that approximate the modus operandi of the practicing professional, even if the methodology is at a more junior level than that used by adult researchers. Third, the work is always geared toward the production of a product or service intended to have an impact on a particular audience."*
> (Renzulli, 2012, p. 154)

Another purpose of research laboratory is to advance business growth (Kumar, 2017). Research laboratory itself leads to research, teaching and service for both academic and business communities. Accordingly, the expanding research could attract international talented academics as well as entrepreneurs and provide job opportunities for students such as research assistants, research officers, and so on. In the engineering field, Medvedeva (2015) pointed out that progressive input from R&D in universities is capable of producing highly skilled experts for the global labour market, conducting scientific research and productivity publishing research output in the reputable journals, and innovating technological changes in terms of patents or licenses.

2.5 Chapter Overview

The discussion in this literature review has covered eight major themes pertaining to developing skilled human capital through the role of university research laboratory.

Firstly, skills in the current knowledge-based economy which are required for graduates in order to adapt with the 21st century were emphasized in this section (Strulik, 2005; Faggian & McCann, 2008). The quality human capital is not merely obtained with knowledge and skills, but also inculcated with good attitude, values, and ethics (Hashi & Xareed, 2009; Binkley et al., 2012; Raj & Devi, 2014).

Secondly, the national policies of research and incentives are also likely to shape the strategies of research laboratory for invention and entrepreneur skills in the respective countries. Consideration towards the attitude of students towards science was also emphasized as a factor that contributes to the strength of the country (Murad, 2004; Toole & Czarnitzki, 2009; Akçayır et al., 2016).

The third and fourth themes that emerged consistently across all literature sections, especially in considering HOT lab model, are the support for research and research culture. Based on the human capital, queuing, and closure theories, the activities of formal, informal, and non-formal are organized by the laboratory to connect the in-house and outside practices. Both laboratory practices aimed to leverage its capacity with potentially great output, minimal risk, and cost-effective for the skilled human capital (Feller et al., 2002; Mullen et al., 2008).

The fifth theme is positioning student to a research group that is consistently linked across three main sections in the literature (Coen et al., 2010; Azizan, 2011; Falk et al., 2013; Stroth, 2015). The multiple layers in the research organization have been an important indicator for effective communication and they create an identity of belonging to a certain research group. This is an on-going process for research and professional skills growth among graduates.

The sixth and seventh points that consistently emerged across literature, especially connected to KSAVE model, are mentor-apprenticeship and monitoring student's development (Binkley et al., 2012; Azman et al., 2016; Tyler et al., 2016). The approaches to develop young researchers through mentoring style and closed monitoring between PI-students and students-students were critically given focus to promote their skills growth.

The eighth theme is networking and output that consistently appeared in all the literature sections for the development of research, technical, and laboratory skills whereas the informal activities in workplaces in the research organization could improve transferable skills as in-parallel to the concept of lifelong learning (Murray, 2004; Toole & Czarnitzki, 2009; Linn et al., 2015). In gaining the opportunities to generate effective intellectual simulation, the output of laboratory work is documented, published and sometimes patented, either for the academic or non-academic community.

These eight themes will be revisited in the analysis chapter of this thesis. As shown in **Figure 2.2,** the conceptual framework for this study presents the six capacities building of research laboratory activities that generate human skills and values produced from the laboratory activities in universities. As such, it would then be possible to respond to the research questions shaped in this study: what are the contributions of laboratory activities in universities towards the national R&D performance?; what are the differences and similarities of the S&T situation and laboratory practices in universities for both countries

(Malaysia and Japan)?; and what could be learned from the best practices adapted in the universities' laboratory activities?

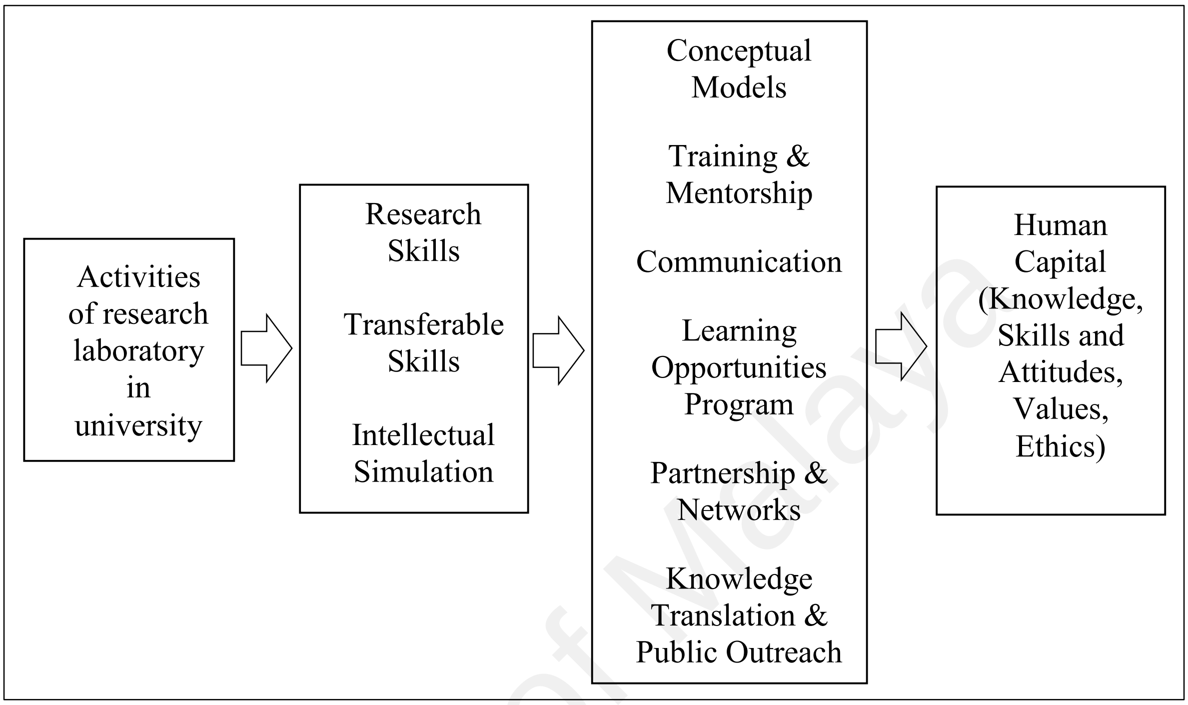


Figure 2.2: A Conceptual Framework

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter focuses on the research design implemented in this study. There are two pertinent aspects discussed in this chapter. The first aspect describes data collection procedure based on qualitative methodology from document review to interviews following informal discussion and how the qualitative data is critically analyzed based on the research questions and prior studies. The second aspect revisits the purpose of this study, provide a bridge and justification on the methodological approach taken in respond to the research questions and criteria selection of participants.

3.2 Research Strategy

Existing studies employed a mixture of methodological approaches in conducting research related to laboratory experience and human capital. There were several studies that used documentation and literature review as a research strategy such as Azman et al. (2016) and Stroth (2015) that focused on the mobility talent in Malaysia and the central importance of research laboratories respectively.

Azizan (2011) employed semi-structured interviews with 7 representatives from public university, private firm, and industry-driven education and development institution to study the strategies of these institutions in order to enhance human capital. The same methodology was used by Boardman and Bozeman (2007), who carried out 20 telephone interviews and 1 face-to-face interview to investigate their experience in the laboratory-induced role strain. On the other hand, Marion (2015) carried out both sets of interviews and observation methods to investigate how the educational policy, global, and economic changes affect the development of human capital and the 21st-century skills in preparing next generation workers in Science, Technology, Engineering and Mathematics (STEM) field.

In contrast to the above methods, Raj and Devi (2014) used quantitative design. By using random sampling techniques in 5 districts of Tamil Nadu, a science process skills inventory survey was used to find out the relationship between science process skills with the achievement in science among high school students. Another same approach was done by Ismail and Abdullah (2011); they administered questionnaires to 16 Malaysian universities. There were about 1,176 responses collected to explore on the strategies used to develop human capital development in Malaysian public universities.

There were also studies that combined both qualitative and quantitative style such as Shibayama et al. (2015). To test their hypotheses on the organizational design in Japanese university laboratories, they interviewed 30 researchers and obtained 396 responses through mailed questionnaires. Likewise, Akçayır et al. (2016) used the similar approach to find the effect of augmented reality (AR) technologies on university student's laboratory skills and attitudes towards laboratories through pre-test/post-test control group design.

Since this study is intended to look at the experience and strategies adopted in the research laboratory to develop skilled human capital in S&T, an inductive investigation method was selected. According to Noor (2010), qualitative data have rich and thick descriptions, whilst enabling the researcher to grasp the situation subjectively. The qualitative data also help to capture social and cultural phenomenon well in the topic area since participants would have more freedom to express their feelings. Instead of sending out questionnaires, a qualitative study is conducted in a more natural setting. In addition, since this research is focusing on lesson-learnt study, it requires primary data from international participants. Thus, the small number of sample size in this qualitative study is feasible in collecting data from research laboratories in Malaysian and Japanese universities. Relatively, the generalizability of data does not necessarily require a large amount of sample size; it can also be made based on the similarity of issues and people (Azizan, 2011).

The major sources for this study were integrated from primary data, secondary data, and non-formal discussion. The primary data were acquired by interviewing professors and associate professor as the head of research group, while the secondary data were obtained through institutional reports/documents and content-literature analysis related to this study. Then, the additional source was obtained through non-formal discussion with graduate students, senior research officers, lecturers, and professors in Malaysian and Japanese universities' research laboratories. This non-formal discussion was carried out in Japan during a-week tour visit at the research laboratory.

3.2.1 Document Review

Data were collected based on the relevant literature reviews which included manuscripts, reviewed article journals, newspapers, internet, books, government reports, and documents related to the research topic. This method was carried out by initiating from phase 1 through library research and online databases. Library research usually refers to the accumulation of data by reading and studying the documents related to the research topics. Data from the national report such as Malaysian National Plan, Ministry of Higher Education Malaysia (MOHE) report, data from Malaysian Science and Technology Information Center (MASTIC), statistics from Ministry of Education, Culture, Sports, Science and Technology (MEXT) and QS world university are also considered as important sources during this process. The document review somehow could help to collect and track changes on national plans to verify the findings of this study. Documentation of data was discussed in the literature review chapter based on the theoretical framework formed and acts as a concept map representing this study. The examples of main documents used in this study are as tabulated in **Table 3.1**.

Table 3.1: Example of Documents

Documentation	Examples
Article Journals	• Coen, S. E., Bottorff, J. L., Johnson, J. L., & Ratner, P. A. (2010). A relational conceptual framework for multidisciplinary health research centre infrastructure. Health Research Policy and Systems, 8(1), 29. • Carnduff, J. and Reid, N., (2003). Enhancing undergraduate chemistry laboratories, Pre-laboratory and Post-Laboratory exercises-examples and advice, Education Department, Royal Society of Chemistry, Burlington House, Piccadilly, London, WIJ OBA.
Newspaper	• Sze Wei, L. (2016, February 28). Nation Builders Wanted. The Star. • Jusoh, Idris. (2014, February 25). More students needed in science stream, The Star.
Institutional Document/ Report	• Academy of Sciences Malaysia. (2015). Science Outlook: Action towards Vision. Kuala Lumpur, Malaysia. • National Survey of Research and Development (R&D) in Malaysia 2013 • Japanese Science and Technology Indicators 2017. • National Institute of Science and Technology Policy (NISTEP)

This documentation is a continuous process before and after fieldwork. One of the advantages of documentation is to support the interview data that were not obtained during the fieldwork. In fact, Azizan (2011) argued that documentation could provide more comprehensive evidence as compared to interviews that happen in a shorter time frame and it functions to support the interview data. Document review is also known as secondary analysis. Furthermore, the utilization of primary and secondary data for analysis could also establish more solid and comprehensive evidence data.

3.2.2 Interview

Since this study aimed to explore the practices in research laboratory, a qualitative design was chosen. One of the qualitative approaches is interview. An interview inherently offers deeper understanding to the documentation analysis by organizing an open discussion between the researcher and participants. In addition, the discussion held may lead to other segmental discussion which was not previously considered but important to the study (Azizan, 2011).

An in-depth semi-structured interview was used in this qualitative study. This in-depth semi-structured interview is usually paper-based for the researchers' guidance, but still flexible in the sequence of questions within a certain amount of time. Unlike quantitative questionnaires, more data can be obtained through the semi-structured interview because it provides a wider discussion of new topics during the data collection (Marshall, Brereton, & Kitchenham, 2015). Additionally, Marshall et al. (2015) claimed that semi-structured interviews can reduce the risk of bias relating to the researcher's preconceived idea and the probes that lead to segmental discussions propelled on the research track. Jasmi, Ilias, Tamuri, and Hamzah (2011) supported this entrusted method insofar to obtain accurate data practically from the experienced person in a small population.

As this study involved case studies in Malaysia and Japan, interviews were done at many universities in the countries. The first interview was conducted during a visit to Kyoto University research laboratory in February 2017. In the next phase, all interviews were done in Malaysia. For Malaysian participants, the study took about four months from March 2017 to July 2017 from setting up meeting consent through emails to agreement and carrying out interviews in UM, UKM, UPM, and UCSI. In respect to the Japanese participants, this study carried out interviews with the Japanese who were appointed as visiting professors at Mara-Japan Industrial Institute (MJII), University of Technology Malaysia in September 2017. The reason was due to considering the cost-limitation and time consumption in conducting field work in Japan. Overall, the field work took 8 months to cover participants from both countries and all answers obtained from the interviews were transcribed. Even though small number of participants was selected, the duration for the in-depth interviews was conducted from 39 minutes to 84 minutes.

3.2.3 Informal Discussion during Short Visit

According to Merriam and Tisdell (2015), fieldwork usually connotes between observation and informal discussion in contributing to the qualitative study. It is an important key to complete library research whilst obtaining new data and allowing for abreast of the current scenario about the research topic. Hence, a-week visits were conducted to Japanese universities twice in this study in June 2016 and February 2017. The objective was to observe and have an informal discussion with the research members there. During the short-term exchange student programme in a Japanese university, the researcher was given an opportunity to present and discuss the practices of Malaysian and Japanese research groups in the laboratory. Afterwards, by observing the facilities and infrastructure in the laboratory tour, it has given meaningful insight on the physical and intellectual infrastructure at research laboratories in Japanese and Malaysian universities. The laboratory tour was guided by Mr. Sho Shin, a Master’s student at Kyoto University. All data were recorded through notes, video, and pictures to support this qualitative-based methodology (refer appendix C and D).

3.3 Participants' Selection

In a qualitative study, sampling is an important component of employing interviewees in the research methodology. According to Robinson (2014), there are four-point approaches to sampling in qualitative interview-based research: (1) Defining a sample population in Malaysian and Japanese universities; (2) Deciding on the sample size (a lecturer or researcher with outstanding research laboratory); (3) Choosing sampling strategy, which is a purposive sampling method; and (4) Sample sourcing, which includes ethical concerns, voluntary participation, and voluntary bias.

The method used to select participants representing Malaysian and Japanese universities in this study is a non-random sampling method. According to Bui (2009), the non-random samples could be categorized into convenience sampling and purposive sampling. Convenience sampling selects individuals who are accessible at the time, while purposive sampling selects individuals to represent a certain community and meet certain criteria stated for this study. By using the purposive sampling method, four universities in Malaysia and four universities in Japan have been selected for this purpose. Professors, associate professors, and experienced senior researchers were selected in this study based on few criteria. First, it is based on their outstanding laboratory performance and in-line with the university's reputation nationally and globally. The second criterion is that the selected participants must be laboratory heads or have many years of experience in managing a research laboratory. Thirdly, the participants must have produced many outputs such as graduated students and publication in the recent five years. The universities of research laboratories selected in Japan are Kyoto University, Kyushu University, Japan Advanced Institute of Science and Technology (JAIST), and Tsukuba University whereas in Malaysia, University of Putra Malaysia (UPM), University of Malaya (UM), National University of Malaysia (UKM), and UCSI University were selected. In general, the participants selected were mainly representing their outstanding reputation as researchers, not merely chosen by the universities.

3.4 Rationale for Selecting the Participants' Universities

Both public and private reputable universities selected have shown remarkable achievement consistently in Malaysia and Japan to produce numbers of quality human capital and skills. The selection of these public and private universities was done to get comprehensive figure on the practices of research laboratory from both sectors. Additionally, all the Malaysian universities situated in the Klang Valley area represent the same demographic area and background. However, due to some limitations of the participants from Japan, the data were collected from participants of different range areas in the country. In spite of that, the most important criterion is the profile of professors who own diverse research experience in universities. Generally, the research organizations involved comprise the faculty members and students who are from various educational levels and background. Such description is the pre-requisite and conditions to present the case studies for the framework proposed earlier. Furthermore, the universities' professors will be represented as participants A, B, C, D for Malaysia and E, F, G, and H for Japan as to keep the data provided by the participants confidential. Therefore, the data and findings cannot be easily identified back to specific laboratories or individuals except to those who are directly involved in this research.

3.4.1 Malaysia

The rationale to select these four universities in Malaysia was due to their relevancy to generalize the population sampling in their countries. Those universities were chosen based on their research activities, reputation, graduate employability, and achievements.

UPM is recognized as one of the Malaysian top universities, which ranks the 3rd place in Malaysia and 202 in the world for 2019 (QS Top Universities, n.d.). Furthermore, the research laboratory in UPM has won a lot of international awards such as "Berend Houwen Travel Award" and "Searca Regional Professorial Chair", and their engineering faculty manages to obtain the status of MS ISO/IEC 17025:2005 Accreditation under Malaysian Laboratory Accreditation Scheme (SAMM) for three years (University of Putra Malaysia, 2016). Interestingly, UPM has also shown the highest graduate employability among Malaysian Higher Educational Institution with 82.2% of its graduates employed after three months of their convocation (University of Putra Malaysia, 2015).

University of Malaya (UM) is renowned as the most experienced university in Malaysia performing human capital outcome since 1905, endorsed with the fact that the former University Malaya vice-chancellor, Tan Sri Professor Dr. Mohd Amin Jalaludin, at that time wanted his university to produce Malaysia's first Nobel Prize Winner. He is optimistic with the goal since RM590 million High Impact Research (HIR) Grant was awarded by the government in 2011, which enabled UM to establish central laboratory research facilities with state-of-the-art technology (University of Malaya Higher Impact Research, 2015). This inspiring vision to equip research laboratory with a mission to produce Nobel laureate has continuously strived UM to be the best university in Malaysia and achieved the 84th place in the 2018 QS World University Rankings (QS Top Universities, n.d.).

The third university is the University of National Malaysia (UKM), which ranked 2nd as a research university in Malaysia. The university also shows a significant leap in the QS World University Rankings 2019 with 46 spots from 230 to 184 (QS Top Universities, n.d.). In 2016, UKM's laboratory received a bronze medal in BioInnovation Award and its representative won the Young Scientist Award in the National PERMATA Nobelist Mindset Workshop Program 2016 (National University of Malaysia, n.d.).

UCSI University was selected because it is a reputable private university in Malaysia. UCSI has shown a remarkable leap which currently ranks as the top private university in Malaysia and 481 in the QS World University Rankings 2019 (QS Top Universities, n.d.). UCSI has also been proudly honored by many organizations such as SETARA Tier 5 (Excellent) Rating 2013, Human Resources Minister Award 2003, and so on. To compare with other universities, UCSI University has been listed among the top five universities in 2014 with 81.4% of its students were offered jobs before their graduation (Borneo Post Online, 2014). As a private university in Malaysia, UCSI University offers wide area of science and engineering courses in both undergraduate and postgraduate fields. In addition, the establishment of the Centre of Excellence for Research, Value Innovation and Entrepreneurship (CERVIE) in UCSI University also depicts its commitment to promote research initiatives through four main strategic thrusts, namely Internal Capabilities, Smart Partnership, Enterprise Value Innovation, and Knowledge Dissemination via the triple helix model (Government, Industry, and University).

3.4.2 Japan

In Japan, representatives were selected from Kyoto University, Kyushu University, Tsukuba University, and JAIST (Japan Advanced Institute of Science and Technology). Kyoto University is also known as one of the best universities in Japan and ranks 38th in the QS World University Rankings in 2015 (Chapman, 2015). The president of Kyoto University, Prof. Dr. Juichi Yamagiwa (2014) eagerly encourages international network linkages and puts utmost effort to cultivate global human capital among his students. Three core missions-education, research, and social contribution manages to lead its laboratory to win several Nobel Prize Laureates from 1949-2014 whereas QS Graduate Employability Rankings 2016 has announced that Kyoto University was listed on the top 60 in the world (Bridgestock, 2015).

In the history of nearly 100 years since 1903, Kyushu University was established as one of the 7 imperial universities in contributing to research and education in Japan. Competing along with Kyoto University, Kyushu University is also one of the top-ranked 128th in QS world university rankings and top 150 in the graduate employability ranking (QS Top Universities, n.d.). In addition, Kyushu University has been actively engaged in the ASEAN University Network (AUN)-Southeast Asia Engineering Education Development Network (SEED)-Net in promoting human resource development in the engineering field (Tullao & Cabuay, 2015).

Besides that, Tsukuba University has a good reputation among 151-160 in the global graduate employability (QS Top Universities, n.d.). Interestingly, the university practices "transborder" initiatives through the Trans-Pacific Human Capital Development Program to promote global research collaboration. Based on the Transborder Medical Research Center in Tsukuba University, there are five strategic pillars of the development: research subject, research focus, research method, research organization, and translational research (Tsukuba University, n.d.).

JAIST was founded in 1990 and practiced Japanese modern style of education which aimed at training research students with interdisciplinary knowledge for society. As a modern educational institution, JAIST set up ASANO Vision 2020. The vision aimed to establish itself as a research university to develop global human resources in meeting the industrial needs and is research-oriented towards the internationalization and multidisciplinary approaches.

3.5 Analyzing Data

All findings were first transcribed verbatim from the audio-record to organize data for analysis. In a qualitative study, data are mostly narrative and would involve coding and thematic process for interpretation and analysis (Bui, 2009). During the coding, the data were organized into chunks and interpreted according to the theoretical framework by using an inductive process. Generally, the inductive method is defined as generalizing data into larger theoretical perspective from a specific form. On the contrary, a deductive method is used to clarify data from general form into a specific conclusion. Qualitative study is commonly associated with the inductive approach; prevailing studies have shown that qualitative inquiry may also intend to test a theory or a wide phenomenon (Bryman, 2012). However, there is an argument where qualitative study can start with both inductive and deductive processes (Daymon & Holloway, 2010). Correspondingly, Merriam (1998) also insisted that qualitative study may also start with a theory:

> *…many believe mistakenly that theory has no place in a qualitative study. Actually, it would be difficult to imagine a study without a theoretical or conceptual framework* (Merriam, 1998, p. 45).

Therefore, this study starts with a deductive analysis. This occurs when a study wishes to use qualitative research to test an existing theory (occasionally happen) or investigate the transferability of theoretical ideas to a different social context (Daymon & Holloway, 2010). In this study, the analysis incorporated some of the research capacity building framework done by Coen et al. (2010) and Langille et al. (2009) into a category scheme to look at the application of the theoretical framework to the laboratory setting. Then, the inductive process interprets the categories into broader codes. Throughout the analysis, the data were studied between research laboratories in both Japanese and Malaysian universities as applied in response to the research questions. Using this method, this study began to relate and triangulate the document content analysis, interviews data, informal discussion, and observation at the universities' research laboratories. The pattern of data enables us to link concepts and themes in the literature. This will help to generate a theory-based generalization for this study on the best practices of research laboratory in universities.

3.6 Challenges of Research

There were several challenges faced when conducting the research. The main constraint occurred in this research was the availability of data. Since the focus of this research is not only in Malaysia but also in Japan, some participants not easily agreed to participate. There were also no replies from the Japanese professors for the invitation to cooperate as research participants. In addition, language barrier also became one of the factors that hindered the progress of research. Some of the documents in Japan could only be studied with the assistance of Japanese language experts.

A short visit during the short-term exchange program at Japan was also a challenge. One week program at the research laboratory in Kyoto University with the assistance of laboratory members enabled more data to be accumulated. In addition, the limited number of Japanese respondents had also required this study to conduct interviews with Mr. Aludin Mohd Serah who wrote many books and articles on Japanese research laboratory and Japanese professors who are on sabbatical leave as well as attending conference in Malaysia.

The next chapter will discuss in detail the practices of research laboratory in Malaysian universities.

CHAPTER 4: MALAYSIAN UNIVERSITIES RESEARCH LABORATORIES

4.1 Introduction

The context of discussion in this section is focused on a demographic case of Malaysia. The first part provides an introduction to R&D and S&T activity in Malaysian higher education. It includes the history of S&T activity in higher education, which overviews the current R&D performance, contribution of universities laboratory towards national economy, human capital in S&T, Malaysia's strength and weaknesses and Researcher Scientist and Engineer (RSE) graduate's enrollment. In the second part, thematic analyses from studies in four research laboratories based on the theoretical framework built earlier are then divided into several components, including of research models, mentorship and training, communication, learning opportunities program, partnership and networks, knowledge translation and public outreach. These themes are discussed in the context of activities and challenged occurred in developing the human capital and skills among students.

4.2 History of S&T Activity in Higher Education

The development of S&T in Malaysia can be categorized into two periods. The first period is before independence and the other one is after independence. The emergence of S&T could be seen through Malay vessel builders in the East Coast and West Coast during the post-Malacca centuries (Abadi, 2013). The strategic location like Strait of Malacca that connects Europe, Middle East and Pacific Asia became the significant point for vessels' transit and trade to occur. It is also reported that approximately 100 big vessels and 30-40 small vessels from China, Portugal, India and Arab came to Malacca Port every year in 1512-1515 (Hassan & Omar, 2003). The great stride made during that period has developed Malay land to become the focus point or hallmark for economic growth. Then, the first formal period occurred during the British colonial. During this period, Malaysian informal education was established only to educate locals with basic living skills (Grapragasem, Krishnan, & Mansor, 2014). Under the general policy of "*To bring forward the natives of the country as much as possible*", British colonials only started to implement a better system structure to satisfy their political and economic interest after the World War II. According to Zain, Aspah, Abdullah, and Ebrahimi (2017), the principle was mainly created to encourage English education as the main language for business as well as locals to explore the field of science and knowledge. However, there were only a few local students selected from the elite to study at British Schools in limited townships. In October 1925, the new phase of S&T educational development took place at the opening of the technical school in Kuala Lumpur after the earlier technical school was closed down (1914). This was followed by the opening of School of Commerce in 1926 and School of Agriculture in May 1931 in Serdang, Selangor. During the period, there was no other significant effort that could be seen to develop further on technical or engineering schools. At this point, the intention was to protect the British's interest for skilled agricultural workers. Therefore, majority of the locals will return to work as farmers and fishermen after finishing these schools. After a long period until in 1949, University of Malaya (UM) was officially inaugurated in Singapore from the support of the Carr-Saunders Commission to combine the King Edward IV College of Medicine with Raffles College. This revolution saw a higher opportunity for locals to attain higher certificates of degrees in science and arts.

The second stage of S&T development in the Malaysian Higher Educational system occurred after Independence Day in August 1957. This stage can be explained via three periods, which are 1957-1970, 1971-1990, and 1990-present. During the first phase (1957-1970), UM played an important role to provide skilled and knowledgeable human capital in the agricultural sector. The reason was due to the main focus of national economy in the field of rubber, palm oil, fishery, and forestry activities during that period (Azizan, 2011). In addition, an establishment of University College in 1970, later known as University of Science Malaysia (USM), was to expand its science and technical disciplines such as medicine, science, engineering, dentistry, and other technical programs (Sato, 2005). The phase denoted the significant role of the university to train qualified graduates in addressing wider issues and expertise in order to improve Malaysia into becoming an independent nation globally.

In the second phase (1970-1990), the S&T sector began to shift its focus from agriculture to industrial-based. To guide the initiative, the R&D activity in S&T was first dedicated in the 5th Malaysian Plan (1986-1990). The bold strategy of the local government to invest for knowledge-based R&D in the national plan was after realizing the value it brings in driving developing countries to a higher level. The investment was made through several initiatives such as the funding of R&D, developing talent at academic institutions, promoting national policies, intensifying economic activities, and issuing tax incentives in the agricultural and industrial based-sectors. As a result, there were four more universities built between 1969-1972 after the University of Science of Malaysia (USM), including the University of Technology Malaysia (UTM), University of Putra Malaysia (UPM), and National University of Malaysia (UKM) to increase the number of S&T graduates from higher educational institutions. Later, the International University of Islamic Malaysia (IIUM) and Northern University of Malaysia (UUM) were founded in 1983 and 1984 respectively to offer wider and diverse science and technical fields such as administrative science and management. The higher number of graduates from universities could accommodate the demand of human capital for newly established R&D institutions such as Malaysian Agriculture Research and Development Institute (MARDI) in 1971, Standards and Industrial Research Institute of Malaysia (SIRIM) in

1975, and Palm Oil Research Institute of Malaysia (PORIM) in 1979. In 1989, the national philosophy of education was launched to initiate a base for supporting a long-term mission known as Vision 2020. This Vision was the national aim to become a fully developed country by the year 2020 (Zain et al., 2017).

In the third phase (1990-present), 6th and 7th of Malaysian Plan were released to formulate strategies to enhance S&T activities to reach the targets made in Vision 2020. After the Ministry of Higher Education (MOHE) was established on 27 March 2007, several national policy plans were introduced to aim at creating Malaysian higher education as the hub of excellence in the South East Asian region by 2020 and producing graduates who are able to satisfy the national and international employer's requirement as well as achieving 75% employment rate within 6 months of graduation. Since the establishment of research universities in 2007 (i.e. UM, UPM, UKM, and UTM) and apex university (i.e. USM), research activities in higher education were continuously intensified at the country's S&T base. As delineated under the rubric 2020, the appointment of these universities was to create R&D centers of excellence by giving them greater autonomy and to operate with optimum capacity. In addition, following the 10th Malaysian plan (2011-2015), commercialization and innovation was assigned as 'Niche 1', remarking an important indicator for MOHE in promoting higher educational research through innovation and R&D infrastructure. Hence, MOHE released the National Education Blueprint (NEB) in December 2012 to strengthen Vision 2020 and prepare students for the need in the 21st-century. NEB was implemented through the National Higher Education Action Plan (NHEAP) and National Higher Education Strategic Plan (NHESP) in four phases as follows (see **Figure 4.1**):

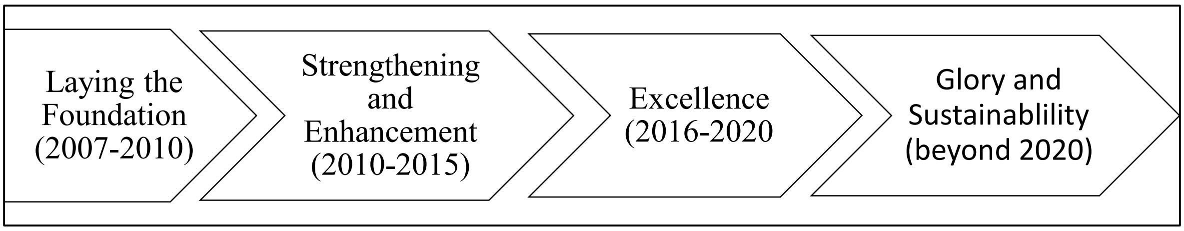


Figure 4.1: Phases of the National Higher Education Strategic Plan
(Source: Balasingam, 2014)

These continuous strategic policies plan have been inspired by the government in order to increase the quality of graduates for innovative research and to compete in the global knowledge-based market in education. As stated in the 11th of Malaysian plan, quality of governance in higher education is extremely important towards strengthening socio-economic human capital for a developed country as inspired in and beyond 2020.

4.3 Overview of the National R&D Performance

According to Azizan (2013), R&D activities in Malaysia have shown gradually positive indicators on the gross domestic product (GDP) expenditure from 0.2% to 0.6% between 1991 to 2010. During the event, the amount kept growing to 1.13% in 2012, 1.30% in 2015, and is targeted to achieve 2.0% in 2020 covering basic research, applied research, and experimental development as shown in **Figure 4.2** (Malaysia, 2015). GDP expenditure in Malaysia stood at 1.26% in 2014 and 1.30% 2015, higher than Thailand (0.6%) in 2015 but relatively lower than the neighbouring country, Singapore (2.1%) in 2014 (UNESCO Institute of Statistic, n.d.). In research areas, information and communication technology (ICT), natural sciences and engineering sciences/engineering & technologies have been given considerable amounts of focus for more than 70% in the R&D expenditure. Investment on those sectors, especially biotechnology and ICT, had greatly resulted in positive return on investment (ROI), publication, and patenting (Academy of Sciences Malaysia, 2015). The focus is also parallel with the 4th Industrial Revolution, which encompasses the area of technology, systems, networks, and interactions (Academy of Sciences Malaysia, 2017).

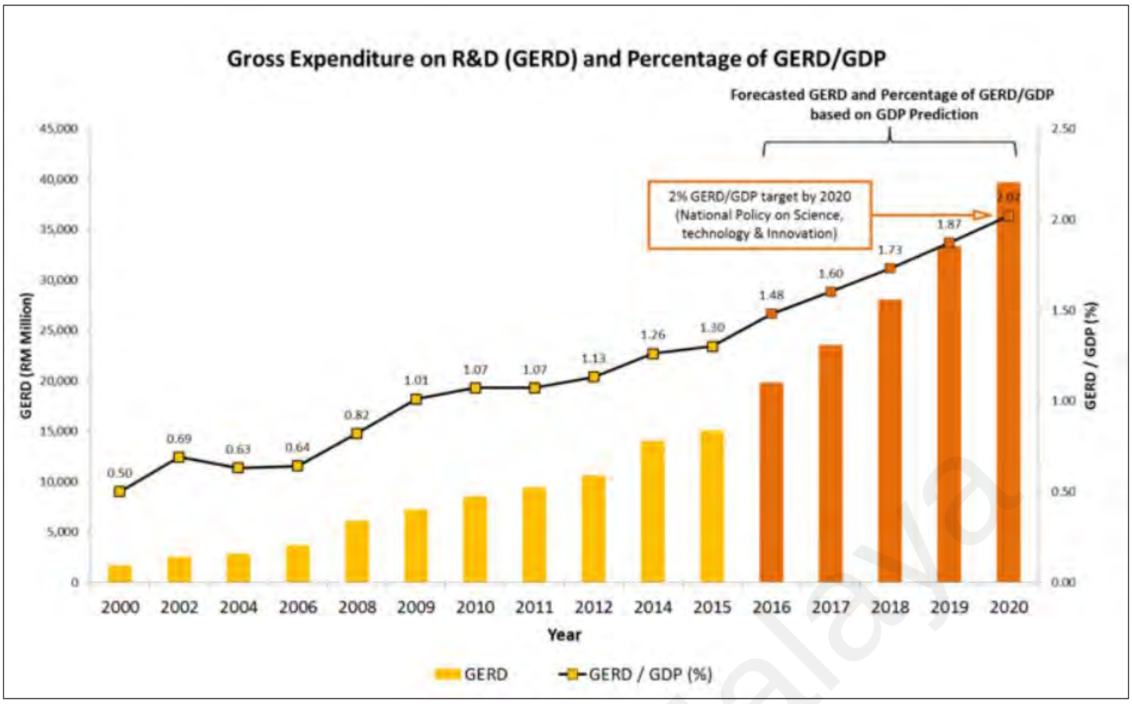


Figure 4.2: GERD (RM) and GERD/GDP (%) in Malaysia from 2000 until 2020
(Source: Academy of Sciences Malaysia, 2017)

Based on the report published in January 2017 by MASTIC (2016), the progress of publications and patents have contributed Malaysia further in the global ranking. In the Global Innovation Index (GII), the positive impact improves ranking in the related areas of knowledge and technology, such as local resident patent applications, Patent Cooperation Treaty (PCT) resident patent applications, scientific & technical articles, and h-index articles cited. As illustrated in **Table 4.1**, Malaysia has improved its position in GII for scientific and technical publication from rank 79 in 2011 to rank 54 in 2015. The h-index documents cited were also gradually moving from rank 52 in 2014 to rank 51 in 2015. Besides that, Malaysia has continuously maintained range ranks from 2011-2015 for domestic resident patents between 45-50 and PCT resident patent applications between 31-42. Despite the increasing trend of publications and patent counts, the growth rates are still low in the present.

From the indicator's report by MASTIC (2017a), the number of R&D personnel and researchers indicated an upward trend from 103,986 in 2012 to 114,539 in 2014, whereas the ratio of researchers to 10,000 workforce was significantly increased from 57.45 in 2006 to 60.66 in 2014. In 2014, the total number of R&D personnel in Malaysia comprised 84,516 Researchers, 17,508 Support Staff, and 12,515 Technicians. To compare a relevant sample at the international level, total R&D personnel per capita – in terms of Full Time Equivalent (FTE) per 1,000 people, Malaysia ranked 40th with 2.45, far behind Singapore (7.78) as among the ASEAN countries in 2014. To highlight, China (2.71) and Malaysia were still the only two East Asian Newly Industrialised Economies (NIEs) that were listed among the top 40 performing nations **(Figure 4.3)**.

Table 4.1: Global Ranking of Malaysia in the Global Innovation Index

	2011	2012	2014	2015
Global Innovation Index				
Local resident patent application	Rank 50	Rank 45	Rank 50	Rank 49
PCT resident patent application	Rank 31	Rank 34	Rank 35	Rank 42
Scientific and technical publication	Rank 79	Rank 67	Rank 53	Rank 54
H-index documents cited	-	-	Rank 52	Rank 51

Source: MASTIC, 2016

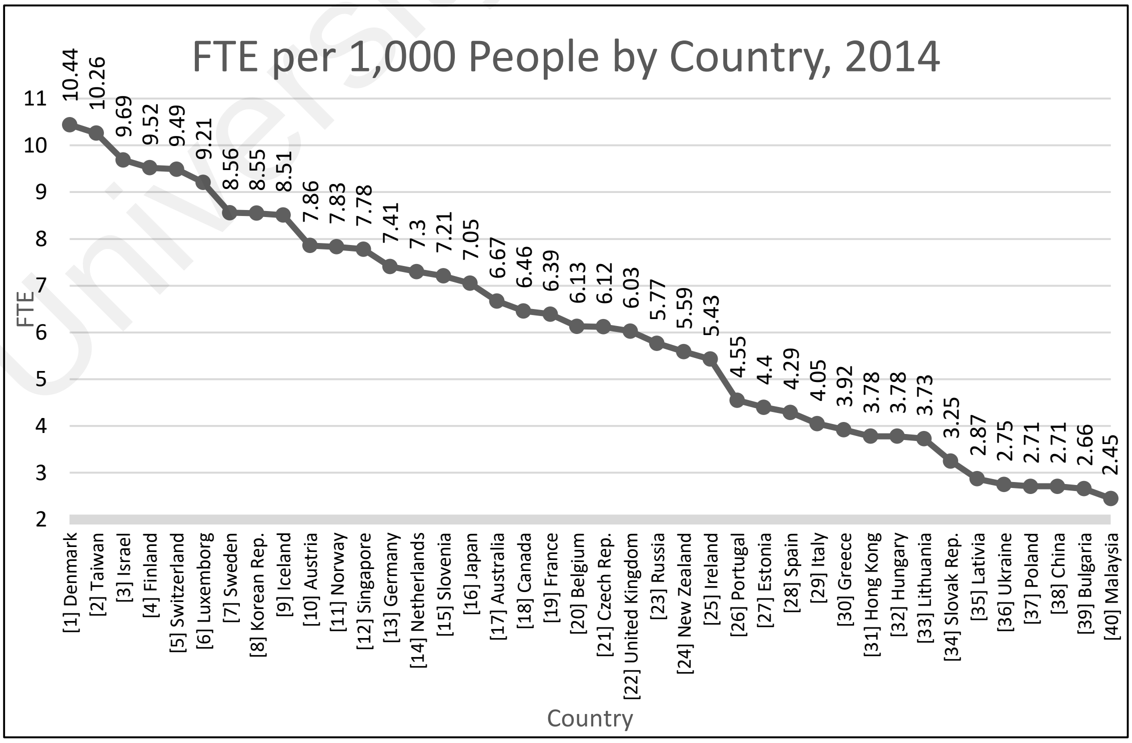


Figure 4.3: FTE per 1,000 People by Country, 2014
(Data Compiled from: MASTIC, 2017a)

4.4 Contribution of Laboratory Activities towards National R&D Performance

The higher education system in Malaysia has faced various changes in meeting the current anticipation of global changes of economic and political environment. The higher national educational system has been restructured according to the national economic interest. Referring to Zain et al. (2017), the role of higher education has been shifted in 2000 from an agricultural-based economy to commit on the development of skilled human capital as well as R&D production in the emergence of a knowledge-based economy. A resultant statistical portrait helps to capture the growth of R&D sector in higher educational institution (MASTIC, 2017b, n.d.).

In terms of gross expenditure on R&D (GERD), business enterprise dominated the research expenditure from 57.9% in 2000 to 64.45% in 2012, but decreased to 45.66% in 2014 before ascending to 51.95% in 2015, whereas the higher educational institutions remained the second contributor to the R&D activities with 17.1% in 2000 and showed distinctive growth and dominated with 46.13% in 2014 before descending to 28.48% in 2015 (e.g. laboratory, equipment, etc.) **(Figure 4.4)**. The trend of government research institutions fluctuated from 25% in 2000 to the lowest 5.2% in 2006 and 19.56% in 2015. Furthermore, in 2015, it was also reported that 103,045 R&D human capital was trained from higher educational institutions rather than only 19,017 in the government research institutions and 14,621 in the business enterprises (MASTIC, 2017b).

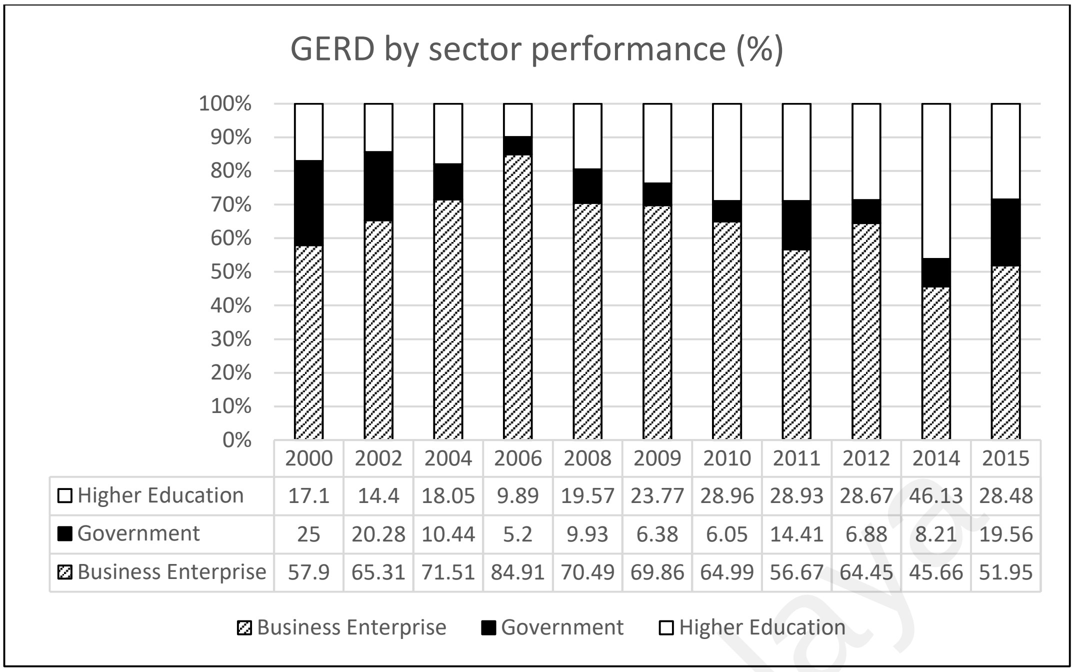


Figure 4.4: GERD (by Sector Performance) in Malaysia from 2000-2015
(Data compiled from: MASTIC, 2017b)

Apart from that, another indicator to delineate the quality of STI graduates in research is the number of publication. As of June 2014, the target numbers of 750 publications in STI was still far with only 28 publications recorded. To recap, this rate is still low compared to Japan and Korea (Azman et al., 2016).

In the context of Malaysian universities, research laboratory is commonly featuring the field of science and engineering, which is a key component to the economic trends today (Amran et al., 2014; Shibayama et al., 2015). As an institutional hub for R&D in STI, the higher education nowadays have invested worthy amount of money on the laboratory activities to train and educate students with S&T knowledge, lifelong learning skills, and R&D expertise before going into the realm of profession.

4.5 Challenges of Developing S&T Human Capital in Malaysia

As Malaysia progresses towards becoming a developed country and approaches industry 4.0, the necessity of skilled human capital is inevitably valuable. Tremendous efforts have been formulated within higher education to ensure that skilled graduates are able to meet the current national and global needs. Nevertheless, the quality and shortage of skilled S&T human capital still persists. The issues identified are discussed as below:

4.5.1 Human Capital in S&T

S&T human capital is the people who have completed at the tertiary level of education in S&T field and/or not formally qualified but working in the S&T field (Auriol & Sexton, 2002). The highly skilled human capital in S&T covers very broad population of highly skilled scientists and engineers, IT workers and researchers in the field of S&T. In that circumstance, development of the R&D sector can also be viewed in a number of researchers per 10,000 workforces, as it was reported 20.3 in 2008, 53.08 in 2010, 57.45 in 2012, 60.7 in 2014 and it is targeted to achieve at least 70 of RSEs by 2020 as shown in **Table 4.2** (Malaysia, 2010, 2015; MASTIC (n.d.)). Based on the data reported in UNESCO Institute of Statistic (n.d.), Malaysia has recorded 2,563.56505 in 2012, 2,779.15613 in 2014, and 2,908.73193 in 2015 for the number of researchers per million headcount. The growing number of intellectual researchers and GDP expenditure pointed out the focus of the government towards sustainable development of the nation through this sector. However, the number is still low when compared side-by-side with the neighbouring country such as Singapore (7,396.5975 researchers per 10,000 headcounts), western country like the United States (7,604.0875 researchers per 10,000 headcounts), and Asian countries like Japan (7,308.4442 researchers per million headcounts) in 2014. In spite of that, Malaysia is still exceeding other developing countries such as Thailand (1,592.5253 researchers per million headcounts) and Uzbekistan (1,059.7626 researchers per million headcounts) in 2015.

Table 4.2: Talent Juxtaposition of Targeted Cohort Size

Cohort	2012	2020 (Projection)
Total Workforce (WF)	13 million	15 million
Skilled Workforce	29% (3.48 million)	40% (6 million)
STEM Workforce	1% (120,000)	6.7% (1 million)
Highly Skilled STEM Workforce	0.7% (85,000)	3% (500,000)
RSEs	58:10,000 WF (69,000 RSEs)	70: 10000 WF (105,000 RSEs)

Source: Academy of Sciences Malaysia, 2015

4.5.2 RSE Graduates' Enrollment

To support the expansion of R&D production, the Malaysian government has listed out two important aspects to be considered in sustaining the development of the R&D sector (Grapragasem et al., 2014). The first aspect is building up a critical number of RSEs and secondly, by enculturating the right research culture reflecting themselves in the R&D field. The strategies are vital in order to achieve about 493,830 skilled workforces in RSEs as inspired by the government by 2020. However, it is currently going through serious depletions in the number of science, technology, and innovation (STI) talent with only 21% of Malaysian students currently enrolled in science courses as illustrated in **Table 4.3** (Academy of Sciences Malaysia, 2015). The low mass number of STI talent is far from the government's target ratio of 60:40 (Samsudin et al., 2012; Academy of Sciences Malaysia, 2015; Azman et al., 2016). In addition, many would also prefer to not pursue in the STEM-related careers due to the unclear job prospects and dynamic career paths provided in S&T. As a result, low number of STEM graduates recorded a shortage of S&T human capital between 20% - 30% approximately across all level of scientific, engineering, and technical areas (Azman et al., 2016).

Table 4.3: Trend of Mass Ratio Science : Non-Science Students

	Science	:	Non-science
Target	**60**	**:**	**40**
1986	31	:	69
1993	20	:	80
2001	29	:	71
2004	36	:	64
2011	44	:	56
2014	21	:	79

Source: Academy of Sciences Malaysia, 2015

Besides that, existing graduates are not able to meet the requirements set by their employers due to poor communication skills and language proficiency especially English as the medium of communication in the 21st century, critical thinking, and professional etiquette (Grapragasem et al., 2014). As a result, this worrying issue will subsequently affect the objective to achieve an adequate number of human capitals needed in the S&T field. In relation to that, the Ministry began developing the Malaysian Education Blueprint (MEB) 2015-2025 to fulfil adequate number of scientists and engineers in 10 years. One of the government aspirations through this MEB is quality. Hence, the quality of laboratory management practices is indisputably important for the formation of quality graduates.

> *"The Ministry's aspiration covers three aspects: quality of graduates, quality of institutions, and quality of the overall system. On quality of graduates, the Ministry aspires to increase the current 75% graduate employability rate to more than 80% in 2025. On quality of institutions, only one of Malaysia's universities is currently in the Top 200 QS global rankings. By 2025, the Ministry aims to place one university in Asia's Top 25, two in the Global Top 100, and four in the Global Top 200. Finally, on quality of the overall system, the Ministry aspires to raise its U21 ranking for research output from 36th out of 50 countries to the top 25, and to increase the number of international students in HLIs from 108,000 today to 250,000 students in HLIs and schools by 2025."* (Ministry of Education Malaysia, 2015, p. 5)

4.5.3 Postgraduate Education

In 2016, there were about 4,003 PhD and 23,528 Master's graduates from both public and private universities. The number is relatively higher as compared to 3,709 PhD and 19,229 Master's graduates in 2015 (MOHE, 2015, 2016). This increment was attributed to various policies promulgated to develop human capital in universities in the competitive knowledge-based economy era today. Under the National Higher Education Strategic Plan (NHESP), the government has introduced several schemes and strategies such as MyBrain15, graduate assistant scheme, postdoctoral training, and recruitment of international students to attract more talent in the national higher educational (Grapragasem et al., 2014; Azman et al., 2016). According to Shariff, Rodzi, Rahman, Zahari, and Deni (2016), this endeavour has also welcomed the government's commitment to produce graduates with higher degrees and hopes to achieve approximately 48,000 PhD holders by 2020 and 60,000 PhDs by 2023. In addition, the total amount of MyBrain15 was allocated to 80:20 for science to social science in order to attract more graduate students to pursue their studies in the science field. Shariff et al. (2016) reported that the number of PhD students in S&T is 1,042, which was higher when compared to 674 in business and management and 208 in social science. However, in 2014, there were only 6.8% PhD candidates that were predicted to graduate on time (GOT) as matched to the number of graduated students. Hence, the quality of educational system needs to be considered despite various policies implemented to recruit postgraduate students, especially in the field of S&T.

4.5.4 Job Opportunity in S&T Field

Theoretically, a person in a certain stream of education would choose to build his/her career in the related field. For a person with an engineering background, he/she would aim to be an engineer and a person in a physics stream would aim to be a physicist. However, the reality is that many would shy away from the science-career (Ibrahim, 2017). According to Ibrahim (2017), many in the science profession claimed that the working environment is not conducive enough to support R&D in science. Availability of equipment and facilities are rather inferior than other developed countries like Singapore. In terms of maintaining equipment, GDP expenditure on R&D was less than 1%, in contrast to other developed countries that spent 2% - 3% of the GDP. Moreover, ineffective process in R&D is also one of the factors that hinder the development of science career.

In a study carried out by the Malaysian Foresight Institute in 20 top Malaysian companies from the following sectors of oil & gas, telecommunications, constructions, pharmaceuticals, and engineering, the result revealed that 61% of high-ranked positions were from a non-technical background such as business and administration. It was only recorded that 34% were from S&T stream and 5% from other qualifications (Emran & Rahman, 2013). Therefore, it seems that promising future job prospects in social science would be brighter than in the science stream. In fact, there are many ways for science careers to be very attractive. Not only by offering remunerative packages, but also through conducive supporting system and a good laboratory infrastructure that also play pivotal roles to attract the best brain to drive Malaysia in a knowledge-based economy and global innovation.

4.6 Laboratory Activities in University

As discussed in the literature review section, good management of R&D practices in laboratories are important in projecting towards quality graduates. To highlight, research activity is not only restricted inside laboratory boundaries. The right research practices and activities using inside and outside parties must be undertaken particularly to build research experience within graduates. This section is organized based on the research capacity building practiced in laboratory, namely: research models, training and mentorship, communication, learning opportunity program, partnership and networks, knowledge translation and public outreach. The topic discusses how practices were organized, students' involvement and challenges of various strategies.

4.6.1 Conceptual Models

Four issues in modelling research that include formulating research, curriculum design, safety, and benchmarking were categorized under the label of models and conceptual lenses.

All research formulation in the universities is initially driven by the national imperatives, such as the governments' need, novelty, university ranking, build roadmap, and socio-contextual focus. For example, participants A and B recognize that the system needs to be kept abreast with the current interest in the global trends such as (IoT) Internet of things, nanosensor, green technology, and water quality. Notably, certain research operation is not only utilized to fulfil the research proposal applied for grants, but it is also responsible for the community needs. Since global ranking has become an important indicator for universities, all participants paid much attention to benchmarking with other universities, successful colleagues, and previous professors to enhance their strength in research. Their attention focused mainly on competitive QS universities' world ranking underlying these four factors, namely patents, staff ratio, international students, and publication of research papers. In terms of the community needs, participant C further elaborated on research design from the socio-contextual focus. The participant adapts his research in laboratory to the trending issues in Malaysia, but the factor of their economic strength is the first condition to decide “where they belong to” and “where to find money through industrial partnership”. In addition, participant D emphasized on novelty that is to explore new research areas. This is the fundamental principal research skills trained among students. Nevertheless, all these efforts could not be done if there was a limited budget; hence, there must be a research formulation to set up a roadmap in order to balance broad areas of research with research members, money, equipment, and make useful research for publication and non-publication.

Relatively, the actual competency of graduates will depend largely upon the curriculum design. After deciding on the research formulation, the research group ought to create conducive physical and intellectual infrastructure in the laboratory. All participants agreed that good laboratory leader or principal investigator (PI), good technical support, and platform to cultivate interest in research are crucial in this intellectual infrastructure. The leader must possess integrity, well-diversified experience, team-supportiveness, and become a good role model who respects his/her younger researchers. Moreover, the quality of academic community, researchers, practitioners, educators, and academic support staff or technical support is also vital in creating a conducive and meritocratic environment for the talent’s excellence. However, most of the participants stressed that their research systems are still lacking in terms of supportive system that facilitates the research processes.

> *We are not really innovative or very supportive of the fundamental policies to employ and concentrate on the technical service; on how we train and maintain them to foster the right environment. For example, the expensive equipment in our laboratory, we have technical staff that is very good, but after investing on their training and after they got promoted, suddenly, they are transferred to another laboratory.*
>
> (Participant A, Interviewed on July 13th 2017)

For all equipment here, we have to depend on the lecturers, seniors, officers, or postdoctoral researchers. We don't have technician experts to handle it, even though it is very important to have them.

(Participant B, Interviewed on April 4th 2017)

Sometimes, things are not really going as what we expected. For example, when we order chemicals, it takes like 2-3 months to get the order. I am afraid this practice will somehow undermine and hinder the progress of our research.

(Participant C, Interviewed on July 14th 2017)

The necessary intellectual infrastructure is also important in cultivating a vibrant research culture in laboratory.

It is a foundation for final year undergraduate students to move forward to the postgraduate research. This would be the best platform to implement… What they learnt in the past… And also for their critical thinking and problem solving. I think this is very essential... The best platform for them to cultivate the research culture. As they start to found their interest in research…

(Participant D, Interviewed on March 20th 2017)

In the research unit of participant D, students are also trained to work independently with problem-solving skills and right safety knowledge such as OSHA (Occupational Safety & Health Administration-Exposure to Hazardous Chemicals). The established supportive intellectual infrastructure will ensure that students use the right Problem-based Engineering (PBE) model when dealing with hazardous materials and heat.

4.6.2 Mentorship and Training

Training and mentorship include the items of equipment training, research management skills, teamwork culture, and industrial training. For participant A, high-technology equipment would require only a specialized and expert technician to operate and troubleshoot the equipment. In Malaysia, there is only small number of research laboratories using certified experts to take responsibility on any particular equipment. However, due to limited budget, they invest on their excellent students and staff to go for industrial training and laboratory abroad to learn the latest technology and gain new knowledge and experience.

> *...even to get professional certificates to use machine is very expensive. Sometimes you have to go to overseas which costs a lot of money... When a new machine is coming out, then we send one or two best student(s) to learn about the machine.*
>
> (Participant A, Interviewed on July 13th 2017)

The partnership and collaborative training enable them to utilize equipment and machine in producing maximum data or output. Through talent management, the selected students and staff will then train the juniors to be kept updated with the latest technology. The mentoring process between Principal Investigator (PI)-students and senior-junior is not only limited in the equipment training but it also trains their research management skills and achieve a certain milestone while the research is progressing. Training must be carried out continuously due to rapid development in science and technology even though it might be hard to catch-up on every new machine coming out with more advanced technology.

While for participant B, the focus on getting research students to interact and engage in small team supervision is overwhelmingly popular. The rationale to practice this committee supervision is for continuous monitoring purposes and evaluation processes. Participant B describes the team supervision as follows:

> *...PhD students will have three supervisors. It is called "committee supervision".... One is chairman and another two are committee members... For PhD is three and for Master's is at least two... This is the university's regulation... The reason behind this is that if anything happens to any of the supervisors, the other supervisors will continuously monitor the progress of the students.*
>
> (Participant B, Interviewed on April 4th 2017)

In the same way, multiple layers of laboratory members are encouraged to work together, in which final undergraduate students are guided by PhD and Master's students.

Hence, multiple layers of mentoring start from team supervision, PhD, Master's, and undergraduates. The mentoring activities are monitored by postdoctoral researchers who replace the role of the main supervisor at that certain time. In terms of research grant management, students are expected to be independent to do the research order and write a draft for grant application proposals guided by a postdoctoral researcher.

> *In terms of research grant management, normally, we did it together… It was easier when I have my postdocs… I also gave tasks for students to buy what they need for research … and proceed by doing purchase order if all is fine. For research proposal, normally, I write one with my postdocs for external grants and certain internal grants. While for postgraduate grants, I asked the students to write it because it is based on their own research.*
>
> (Participant B, Interviewed on April 4th 2017)

> *…in research particularly, equipping students with skills like research management and the most important thing is on how to write papers and reports.* (Participant C, Interviewed on July 14th 2017)

Research mentoring aims to focus on the talent management or commonly called as succession planning, where senior researchers guide junior researchers to take over and keep their chain of research over a period in the future. Nevertheless, according to participant C, sometimes in the process of managing talent, students might misinterpret the role of mentors in assisting them. Mentors are assumed as assistants in doing their work instead of giving direction and guidance. Hence, there is still a challenge in the development of mentor-apprenticeship concept that needs to be taken in order to give better training exposure for both mentor and mentee.

For participant D, research collaboration occurs more frequently between the undergraduate laboratory partners due to small facilities to be better equipped in the laboratory. To compare with an elite university, they solely depend on the local network between PI and a layer of research team. When compared with participant A that viewed industrial training as an access to alternative funding and research opportunities, the university represented by participant D regulated for each student to participate in industrial training twice, which is in the 1st and 3rd years of their studies before going for their final year research project. This strategy develops the students' sense of laboratory work and skills.

> *...so that students know what skills and research are needed in the industry before they do research projects in the laboratory.... They will know how to appreciate how the laboratory works, how to limit them, and they will start to appreciate what they learnt in the previous lecture...* (Participant D, Interviewed on March 20th 2017)

4.6.3 Communication

This theme comprises three items: the proximity of principal investigator (PI), social skills, and mixed role. According to participant A, physical infrastructure of laboratory is built to facilitate the communication between research members. Through glass wall, PI works closely with students and can monitor their progress more often. The professional relationship exists between PI-students has formed social skills through social activities such as dinner, lunch, sport, and celebration parties for any glorious achievement. In light of the event, the laboratory members are given acknowledgement and motivation for their productive effort for publishing in high impact journals. Meanwhile, participant B believes that the committee supervision practiced in their laboratory creates space where students can learn explicitly in a positive collaborative research culture.

> *Our regular meetings with all members are at least once a month or once every two weeks... But in formal meetings with committee supervision, students will present their progress for at least once per semester to get feedback from all supervisors.*
> (Participant B, Interviewed on April 4th 2017)

The members in the research groups comprise various generation researchers from professor, associate professor, postdoctoral researcher, staff, to students. These various types of researchers imply that there are very young and naive individuals, seniors who are already experienced for 5 years, 10 years, and more than 15 years in a research group. As there are multiple layers of researchers and students with different research specializations and ages, participants A, B, and C have developed a teamwork spirit to complement each other. An example of a task allocation within a research group is as follows:

> *Research assistant manages research procurement and reporting… Postdocs involve more towards planning officer, mentoring, and writing papers… Research Officers are in-charge of management. For example, purchasing large equipment... Managing seminars…Writing report, entering data, and lot of research management tasks.*
>
> (Participant B, Interviewed on April 4th 2017)

Furthermore, social activities organized by laboratory members according to all participants are important for efficient communication, negotiation, and networking among them. Moreover, for participants C and D, the relationship between PI-students is considered like friends rather than supervisors-students. As a result, this positive relationship will also expand the supervisor's networks with students for future collaborative works. Meanwhile, according to participant D, they do not practice any regular meetings and would rather organize online discussions than face-to-face meeting unlike the other participants. For them, it has to be customized over time and situation.

4.6.4 Learning Opportunities Program

Learning opportunities program was highlighted by participants B and C. There are three aspects discussed in this practice; organize research workshop and seminar, visit industry/agency, and join learner institution. Participant B encourages his students to participate as part of the main committee in the research center. This opportunity could enable the students to learn how to organize events, workshops, conferences, and face-to-face exposure with other researchers. The intellectual climate exists to position students in a sense of belonging to the research group which they are part of and the research community. The research culture would allow formal and informal exchange to occur in the learning program.

Similarly, proper planning by participant C helps students to know how research is applied in the real research industry. Activities like a seminar, agency, and an industrial visit to a well-known and successful company in Malaysia such as the Center of Excellence in Composites and Aerospace (CTRM) could expose the students with the whole process of research, rather than a focused research in the laboratory. Another strategy to augment the students' knowledge in the real working condition is as follows:

> *...not only visiting factory but the government agencies as well. The job scope of the agencies is not only to do research, but also to formulate policies. So, the policies play a very important role in affecting research in terms of "how much money is going to be spent" and "where it is going to be spent" and "what is the method used to spend". This is an important aspect, not only in the industry's real situation, but it is also important to know how the research is funded.*
>
> (Participant C, Interviewed on July 14th 2017)

Besides that, participant C also proposed and sponsored students in the laboratory to join a learner institution for professional development. The learning program could be intended to promote academic or technical skills. In the engineering field, it is important to undergo professional training in order to be more specialized in the field and get certified. In university, there are also seminars and classes that help to widen their research skills.

> *I give them contacts and tell them this is the way you should go for professional enhancement… Giving them form as stirring them along… Equipping them with skills like research management and... How to write papers and reports. The university actually provides structured training but the kind of training is connected to things like writing papers, producing thesis…*
>
> (Participant C, Interviewed on July 14th 2017)

...this will be the session for the lecturers to provide them with knowledge on how to conduct the research.

(Participant D, Interviewed on March 20th 2017)

4.6.5 Networks and Partnership

This theme includes industrial collaborations, conferences, attachment at the laboratories, and career paths. As a prestigious laboratory in Malaysia, the research unit that represents participant A has very a good collaboration and networks all over the world. The research unit also used to collaborate with multinational companies and outside researchers based on the following example:

Some through industry... If we have international grant, then we collaborate with foreign researcher like from the United Kingdom. We can go to their laboratory since the material environment there is better equipped than us. So, we send students there to get some ideas for about 2-3 months... (Participant A, Interviewed on July 13th 2017)

The collaborative link with the industry constitutes several other advantages. The participant's response as follows:

Sometimes, we get visits from (TM) Telekom Malaysia to come to the laboratory for small talks, like the CEO who gave a talk last time. The talk was intended to look for talents, recruit potential job seekers, and employees. (Participant A, Interviewed on July 13th 2017)

The industrial link is able to provide a good career path and know the job spectrum better to fulfil the criteria matched in the industrial advancement. The industrial partnership provides them with required market knowledge and additional source of funding for mass production.

Another example of industrial collaboration could be observed by participant C. As mentioned earlier, a visit to the Center of Excellence in Composites and Aerospace (CTRM) was done from networking and partnership between university and industry. The collaboration will then help them to get funded and partner to carry out high impact research.

> *I have a lot of works on composite and many students work in that field. So, for the composite research, we always visit Composites Technology Research Malaysia (CTRM), Melaka.*
> (Participant C, Interviewed on July 14th 2017)

Furthermore, as one of the requirements for postgraduate candidature, students are required to attend at least one conference. The conference acts as a good medium for students or junior researchers to build networks, meet expertise, exchange ideas, cards, and form collaboration. Research conferences are also another way to inspire better publication opportunities through local collaboration. In addition, from this relationship, participant D managed to send his students for an attachment in Europe every year even though it is still a one-way benefit instead of a mutual exchange. The approach was intentionally done to develop potential students with academic excellence, leadership, and peer skills.

> *…last year, science students went for a conference in Kuching. After their presentation, they managed to publish in a Q2 journal.*
> (Participant D, Interviewed on March 20th 2017)

4.6.6 Knowledge Translation and Public Outreach

This theme includes four items that are knowledge sharing, consultation, commercialization, and competition. The sub-theme emerged can be divided into publication and non-publication, where publications are usually accessed by academicians while non-publications are accessed by non-academicians or communities. All of the participants agreed that successful research laboratories should not only generate research ideas, but also transform into products, services, and applications. To shed light on this practice, the research unit that represents participant A dominates the dissemination knowledge to the academics and public. Bringing up the point of their consultation work with (TM) Telekom Malaysia, it was drawn from successful networks based on trust and mutual benefits. Hence, this center aims to give students a broad outlook and awareness of the real industrial operation and demand. According to participant A, it is quite successful for community engagement. Since two years ago, they have been actively engaged in sharing their knowledge with Imtiaz Islamic Secondary Schools under *Yayasan Terengganu*. At this rate, the laboratory members organized a workshop at the school to share ideas and innovative technology as well as competitions. At the moment, they managed to create a science club at the school to carry out series of activities. Until recently, in August 2017, the research laboratory was approached by another school in Kuala Lumpur for this purpose.

> *...give workshop to the lower and higher secondary students to build a group of photonics. We give some workshops to explain what photonics is. We brainstorm because they have to compete with other groups in the photonics innovation challenge after their exams. Like me, they present to me and I give them some ideas to improve their products through this workshop; how to do the documentation and presentation. This year too, we will do another workshop in Terengganu.* (Participant A, Interviewed on July 13th 2017)

Patenting is hard to be carried out due to limited funding and it normally takes within 3-4 years to give off one patent. Currently, commercializing products at even prestigious research universities such as universities of participants A, B, and C are not encouraging in Malaysia. They agreed that commercialization in Malaysia is still weak when compared with developed countries like Japan and the United States. Formulated policy is a critical factor to initiate the commercialization process since it is one of the sources of economic development.

> *The universities are not ready for commercialization, they don't have the paradigm and infrastructure to commercialize their product.*
> (Participant A, Interviewed on July 13th 2017)

In addition, in terms of focusing on getting research students to interact in a public outreach, participant D provided an opportunity for the students to take part in an innovative competition. The opportunity could build their confidence, see the world, and appreciate them as part of a research community in Malaysia. The international competition will measure their level of performance, knowledge, and they begin to form networks from there. However, this is minor compared to other developed higher research institutions. The data are not processed to commercialize or develop into a product, as stated by participant D

> *...Based on my general observation in Malaysia, we only process our data and output into results and publication and unfortunately, most of our lines stop there.*
>
> (Participant D, Interviewed on March 20th 2017)

The next chapter will discuss in detail the practices of research laboratory in Japanese universities.

CHAPTER 5: JAPANESE UNIVERSITIES RESEARCH LABORATORIES

5.1 Introduction

Similar to chapter 4, this chapter discusses the contextual section of case studies in Japan. This chapter is divided into two sections. The first section provides the history of S&T activity in Japanese higher education, contribution of its laboratory activities towards the national economy, human capital in S&T, STEM graduate enrollment and Japan's strength and weaknesses. Then, the second section analyzes findings from fieldworks in four research laboratories and are divided based on the theoretical framework built earlier, namely, conceptual lens, mentorship and training, communication, learning opportunities program, partnership and networks, knowledge translation and public outreach. The themes are discussed in the context of the activities organized and challenges occurred for the growth of human capital and skills among students.

5.2 History of S&T Activity in Higher Education

Referring to Bartholomew (1989), the evolution of education and S&T in Japan started in the feudal era, 400 years ago. Tokugawa period, also known as Edo period (1603-1868) was the first era where scientific development started to exhibit a positive scene. However, the development was seemed as an unflourishing scene for science to go further. This was due to an isolation policy practiced in Japan and scientists would hardly share their work unless they were asked to do so by the authority. Indeed, the definition of 'scientist' during the period was very limited. The term only referred to a person who had interest in the nature and influenced by good reputation for the interest. The opportunity to become a scientist was dominated by the *shogun* (chief commanders) in the government and solely to retain their position in the Tokugawa's community. For low-ranked civil society, mastering science was only an alternative way to gain position as a translator. In this era, the field of science was developed in the sector of medicine and was highly affected by the Chinese medical technique. Astronomy was also another area of focus in science to design better calendars since it was crucially important to identify an accurate time for harvesting season in Japan.

The long independent and isolation period started replacing the modern educational system during the Meiji restoration (1868-1912). The positive vibe could be seen in the field of science as Japan joined an international linkage with the United States of America (USA), Britain, Russia, and Netherlands (Sobian, 2012). Modernization grows by importing technology and hiring expatriates to teach S&T skills to the Japanese by paying them exceptionally high salaries. Even in the early stages of higher education, foreign professors taught most of the courses in universities. In addition, more universities and vocational schools were built to supply skilled workers in the industry. The skilled Japanese workers would then fill in the existing position in several government research institutions such as Hydrographic Department (1874), Tokyo Institute of Hygienic Sciences (1875), and Electric Laboratory (1891). In the late 19th century, S&T education was formally introduced to the Japanese educational system to attract more students in pursuing this field as to focus on modernizing Japan further. Hence, Tokyo University became the first university to introduce the faculty of science with a modern style of the formal S&T education. Later, more imperial universities were founded to offer more subjects of science, engineering, medicine, and agriculture such as Kyoto, Osaka, Tohoku, Kyushu, Nagoya, and Hokkaido University (Bartholomew, 1989).

To promote development of S&T education, several research institutions were also attached to the universities. For example, Research Institute for Iron and Steel attached to

Tohoku Imperial College in 1919 (known as Tohoku University), the Aeronautical Research Institute (1918), and the Earthquake Research Institute (1925) at the Tokyo Imperial College (known as Tokyo University) (Azizan, 2011). At this level, educational and research activities were actively taken place to stimulate S&T culture in universities until the final stage of the World War II (1939-1945); universities were urged to mobilize more students in science and engineering to work in producing foodstuffs and military supplies after they graduated. At the end of the war, after its defeat in 1945, the Japanese school system had been almost completely paralyzed. To overcome the problem, Japan had announced to reform its educational system, enacted under the Fundamental Law of Education in 1947. Following this reform, two educational laws were introduced to promote specific areas of education, namely the "Industrial Education Promotion Law" in 1951 and the "Science Education Promotion Law" in 1953. The initiative listed out national criteria for laboratories, facilities, and equipment to satisfy the industrial and science education. Therefore, all schools as well as public and private universities could apply for national subsidy in order to improve their facilities and infrastructures according to the national criteria (Saito, 2009).

Entering 1970s, Japan underwent another educational reformation after increasing in number and voicing out to improve the quality of higher educational system. Then, the Council for Science and Technology introduced "the policy for developing and improving human capabilities" to provide opportunity for researchers in government research institutions (GRIs) to be educated at university graduate schools (Azizan, 2011). Concerning the focus to attract more outstanding talents into the teaching profession, "Law Concerning Special Measure for Securing Capable Educational Personnel in Compulsory Education Schools for the Maintenance and Enhancement of School Education Standards" was introduced in 1974. As a result, the number of young people venturing into the teaching profession increased drastically after attractive remuneration packages were offered for the position. In 1986, Basic Policy for Science and Technology was launched to encourage university-industry collaboration and basic research in the industry. During that period, the role of the industry in basic research became relatively important and monopolized 95% of the total R&D activities in Japan.

In 1991, the third wave of reformation revised the Standards for the Establishment of Universities. In this reformation, universities were responsible of monitoring and reporting educational and research activities by self-managing and self-evaluating their system. In 1996, the Science and Technology Basic Plan was launched to strengthen the collaboration between industry-university-government, reduce research bureaucratic system, and improve postdoctoral research schemes (Ogawa, 2002; Azizan, 2011). In January 2001, by integrating both Science and Technology Agency and the Ministry of Education, Science, Sports and Culture, new MEXT (Ministry of Education, Culture, Sports, Science and Technology) was formed to empower the development and tackle the problems of S&T in higher education. In 2002, MEXT launched six pillars in the human resource strategy plan. The pillars comprised developing academic ability, cultivating richness in mind, nurturing top-level brains and talents, promoting university reform, providing excitement and fulfilment, and widening horizons in culture, arts, sports, health, and international (McCarty & Hirata, 2010).

5.2.1 The Reformation of Laboratory System

In Japanese universities research laboratories, an academic chair system known as *kouza* plays an important role in organizing research and teaching activities in the laboratory (Ogawa, 2002). This system was modelled from Germany Universities professor chair system in the early 19^{th} to 20^{th} of century. The system is usually headed by a full professor (*kyouju*), following an associate professor (*jun kyouju*), an assistant professor (*koushi*), and assisted by research associates (*joshi*), few postdoctoral students, PhD, Master's, and final year undergraduate students (Teichler, 2013). Members in the research organization are observed based on their seniority in the hierarchical structure with a professor at the top of the structure. The professor has authority towards laboratory activities and financial resources, managing equipment, and creating networks and collaboration with other companies and laboratories. The professor's roles are even extended at securing job positions for their graduated students. Nevertheless, the autonomy in the hierarchical structure exhibited rigid and centralized power by the professorial chair holder. It is believed that the former nature of the chair system attributed to slow response of social needs and the reformation was to evolve for more efficient research organizations (Ogawa, 2002).

Recent criticism on the system has led to the expansion and newly established research center with the mission of research without teaching responsibility. The integration of laboratory structure promotes greater skilled cross-sectional workforce in various disciplines and also reduces centralized power of the professor. For example, in the case of the School of Agricultural Science at Tohoku University in 2000, five former chairs (agronomy, animal science, fishery sciences, agricultural chemistry, and food chemistry) were combined to form two chairs of applied biosciences and applied biological chemistry. The reformation has also affected the nature of research funding as the amount was determined based on the number of graduate students instead of their undergraduate students in the chair. This gives higher opportunities for graduate students to secure research funding due to smaller number per unit price compared to undergraduate students. Furthermore, previous research organizations had greatly influenced the inbreeding rates since vacancies of the *kouza* structure must be filled by the next after the highest person in the hierarchical system. Literally, this means that the associate professor in the same *kouza* system will be the only one who inherits laboratory leadership after the professor has retired. The decision on the employment has promoted high inbreeding rates, in which employee is recruited based on a seniority-basis rather than a merit-basis. The arguments have placed MEXT to increase academic mobility but still maintaining the inbreeding system. Since then, the vacancies can also be filled from other *kouza*. The recruitment is not solely done from the closeness of the applicant's research interest, but also from the individual's merit and the needs of the department.

5.3 Overviews of the National R&D Performance

In observing the R&D input, GERD percentage demonstrated that Japan increased its intensity steadily from 3.209 in 2012 to 3.339 in 2014 but declined to 3.284 in 2015 as shown in **Figure 5.1**. The downtrend that happened in 2015 was due to constraints on its overall national budget as happened globally (Yonezawa & Shimmi, 2015). At this rate, Japan could not expect any drastic increment in its S&T investment anymore.

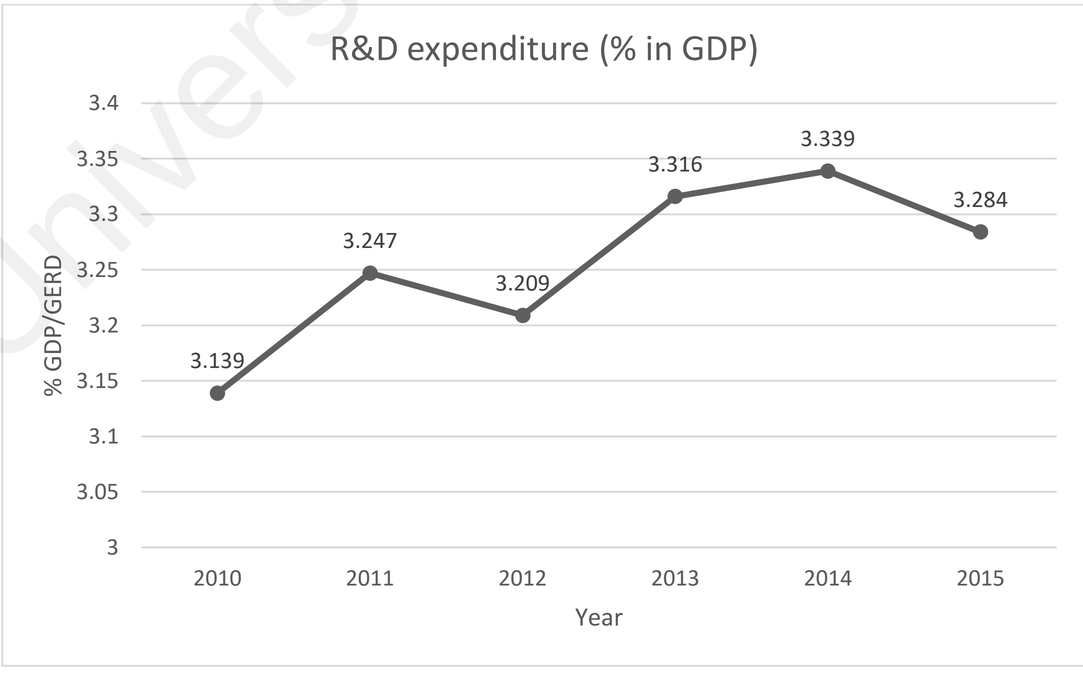


Figure 5.1: GERD (%) in Japan from 2010-2015
(Data compiled from: The World Bank, n.d.)

R&D performance can also be accessed by R&D output of research activities, i.e. patent applied, number of publications, and the number of researchers. **Table 5.1** presents that Japan ranked the highest in terms of patent families, followed by the United States as the largest export market within 2010-2012. The patent filed in multiple developed countries is directly or indirectly related to each by priority rights.

Table 5.1: The Number of Patent Families by Top 10 Countries/Regions

2010-2012 (Average)		
Number of Patent Families		
Country/Region	**Whole Counting**	
	Patent Families	**World Rank**
Japan	64,273	1
United States	48,847	2
Germany	30,097	3
Korea	20,094	4
China	16,144	5
Taiwan	11,932	6
France	11,393	7
United Kingdom	8,647	8
Canada	5,990	9
Italy	5,557	10

Data compiled from: NISTEP, 2017

Another evidence is through the number of paper publications, which is one form of R&D output as tabulated in **Table 5.2** and **Table 5.3**. From 2013-2015, the total number of Japanese papers publication ranked 4th after the United States, China, and Germany in the world rankings. This position was a declination compared to the last 10 years which was 2nd. Citation number that adjusted to only top 1% papers also indicated the same declination. **Table 5.3** shows that Japan ranked 9th after the United States, China, the United Kingdom, Germany, France, Australia, Canada, and Italy.

Table 5.2: Top 10 Countries/Regions in terms of the Number of Papers (Sorted by Publication Year, PY)

All Fields	2013-2015 (PY) (Average)	
	The Number of Papers	
Country/Region	Fractional Counting	
	Papers	World Rank
United States	272,233	1
China	219,608	2
Germany	64,747	3
Japan	64,013	4
United Kingdom	59,097	5
India	49,976	6
France	45,315	7
Korea	44,822	8
Italy	43,804	9
Canada	39,473	10

Data compiled from: NISTEP, 2017

Table 5.3: Top 10 Countries/Regions in terms of the Number of Adjusted Top 1% Papers (Sorted by Publication Year, PY)

All Fields	2013-2015 (PY) (Average)	
	The number of adjusted top 1% papers	
Country/Region	Fractional Counting	
	Papers	World Rank
United States	4,700	1
China	1,954	2
United Kingdom	961	3
Germany Korea	763	4
France	476	5
Taiwan	433	6
Canada	419	7
Italy	384	8
Japan	335	9
Spain	299	10

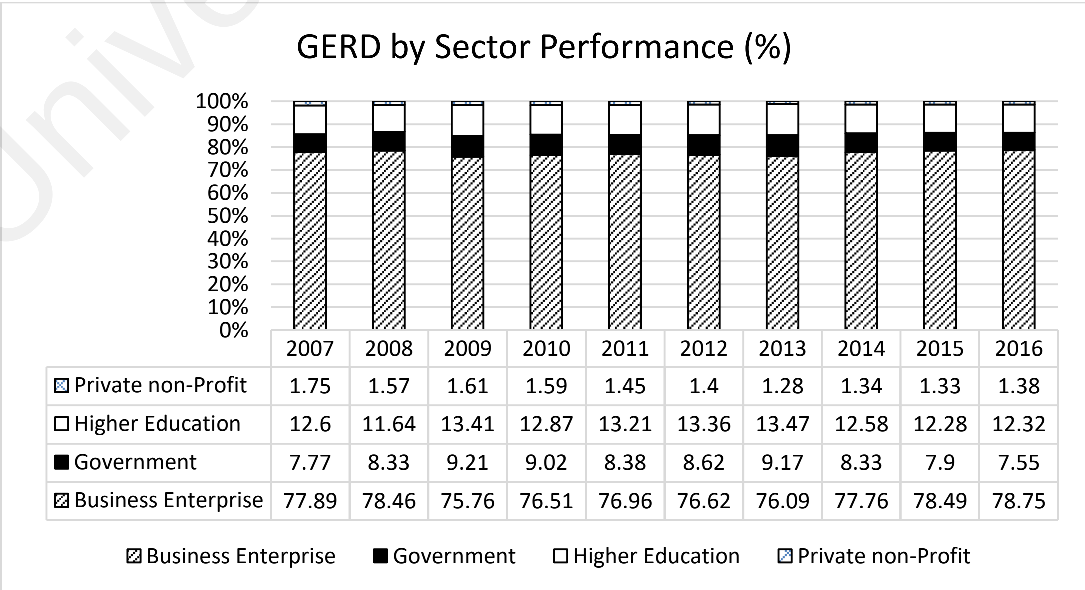
Data compiled from: NISTEP, 2017

In terms of human capital, Japan also has high rates of researchers per 1,000 workforces and is striving to increase its rates even further (Heitor et al., 2014). Given the circumstances, there was a gradual increment indicated from 6,977.0981 in 2012 to 7,027.6509 in 2013 for the number of researchers per million headcount. Similar to

GERD trend, the number of researchers per million headcounts in Japan had also decreased from 7,308.4442 in 2014 to 7,169.3928 in 2015. However, the number of human capital in R&D is still high for a developed country. In 2016, Japan ranked the 3rd with 662,000 researchers (the actual head count is 907,000) in the world after China and the United States (NISTEP, 2017).

5.4 Contribution of Laboratory Activities towards R&D Performance

The involvement of universities in the R&D sector has started since the era of Meiji in 1914. During that period, most research activities were carried out in industrial sectors rather than in higher educational institutions (universities). Hence, the orientation and nature of Japanese R&D lies stronger on the business enterprise as their major source of funds and performance, whilst higher education becomes the 2nd priority in the Japanese R&D system (NISTEP, 2016, 2017). **Figure 5.2** shows that gross expenditure on R&D is dominated by business enterprises compared to higher education. Japan is highly dependent on the industrial R&D for technological and economic growth to catch-up with the United States and other developed countries.



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Private non-Profit	1.75	1.57	1.61	1.59	1.45	1.4	1.28	1.34	1.33	1.38
Higher Education	12.6	11.64	13.41	12.87	13.21	13.36	13.47	12.58	12.28	12.32
Government	7.77	8.33	9.21	9.02	8.38	8.62	9.17	8.33	7.9	7.55
Business Enterprise	77.89	78.46	75.76	76.51	76.96	76.62	76.09	77.76	78.49	78.75

Figure 5.2: GERD (by Sector Performance) in Japan from 2010-2015
(Data compiled from: UNESCO Institute of Statistics, n.d.)

In terms of S&T human capital in 2015, it was recorded that there was 35.49% of total researchers trained in higher educational institutions compared to 59.60% in business enterprise, 3.76% in government, and 1.13% in non-profit private firm (UNESCO Institute of Statistic, n.d.). As of 2015, it was also reported that 28.3% of PhD graduates in S&T preferred to look for employment in the manufacturing industry, 22.2% in non-manufacturing industry (except research and education), 31.9% in education, and 17.6% in the "research" (academics and research institutions) (NISTEP, 2016).

5.5 Japan S&T Strength

The economic growth in Japan after the world war was very eye-catching, particularly from the academicians' point of view. Reflecting upon the history of Japan, it might be startling that Japan had been devastated with an atomic bomb attack once in 1945. However, from the collapsed country, Japan managed to rise up and became one of the most progressive countries nowadays. In fact, it is very common to see many products manufactured and innovated by Japan all over the world as seen in vehicles. As an innovative and creative country, R&D in S&T has been an important indicator in achieving high rates of economic growth in Japan. To highlight, most of the innovation processes and systems in Japan are usually developed based on technology in the United States and other developed western countries. Hence, Japan has always been labelled as an imitator to the precedent. On the other hand, this innovative development has finally brought Japan to own various notorious global brands and companies such as Toshiba, Honda, Toyota, Uniqlo, Canon, Panasonic, Casio, and Nintendo.

5.5.1 Human Capital in S&T

As time flies, prolonged revolution of universities has resulted in their significant role of R&D investments. The role of universities has become more important due to the factor of newly established industrialized East Asian neighbours, such as China, South Korea, and ASEAN countries that made Japan feel the dire need for universities to supply adequate human capital in S&T and support the industrial innovation. Ikeuchi, Motohashi, Tamura, and Tsukada (2017) suggested more interaction between academia and industry to be promoted since scientific knowledge flows to the industry subsequently. This solution provides support to investments on research laboratory activities inside the university instead of benefiting limited resources in the industries. In view of declining population of birth rates and social ageing in Japan, the high quality and capabilities of STI professionals are becoming even more important (Yonezawa & Shimmi, 2015). As presented in **Table 5.4**, the percentage number of R&D personnel in higher education was also among the highest compared to Germany, the United States, France, and Korea.

A lot of effort concerning higher education human capital has been done as delineated in the Science and Technology Basic Plan of Japan. These include enhancing graduate school education as well as the promotion of creative and outstanding young researcher. By the end of the 20^{th}-century, research performance of the highly developed higher education system has been recognized in Asia and become a model for other ASEAN higher institution. (Yonezawa & Shimmi, 2015).

Table 5.4: Percentage of R&D Personnel in Higher Education

Year	Total R&D Personnel in Higher Education (%)			
	Japan	Germany	France	Korea
2010	32.3	37.6	31.8	37.6
2011	33.1	37.4	30.9	35.1
2012	33.9	-	30	32.7
2013	34	39	30	31.8
2014	33	-	29.9	30.8
2015	33.3	-	-	29.8

Data compiled from: UNESCO Institute of Statistics, n.d.

5.5.2 STEM Graduates' Enrollment

As reported by World Economic Forum, Japan ranked fourth with the score of 83.44 in the Human Capital Index 2016. High performances on staff training, low unemployment rates of young ages, high rates of skilled employers, and economic complexity attributed to its ranking (World Economic Forum, 2016). The comparison between the number of natural science as well as human and social science per thousand graduates in Japan could be measured in junior college, undergraduate studies, master's course, doctoral course, and professional degree (Research Institute for Higher Education, n.d.). In Japan, natural sciences are generally composed of science, engineering, agriculture, home economic and health care, while human and social sciences comprised human science, social science, education, and art. The ratio between science and non-science in thousand graduates for junior college is 40:80, undergraduates is 920:1420, master's is 100:40, doctoral is 11.5:2.6, and professional degree is 590:14. From the ratio, the number of science graduates is consistently exceeding the number of non-science graduates for master's, doctoral, and professional degree.

5.5.3 Attitudes towards Knowledge

In general, the Japanese have sense of intrinsic values and high esteem towards knowledge (Sobian, 2012). In Japan, it is normal to see the behaviour of reading books everywhere (i.e. train, bus, home, work, and so on). For them, education and knowledge are the elements of fulfilment and excitement, nurturing richness in mind, and intrinsic values. The same phenomenon was also observed in a study conducted as follows:

> *"When we interviewed doctoral students, there was great hesitation about their career goals but almost none when asked why they entered a doctoral program: they wanted to become scholars and researchers, which we understood to mean that, for them, this education had inherent or intrinsic value."* (Mc Carty and Hirata, 2010, p. 30)

In the study, it was also highlighted that Japanese students pursue doctoral education to attain the highest credentials in education and good job opportunities alongside intrinsic values. The values of education are also translated in their way of respecting professors and seniors, maintaining order and cleanliness of their schools, and being hard-working to complete their studies with great determination. The practice of knowledge is highlighted in each level of education in Japan with the approach of philosophy *Karada de Oboeru*. *Karada de* means "with body" and *Oboeru* means "remember" or "learn" (Serah & Noor, 2012). This approach of "learning by doing" provides good application in the STEM subjects and laboratory works. An international research entitled Trends in International Mathematics and Science Study (TIMSS) in 2015 has shown that Japan ranked third among the forty-six educational system countries in science achievement with a score of 569 for the fourth grade (standard five) and ranked second with a score of 571 for the eighth grade (form two) (Provasnik et al., 2016). It is noted that the TIMSS scale center point is set at 500 and the greater values marked the high achievement of Japanese in science.

5.5.4 Laboratory Organization System

According to Udah, Razak, and Bakar (2010), human relationship (*Ningen Kankei*) in organization is an important asset to assist towards the success of Japan. The concept of *Ningen Kankei* embedded group work culture and became a priority in the Japanese community (Bakri, 2008). Similarly, the habitual group work culture is also practiced in the chair or *kouza* system within the Japanese research organizations. A hierarchical structure was formed mainly based on the basis of social interaction in the research organization. The system exhibits closed mentoring relationship in the research organization. In the mentor-apprenticeship (*totei-seido*) system, the professor carries out responsibilities to guide associate professors and associate guides assistant professors to reach higher level while giving equal attention to their students. The senior-junior (*senpai-kohai)* relationship is also significant at a student level, where postdoctoral guides masters and undergraduate students to conduct research projects. In addition, seniors will always concern on the juniors' development in reaching their maximum potential to avoid any failure. Interestingly, McCarty and Hirata (2010) illustrates the relationship as the siblings system in a family, where the older guides and advises younger brothers and sisters to do research. At the same time, the professor acts as a parent who concerns on his students to study well and get employed after graduation.

The relationship could also be observed through the identification of research groups. The research laboratories are named based on the professor's name such as Shimizu Laboratory (*Shimizu Kenkyuushitsu*), Ishikawa Laboratory (*Ishikawa Kenkyuushitsu*), and so on (Serah & Noor, 2012). Its identity is unique to bring a sense of belonging to each laboratory and a sense of deep loyalty to the supervising professor (*sensei*) and group members. Loyalty to the emperor was practiced since the feudal era, in which *bushido*, an ethical and warrior code to keep samurai warriors loyal to their *sensei*.

5.6 Laboratory Activities in University

Good management of R&D practices in laboratory is important in projecting towards quality graduates (Lai Wan, 2007; Azizan, 2011). Many data reported in this section were initially driven by the participant's experience in providing research for traditional culture in laboratory. Similar to the previous chapters, this section is organized based on the research capacity building practiced in laboratory, namely: research models, mentorship and training, communication, learning opportunity program, partnership and networks, knowledge translation and public outreach. The topic discusses the way the practices were organized, the student's involvement and the challenges of the various strategies.

5.6.1 Conceptual Models

In Japan, it is normal to see a large number of master's candidates in any university. For example, participant E described that usually, there are almost 90% of undergraduate students that will pursue their studies in graduate schools at the university. She viewed that research laboratory is served as a platform to develop their interest in research. Moreover, most of the students usually would not worry about their career opportunities in the job market due to the university's good reputation. Even though there are several arguments of limited job opportunities in Japan, it is only due to the work season practiced there. In the Japanese educational culture, hands-on activity is stressed in every work and task. According to Serah and Noor (2012), this characterization is known as *Karada de Oboeru,* where *Karada* means "with body" or "use body", whilst *Oboeru* means "remember" or "learn". In laboratory work, hands-on activity is highly practiced in Japan to early train independency in researchers or engineers in their research proposal stage.

> *Instead of taking 6 months for research proposal preparation as practiced in Malaysia and the United Kingdom, at the time of gathering information and making a plan, we will just immediately start our experimental research.*
>
> (Participant H, Interviewed on September 12th 2017)

Formulating research based on the infrastructure design is also important to give off cutting-edge research outputs. Under the infrastructure design, participants F, G, and H agreed that the physical infrastructure must be maintained with the latest updated technology and in good conditions as according to the international standard. In light of the increasing importance of multidisciplinary research, the supportive policy system eases the process to import high-technology machines and research facilities from outside.

For example:

> *…Usually, if I purchase certain materials today, I will receive them immediately the next day.*
>
> (Participant G, Interviewed on September 26th 2017)

Even though Japanese research universities are centrally organized by the Ministry of Education, they are also given an autonomy through professoriate to operate their research laboratory (McCarty & Hirata, 2010). The research organization is expected to be independent in order to obtain research funding by themselves as well as managing human capital and internal administrative under the leadership of professors. Professors are the ones who decide the style and tone of research in the laboratory. The academic freedom practiced by Japan not only hastens the research process and bureaucracy, but it also contributes to new knowledge and skills among the students.

> *Research and study are the cultures of freedom here. Professor is always open for discussion and encourages his/her students to apply for research funding and to go overseas. I think many professors here obtained the research funds by themselves. As researchers, we have to be good at brainstorming ideas and be creative. To highlight, Ph.D. student is the one who should find out the way to be a researcher.*
>
> (Participant E, Interviewed on February 24th 2017)

Based on the discussion with participants E, G, and H, they also mentioned that proper research skills are essential in ensuring that the research process works smoothly. The first research skill is reviewing the research problem. However, it is not solely by reading "dozens of literatures" and thousands of arguments but also understanding the reality of the world's problem. The idea would effectively kick-start the research's ability to develop new research tools and output for the community. In addition, reliability of the data would also make the research to be more useful in contributing to the community.

> *Professors informally will go to the research field and listen to what people say. The principle is go to the fieldwork to study before setting up the research framework. This also applies for students by observing the reality and then trying to understand what is going on before constructing the methodology and framework*
>
> (Participant E, Interviewed on February 24th 2017)

> *...students do the research and obtain some data. After that, supervisor and students will discuss to initiate the next step. We definitely design our plan roughly earlier but it is flexible in accordance with the actual data. So, I always ask the students, "How many experiments did you do?" The reason is to ensure the reliability of the data obtained.*
>
> (Participant H, Interviewed on September 12th 2017)

5.6.2 Mentorship and Training

Mentorship (*Totei Seido*) and training includes items of teamwork culture, monitoring, equipment training, and research management skills. In Japan, research laboratories are organized under the basic organizational unit called *kouza* system, which is modelled on a professor chair system in the early of 19th or 20th Germany Universities. The research members are observed based on the seniority-basis hierarchical structure, in which the professor's authority is strong. This chair system used to be very rigid before the third wave of higher educational reformation in 1990, but becoming more flexible nowadays as compared by participants E and F.

> *……sometimes, it does not function like the "pyramid way" but only one-to-one mentoring. I think it is difficult to continue the system.*
>
> (Participant E, Interviewed on February 24th 2017)

> *Sometimes in small kouza, they cooperate to carry out certain research… A student is trained from other groups if they use the same machine and instrument. This student can be trained by senior students from other group, so-called mentor-mentee system…*
>
> (Participant F, Interviewed on September 19th 2017)

The chair system illustrates closed-mentoring relationship between *senpai* and *kohai* in the same or even other groups. Participant H described that the basis of the relationship is formed by making the research community like a family. Within the hierarchical structure, one monitors each other's performances. There is a sequence of mentoring process with professors who carry out responsibility to guide associate professors and assistant professors to reach a higher level and at the same time, both give equal attention to their students. Afterwards, this mentor-mentee interaction is extended with postdoctoral researchers and doctoral students to guide the master's and undergraduate students.

Besides good equipment, good research topic, and adequate research funds, good operation skill trained by many seniors is also necessary to manipulate multiple and complex data by using particular equipment. The *senpai* will guide *kohai* as the next generation not only to do research but also to maintain harmony in *kouza* and share data for any interrelated experiments. The teamwork culture is also translated into *soji*, a cleaning session every Friday at 12.30pm. Every laboratory member will be responsible to participate in this cleaning activity. Overall, all participants E, F, G, and H equally express similar behaviour of teamwork culture practiced in Japan.

In terms of closed mentoring, there are several scheduled presentations held to promote students' active participation. The activities are held with seniors in a small group for any theoretical discussions to develop the research. For bigger discussions in laboratory seminars, it is known in multi-terms such as *shorokukai, bunken zemi, zasshikai,* and so on. The discussion is held in a certain way for every research laboratory in universities as follows:

> *When I was working as an assistant professor, I had meetings once or twice per weeks with my small research group.*
>
> (Participant E, Interviewed on February 24th 2017)

> *In Japan, we have a meeting once a week depending on the number of students. In my laboratory, a student has to present literature review in 1-2 papers… Usually, the professor does not ask a lot of questions rather than other research members.*
>
> (Participant F, Interviewed on September 19th 2017)

> *In Japan, all students must present their research progress twice a month for the whole day. So, a student needs to present every 2 weeks and an hour progress.*
>
> (Participant G, Interviewed on September 26th 2017)

> *All members gather once a week for seminar/zemi every Friday to give presentation for general review or progress report. At the moment, they ask many questions. In order to create the questions, they also must have certain skills and understand the content.*
>
> (Participant H, Interviewed on September 12th 2017)

In Japanese universities, laboratory activities are also the medium to train research management skills. Through structured mentoring process, students are trained to be good at leadership management, research funding, research partners, and projects. According to participant H, students in the laboratory are trained to perform all techniques related to the research. For example, laboratory and manipulative skills are emphasized to manage proper analytical machines with safety rules. They are highly accustomed to the standard operating procedure (SOP) for every machine, material, and task in the research laboratory. In addition, students would also be familiar with the SOP related to recycling, scheduled waste, burnable waste, and clean room culture.

5.6.3 Communication

This theme comprises three items: communication skills, social interaction, and the proximity of the professor. As a non-English-speaking system, Japan has encountered problems to discuss and motivate in the English medium. Similar to Yonezawa and Shimmi (2015), participant G pointed out that among the strategic approaches done were by recruiting more international students in the laboratory to provide a platform for the discussions to be in English. For external research activities, participant E highlighted that communication skill is the prominent key to carrying out research effectively. Students should be able to deal with external researchers properly and in a better way, negotiate with people from overseas, and identify the key person in the community, private, and government entity.

> *Let's say you conduct a study in a Fijian village. One way is by visiting and introducing yourself there. Another way is that you might ask any Fijian's friend or government entity to introduce you to the village… The most important thing is to know the right person to smoothen your research. In contrast, if you choose the wrong way, your work might be hardly initiated to the next step.*
>
> (Participant E, Interviewed on February 24th 2017)

Besides stressing on laboratory work, students can also have non-academic time together. As expressed by participants E, F, and H, students will normally be the ones who organize events such as *kai,* which means gathering and *hanami* (green tea party or birthday party). In a group of different cultures and nationalities around the world, they also celebrate various days of significance, such as *Hari Raya*, Christmas, and others by supporting each other in terms of money to bake cakes and desserts for the celebration. Since research centers are usually made up of a federation of research laboratories, there are also events held outside the laboratory such as hiking and camp for 1-2 days in the mountains and hills. Interestingly, as documented by Megat Mohamed Noor et al. (2011), another outdoor activity held between laboratory members was *undokai* (sports tournament). Students from a laboratory may form a team with the other laboratory members to compete in the tournament, commonly in *yakyu* (softball game).

In addition, the proximity of supervisors is different following the universities' policy. As expressed by participant F, the buildings for laboratories and professors offices were built separately in a certain university. In some universities, the laboratories and professors' offices are divided into certain blocks in the same building. For professor H, he stays in the laboratory to communicate and write papers with staff and students efficiently. The proximity of supervisor in the laboratory is due to his significant responsibility to maintain the laboratory room, compute machine, control over financial resources, discipline students to handle equipment properly, and determine the research culture to be embedded in the research laboratory. This is due to the fact that the authority of organizational system in a laboratory is centralized by the professor. The professor's role is extended to even finding job positions for his graduated students. It is noteworthy that the leadership he has somehow leads to the scenario as expressed by participants E and H.

> *...in my laboratory, the professor is very strict. There was one time when the professor made all students cried in a seminar. His words were very harsh in order to improve your weaknesses. Sometimes, he is very encouraging.* (Participant E, Interviewed on February 24th 2017)

> *...it depends on the personality of the professors. Maybe a professor tells students not to cry and another professor scolds the students. For me, just be friendly, not to scold but to better encourage gently.*
> (Participant H, Interviewed on September 12th 2017)

5.6.4 Learning Opportunities Program

Learning opportunity programs were highlighted by participants E and G. Professors who own large research grants could provide an opportunity for students to go overseas.

As discussed in the section of model and conceptual lens, participant E stressed the authentic investigation when doing field work to see the reality of the research problem. Based on further interviews with participant E, the professor sponsors students to carry out field works in India. Sometimes, the professor also offers some external projects so that the students can learn how to manage research funds, research administration, collaborative research, and so forth.

Likewise, there is a special system practiced in the laboratory system as explained by participant G.

> *...students need to do 6 months research for PhD and 3 months research for the master's in other experiment and supervisor... For example, my major is in nanotechnology but my short research focuses on biological field. In the end, I have to make some short report based on the research. At the same time, students need to enrol in several courses before joining the laboratory. The courses might also not only be related to the field of nanotechnology. For instance, material sciences in our school comprise physics, chemistry, and biology. So, the students need to take classes in all the three different fields... Usually, the class will be conducted 2 times for a course per week. Students would be able to finish all the courses within 2 months in the semester. In short, students have to take class for only the first two months of their study and after satisfying the duration, they are permitted to enter the laboratory to do their experiments.*
>
> (Participant G, Interviewed on September 26th 2017)

Through this system, students will gain fundamental knowledge in broader fields. To reflect, this is a good mechanism to implement interdisciplinary and multidisciplinary research in the research laboratory. Students who possess a broad range of knowledge and skill would be able to develop high quality and cost-effective researchers. For instance, there is a certain field in computer science that can predict the best materials and advanced characterization of instruments at a higher level. The collaborative field could optimize the necessary experiments for high cost-consumption researches like physics and chemistry.

5.6.5 Networks and Partnership

This theme includes collaboration, industrial linkage, and recruitment. In the *kouza* system, local collaboration occurs between all research groups. Participant F mentioned that under a particular research, his research group will collaborate with other groups to carry out research with certain tasks assigned for each group. The tasks of this collaboration are formulated based on the research theme. In addition, as explained in the section of communication, participant E perceived the ability to communicate excellently and will therefore lead the community's networks. This is important since the ability to create networks will smoothen and hasten research trajectories and give different perceptions in people's views.

> *Depending on how you were introduced to the village, you will be viewed differently and how the villagers will collaborate with you.*
> (Participant E, Interviewed on February 24th 2017)

However, the collaboration with the community is likely to depend on the research theme. Participant H emphasized on their laboratory work as the inventor and fundamental support at an early stage in the industrial processes as follows:

> *...in the case of algae. We have a company that produces supplement pertaining to the process of microalgae. I also have connection with nori seaweed company because my research is partially concerning the nori.* (Participant H, Interviewed on September 12th 2017)

> *We committed to research groups and companies. In order for the companies to have an investigator, they should have the fundamental knowledge and how to improve materials or small component devices. We are the ones who take care of that part.*
> (Participant E, Interviewed on February 24th 2017)

Furthermore, through partnership and networks, it is common to see professors from other universities recommend their students to develop their research interest in other laboratories.

I ask some professors from Fukuoka University if there are good students... (Participant F, Interviewed on September 19th 2017)

...students from other university are recruited via colleagues and friends. If there is any final year student who wants to do research on algae, my friends will introduce him to me. That is common. (Participant H, Interviewed on September 12th 2017)

Another way is through lecturers and laboratory websites. Research laboratories in Japan use wider audiences through their websites to communicate, either to promote their research or attract partners and graduate students.

I do have a homepage for my microscopic laboratory in case any students are interested in Nano-characterization of materials. (Participant F, Interviewed on September 19th 2017)

....one way to recruit final year students is through lectures and research demonstration of how the micro-algae contribute to the world… Sometimes via the information in our laboratory's website. (Participant H, Interviewed on September 12th 2017)

5.6.6 Knowledge Translation and Public Outreach

This theme includes four items that are publication, conference, commercialization, and knowledge sharing. Participant F emphasized on the importance of assessing students who are publishing their output via publication and conference, apparently to create quality scientists and engineers in university.

Basically, we are scientists and engineers who are working at the university. For me, the first operation is necessarily doing paper writing. However, if the students cannot write a good paper, so I suggest my students to give presentation at a conference. (Participant F, Interviewed on September 19th 2017)

Becoming scientists and engineers implies the focus to build entrepreneur graduates with inventor skills. The students need to understand the culture and their roles in the national and industrial economy. In Japan, since the business entities play major roles in the R&D production, the early stage to contribute in fundamental knowledge towards that is prominent. The following conversation with participant F clarifies the roles of university research laboratories in terms of knowledge translation:

> *...my research topic is not directly related to manufacturing but it clarifies the phenomenon for that. In order to manufacture or fabricate high-quality information technology management (ITM) or device, there are several steps to be taken. Generally, we design and improvise the properties of materials. Then, the industry fabricates and creates the real one. The bigger step directly connects to the real world. But my research is at the early stage, so when we have results on the research topic, we published papers and give presentation to the society* (Participant F, Interviewed on September 19th 2017)

> *...we patent our research... In the case of biomass, my laboratory studies how to produce some oil with the ability to keep moisture-squalane... From there, a company produces skin cream and cosmetics, while another company makes a supplement. Therefore, basically, my laboratory is very academical and it is not easy to connect to the production.* (Participant H, Interviewed on September 12th 2017)

Knowledge sharing is another way to involve students in disseminating knowledge to the community. With its stated aim to augment research laboratory learning, participant G encouraged the participation of students alongside researchers and academics to give presentations and lectures to high school students. A wider group of community with high school teachers and academicians in university from chemistry fields gather to discuss and organize events.

The next chapter will provide a detailed analysis, similarities and differences between the strategies of research for skilled human capital in Malaysian and Japanese universities.

CHAPTER 6: ANALYSIS ON EXPERIENCE IN MALAYSIA AND JAPAN

6.1 Introduction

Chapter 4 and 5 presented the S&T situation and laboratory activities in Malaysian and Japanese universities to be analysed in this chapter. It is important to understand the research culture practiced in universities from both countries to link with the skills obtained by students. Drawn from the literature reviews and earlier chapters, there are eight key themes discussed in this chapter. They are (1) Historical development; (2) S&T strength; (3) Support for research; (4) Research culture; (5) Positioning student to a research group; (6) Mentor-apprenticeship; (7) Monitoring students' development; and, (8) Networks and output.

6.2 Historical Development in S&T

The development of S&T in Malaysia was influenced by the British colonials to satisfy politic and economic of colonial interests. The first establishment of University of Malaya with the merger of King Edward IV College of Medicine with Raffles College in 1949 denoted the phase of S&T revolution in higher education. After shifting the national economic interest from agriculture to industrial-based in 1970, laboratory activities in higher education started to show remarkable points in R&D as supported by the 5th-Malaysian Plan (1986-1990). The development phase of S&T resulted in more universities and research institutions founded during that period. The positive progress of higher education for the R&D center of excellence has created research and APEX University to enhance the research capacity.

The S&T culture in Japan has been implemented since 400 years ago during the Edo period (1603-1868). During this period, slow development of S&T was observed in improving the quality of life and was usually devoted to high-ranked civil society like *Shogun*. Later in the late 19th century of Meiji period (1868-1912), the S&T education was revitalized to the fullest and saw even more openings of research institutions as well as the Tokyo Imperial University. The historical development of S&T in Japan was also affected in the World War II in 1945, where the educational system had been almost completely paralyzed. To adapt with the wartime experience, Japan started to imitate the imported technology and education in the national reform and rebranded it in their own way. The reformation had also recorded impacts on laboratory roles and its structure in higher education. The reformation discussed in the numbers of literature denotes the significance of laboratory organization in Japan (Ogawa, 2002; McCarty & Hirata, 2010; Megat Mohamed Noor et al., 2011; Serah & Noor, 2012). In terms of S&T history, the longer research culture in Japan implies more advanced and sophisticated research infrastructures that can be seen in Japanese universities as compared to Malaysia.

6.3 S&T Strength

Closer examinations on the structure of Malaysian GERD and GDP as presented in Chapter 4 and Chapter 5 revealed that greater focus was given to the R&D business enterprise, following higher education as similar to other developed countries like Japan. Considering the highly required skilled human capital, the investment on higher educational research is necessary to give supply of trained human capital in the industry with higher number of researchers trained in Malaysian higher educational institutions. In addition, since huge investments have been made in the universities' R&D sector, this sector needs adequate numbers of total workforce especially in S&T field.

Even though Malaysia ranked among the highest S&T human capital in developing countries, as presented in Chapter 4 and **Table 4.3**, there is 20%-30% shortage among science graduates and infrastructure provided is inadequate to support the process (Azman et al., 2016; Jusoh, Yusoff, & Mohtar, 2017). Most of the research products from Malaysian universities were not be commercialized, whilst the industry would rather rely upon imported technology from overseas. Besides that, the investments are contributed in terms of various schemes introduced to attract more S&T graduate talents. Even though the number of students currently enrolled in science courses is low, the percentage number of postgraduate education has increased and been greater in the science field as compared to the other field after several governments initiatives were introduced as reported in Chapter 4 and Chapter 5.

Based on the report presented in Chapter 5, GERD in Japan is also prioritized more in the business enterprise. Greater reliance on the industry causes more researchers to be trained in large business corporation compared to higher educational institutions. Nevertheless, the percentage of R&D personnel in higher education is higher when compared to other developed countries. Since the 1970s, Japan has aggressively imported and digested technology from outside for active in-house R&D. The Japanese government's focus to catch-up with the United States economy lies heavily on the industrial R&D to innovate indigenous technology. In that sense, research in universities is regarded as the early stage in contributing to the fundamental knowledge of the industry. Therefore, the role of research laboratory is important to promote entrepreneur graduates with invention skills. The students need to clearly understand their research cultures and roles in the national and industrial economy. In addition, good interaction between academia and industry has also been emphasized on after realizing their strength in business enterprise for the national economic growth. Good collaborative networks between university and industry could provide career pathways and train marketable skills needed by the employers in the 21st century. As reported in Chapter 5, their attitude towards knowledge and laboratory institutions also contribute to the S&T strength in Japan. High moral values and ethics embedded in the Japanese education instil deep soul and spirit in striving towards excellence.

6.4 Support for Research

Adequate number of research students and facilities in a laboratory could support effective research (Mullen et al., 2008). In both countries, a research laboratory is served as a platform to cultivate research and science interest in pursuing higher educational levels. The number of postgraduate students in the field of S&T is also consistently higher when compared with other fields for both countries. Nevertheless, in terms of the total graduate population, the Japanese participants present a nuanced account from the Japanese education when commonly there is majority of undergraduate students that tend to further their studies in graduate schools of the same or different research laboratory.

In terms of total S&T human capital, Japan exceeds 7,169.3928 researchers per million headcounts compared to Malaysia with 2,908.73193 researchers per million headcounts in 2015. The difference is due to longer research culture exhibited in Japan. Therefore, higher number of researchers with good research and analytical skills contribute to better economic growth. Nevertheless, the high percentage of S&T human capital in Japan is also attributed to the low number of birth rates and social ageing. Besides that, researchers with higher educational level will provide better promising point to be employed as presented in the human capital and queuing (Yonezawa & Shimmi, 2015). Besides that, researchers with higher educational level will provide better promising point to be employed as presented in the human capital and queuing theories (Di Stasio & Van de Werfhorst, 2016).

In addition, a conducive research support is important to manage data and deal with the external environment. The effectiveness and its supporting system will facilitate research production and its equipment's troubleshooting (Mullen et al., 2008). This has however become a laboratory strain in Malaysia, where the process to import and buy high-technology machines and research facilities from outside consumes longer time and involves many processes. This situation is the opposite of the Japanese research laboratories, whereby research order for experimentation is easy and would take shorter time. The reason is due to the accessibility of high technology in Japanese industry. Positive progress supports the development of research and transferable skills among graduates. Students would also learn the knowledge in terms of dealing with suppliers, e-procurement, and managing research funds.

6.5 Research Culture

As discussed by Biao (2015), the combination of both formal and non-formal education is important to deliver lifelong learning skills to the students. In parallel to the skills, Malaysian research students have always been kept updated with the latest development in all aspects of human living and technology for quality research taken. The focus of global interests such as IoT, nanosensor, green technology, and water quality in Malaysian universities has been a paramount focus by the government today in R&D (Academy of Sciences Malaysia, 2017). Nevertheless, in doing so, research formulation is prominent in carrying out research in a limited-resource setting. In the situation, fostering multidisciplinary research is significant for universities as practiced by the University of Colombia (Heitkemper et al., 2008; Coen et al., 2010). This practice is necessary to instil the values of critical thinking and individual nature of researchers to adapt to any situation. This cognitive learning will continuously be able to equip graduates with the seven survival skills discussed by Marion (2015) and Wagner (2008).

As mentioned in the literature section, the cognitive learning will be able to increase the graduate's competency and confidence level to become a scientist.

Recruiting international talent, patents, and publication have also become the indicators in the QS World ranking as well as to produce human capital and skills in higher education. In that sense, there is no difference in Japanese universities that aim to enculturate students to be part of an economically competitive community. What stands out in the Japanese education is the fulfilment, excitement, and cultivation in terms of richness of mind alongside the economic interest (McCarty & Hirata, 2010). This could be understood from the behavior of professors and students that go into the field to understand the reality of research problems before constructing research methodology and framework. This is the basic to master research skills as proposed in the inductive model (Renzulli, 2012). In addition, the Japanese educational system stresses laboratory work based on the principles of *Karada De Oboeru* and *Ningen Kankei* (Megat Mohamed Noor et al., 2011). Therefore, the Japanese carries out long plan and research experimentations before proposal defence instead of only several months required for research proposal preparations as practiced in Malaysia.

6.6 Positioning Student to a Research Group

A research organization in a laboratory is built based on the teamwork of multiple generations of researchers. The relationship between professors and students for both countries are inclined towards a professional relationship among them. Nevertheless, it is noted that the authority of a research organization in the Japanese laboratory is centralized to the professor. Thus, it is normal to see the critical roles played by a professor to discipline the students, control over research processes, and even finding job positions for his students after graduation. It could be seen through various activities held outside the laboratory to strengthen social networks and skills, whether to organize events or social activities such as dinner, appreciation party, and so on. In Malaysia, students are given bigger opportunities to participate in professional learning and position themselves as part of a wider research community. As a whole, the activities presented both non-formal and informal education to generate lifelong learning skills and knowledge through laboratory-based learning as stressed by Affeldt et al. (2017) and Coen et al. (2010) in the previous literature section.

On the other hand, the identity of belonging to their research group is one of the impressive characters found in the Japanese research laboratory. For example, the research laboratories in Japan are named based on the laboratory's head such as *Abe Kenkyushitsu, Suzuki Kenkyushitsu, Tanaka Kenkyushitsu,* and others (Megat Mohamed Noor et al., 2011; Serah & Noor, 2012). In Malaysia, research laboratory is rather known with its course name such as Photonics Research Laboratory, Biomass Energy Laboratory, Materials Science, and Characterization Laboratory.

Furthermore, the teamwork culture between student-professor and senior-junior is also a contributing factor towards a sense of belonging in a group. This could be seen from scheduled activities like cleaning the laboratory every Friday to inculcate collaborative attitude, punctuality, and confidentiality levels in any work in the future. This also points the elements of attitude, values, and ethics to complement the holistic approach of human capital (Binkley et al., 2012). It is reported that students who are willing to give better commitment towards the group have commonly been trained with good mentoring style (Hashi & Xareed, 2009; Stroth, 2015).

This fact was shown by some programs held between the alumni from Japanese universities. For instance, in the Kyoto Asean-Forum 2016 and the annual ISTECC

(International Sustainability Technology, Environment and Civilization Conference), majority of the participants were alumni from the same *kouza* or affiliated *kouza* and learnt from the same professor (http://www.oc.kyoto-u.ac.jp/overseas-centers/kyoto-asean-forum-2016/en/). The event was organized to share their current research output and strategy. The long-lasting relationship is therefore beneficial in creating research networks among them within their own respective field of study. This idea leads to academic genealogy, where the chain of knowledge could be traced; creating diverse networks.

6.7 Mentor-Apprenticeship

In Malaysia and Japan, it is common to see a research laboratory managed without a technician in the laboratory due to limited cost-factor. This is however against the strategy to adapt to the complex mode of the 21st century knowledge as delineated by Heitkemper et al. (2008). Both depend on the research members under the principles of mentor-apprenticeship to operate and manage equipment as well as manipulate multiple and complex data. In fact, this mentor-apprenticeship system is a common system practiced in the Malaysian and Japanese research laboratories. Despite the similarities, the system is a one way and a non-chain mentoring structure in Malaysia rather than a hierarchical structure in Japan. The pyramid system that is also known as *kouza* in Japan is practiced through a closed-mentoring relationship, where the older guides the younger.

This notion rejects negative claims on professors who are simply taking a role to provide infrastructural environment of laboratory but neglecting the responsibility towards the development and performance of their students (Stroth, 2015). Since education is regarded as an intrinsic value in Japan, mentors will always have concerns on the mentee's development to reach their maximum potential, since it gives connotation to the mentor's failure if the students failed.

Another factor that differentiates Malaysia and Japan in terms of mentorship is the proper guidance from top assistant professors and associate professors to go to a higher level. The mentoring system in Malaysia is focusing on the level of PI-students and postgraduate (senior)-undergraduate student (junior), whilst the mentoring system in Japan encompasses sequence chain of mentoring from professors, associate professors, lecturers, to students based on the *senpai-kohai* relationship. This concept of learning by teaching enables social interaction and guidance from experts for a collaborative culture as highlighted in the social constructivism theory (Serah & Noor, 2012). The proper system in mentor-apprenticeship as practiced in Japan could also avoid misinterpretation on the role of a mentor to assist them as described by the Malaysian participant. The continuous chain mentoring is consistent to characterize the sequential teamwork of research group as discussed by Shibayama et al. (2015), Hulcombe et al. (2014), and Etzkowitz (2003) in the previous literature section.

It is also noted in the literature section that communication skills, teamwork skills, leadership skills, information management, ethics and professional morals are frequently mentioned in job advertisements (Ooi & Ting, 2017). Following this, proper mentoring system in projecting activities in research organization will be able to improve these skills and meet the current needs of the Malaysian industrial firms.

6.8 Monitoring Student's Development

As discussed by Binkley et al. (2012), Azman et al. (2016), and Tyler et al. (2016), research monitoring is crucial in managing the students' talent development. Research monitoring can be discussed in two aspects. The first one is proximity of a professor and next is through research meeting. In both countries, certain professors work in the same research laboratory to monitor the students' progress closely. At the same time, there are also professors who work at other buildings and blocks with the assistance of postdoctoral researchers for continuous monitoring and research laboratory management. The coordination between professor and postdoctoral is important to maintain the mentor-apprenticeship system to occur smoothly. The role of *senpai-kohai* (senior-junior) is important in this situation to especially guide the experimentation process.

In terms of research meeting, there are regular but not scheduled meetings held with PI or supervisors in Malaysia. Sometimes, the formal meeting is held at least once a month or once every two weeks. There are also irregular meetings in certain Malaysian universities and online discussions held rather than face-to-face meetings. In contrast, there are scheduled meetings practiced in Japan to promote continuous and active participation among the students. There are scheduled laboratory seminars known in multi-terms such as *shorokukai, bunken zemi, zasshikai,* and so on. Despite various terms, this scheduled mentoring for a certain period every week and every two weeks would cultivate the students' critical thinking, keep them updated, and track the research progress of every member in the laboratory. The research culture is established to be promoted as a training medium to students with adequate knowledge, skills, and attitudes in the future.

The scheduled mentoring process is also translated into managing the analytical machine properly with safety rules. Every machine, materials, and tasks in the research laboratory is highly accustomed to the standard operating procedure (SOP). Students would also be familiar with the SOP related to recycling, scheduled waste, burnable waste, and clean room culture. The responsibility to utilize equipment properly develops the sense of belonging and adaptation to the equipment, materials, and laboratory facilities.

6.9 Networks and Output

All universities acknowledged in multiple ways that collaboration develops and enhances skills formation and research productivity. The analyses from both countries exhibit parallel findings to the literature section that social networks can be broadened through laboratory alliances between universities, industries, and government research institutions (Murray, 2004; Toole & Czarnitzki, 2009). The activities that operate not only in-house, but also outside the research laboratory could ease the flow of knowledge and skills effectively among the organizations (Hulcombe et al., 2014).

In Malaysia, the existing collaborative network between a university and industry provides a career path for the students after graduation. There is a mutual interest in gaining expertise and research funds to support the development of R&D. In addition, the collaboration could add values to knowledge sharing towards the educational community. In spite of that, in terms of commercialization, students are not exposed to be scientists with commercial opportunities. Since the infrastructure to develop the commercialization process is still inadequate, the objective to develop technopreneurship graduates is hardly achieved.

Meanwhile, in Japan, most of the commercialization process is carried out by the industry. Research laboratory in universities is only provided at the early stages of the commercialization process. Major processes are executed by the industry or business enterprises to make the commercialization state a favourable condition. Furthermore, knowledge sharing amongst a wider group of community with high school teachers and academicians in university would enable students to implicitly and explicitly learn soft and hard skills to organize the event.

The collaboration between universities' laboratory and firms in both countries is also stressed in terms of writing grants proposal, research papers, and conference presentation. This orientation enables students to advance their skills and exchange ideas as well as social interaction effect in exploiting scientific opportunities to increase their research funding and identities even in resource-limited settings.

6.10 Chapter Summary

This chapter discusses the differences and similarities of laboratory practices in Malaysia. These differences and similarities are given in **Table 6.1** and **Table 6.2**. Historical development in S&T in Japan has started earlier since 400 years ago than 100 years ago in Malaysia. For both countries, the higher educational institutions have consistently remained as the second contributor after business enterprise in terms of R&D activities and the number of postgraduate education is consistently greater in science than social science field. In spite of that, the number of researchers trained in the Japanese higher education is lower than the numbers trained in the business enterprise, whilst researchers are mainly trained in Malaysian higher educational institutions. It is also noted that positive attitude towards knowledge and laboratory learning in Japan becomes a factor for skills growth in Japan. To compare in terms of support for research in the university's laboratory, the higher number of Japanese students would pursue master's course as compared to that of Malaysia's. Furthermore, the process to import and buy high-technology machine and research facilities from outside is also more efficient and take shorter time.

For research culture, Japan practices hands-on learning, in which research experimentation is conducted since their early proposal defence, whilst the practices in Malaysia require several months for proposal before going into experimentation. Next, it includes positioning student to a research group. There are various activities held outside the laboratory to strengthen the social networks and skills in both countries. To highlight, Japan applies a sense of belonging to a certain research group. For the sixth theme, Japan implements the *kouza* system for mentor-apprenticeship and there is no specific technician hired in the laboratory generally. The seventh theme is monitoring students' development. In both countries, there are regular meetings to be held to observe the students' development, but there is scheduled closed mentoring from *sensei* and seniors in a week or every two weeks. All laboratory facilities in Japan is also strictly accustomed to the standard operating procedure (SOP). For networks and output, it is found that collaborative networks occur between laboratory with the community, industry, and other research laboratories.

Table 6.1: Differences between Research Laboratories in Malaysia and Japan

No.	Themes	Malaysia	Japan
1	Historical Development in S&T (University)	S&T culture in Malaysia has just started 100 years ago and the establishment of University of Malaya officially in 1949 denoted the research culture is still new in university.	S&T culture in Japan has longer timespan since 400 years ago and research culture has started officially during the opening of Tokyo University in 1868-1912. The longer research culture exhibits more advanced and sophisticated research infrastructure.
2	S&T Strength	- The number of researchers trained in higher educational institutions is the highest when compared to government research institution and business enterprise.	- The number of researchers trained in higher educational institutions ranked second after business enterprise. - The high moral values and ethics embedded in the Japanese education causes deep soul and spirit towards knowledge and laboratory institutions.
3	Support for Research	- Process to import and buy high-technology machine and research facilities from outside consume long timespan and involve many research processes.	- Process to import research materials take shorter time period and effective processes.
4	Research Culture	Several months required for research proposal preparation before doing experimentation as practiced in Malaysia.	Research experimentation with an early long planning is conducted since the early of proposal defence

5	Positioning Student to a Research Group	- Research laboratories are named based on the course name - Students are given bigger opportunity to participate in the professional learning and position themselves as a part of the wider research community	- Research laboratories are named based on the name of laboratories head - Sense of belonging to a certain research organization - Scheduled activities are organized between research laboratories in the tournament such as *yakyu* (softball game)
6	Mentor-Apprenticeship	- One way and non-chain mentoring system - Not practice long-term planning or system where professor can clearly help to assist and provide right track for younger staffs to follow	- Pyramid and hierarchical structure (*kouza* system) - Proper guidance from the top for assistant professor and associate professor to go for higher level
7	Monitoring Student's Development	- Regular but not scheduled meeting and sometimes discussion is also made through online. - The standard operating procedure (SOP) is not strictly accustomed to every items in laboratory.	- Scheduled meeting in every week and every two weeks - Every machine, materials and task in the research laboratory is highly accustomed to the standard operating procedure (SOP)

Table 6.2: Similarities between Research Laboratories in Malaysia and Japan

No.	Items	Malaysia and Japan
1	S&T Strength	- Higher educational institutions consistently remained as the second contributor after business enterprise to the R&D activities. - The percentage number of postgraduate education is greater in science field when compared to social science field.
2	Research Culture	- Recruiting international talent, patents and publication also become the indicators in the QS World ranking as well as to produce human capital and skills in the higher education - Emphasizing multidisciplinary research
3	Positioning Student to a Research Group	There are various activities held outside the laboratory to strengthen social networks and skills.
4	Mentor-apprenticeship	Commonly, research laboratory is managed without a technician in the laboratory due to the limited cost-factor.
5	Monitoring Student's Development	Certain professor works in the same research laboratory and certain professor works at the other building and blocks with the assistance of postdoctoral researchers for continuous monitoring.
6	Networking and Output	Create collaborative networks with community, industry and other research laboratories.

CHAPTER 7: SUMMARY AND RECOMMENDATIONS

7.1 Introduction

The concluding chapter draws together the highlighted points of a research laboratory's role in universities towards enhancing skilled human capital. The main findings are presented in relation to the research questions of this study. Next, some recommendations are discussed on the role of laboratory to develop skilled human capital.

7.2 Summary of the Chapters

The main idea for this work is to study the practices of laboratory education and its role for skilled human capital production, focusing on students and graduates in university. Henceforth, main findings of this study will contribute to the ongoing efforts in Malaysia to increase its quality of human capital and skills.

Firstly, the scenario of a nation's political and economic situation is discussed in detail. The case in Malaysia is discussed from the aspect of employability skills and quality of S&T graduates. How the research laboratories in universities manage to play their role, hence, became a key research question.

Chapter 2 discussed the conceptual framework of this study. The framework consists of the capacity building of research laboratory in generating skilled manpower for the economic growth. The significance of universities in producing practical skills, transferable skills and intellectual simulation due to the circumstances of the 21^{st}-century learning was also documented. The formal and informal activities through in-house and outside organization of research laboratory were also considered to be critically discussed.

Chapter 3 introduced the methodology of documentation, in-depth interviews and informal discussions used in this study. The justification of this method was provided in relation to the present study.

Chapter 4 and 5 described the situation of S&T and R&D in Malaysia and Japan respectively. Malaysia and Japan's historical background, R&D performance, challenges and strength of S&T and, contribution and activities of research laboratory were also examined. The challenges faced by research laboratories in fostering skilled human capital were identified.

Chapter 6 provided a critical analyses and findings in case studies. The themes identified were categorized into: (1) historical development; (2) S&T strength; (3) support for research; (4) research culture; (5) positioning student to a research group; (6) mentor-apprenticeship; (7) monitoring students' development; (8) networks and output. This chapter presented strategies implemented by research laboratories in Malaysian and Japanese universities to enhance the human capital development. This chapter also provided the differences and similarities of the universities' approach between both countries. The idea will be refined further in Malaysian context in relation to the key findings and conclusion.

7.3 Key Findings: Lessons Learned from Japanese and Malaysian Universities

The important lessons learnt from successful countries like Japan draw attention on the best practice to be studied for the skills required in the 21st-century. Experiences from the practices to develop skilled human capital in Japanese universities are as follows:

- An observation at the Japanese research laboratories reveals that they are more sophisticated and advanced in terms of their infrastructure. The wartime experience, longer research culture, innovative culture, and attitude towards science are among the contributing factors.
- The Japanese assimilate a lot of traditional philosophies in education. Education is not solely regarded as to get credentials, but also the intrinsic and instrumental values beneath it. This is reflected through strength and a sense of belonging to the research group. The *senpai-kohai* relationship is practiced not only in the laboratory, but also in the industry and community.
- The support for research in Japanese universities is translated in terms of efficient research. Effective research process is widely practiced in Japan to allow for smooth research processes and supportive physical as well as intellectual infrastructure.
- The mentoring system is properly guided from top for assistant professors and associate professors to go to a higher level. The long-term planning or system is executed where professors can clearly help in assisting younger staff and providing the right track to follow. This concept of a pyramid system will enable sustainable goals and lifelong networks.
- The Japanese stress the process of "learning by doing" especially in S&T education. Thus, laboratory work or practical training is highly implemented under the SOP for every machine, material, and task. Therefore, lot of activities are scheduled in the laboratory through academic meetings, cleanings, sports, and so on.
- Since GERD on higher educational institutions remains the second contributor after business enterprise, inventor and entrepreneur skills are necessary for intellectual simulation to occur with the support from networks and collaborative interaction between the government, university, and industry.

To sum up, the study demonstrated that supportive physical and intellectual infrastructure must be formulated to aid skilled human capital growth. Appropriate human capital approaches should be studied for Malaysia in order to increase further and to move from developing to a developed country in the future.

7.4 Managerial and Policy Implication of Findings

There are several managerial and policy implications arising from the findings of this study.

Firstly, both local and broader networks of research laboratories within and from different institutions need to be strengthened. It is noted that activities in the laboratory are organized for the universities' long-aim investment to produce graduates with actual competency in S&T skills. As stressed by Wantchekon et al. (2015), skilled human capital could contribute significantly to the economic growth of a developing country like Malaysia. In the laboratory, there are multiple layers of students, researchers, and generations educated and involved in various laboratory activities. The activities that operate through both in-house and outside the organization should deliver great output with minimal risk and cost-effective. From designing research models, the researchers communicate with each other in the sense of mentorship and training as well as involving many learning opportunity programs. Thus, the Malaysian education has to formulate a system to develop researchers and academicians through collaborative culture within the research organization. At the same time, ideal partnership and networks between industry and academics should consist of active interactions between them. The combination of these parties will then allow for translation of knowledge and public outreach to the community. All of these key players should be coordinated well by a great effort of sharing mutual interest between the academics and industry. Through well-coordination, different parties require each other to complete and complement the process of producing skilled graduates.

Secondly, since the higher education system in Malaysia is centralized to the government, the current policies formulated by the government are of major factors determined for the direction of the university. The policies should formulate research towards the global interest integrated with excitement and intrinsic values of education. Under the government's aspiration, the university's autonomy should be considered in the effort to gear towards effective research process and supportive infrastructure under the government's agenda. In addition, the government's incentives to retain and train graduate talents would not only expand the research community, but also increase multiple layers of competent human skills in adapting to the ever-changing technology. The supportive research infrastructure is inevitably formulated to increase the numbers in S&T experts especially among PhD graduates as discussed Chapter 4. Moreover, Malaysia is also known as one of the best destinations for international students; therefore, becoming the hub of education could benefit Malaysia in terms of mobilizing and retaining talent for its skilled labour.

Furthermore, this study supports the Critical Agenda Projects (CAP's) 2007-2010 in restructuring higher education that focuses on the employability of Malaysian graduates. (Zain et al., 2017). The project that focuses on producing graduates that can adapt, maintain, and meet any industrial job requirements has been discussed among parliamentarian and public since the early stage of the projects. In research laboratories, there are formal and informal learning activities that would provide students with not only research skills, but also employability skills. The importance of gaining soft skills through laboratory activities is consistent based on the findings from Sarkar, Overton, Thompson, and Rayner (2016) that viewed soft skills as highly important for science graduates, irrespective of whether they are employed or further their studies. The endeavour of this study also proposes the best practice of laboratory learning as delineated under the MEB 2015-2025. The plan "Three B's", *Bakat* (Talent), Benchmarking via Global Standards, and Balance are introduced and should be practically implemented in the laboratory. Within the circumstance, 5Cs'components comprising Critical thinking and problem solving, effective Communication skills, Collaboration and team building, Creativity and innovation, and Cultural literacy are closely embedded to encourage innovative research and translate knowledge into impact and commercialization (Zain et al., 2017). Therefore, laboratory activities should engage in more research sharing among the academicians and with the communities in order to expose graduates with transferable and soft skills in organizational behaviour or academical management.

7.5 Recommendations for Skilled Human Capital Development in S&T

The previous section has described a research laboratory as an agent in university to ensure R&D workforce is equipped with the necessary skills and to keep updated with the current inventions. This thesis submits some recommendations towards increasing the role of research laboratory in Malaysia towards developing skills in human capital. The recommendations will be focusing on creating and sustaining talent among graduates.

7.5.1 National R&D interest

The policy implications provided in Section 7.4 highlights specific recommendations relating to skilled graduates. Concerning the importance of knowledge-based economy, the long-term investment in a university's R&D sector has been an essential factor that contributes to the economic and human growth. The finding of the case study provided in Malaysia revealed that the priority of research areas that incline towards a global interest is consistent with the Malaysia's National Science & Research Council (NSRC) (Rahim & Emran, 2012). In promoting the national focus area, NSRC points on benchmarking the best practice of other countries in allocating their R&D resources and focus areas. To highlight, greater focus of the government on higher educational research signifies the importance of universities in generating their national workforce. Therefore, it is crucial for the educational and training hub in universities to be complemented with good management practices.

In comparison with Japan that puts priority on industrial research, higher educational institutions play an important role to evaluate education as the intrinsic and instrumental values. The findings of this study suggest that laboratory education in Malaysia could learn the way to embed the values of fulfilment, excitement, and cultivation of richness of mind alongside the economic interest. Researchers should be well-adapted to the personalization of real problems as suggested by Renzulli (2012) in his inductive model. In addition, Marion (2015) and Wagner (2008) also highlighted on critical thinking to solve problems as the first and utmost survival skill in the 21st century. The practice of hands-on learning such as *Karada De Oboeru* for each S&T task could also be made into a philosophical consideration to develop formal and informal learning to a higher level.

Moreover, multidisciplinary research could also contribute to collaborative networks between academics, industry, and government. Situating the global context, the research members from multiple laboratories and disciplines could work together for more advanced research in a limited-resource setting. The quality of graduates who are multi-talented with different modes of knowledge will be able to adapt to the 21st century skills as needed.

7.5.2 Research Organization

The growth population of postgraduate education could help to serve a supportive R&D management system. In Japan, higher number of postgraduate population especially in the field of S&T will allow the academia to grow and compete and creating supportive infrastructures for R&D activities to take place using the government's initiative funding. The expanding research community reflects greater research production and requires them to share laboratory equipment and consumables as well as encouraging collaboration among them. The element of teamwork or *senpai-kohai* relationship shows success in relation to the research organization's strength. In spite of that, there were several studies which claimed that the higher number of researchers is not necessarily better due to "higher coordination costs, lower decision process, and higher administrative burden, etc." (Carayol & Matt, 2004; Stroth, 2015). Strong research organizations in larger laboratories with values of *Ningen Kankei* could solve this problem with formal training, supportive management, and experienced postdoctoral and research associates. This effort must be done carefully to promote academic and scientific freedom as well as creative scientific investigation (Stroth, 2015).

The policy also urges universities to provide training and skills that are fully relevant to the national needs, particularly with respect to significantly contributing the development of successful S&T management systems. Various schemes were introduced in Malaysia to attract and retain more local and abroad talents in forms of long-term investment. This study acknowledges various schemes introduced by the government to attract more students towards postgraduate education. Consequently, globalization and internationalization attract more students from different parts of the world such as China, Indonesia, Bangladesh, Iran, Nigeria, Sudan, Yemen, Thailand, and Saudi Arabia. In a study conducted by Asari, Muhamad, and Khalid (2017), it was reported that Malaysia ranked 9th in 2014, a slight improvement from the 11th place in international students' world destination in 2009 . The multi-cultural talent in a group could spur research productivity and improve language skills among them. It is also supported from the literature section that the availability of intellectual human capital or researchers in a laboratory could provide full support for mentor-apprenticeship in the skilled development (Mullen et al., 2008).

7.5.3 Supportive R&D Management System

In order to ease and secure the Malaysian R&D management process, it is important to create an environment where researchers are given the autonomy to carry out their research efficiently. In a certain way, the research university should be able to behave like corporate entities to revise the policy of research operations. Accordingly, the autonomy for the university's research laboratory to be fully functioning will fulfil their research agenda under the government's aspiration (Ahmad & Farley, 2013). As a result, it will facilitate the research progress as planned without too much bureaucracy. Moreover, the conducive research environment also inspires researchers to concentrate on their meaningful research work with adequate supply of equipment and consumables.

Besides the physical infrastructure, an intellectual infrastructure is also important. Nevertheless, findings from this study have found that supportive infrastructure of technical service is still inadequate in Malaysia and Japan. The government policy must be formulated only to increase the number of technicians with diploma holders rather than getting the highest professionalism in certain fields (Ahmad & Farley, 2013). In a research laboratory, technicians are not necessarily well-qualified as academicians with the highest certificates of education, yet it is still important for them to get good technical professionalism. Taking an example from the Engineering Research Centers in eighteen

European universities, it was recorded that 42% of respondents viewed the technical staff as extremely important to support the research productivity (Feller et al., 2002).

7.5.4 Maintaining Lifelong Networks

One way to nurture lifelong networks is through a sense of belonging to the research group. The scheduled research progress could always be kept updated and continuously monitor the students' progress. From there, the professors or principal investigators will also create a close relationship and lifelong networks with the students. This unusual camaraderie creates life-long friends and could build networking businesses and research among them after graduation. Based on the social interaction effects, the sense of belonging to the group would encourage students to imitate their laboratory members (Falk et al., 2013). Hence, good personalization and knowledge from professors could be inherited in the students. Furthermore, this identity is unique, leading to academics genealogy that links scholars or scientists with their dissertation supervisors. The chain of knowledge from professors could be traced and create diverse networks.

Therefore, more scheduled social activities should be arranged in the laboratory to educate students to nurture the sense of belonging. Social interaction in the laboratory is necessary to ensure positive development in students from different aspects of knowledge, skills, and attitudes. It is also suggested to place a room in laboratory, so that professors or PIs could monitor students' development more frequently and closely. Further, there is no clear evidence from the previous study to highlight the laboratory's name to promote any sense of belonging to a research group.

Nonetheless, in many universities, laboratory is named after the principal investigator, e.g. Britton Group and the shared objectives, e.g. “Experimental Micromechanical Characterisation Research Group” (Please refer https://medium.com/@BMatB/group-names-a-sense-of-identity-andbelonging-be3bc9 b8e97d).

7.5.5 University-Industry-Government

In relation to the phase which aims beyond 2020, productive collaboration between the academia-industry-government particularly towards R&D&C and human training must be developed to cultivate vibrant research cultures, provide the best practice guideline for multi-character pathways, and instil a mind-set to be capable of maximizing output in a limited-resource setting. According to Grapragasem et al. (2014), the government has implemented Educity in Iskandar Malaysia in Johor and Kuala Lumpur Education City (KLEC) in order to support academic-industry collaboration through joint research laboratories and design centers. Through the KLEC, environment-friendly, energy-efficient, and networked knowledge-based regional center are well-provided alongside the development of human capital necessary for the knowledge-based economy.

Furthermore, the existence of University-Industry-Higher Education Collaboration Council (UIHCC) in a collaborative model between university-industry-government must be able to improve cooperative teamwork among these three entities (Salleh & Omar, 2013). Indeed, the council may equitably coordinate the strategic roles of building particular research collaborations among these three research institutions in a priority area. The distributed cooperative pattern through local and international collaborations could provide alternative funds whilst giving better opportunities to train students and attachment at industries and universities. Collaborative research between these institutions provide infrastructure that develops technopreneurship graduates who are good at scientific and commercialization skills. The productive technopreneurship graduates could promote ‘Niche 1’, which encompasses commercialization and innovation in the R&D infrastructure as presented in Chapter 4. As parallel to the findings, this study has discovered that career path and knowledge transfer that exist from industrial networks could aid the process of human capital development. Both are driving each other’s progress, where the academic has expertise and the industry knows how to fulfil the market demands.

It is suggested to position students and researchers in the research community so that they could reflect themselves as scientists and be exposed to the real working conditions. Consultation with industries is one way to place researchers from the industry or students’ attachment in the industry for practical training. The placement would be able to create more career opportunities and train the S&T students with management skills to hold higher ranked position in S&T firm in the future.

7.6 Further Research

This study has focused on developing the skilled graduates, particularly through practices in research laboratory in Malaysian and Japanese universities. It is also looking at the aspect of how Malaysia can learn from the successful approaches by Japan in adopting supportive research environment for skills development. The information of this study can be further elaborated in case studies by comparing research laboratories in universities, government research institutions and the industry. To enhance data for this study, future study could also examine the application of laboratory learning among employees in their workplace.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

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