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Education and Human Capital Development to Strengthen R&D Capacity in the ASEAN

Tereso S. TULLAO, Jr.
Angelo King Institute for Economic and Business Studies
De La Salle University Manila

Christopher James CABUAY
Angelo King Institute for Economic and Business Studies
De La Salle University Manila

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Abstract: *The role of education is crucial in process of economic development. Initially, investments in training and education produce the necessary technical workers. At higher levels of economic development, the formation of highly skilled technicians, engineers, and professionals are made through advanced levels of education. The accumulation of sophisticated types of human capital is a major factor in creating the research and innovation infrastructure of a mature economy. Looking at the research and development (R&D) capacity of the ASEAN region, we see that most countries still have ways to go in order to fully develop their innovative capacity. Engineering, which is a significant source of innovations in a country, needs to have its curriculum revamped to adapt to global competition as well as to cater to the need of countries to innovate. This study recommends the improvement of technical competence of engineering education, the exploration of possible cooperation among engineering schools and professionals, learning from advanced economies on the development of advanced skills, the development of the soft skills of engineering students, and adopting an innovation perspective in the development of a nation.*

Keywords: Education, human capital, research and development, innovation, engineering education
JEL Classification I23, I25, J24, O31, O32

1. Introduction

There has been a noticeable transformation in the ASEAN economy in recent decades. The rapid and sustained growth of its several economies has increased the region's share in global trade and output. Accompanying this growth were several countries' shift into the middle-income status, the reduction in their poverty, and a bigger middle class.

This remarkable economic performance has been attributed to a great extent to rapid industrialization and the increasing intra-ASEAN trade over time, thanks in part to the extensive networks of clusters in several economic sectors. Today, the presence of global production networks (GPNs) is evident in the ASEAN region.

As these ASEAN economies map out strategies to sustain their past performance, there is a consensus that the region has to deepen its links within the East Asian and GPN nexus, on the one hand, and to address how to overcome the middle-income trap, on the other hand. One of the proposed strategies is the promotion of innovation and creativity in a highly competitive and interconnected global setting. Education, research and development (R&D) as well as the influx of creative and highly skilled talents through a more liberalized immigration regime will definitely influence how innovation and creativity will take shape in the region in the near future.

The capacity of ASEAN Member States (AMSs) to adapt technologies and innovate does not only depend on the quality of laboratories and other physical infrastructure but perhaps, more fundamentally, on the quality of its human resources as well, especially scientific and engineering human capital.

This paper looks into the scientific and engineering human capital in ASEAN, examines the ASEAN education system's capacity to produce the scientific and engineering capital in the context of competitor-countries such as China and India, and draws lessons and insights from the research literature and experiences of other countries.

The following are the objectives of the paper:

1) To trace the role of human capital in the economic growth
2) To trace the role of human capital in the innovation process

3) To trace the link of engineering and technology education in the development of innovation and technology
4) To cite examples of development of innovation in China, India, Japan, and Korea
5) To learn from the experiences of countries in the region that are currently cooperating toward engineering education
6) The emerging engineering education for the 21st century
7) What policy recommendations are needed to enhance engineering education and to get it to contribute to R&D and innovation.

2. Role of Human Capital in Economic Growth

In trying to understand the role of human capital in economic growth, one must look at it from the evolution of growth theory, starting from the classical model of Solow, then moving to Denison's explanation of the Solow residuals, to Becker's findings on the role of education, and finally, to Romer's model of endogenous growth.

One of the earlier growth theories is the model proposed by Solow (1957), which suggests that growth is accounted not only by changes in factor inputs, labor and capital, but by technical change. Technical change accounts for *any kind of shift* in the production function that may come from slowdowns, speedups, education, total factor productivity (TFP), etc. (Solow, 1957). This study was a landmark in growth accounting although it was not the first in claiming that labor productivity growth in the US was attributed to TFP's residual contribution (Crafts, 2008). Such has been the conclusion of many works from the National Bureau of Economic Research (NBER) such as Fabricant (1954) and Abramovitz (1956), and the pioneering work of Tinbergen (1942).

The Solow model is primarily a model of capital accumulation. Its applications on growth accounting show that technological progress is the primary determinant of growth of labor productivity (that is, output per worker) in the long run. However, in the short run, growth is attributed to either technological progress or capital accumulation. Capital accumulation depends primarily on the following: the savings rate, the marginal productivity of capital, and the growth rate of population, technological progress, and depreciation. (Romer, 2001). Growth in output may therefore be attributed to the growth of labor and capital, and what is called the *Solow residuals* - i.e., the elasticity of output to technology multiplied by the rate of technological growth, which may be represented by TFP.

As accounted for in the *Solow residuals*, factor productivity and technical progress play a role in the growth of an economy. Edward Denison (1962) came up with a more significant approach in accounting for the factor residuals. He said that the contribution of labor quality was represented through the effect of education on earnings (Crafts, 2008). This gave rise to many studies trying to explain TFP in order to follow Denison's agenda of downsizing the sizeable residual.

Total factor productivity is a catch-all variable representing output that may not be explained by changes in factor inputs (Solow, 1957; Chen, n.d.). The TFP may not only be attributed to technological change, but also to human resource development and management, institutional restructuring, and socio-demographic factors (Jajri, 2007). It may be measured by the product of technical efficiency change (the catch-up) and technological change (innovation). Jajri (2007) summarizes the determinants of TFP as follows: (1) education and training of the workforce to upgrade skill and knowledge; (2) economic restructuring into sectors with higher productivity; (3) capital structure related to the investment in productive capital inputs; (4) technical progress related to the effective and efficient utilization of technology, capital, work attitudes, and management effectiveness; and (5) demand intensity that reflects the extent of the economy's productive capacity. Hall and Jones (1998) postulate that the differences across countries' physical and human capital accumulation, productivity, and output per worker are hinged on differences in social infrastructure. Social infrastructure pertains to the institutions and government policies that facilitate the economic environment. These include good governance, trade openness, facilities for technology transfer, and enforcement of intellectual property rights (Hall and Jones, 1998).

Psacharopoulous (1984), however, criticized that the Denison method of growth accounting underestimates the contribution of education to economic growth. This is because it neglects the educational maintenance component of a growing labor force, wherein educational systems are burdened with maintaining the level of educational attainment as well as augmenting it. Growth accounting typically determines the link of educational attainment to wages measured by surveys for skilled labor only, but fails to account for the effects of education on individuals that do not work for wages but rather for subsistence (i.e., farmers) (Psacharopoulous, 1984). Effects and contributions of public and private sector wage differentials, gender wage differentials, on-the-job training investment, migration, and life expectancy are also not easily accounted for (Psacharopoulous, 1984).

In trying to account for the factor residuals, it was suggested by Becker (1964) and Mincer (1974) that human capital serves as a strong driving force for economic growth. "Until the 1950s, economists generally assumed that labor power was given and not augmentable" (Becker, 1992). Becker and Mincer both found that investment in human capital generally increases the earnings of an individual. This has been known to be the human capital theory that suggests education and training---by imparting knowledge and skills---raise the productivity of workers, thereby raising their earnings in the future (Xiao, 2001; Mincer, 1974; Becker, 1964).

Although the earlier works of Becker and Mincer suggested the above, many works have explained differently how education enhances productivity: Spence (1973) argues that education serves as a market signal wherein employers look at educational attainment to gauge the potential productivity of the worker; Thurow (1975) adds that productivity is characterized by the job rather than the workers; Schultz (1975) suggests that education is the ability of workers to cope with disequilibria in the economy; Hall and Jones (1998) attribute this to differences in social infrastructure.

Human capital has served as a very contentious explanation to differences in earnings since these differentials may be due to several reasons, including the distinction between general and specific training, talents, family background, endowments, formal and informal education, and gender. In addition, human capital investments may be described by a life-cycle chronology (Mincer 1981): child care and development, formal school education, labor market mobility, job choice, job training, and work effort during working life, as well as health and other maintenance activities. Human capital has been seen to be a major contributor to economic growth, and although classical growth theories failed to classify the differences in human capital, this was later revived in the endogenous growth models (Becker, 1992).

Endogenous growth theory developed by Romer (1986) revived the study of economic growth because of the shortcomings of the classical models. His alternative model eliminates the assumption of decreasing returns to capital as he broadens the definition of capital to include human capital or knowledge capital. On the other hand, while it may not be possible for firms to experience increasing returns, it is very likely for an industry. Increasing returns of capital plays a central role in Romer's model, along with decreasing returns to knowledge. Per-capita output may grow without bound---that is, without being limited by decreasing returns to capital, and possibly monotonically increasing over time (Romer 1986). Romer's model posits that in the long run, growth is driven primarily by the accumulation of knowledge by forward-looking, profit-maximizing agents.

Education and technological progress are not exogenous factors. In fact, they are endogenously determined by several factors such as the savings rate and interest rate. Human capital is different from knowledge capital as well. Human capital encompasses health, education and training, which at first glance may be equal to knowledge capital. Human capital is a rival good in nature.

On the other hand, knowledge capital is a non-rival good, because it entails investment in R&D, which may not be kept to individual agents themselves, but is available for all individuals to benefit (Romer, 1990). This knowledge capital interacts with the other factor inputs to enhance their productivity, and thereby facilitate increasing returns.

3. Role of Human Capital in the Innovation Process, Research and Development

The previous section had explained the important roles played by human resources in the development of nations. Initially, the economy sourced its unskilled labor from its vast human wealth. As the economy develops, the needed skilled manpower is supplied by human capital endowed with training, education, and improved health. Subsequently, as the economy advances, more sophisticated human resources form the core of the country's knowledge capital.

Human capital has an overriding influence on the development of new innovations, as well as the R&D of new technologies (Tullao, 2012). A country's labor force should have sufficient human capital to conduct research that will contribute to the nation's knowledge capital. Such nation's capacity to innovate will eventually determine its competitiveness. This covers technological improvements such as the development and diffusion of new products and services, and organizational and institutional innovations such as new marketing strategies, management, policies, new services, and improved approaches to internal and external communications positioning (Tullao, 2012).

In this light, two primary concerns arise when it comes to the development of human capital in countries: the supply of educated manpower should be congruent with the demand for educated manpower; and the country's level of educational development should match its level of technological development. Otherwise, a set of problems may arise, including mismatch of talents and skills, unemployment of the educated, and brain drain.

3.1. Congruence between Supply of and Demand for Educated Manpower

3.1.1. Mismatch of Talents and Skills

Should the supply of the educated manpower be incongruent with the demand for them, a mismatch of talents and skills may arise. Simply put, this means people with a particular skillset take up jobs that require a different skillset. Desjardins and Rubenson (2011) differentiate the concept of skill mismatch from education mismatch by defining the former as one that pertains to the "right" education and the "right" skillsets required by occupations (while the latter, education mismatch, will be discussed in the next section). Quintini (2011) further defines skills mismatch as either skill deficits (the inadequacy of workers' skills relative to the job requirements), or skill underutilization (where workers' skills exceed job requirements). This makes up the notion of *horizontal mismatch* (Desjardin and Rubenson 2011).

Education mismatch is less precise in accounting for skills because it does not account for the gain or loss of skills that follow the attainment of qualifications in the workplace as well as relevant experience. This mismatch is primarily caused by asymmetric information, mobility costs, and principal-agent problems (Tullao, Rivera, and See 2012). Meanwhile, the largest factor to the skill mismatch would be asymmetric information: a lack of linkage between human talents and skills, and the requirements of enterprises.

As mentioned earlier, the mismatch is attributed greatly to the imbalance between demand for and supply of labor. On the one hand, individuals are naturally inclined to over-invest in education and training because it increases their productivity and hence their earnings in the future (Linsley 2005) and supposedly, their employability and career mobility (Sicherman and Galor 1990). On the other hand, firms are left to adjust their production process to accommodate an increasingly skilled workforce (Tullao, Rivera, and See, 2012). On the supply side, the mismatch is due to inadequacies of the education and the training system, wherein the solution requires either a decrease of produced qualifications or an increased responsiveness to the needs of the labor market (Desjardins and Rubenson, 2011). On the demand side, the mismatch is attributed to inadequacies of labor market practices, wherein the solution requires enterprises to provide additional education as well as to be ready to adopt advancements in their technologies; otherwise, they may underutilize highly skilled labor, contributing further to the skill mismatch (Desjardins and Rubenson, 2011).

According to the 2012 Talent Shortage Survey of the Manpower Group (2012), nearly 45 percent of employers in the Asia Pacific continue to encounter talent shortages in 2011 due to post-recession repercussions. This percentage has increased from 28 percent in 2006. Specifically, this talent shortage is experienced by nearly 81 percent of employers in Japan: 50 percent in Australia; and 48 percent in India and New Zealand. Occupations that are most difficult to fill are sales representatives, engineers, technicians, skilled trade workers, IT Staff, Accounting and Finance staff, management and executives, laborers, researchers, and Marketing and Public Relations staff. The leading cause of the difficulty is attributed by 35 percent of employers to the lack of available applicants, followed by lack of technical competencies (hard skills) (29%), lack of employability skills (soft skills) (28%), lack of experience (17%), individuals looking for more pay than what is offered (13%), undesirable geographic locations (6%), and poor image of the business sector (5%) (Manpower Group 2012).

3.1.2. Educated Unemployment

When the demand and supply of educated manpower are incongruent, a consequence is unemployment---and more likely, educated unemployment. Educated unemployment is when there is an excess in the production of highly-skilled manpower that is unable to find employment opportunities. Desjardin and Rubenson (2011) and Quintini (2011) qualify this as education mismatch---or qualification mismatch---which is the more-studied concept than skill mismatch because of the ease in the procurement of data. The concept refers to differences between educational qualifications held by individuals and those required by the employer for adequate performance. Workers are either over-qualified (over-educated), under-qualified (under-educated) or required-qualification (required-educated).

As discussed in the previous section, imbalances in the demand for and supply of educated labor may arise because people have the tendency to invest in higher education, while firms are faced with rigidities in adjusting to technological changes. This imbalance may lead to the phenomenon of educated unemployment. At the aggregate level, skill mismatches are likely to increase structural unemployment and unemployment persistence (Quintini 2011; Olitsky 2008). If people are under-skilled or under-qualified, they may not be hired by companies. On the other hand, if candidates are over-skilled or over-qualified, companies may not have sufficient resources or may not have adjusted to the availability of these skills. Such scenario may lead to either educated unemployment or under-utilization of skills.

Table 1: Total Unemployment in the ASEAN as Percentage of Labor Force.

ASEAN Countries	Total Unemployment		
	2001	2005	2010
Brunei Darussalam	-	-	2.7*
Cambodia	1.7	-	-
Indonesia	8.1	11.2	7.1*
Lao PDR		1.4	-
Malaysia	3.5	3.5	3.2*
Myanmar	-	-	-
Philippines	11	7.7	7.4
Singapore	2.9	5.6	3.1*
Thailand	2.6	1.3	-
Vietnam	2.8	-	-

Note: *taken from ASEAN (2012). ASEAN Community in Figures 2011.
Source: World Bank.

Table 1 shows that unemployment has decreased and has remained low in 2010. This indicates that companies are hiring. However, this does is not an indication that the right skills are being employed, and in fact might still be facing educated unemployment.

Table 2: Unemployment by Educational Attainment in the ASEAN (% of Unemployment)

ASEAN Countries	Primary Unemployment			Secondary Unemployment			Tertiary Unemployment		
	2001	2005	2010	2001	2005	2010	2001	2005	2010
Brunei Darussalam	86.4	-	-	3.6	-	-	4.7	-	-
Cambodia	-	-	-	-	-	-	-	-	-
Indonesia	46	49.4	-	36.6	36.8	-	6.7	5.9	-
Lao PDR	-	-	-	-	-	-	-	-	-
Malaysia	13.4	11.5	-	68.9	62.4	-	14.7	23.6	-
Myanmar	-	-	-	-	-	-	-	-	-
Philippines	21.3	15.2	13.1	43.2	44.5	45.2	33.5	39.5	41.2
Singapore	41.2	-	-	26.7	-	-	32.1	-	-
Thailand	-	39.7	-	-	46.3	-	-	0.2	-
Vietnam	-	-	-	-	-	-	-	-	-

Source: World Bank.

By disaggregating the unemployment according to educational attainment, one finds that the largest proportion of the unemployed in 2005 are those with secondary education (Table 2). This indicates that a significant portion of the unemployed is under-qualified. Such is mostly evident in Malaysia, the Philippines, Indonesia, and Thailand. Meanwhile, statistics on the unemployed that have attained tertiary-level education shows Malaysia registering 23.6 percent of tertiary-level unemployed in 2005; and Singapore with 32.1 percent in 2001. The Philippines has the highest level at 41.2 percent in 2010---which is a close second to the 45.2 percent of its secondary-level unemployed. This represents direct evidence of educated unemployment, particularly in the Philippines.

A particular case worth exploring on distortions caused by the international migration of Filipino nurses was presented by Tullao, *et al.* (2010). There has been a high demand for nursing graduates in developed countries, inducing many graduates to migrate because of the high wage differential. Because the rate-of-return to nursing has remained high in the previous decade, an accompanying increase in the demand for nursing education ensued. However, because of the low passing rate of nursing graduates in both the national and international licensure examinations, only a small proportion get to migrate and reap the rate-of- return of their investment. The remaining proportion that was unable to migrate was left unemployed due to a weak domestic absorption or if employed, most use their hospitals as training grounds for their dream to migrate. Furthermore, those that did not pass the national licensure examination either retake it recursively, or resort to alternative employment that may not be related to nursing. This may account greatly for why the Philippines has a high level of tertiary-level unemployment. This also induces skills and qualification mismatches especially if the graduates sought alternative employment.

3.1.3. Brain Drain

If the demand of educated manpower in a country is not enough to cater to the large supply of educated manpower, (ie., not enough jobs to accommodate graduates), these graduates may seek alternative employment in other countries. Hence, here is where the phenomenon of brain drain comes in. Because of the skill and qualification mismatch, over-qualified workers tend to be underpaid, and because of this, they have very high mobility (Quintini, 2011). When wage differentials among countries exist, over-qualified individuals have incentive to migrate.

Table 3: Percentage of Tertiary-level Emigrants from ASEAN Countries

ASEAN Country	1990	2000
Brunei Darussalam	22.12	15.05
Cambodia	22.51	21.47
Indonesia	5.56	2.92
Lao PDR	30.21	37.25
Malaysia	26.27	10.54
Myanmar	4.31	3.93
Philippines	12.57	13.55
Singapore	25.34	14.48
Thailand	2.39	2.21
Vietnam	23.77	26.99

Source: World Bank.

As can be seen in Table 3, the proportion of tertiary-level emigrants from ASEAN countries had fluctuated from 1990 to 2000. Emigrants with tertiary-level education have decreased for most ASEAN countries. However, it increased for Lao PDR from 30.2 percent in 1990 to 37.2 percent in 2000; for the Philippines from 12.6 percent in 1990 to 13.6 percent in 2000; and for Vietnam from 23.77 percent in 1990 to nearly 27 percent in 2000. In the Philippines, particularly, its service export is the primary driving industry, growing from 39.7 percent of total employment in 1990, 46.7 percent in 2000 and 50 percent in 2009 (World Bank 2012).

3.2. Various Stages of Technology Development

Unemployment as well as brain drain can also be addressed by matching the level of technological development and the stage of economic development of a country. Aside from pursuing efficient use of resources, this matching can bring about economic growth.

3.2.1. Stage of Traditional Technology

At the initial stage of economic development, both the production and distribution processes are described with the use of technologies. These simple technologies are usually implemented in traditional agriculture and cottage industries. Their methods of production need uncomplicated implements and unskilled, if not semi-skilled, workers for manual labor.

In Table 4, one observes a decreasing trend in the share of agriculture in gross domestic product of various economies over time. Likewise, there is a decline in the share of agricultural employment in total employment. This is a structural transformation often experienced by economies as they grow over time. Although they follow a similar trend, the share of valued added is significantly lower than the share of employment. This may imply that agricultural productivity in several economies in the region is low or growing slowly.

Also, a substantial portion of the agricultural labor force is unable to move or transfer to other emerging and more productive sectors. This inability to move can be attributed, to some extent, to the labor force's inability to meet the skills required in other sectors. These workers may be coming from a traditional technology that uses unskilled and semi-skilled workers.

Table 4: Gross Value Added as percentage of GDP, and Employment as percentage of Total Employment in ASEAN+4 Agriculture

ASEAN Country		1960	1970	1980	1990	2000	2010
Brunei Darussalam	GVA	-	-	0.63	0.97	1.02	0.76
	Employment	-	-	-	-	-	-
Cambodia	GVA	-	-	-	-	37.84	36.02
	Employment	-	-	-	-	73.70	-
Indonesia	GVA	51.46	44.94	23.97	19.41	15.60	15.31
	Employment	-	-	56.4	55.9	45.3	38.3
Lao PDR	GVA	-	-	-	61.23	45.17	32.75
	Employment	-	-	-	-	-	-
Malaysia	GVA	34.32	29.44	22.61	15.22	8.60	10.39
	Employment	-	-	37.2	26	18.4	-
Myanmar	GVA	-	38.00	46.54	57.26	57.24	-
	Employment	-	-	67.1	69.7	-	-
Philippines	GVA	26.94	29.52	25.12	21.90	13.97	12.31
	Employment	-	-	51.8	45.2	37.1	-
Singapore	GVA	-	-	1.57	0.34	0.10	0.03
	Employment	-	-	1.3	0.4	-	-
Thailand	GVA	36.44	25.92	23.24	12.50	9.02	12.39
	Employment	-	-	70.8	64	48.8	-
Vietnam	GVA	-	-	-	38.74	24.53	20.58
	Employment	-	-	-	-	65.30	-
China	GVA	22.32	35.22	30.17	27.12	15.06	10.10

	Employment	-	-	68.7	60.1	50	-
India	GVA	42.56	41.95	35.39	29.02	23.12	17.98
	Employment	-	-	-	-	59.8	51.1
Japan	GVA	-	5.13	3.08	2.09	1.50	1.159
	Employment	-	-	10.4	7.2	5.1	3.7
Korea	GVA	-	29.25	16.17	8.94	4.63	2.64
	Employment	-	-	34	17.9	10.6	6.6

Source: World Bank.

3.2.2. Stage of Borrowed Technology

As the economy further develops, the share of the industrial sector in generating income and employment becomes more prominent when compared to that of the agricultural sector. This structural shift can be due to changes in the tastes of an expanding and increasingly affluent population as well as an adjustment mechanism to the limits of agricultural land for further cultivation.

Accompanying these structural changes in production and demand is the change in the utilization of technology. The simple implements and unskilled workers of the traditional agriculture may no longer be applicable and efficient in the mechanized and large-scale manufacturing process. Instead, a more advanced technology, often borrowed from more developed economies, may be more apt for this sector.

At the initial stage of industrial development, a labor-surplus economy may exploit the opportunities offered by light- and labor-intensive manufactures. In such a setting, the borrowed technology used for labor-intensive manufacturing may require middle-skilled and technical workers. These workers may require have some basic education and technical/vocational training to implement more improved production techniques.

In Table 5, notice that at the early stage of an industrial development, the share of industrial sector in generating value added increases over time until the share stabilizes. The proportion of employment in the industrial sector is likewise increasing. Although both shares are increasing, it is to be noted that the share in value added is substantially higher that the share in employment, which is the exact opposite of the temporal development in the agricultural development. For one, this may imply that the productivity in the industrial sector is higher than the productivity in agriculture. Such improvement in productivity may be attributed to the utilization of improved technology borrowed externally.

Table 5: Gross Value Added as percentage of GDP, and Employment as percentage of Total Employment in ASEAN+4 Industry

ASEAN Country		1960	1970	1980	1990	2000	2010
Brunei Darussalam	GVA	-	-	84.82	61.56	63.67	66.77
	Employment	-	-	-	-	-	-
Cambodia	GVA	-	-	-	-	23.03	23.25
	Employment	-	-	-	-	8.4	-
Indonesia	GVA	15.05	18.69	41.72	39.12	45.93	46.98
	Employment	-	-	13.1	13.7	17.4	19.3
Lao PDR	GVA	-	-	-	14.51	16.61	31.80
	Employment	-	-	-	-	-	-
Malaysia	GVA	19.40	27.39	41.04	42.20	48.32	41.09
	Employment	-	-	24.1	27.5	32.2	-
Myanmar	GVA	-	14.18	12.67	10.53	9.69	-
	Employment	-	-	9.8	9.2	-	-
Philippines	GVA	31.27	31.89	38.79	34.47	34.46	32.57
	Employment	-	-	15.4	15	16.2	-
Singapore	GVA	-	-	36.16	31.88	34.54	27.89
	Employment	-	-	35.7	37.9	33.8	-
Thailand	GVA	18.52	25.31	28.68	37.22	41.99	44.65
	Employment	-	-	10.3	14	19	-
Vietnam	GVA	-	-	-	22.67	36.73	41.10
	Employment	-	-	-	-	12.4	-
China	GVA	44.89	40.49	48.22	41.34	45.92	46.72
	Employment	-	-	18.2	21.4	22.5	-
India	GVA	19.30	20.48	24.29	26.49	26.11	27.57
	Employment	-	-	-	-	16.1	22.4
Japan	GVA	-	43.53	39.03	37.52	31.12	27.38
	Employment	-	-	35.3	34.1	31.2	25.3
Korea	GVA	-	26.02	36.55	41.57	38.06	38.82
	Employment	-	-	29	35.4	28.1	17

Source: World Bank.

3.2.3. Stage of a Mix of Borrowed Technology and Incipient Local Technology

The next stage of industrial development may be characterized by the development of heavy manufacturing that will supply intermediate inputs in the production of labor-intensive consumer goods. To maintain competitiveness in the production of labor-intensive manufacturing as well as to expand further their global market, the economies have to develop their intermediate inputs industries using foreign and locally developed technologies. Here, the engineers, technicians, technologists and other educated professionals are needed to further exhaust the comparative advantage of the country along its resource endowments. The development of middle-skilled and technical workers has been critical to the growth of the ASEAN countries, particularly in helping them reach middle-income status (Tullao, 2012).

In Table 6, one observes that the economies in the region are becoming more open to international trade as shown by the share of export to GDP. Since exports are being used as a driver for economic growth, continued prosperity of the economies will depend on how they can make their exports more competitive through the use of borrowed and local technology.

Table 6: Goods and Service Exports of ASEAN+4 Countries as Percentage of GDP

ASEAN Country	1960	1970	1980	1990	2000	2010
Brunei Darussalam	-	-	93.36	61.81	67.35	81.44
Cambodia	13.90	5.76	-	-	49.85	54.08
Indonesia	15.04	13.45	34.18	25.33	40.98	24.62
Lao PDR	-	-	-	11.33	30.10	35.54
Malaysia	50.60	41.41	56.69	74.54	119.81	93.75
Myanmar	19.69	5.21	9.10	1.94	0.49	-
Philippines	11.95	21.58	23.57	27.52	51.37	34.80
Singapore	-	126.10	202.61	177.45	192.34	207.17
Thailand	15.68	14.99	24.11	34.13	66.78	71.29
Vietnam	-	-	-	36.04	55.03	77.53
China	-	2.61	10.65	16.07	23.33	30.61
India	4.39	3.72	6.03	6.93	12.82	21.94
Japan	10.72	10.59	13.42	10.29	10.88	15.19
Korea	3.16	13.63	32.06	27.95	38.56	52.28

Source: World Bank.

3.2.4. Stage of Developing Competitive Technologies

After heavy manufacturing of intermediate inputs, the economy may move further by developing differentiated manufactures, innovative products and high value-added services. Once an economy has exhausted its comparative advantage given its resource endowments as well as the availability of borrowed technology, the next step to its development lies in its capacity to innovate, or generate knowledge capital (Romer 1986) so as to develop its own technology (Tullao, 2012). This requires the production of scientists, highly educated engineers and highly skilled professionals. This also requires strong linkages between higher education and R&D institutions in the public and the private sectors, which will significantly depend on the level of higher education in the country. Innovation entails the production and trading of highly differentiated commodities, improved management and supervisory practices, improved regulations and standards in conducting business, as well as better governance practices.

As shown in Table 7, the share of the services sector is increasing over time as a proportion of GDP. Also, the share of services employment is increasing over time in several economies. What is observable in this table is that there are mixed results on the magnitude of the share of value added relative to the share of employment. There are economies with higher values for share in value added compared with share in employment, thus reflecting a highly productive service sector. On the other hand, there are economies with higher share of employment relative to the share of value added. Aside from productivity differences, this variation may be due to the magnitude of low value-added sub-sectors within the services sector.

However, by referencing back to Table 5, one can note that economies that have developed their own technologies such as Japan and South Korea have produced and exported innovative and differentiated manufactures. These are also the same economies that exhibit higher productivities in the industrial sector as well as very productive services sectors in more recent years.

Table 7: Gross Value Added as Percentage of GDP, and Employment as percentage of Total Employment in ASEAN+4 Services

ASEAN Country		1960	1970	1980	1990	2000	2010
	GVA	-	-	14.54	37.48	35.31	32.47
Brunei Darussalam	Employment	-	-	-	-	-	-
	GVA	-	-	-	-	39.13	40.73
Cambodia	Employment	-	-	-	-	17.9	-
	GVA	33.50	36.37	34.31	41.47	38.47	37.71
Indonesia	Employment	-	-	30.4	30.2	37.3	42.3
	GVA	-	-	-	24.26	38.23	35.45
Lao PDR	Employment	-	-	-	-	-	-
	GVA	46.28	43.17	36.35	42.59	43.08	48.52
Malaysia	Employment	-	-	38.7	46.5	49.5	-
	GVA	-	47.82	40.79	32.20	33.07	-
Myanmar	Employment	-	-	23.1	21	-	-
	GVA	41.79	38.59	36.10	43.62	51.58	55.18
Philippines	Employment	-	-	32.8	39.7	46.7	-
	GVA	-	-	62.26	67.78	65.36	72.08
Singapore	Employment	-	-	62.6	61.7	65.5	-
	GVA	45.04	48.78	48.08	50.28	48.99	42.96
Thailand	Employment	-	-	18.9	22	32.2	-
	GVA	-	-	-	38.59	38.73	38.32
Vietnam	Employment	-	-	-	-	22.3	-
	GVA	32.80	24.29	21.60	31.54	39.02	43.19
China	Employment	-	-	13.1	18.5	27.5	-
	GVA	38.25	37.22	39.92	44.18	50.76	54.45
India	Employment	-	-	-	-	24.1	26.5
	GVA	-	51.34	57.89	60.39	67.38	71.46
Japan	Employment	-	-	54	58.2	63.1	69.7
	GVA	-	44.72	47.28	49.49	57.31	58.54
Korea	Employment	-	-	37	46.7	61.2	76.4

Source: World Bank.

Table 8: ASEAN+4: Research and Development Expenditures as Percent of GDP

ASEAN Country	2000	2001	2002	2003	2004	2005	2006	2007
Brunei Darussalam	-	-	0.016	0.018	0.037	-	-	-
Cambodia	-	-	0.050	-	-	-	-	
Indonesia	0.068	0.048	-	-	-	-	-	-
Lao PDR	-	-	0.036	-	-	-	-	-
Malaysia	0.469	-	0.653	-	0.600	-	0.635	-
Myanmar	0.113	0.071	0.162	-	-	-	-	-
Philippines	-	-	0.137	0.130	-	0.111	-	0.110
Singapore	1.851	2.057	2.098	2.048	2.132	2.195	2.169	2.372
Thailand	0.252	0.263	0.244	0.262	0.255	0.235	0.249	0.214
Vietnam	-	-	0.193	-	-	-	-	-
China	0.903	0.951	1.070	1.134	1.223	1.325	1.388	1.396
India	0.771	0.748	0.737	0.729	0.744	0.779	0.767	0.758
Japan	3.043	3.123	3.165	3.199	3.167	3.323	3.405	3.444
Korea	2.296	2.473	2.404	2.486	2.683	2.792	3.009	3.210

Source: World Bank.

Table 8 shows that among the ASEAN nations, only Singapore registered significant R&D expenditures over the past decade. That is, it has 2.37 percent of its GDP spent on R&D as of 2007. Other ASEAN members' spending on R&D pale in comparison to Singapore's, and this may reflect poorly on their capacity to generate knowledge capital and hence, to innovate. In fact, only Singapore comes close to the values of the Plus-4 countries.

Among the Plus-4 countries, Japan and Korea have R&D spending in 2007 accounting for 3.4 percent and 3.2 percent of GDP, respectively. Meanwhile, China spends 1.39 percent and India spends 0.75 percent of their GDP for R&D. Although R&D expenditures in China and India are relatively small as compared to Japan and Korea, theirs are still a lot larger than the average across ASEAN members except Singapore

Table 9: ASEAN Researchers in R&D (Per Million People)

ASEAN Country	2000	2001	2002	2003	2004	2005	2006	2007
Brunei Darussalam	-	-	289.83	280.99	286.28	-	-	-
Cambodia	-	-	17.36	-	-	-	-	-
Indonesia	210.80	197.60	-	-	-	-	-	-
Lao PDR	-	-	15.83	-	-	-	-	-
Malaysia	274.31	-	291.94	-	495.09	-	364.64	-
Myanmar	-	12.66	18.35	-	-	-	-	-
Philippines	-	-	-	71.21	-	80.61	-	78.47
Singapore	4243.82	4205.13	4493.86	4900.54	5134.23	5576.49	5676.57	5954.64
Thailand	-	277.16	-	277.10	-	307.44	-	315.53
Vietnam	-	-	115.87	-	-	-	-	-
China	547.67	581.21	630.30	666.55	712.20	855.54	930.91	1077.11
India	110.01					135.81		
Japan	5150.89	5187.09	4942.83	5169.98	5176.17	5385.04	5415.61	5408.91
Korea	2356.50	2950.34	3057.18	3244.07	3335.84	3822.21	4231.01	4672.24

Source: World Bank.

Among the ASEAN nations, it is no surprise that Singapore has the most number of researchers involved in the generation of new knowledge (Table 9). Singapore has 5,954.6 researchers for every million in its populace---considering that the country only had around 4.588 million people in 2007 (World Bank 2012). The next largest would be Malaysia, which had about 364.63 researchers (a decline from 495.09 in 2004) per million people in 2006. According to the latest data, Thailand had 315.53 researchers per million people in 2007. The Philippines trails behind with only 78.47 researchers per million people. Brunei Darussalam, Indonesia, and Vietnam registered rising record-highs within the period 2000-2007. Brunei Darussalam had about 289.82 per million in 2002, Indonesia had about 210.8 in 2000, and Vietnam had 115.87 in 2002. Cambodia, Lao PDR, and Myanmar trail largely during the early part of the sample.

Among the Plus-4 countries, India appears to be the most similar to the ASEAN in its number of researchers. Once again, for most ASEAN countries, the number of researchers for every million people pales in comparison to that of China, Japan, and Korea. As of 2007, China had 1,077.11 researchers for every million. Japan and

Korea had 5,408.911 and 4,672.236 researchers per million (and this is most certainly because their population is not as large as China's). Only Singapore's number appears comparable to Japan and Korea's, and that is because all three have a very small population.

Table 10: Cumulative Number of Scopus-listed Documents per ASEAN University Network (AUN) Member-University, and Top Universities in Japan and China

Country	AUN Member	# of Documents in Scopus
Brunei Darussalam	Universiti Brunei Darussalam	874
Cambodia	Royal University of Phnom Penh	52
	Royal University of Law and Economics	n.a.
Indonesia	Gadjah Mada University	1,531
	University of Indonesia	2,598
	Universitas Airlangga	484
Lao PDR	National University of Laos	171
Malaysia	University of Malaya	21,240
	Universiti Sains Malaysia	16,824
	Universiti Kebangsaan Malaysia	14,800
	Universiti Putra Malaysia	16,011
Myanmar	Institute of Economics	n.a.
	University of Yangon	109
Philippines	De La Salle University	1,028
	University of the Philippines, Diliman	2,108
	Ateneo de Manila University	440
Singapore	National University of Singapore	74,560
	Nanyang Technological University	44,486
	Singapore Management University	1,832
Thailand	Chulalongkorn University	16,599
	Burapha University	793
	Mahidol University	20,164
	Chiang Mai University	8,485
Vietnam	Vietnam National University, Hanoi	1,214
	Vietnam National University, Ho Chi Minh	196
Japan	University of Tokyo	181,112
	Kyoto University	144,067
	Osaka University	115,368
China	Chinese Academy of Sciences	91,183
	Tsinghua University	107,851
	Zhejiang University	90,615

Source: Scopus.

Table 10, which shows the number of Scopus-listed articles for each ASEAN University Network (AUN) member-university in each ASEAN country, further indicates the ASEAN's capacity to conduct R&D. Evidently, the two universities from Singapore---National University of Singapore and Nanyang Technological University---have the highest cumulative number of Scopus-listed documents in the ASEAN. The National University of Singapore has produced 74,560 documents, and the Nanyang Technological University has reached 44,486.

These Singapore-based schools are followed by the University of Malaya, Malaysia, with 21,240 documents; Mahidol University, Thailand, with 20,164 documents; Unversiti Sains Malaysia, Malaysia, with 16,824 documents; Chulalongkorn University, Thailand, with 16,599 documents; Universiti Putra Malaysia, Malaysia, with 16,011 documents; and Universiti Kebangsaan Malaysia, Malaysia, with 14,800 documents. These universities have already produced quite a number of documents nearly comparable to that of Singapore's. The rest of the universities in other ASEAN member-countries, however, are lagging behind in comparison to Singapore, Malaysia, and Thailand. Even more so, note that Singapore---which is ASEAN's apparent leader in the number of documents produced---only accounts for less than half of Japan's University of Tokyo, which alone produced 181,112 documents; Kyoto University, which produced 144,067 documents; and Osaka University, which released 115,368 documents.

Neither can the ASEAN universities compare with China's Tsinghua University, which produced 107,851 documents; the Chinese Academy of Sciences, which had 91,183 documents; and Zhejiang University, which made 90,615 documents. Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Myanmar, the Philippines, and Vietnam need to develop their R&D capacity so as to catch up with the region's leaders as well as with neighboring countries. Otherwise, the ASEAN may be seen as a laggard in terms of its capacity to produce innovations, although Singapore, Thailand and Malaysia may be considered as exceptional cases.

Table 11: Rankings of ASEAN and Other Selected Countries by Documents Listed in SCImago Journal for the period 1996-2007

SJR Rank	Country	Documents
133	Brunei Darussalam	1,064
128	Cambodia	1,296
63	Indonesia	16,139
141	Laos	853
42	Malaysia	75,530
139	Myanmar	906
70	Philippines	11,326
32	Singapore	126,881
43	Thailand	69,637
67	Viet Nam	13,172
2	China	2,248,278
10	India	634,472
4	Japan	1,604,017
13	South Korea	497,681
1	United States	6,149,455

Source: SCImago Journal & Country Rank. Available at www.scimagojr.com .

Table 11 presents the global ranking of the ASEAN member-states and a few selected countries, according to SCImago Journal and Country Rank (www.scimagojr.com), a database of indicators developed from the information in the Scopus database. These indicators are used to analyze the progress of scientific disciplines by measuring the number of documents produced (conference papers, journal publications, book publications), citations, and the H index. Based on the number of documents produced (126,881), Singapore stands out again as the one that has produced the most documents from 1996-2007, and ranks 32nd globally (out of 238 countries). This is followed by Malaysia (ranking 42nd with 75,530 documents), Thailand (43rd with 69,637 documents), Indonesia (63rd with 16,139 documents), Vietnam (67th with 13,172 documents), and the Philippines (70th with 11,326 documents). These six ASEAN member-countries reflect a relatively better research capacity as compared to the remaining four ASEAN nations. Also, on the global scale, these six countries belong to the upper 30 percent of the world's producer of documents.

While Cambodia, Brunei Darussalam, Myanmar, and Lao PDR have only produced a handful of documents compared to the other ASEAN members, they may still fare relatively better than the rest of the world, given that they still belong to the upper 60 percent in terms of documents produced.

Collectively, research in the ASEAN still lags behind that of neighboring countries such as India and South Korea, and pales in comparison with the world's research leaders: the United States of America, China, United Kingdom (not reported in Table 11), Japan, Germany, and France (not reported in Table 11), all of which produced documents over one million. These country rankings are available at http://www.scimagojr.com/countryrank.php.

4. State of Engineering Education in the Region

The development of knowledge capital is crucial in the creation of innovative products and services. Meanwhile, the production of highly skilled professionals, scientists, technologists, and engineers is the foundation in the development of knowledge capital. Thus, it is important to know how these highly specialized skilled professionals are formed. This section will review the state of engineering education in the region, with a specific focus on regional cooperation to improve the pool of engineering talents in the region.

Looking back at Table 10, it may be said that as a whole, the capacity of the ASEAN to produce knowledge still has to be developed. While Singapore, a small country, already has a sizeable research base, all the other ASEAN members combined could only produce about half of Singapore's research output. This in itself implies a need to further develop the ASEAN's capacity to produce knowledge, and eventually, to innovate.

Central to the development of engineering education in the ASEAN is the ASEAN University Network (AUN)-Southeast Asia Engineering Education Development Network (SEED-Net), an autonomous sub-network of the AUN established in April 2001. Since it started operating in 2003, the AUN SEED-Net has aimed to promote human resource development in engineering in the region (AUN SEED-Net 2012). It is a collaboration among the ASEAN's 19 leading higher education institutions and supported by 11 leading Japanese universities through the Japan International Cooperation Agency (JICA). Table 12 shows the members of AUN SEED-Net while Table 13 lists the host universities for each engineering field.

Table 12: AUN SEED-Net Member Universities

Brunei Darussalam	Institut Teknologi Brunei (ITB-BRU) Universiti Brunei Darussalam (UBD)
Cambodia	Institute of Technology of Cambodia (ITC)
Indonesia	Universitas Gadjah Madah (UGM) Institut Teknologi Bandung (ITB-INA) Institut Teknologi Sepuluh Nopember (ITS) Universitas Indonesia (UI)
Lao PDR	National University of Laos (NUOL)
Malaysia	Universiti Malaya (UM Universiti Putra Malaysia (UPM) Universiti Sains Malaysia (USM) Universiti Teknologi Malaysia (UTM)
Myanmar	University of Yangon (UY) Yangon Technological University (YTU)
Philippines	De La Salle University (DLSU) Mindanao State University-Illigan Institute of Technology (MSU-IIT) University of the Philippines-Diliman (UPD)
Singapore	Nanyang Technological University (NTU) National University of Singapore (NUS)
Thailand	Burapha University (BUU) Chulalongkorn University (CU) Kasetsart University (KU) King Mongkut's Institute of Technology Ladkrabang (KMITL) Thammasat University (TU)

Vietnam	Hanoi University of Science and Technology (HUST) Ho Chi Minh City University of Technology (HCMUT)
Japan	Hokkaido Univeristy (Hokkaido) Keio University (Keio) Kyoto University (Kyoto) Kyushu University (Kyoto) Nagoya University (Nagoya) National Graduate Institute for Policy Studies (GRIPS) Osaka University (Osaka) Shibaura Institute of Technology (SIT) Tohoku University (Tohoku) Tokai University (Tokai) Tokyo Institute of Technology (TIT) Toyohashi University of Technology (TUT) University of Tokyo (Tokyo) Waseda University (Waseda)

Source: AUN SEED-Net Factsheet.

Table 13: Host Institutions and Coordinating Japanese Universities for Each Engineering Field

Host Fields	Host Institutions	Field Coordinating Universities
Chemical Engineering (ChE)	<u>DLSU</u>, UGM, UM	Kyoto University <u>Tokyo Institute of Technology</u> The University of Tokyo
Civil Engineering (CE)	<u>CU</u>, TU, UM, UTM	<u>Hokkaido University</u> Tokyo Institute of Technology
Computer & Information Engineering (CIE)	<u>KMITL</u>, UGM	Hokkaido University <u>Tokai University</u> Toyohashi University of Technology
Electrical & Electronics Engineering (EEE)	<u>CU</u>, ITS, UM, UP	Keio University <u>Tokyo Institute of Technology</u>
Geological & Geo-Resource Engineering (GeoE)	CU, <u>UGM</u>, USM	Hokkaido University <u>Kyushu University</u> Waseda University
Materials Engineering (MatE)	UGM, UM, <u>USM</u>	Kyoto University Tokyo Institute of Technology <u>Toyohashi University of Technology</u>
Mechanical & Manufacturing Engineering (MME)	DLSU, <u>ITB-INA</u>, UM, UPM	<u>Keio University</u> Tokai University Toyohashi University of Technology
Energy Engineering (EnE)	<u>ITB-INA</u>, KMITL, USM	<u>Kyoto University</u> Kyushu University
Environmental Engineering (EnvE)	CU, ITB-INA, KU, <u>UPD</u>	Kyoto University <u>The University of Tokyo</u>
Natural Disaster (ND)	CU, ITB-INA, <u>UGM</u>	<u>Kyoto University</u> Kyushu University Tokyo Institute of Technology

Note: *underlined institutions are the leading host institutions.
Source: AUN SEED-Net.

The AUN SEED-Net's activities include

1) Providing linkage and strengthening linkages among member institutions, industry and communities;
2) Enabling systems to conduct research activities addressing regional issues;
3) Enhancing the capacity of member institutions' academic staff to perform research and education; and
4) Strengthening the academic network among member institutions and Japanese supporting universities (AUN SEED-Net 2012).

Within 2001-2011, AUN SEED-Net has increased the number of academic staff with higher degrees, improved graduate programs and the internationalization of member institutions; increased collaborative research with industries and member universities; increased research publications; launched the *ASEAN Engineering Journal*; increased exchanges in faculty and other resources; and conducted regular regional conferences. The most popular fields that have attracted nearly 160 masteral applications with 45 scholarships in 2011 are environmental engineering, civil engineering, and geological engineering. The most popular fields that have attracted nearly 33 doctoral applications in 2011 were environmental engineering, civil engineering, electrical and electronics engineering, information and communication technology, and chemical engineering (AUN SEED-Net, 2012). A PhD sandwich program, PhD in Japan, and PhD in Singapore programs were also established. Japanese professors have been dispatched to the ASEAN members to help facilitate research among academics in member universities.

In terms of collaborative research, AUN SEED-Net's collaborative research umbrella enables members to pool knowledge, expertise, and resources so as to solve common issues that are relevant to the ASEAN region. Table 14 summarizes the research thrusts of each engineering field and the higher institution leading the collaborative research.

Table 14: Collaborative Research Program of AUN SEED-NET in Various Fields of Engineering

Field	Higher Institution	Collaborative Research Umbrellas
CE	CU	**Transportation** - Improving Transportation Infrastructure Utilization by Effective Planning and Policies - Operations and Control of Transportation Infrastructure **Structure** - Strengthening of Structures - Structural Health Monitoring (Structural Assessments and Monitoring of Existing or Newly Constructed Infrastructure) - Local / Low-cost Material - High Performance / Durability of Concrete - Precast Structure - Seismic Performance of Infrastructure - Disaster Mitigation and Management **Geotechnic** - Innovation in Design and Construction of Infrastructure in Regional Subsoils **Construction Management** - Productivity Improvement of Infrastructure Construction in Developing Countries
EEE	CU	**Electronics** - Semiconductor Device Research Laboratory (SDRL) - Integrated Circuit Design and Application Research Laboratory (IDARL) - Bioelectronic Research Laboratory (BERL) **Control** - Control System Resarch Laboratory (CSRL) **Power** - Power System Research Laboratory (PSRL) **Communication** - Digital Signal Processing Research Laboratory (DSPRL) - Telecommunication System Research Laboratory (TSRL) - Electromagnetic Wave Research Laboratory (EWRL)
ChE	DLSU	**Environmental Protection Technologies**

		Catalysis Possible research: - Catalysis - Natural Gas Utilization - Nanotechnology - Biotechnology - Biofuels and Bioenergy - Environmental Engineering - Process Design, Systems Engineering, Process Control and Simulations - Renewable Energy: Development of Dye Sensitized Solar Cells - Natural Bioproducts - Supercritical Fluid Extraction - Carbon Capture, Fixation and Utilization
ICT	**KMITL**	**Applications of ICT** Applications of ICT in Telecommunication Industries Applications of ICT in Computer and Electronic Industries Applications of ICT in Electricity Industries
ME/AE	**ITB**	Vibration / Dynamic and Control
		Fracture Mechanics and Impact + Composite Material
		Internal Combustion Engine / Fuel Alternatives
		Refrigeration and Thermodynamics Properties
		Mass and Heat Transfer / Drying
		Aerodynamics / Flow Separation
		Flight Mechanics
GeoE	**UGM**	Petroleum Geology Exploration
		Coal Bed Methane
		Spatial and Temporal Relation between Volcanism and Hydrothermal System
		Mineral Resources Exploration - Characterization and Utilization of Bentonitic Tuff for Solving AMD Problem - Characterization and Utilization of Zeolitic Tuff for Groundwater Purifier - Characteristics of Volcanic Ash and Its Effect on Human Health

		Water Resources - Urban Groundwater Management - Drought and Groundwater Utilization - Groundwater Resources Assessment and Management - Conservation of Groundwater Recharge Area and Recharge Rate - Groundwater Management in Adaptation to Climate Change - Pollution Prediction and Control Site Selection for Hazardous Waste - Site Selection for Radioactive Waste - Site Selection for Liquid Hazardous Waste - Site Selection for Solid Hazardous Waste - Site Selection for Municipal Solid Waste
ManuE	**UM**	**Manufacturing Processes** Materials Processing / Powder Metallurgy / Coating Technology / Machining / Non-Traditional Machining / Surface Engineering / Joining Technology Possible research under this umbrella: (1) Identification and processing of indigenous materials for engineering application (2) Development of welding processes for structural application (3) Microfabrication by traditional and non-traditional processes **Product Design and Development** CAD/CAM/CAE, Environment, Robotics, Metrology Possible research under this umbrella: (1) Development of mobile robots for (i) search and rescue; (ii) inspection (2) Development of biocompatible prosthesis (3) Development of rapid prototyping machine for metal based material **Manufacturing Systems** Human Engineering (Ergonomics) / Manufacturing Management (Information Technology Aided Manufacturing; Posture Analysis Study; Enterprise Solutions) Possible research under this umbrella: (1) Comparative study of worker attitude and motivation in ASEAN countries (2) Design of customized database system (3) Comparative investigation of localized logistics management in manufacturing industries (4) Development and design of hardware tool and equipment for logistics performance improvement in manufacturing industries
EnvE	**UP**	**Main Theme "Urban Environmental Problems in Major ASEAN**

		Countries" Water Resources Waste Water Treatment Solid Waste Hazardous Waste Air Pollution
MatE	**USM**	Nanomaterials, Biomaterials, Advanced Composites Materials

Source: AUN SEED-Net.

Aside from these discipline-specific research thrusts, AUN SEED-Net also facilitates collaborative research in interdisciplinary areas and in any field. These include Biotechnology (biomaterials, biofuels, food engineering), Disaster Mitigation (soil erosion control, landslide and debris flow mitigation, earthquake mitigation, groundwater hazard mitigation), Global Environment (technologies for climate change mitigation, environmental assessment and management system, large area monitoring of environmental change, environmental concerns in Maritime industry), Natural Resources and Materials, and New and Renewable Energy (AUN SEED-Net 2012).

Also, the AUN SEED-Net facilitates collaborative research with industries/the private sector through local companies' participation in the Collaborative Research Program and Regional Conference Program. This aims to cater to the needs of local industries while reinforcing the network linkages between universities and industries. The network also provides short-term research visits to Japan and the ASEAN.

In 2011, the AUN SEED-Net started publishing the *ASEAN Engineering Journal* to create a platform for ASEAN Engineering scholars and junior researchers to publish their research. The top 40 percent of these papers are presented in regional conferences also conducted by the network. As of March 2012, 116 papers have been received, 20 percent of which are in environmental engineering, followed by mechanical and applied engineering.

All in all, AUN SEED-Net has provided 795 scholarships (496 master's, 143 PhD Sandwich, 128 PhD in Japan, 28 PhD in Singapore); 514 graduates (379 master's, 135 PhD); 426 collaborative research projects amounting to USD 4,424,172.00; 63 research grants for alumni; 1,500 research publications; four issues of the *ASEAN Engineering Journal* with 33 published papers; 94 special equipment items amounting to US$ 798,439; and 92 field-wise seminars, two special seminars and 56 regional conferences (AUN SEED-Net 2012).

5. Innovation and Technology in the Region

Aside from the production of highly skilled professionals including scientists and engineers, the establishment of knowledge capital of an economy is based on the extent, depth, quality, and strength of its innovation system. This section outlines the various national innovation systems in the ASEAN and in some of the leading economies in Asia. It will also cover the link of higher education systems with the innovation systems of various nations.

Innovation is the invention and commercialization of new products or improvements to existing products, processes and services, going through the three-phased process of conception, implementation and marketing (Herstatt, *et al.* 2008). National Innovation Systems (NIS) serves as *the* institution or "network of institutions of both public and private sectors whose activities and interactions initiate, import, modify and diffuse technologies" (Freeman, 1987). The concept of the innovation system may pertain to new, economically useful products and knowledge, which is founded within a nation state" (Lundvall, 1992).

As mentioned in the second part of this paper, the production of knowledge capital and innovations through R&D is essential to the growth of countries. The International Development Research Center (IDRC), through the Chulalongkorn University-Department of Urban and Regional Planning of Thailand, De La Salle University-Angelo King Institute of the Philippines, and the Noviscape Consulting Group had already taken steps in studying the state of innovation and technology in the ASEAN. These institutions have recently concluded the project, *Towards Innovative, Livable, and Prosperous Asian Megacities: City Innovation Systems Asia (CIS-Asia),* which aimed to help six ASEAN megacities---Bangkok (Thailand), Manila (Philippines), Kuala Lumpur (Malaysia), Singapore City (Singapore), Ho Chi Minh (Vietnam), and Jakarta (Indonesia)---foster their innovativeness, productivity, and competitiveness in various sectors of the economy. The study looked at the state of innovation systems, innovation cases, and driving and inhibiting factors of innovation, as well as produced foresights for the six participating cities.

This paper will rely heavily on the conclusions of the above project when looking at the current status of the innovation systems of Indonesia, Malaysia, the Philippines, and Vietnam.

5.1. Innovation Systems in Various Countries in the ASEAN

Indonesia. Innovation is not explicitly discussed in Indonesia despite the establishment and adoption of a formal NIS framework by the science and technology (S&T) community. The NIS is already in place, but it is not yet enough to spur economic competitiveness. The current NIS is weak because research institutes, universities, and research laboratories are not linked with industries despite a four-year program on industrial development. There is also an institutional problem because very little funding from the government goes to R&D; hence, there is very limited knowledge spillover.

While there are innovative firms in food, furniture, and garment industries, most sources of innovations are limited to universities and government R&D institutions. This results in low-technology manufacturing products. Indonesia therefore needs reforms in R&D funding as well as a coordinating agency that can help link the various actors within the NIS (Hidayat, 2010).

Malaysia. The Malaysian NIS is dominated by the public sector and is focused on the dissemination of knowledge instead of knowledge creation. Not much research has gone into learning. There is also a lack of linkage and diffusion among the various innovation groups.

Malaysia has institutionalized S&T with the adoption of S&T policies in 1986 and 2003, and regular planning every five years. A National Innovation Model was launched in 2007 but is still market-driven. The S&T policies have aimed to increase expenditures on R&D, generate R&D capacity, promote commercialization, enhance public understanding, and foster collaborations. However, Malaysia's NIS has encountered several concerns: bottlenecks in post-graduate education, lack of motivation for R&D technicians, emigration of senior researchers, maximizing returns from R&D expenditures, improvement of R&D grant systems, support for micro, small and medium enterprises (MSME), low rate for patenting of domestic companies, low number of research publications, and need to raise public awareness (Thiruchelvam, 2010).

Philippines. The Philippines has very low R&D expenditures and researchers, but many of its firms are good innovators. It contains many elements that would help foster innovations such as good institutional practices (auditing and financial reporting), macroeconomic stability, prevalence of higher education, goods market efficiency, buyer sophistication, technological readiness, large market size, and significant R&D spending by corporations. However, there are also elements that hinder innovation such as corruption, poor work ethics, and poor public health.

Despite considerable R&D spending at the corporate level, this remains absolutely small as a whole because 99.6 percent of Philippines businesses are MSMEs. There is no formal innovation system as well. Corporations have, however, started with *Filipinnovation,* which is seen in some companies that offer technology-based products for households and innovation on expired patents. Universities have started to commercialize research outputs through partnerships with business schools and grants from different companies. Innovation in the Philippines has focused on the development of products, capacity-building, and development of business incubators (Velasco and Habaradas, 2010).

Vietnam. Vietnam is experiencing a most drastic innovation: the transition from a centrally-planned economy to that of a market economy. Developments in S&T are still very limited. There remains a mismatch between the capacity for R&D and demand for it, lack of information channels and intermediary agencies, little state funding for R&D and S&T development, a lack of capital for different ventures, and lack of domestic technological diffusion. The NIS is characterized by three major problems: weak linkages among innovators and stakeholders, poor institutional frameworks, and the lack of motivation for innovation.

Vietnam needs to develop R&D capacity by developing collaborations among business, universities and research institutes, and needs to start with the development of institutional innovations, before it can begin with technological innovation (Tan Sinh, 2010).

5.2. Innovation Systems and Structures in China, India, South Korea and Japan

Whether or not innovation systems are formalized in the four countries studied in the CIS-Asia project, the fact remains that innovation is slowly being pursued by these respective nations. Similarities surface with regard to the difficulties encountered in the course of developing their innovation systems. The greatest difficulty lies in fostering linkages between innovators and stakeholders---that is, among enterprises, universities, research institutes, and governments. Furthermore, these countries still have to build more capacity to perform the R&D that can contribute to knowledge capital, as well as to elicit their respective governments and enterprises' support in the form of funding or grants as incentive to perform R&D.

The following section investigates the national innovation systems in China, India, Japan and Korea.

China. China has a controversial innovation system because of intellectual property issues raised against many existent innovations. A large portion of the transformation of China's NIS comes from its transition from a command economy (Boeing and Sandner, 2011; Liu and White, 2001). Initiatives to formulate an NIS started in the early 1920s to 1930s, although the first National Science and Technology Development Plan defined the formation of the NIS in the period 1956-1967, with China importing 156 heavy-industry facilities from the Soviet Union and establishing 400 research institutes focused on reverse engineering (Boeing and Sandner, 2011; Liu and White, 2001). During this time, state-owned enterprises were focused on manufacturing (Serger and Breidner, 2007). This underwent further transitions. First, there was the slowdown in China's R&D capacity in 1966-1976 due to the cultural revolution, then the reform and opening-up policies implemented after the 1978 National Science Conference, as well as several laws passed on the creation and protection of innovations (the Trademark Law in 1982, the Patent Law in 1984, the Technology Contract Law in 1987, and the Copyright Law in 1990).

Currently, China's innovation policy is geared toward overcoming domestic challenges as stated in its National Medium- and Long-Term Science and Technology Development Plan. These domestic challenges include high environmental cost, energy and resource consumption dependence, frail agricultural base, and lagging high-tech industry and modern service industry, and firms' lack of competitiveness (PRC State Council, n.d.; Kennedy, 2013). In reforming their S&T sectors, China looks to support and encourage enterprises to play a central role in technological innovation, to deepen institutional reforms and establish a modern research system, and to advance the S&T management systems (Yan, n.d.). China's NIS also includes five autonomous but strongly-linked sub-systems:

1) Technology innovation system;
2) Knowledge innovation system;
3) Defense S&T innovation system;
4) Regional innovations systems; and
5) S&T service agency system.

Furthermore, the government is set to play an increasing role in the NIS through taxation, intellectual property regimes, re-innovation of imported technologies, and in addressing cultural factors (Kennedy, 2013).

India. The Indian innovation system is not as complete as China's, although it possesses more obvious features: national research institutes, higher education systems, a sizeable technical workforce, world-famous network research centers, and national laboratories (Kong and Xu, 2010). In the mid 1980s, the focus was internal liberalization and competition. This entailed upgrading industries by acquiring technology through importation. But in the mid-1990s, the country experienced a change in its economic and technological environment due to trade and investment liberalization. India's national research institutes are administrated by the central government via a Research Council, which commissions a small number of universities to conduct research geared toward addressing national objectives (Kong and Xu, 2010). The key elements of the Indian NIS are hinged on the extensive S&T network based on public-private partnership among: the central government S&T departments, central socio-economic and other ministries, state government S&T departments, S&T in non-government organizations, independent research institutes, and in-house R&D in private industries (Herstatt, *et al.*, 2008).

India's innovation strength lies in the availability of scientists and engineers as well as the quality of scientific institutions. On the other hand, its weakness lies on the government's procurement of advanced technology products (Herstatt, *et al.*, 2008). Rajan (2012) enumerates the key drivers of India's NIS such as:

1) Government bodies such as the Council of Scientific and Industrial Research (CSIR), Defense Research and Development Organization (DRDO), Indian Space Research Organization (ISRO), Department of Science and Technology (DST);
2) Its nongovernmental organization facilitators such as Centers of Excellence working with MSMEs at the grassroots level;
3) Availability of funding sources within and outside the government such as the CSIR, DRDO, public-private partnerships such as the National Skill Development Corporation (NSDC) and the Global Innovation and Technology Alliance (GITA);
4) Intellectual property rights; and
5) Design through the India Design Council, which significantly contributes to India's culture, environment, and economy.

Japan. Freeman (1988) originally conceptualized the NIS by outlining the major factors of Japan's speedy development: a central government, the *keiretsu* (the large firms), and strong social and educational institutions (Marinova, 1999).

The role of Japan's central government in its NIS is hinged on the role of the Ministry of International Trade and Industry (MITI) on the following:

1) Establishing linkages with large corporations;
2) Committing to long-term strategic goals wherein Japan became a technology exporter due to its self-reliance and ability to absorb all needed technologies through technology transfer (Hayashi, 1990);
3) Promoting generic technologies particularly in ICT;
4) Technological forecasting through collaboration with the Science and Technology Agency; and
5) Developing the capacity to mobilize very large resources in pursuit of strategic priorities (Marinova, 1999).

The *keiretsu* have maintained close linkages with the central government, which helped in the implementation of strategic technological goals that were developed at the policy level (Okimoto, 1989). The keiretsu contributed to Japan's technological prowess by focusing on reverse engineering and eventually producing incremental innovations to existing products. Such strategies resulted in a very high number of domestic and foreign patents, improved quality in products, R&D departments that are horizontally linked with production and marketing, and the formation of the *keiretsu* themselves (Marinova, 1999).

Ultimately, Japanese innovation came from very strong social and education institutions: That is, innovation is due to the mindset of the people and how they successfully translated ideas into blueprints, prototypes, working technologies, and scientific discoveries (Marinova, 1999). It helped that many Japanese received higher education particularly in science and engineering or high-quality industrial training at the enterprise level, and that employment has broken down the barriers between blue-collar and white-collar work.

Korea. Feinson (n.d.) attributes Korea's success on the country's view of technological development: Korea sees such as a complex system in the creation and maintenance of a dynamic and responsive technology policy. The first step in developing Korea's NIS was the promotion of the flow of technology into the country, particularly in turnkey industries such as steel, paper, chemical, and cement industries. The foreign direct investment (FDI) restrictions were kept high so as to focus on the reverse engineering of mature technologies (Feinson, n.d.). Next, Korea promoted the use of technology and the diffusion of imported technology to keep industries well-informed about local and foreign developments. The strong absorptive capacity of the society, substantial R&D investment, and economic and political stability enabled Korea to innovate.

The strong absorptive capacity was made possible because of very high levels of investment in human capital: that is, higher education. By the 1980s, education represented 22 percent of the national budget, and only one-third of the spending on education is accounted for by public spending. Furthermore, an outward orientation played a key role in each firm's success. That is, exports and favorable trade environments kept their firms internationally competitive.

In the 1960s, Korea's first R&D activities involved the establishment of government research institutes, which led to remarkable GDP growth from the 1970s to the 1980s, and further growth to at least 253 billion dollars in 1990 (Yim, n.d.). After the late 1980s, however, firms and universities cited the ineffectiveness of Government-Sponsored Research Institutes (GRI), leading the government to change the research funding system in 1996 from a lump-sum system to a project-based system. In 1999, the Research Council System (RCS) was created based on the German and British system (Yim, *et al.*, 2003). This puts the various ministries'

GRIs under the unified control of the prime minister's office, and established five research councils that act as supervisory bodies of the member-GRIs. The National R&D program was first initiated by the Ministry of Science and Technology in 1982 to strengthen the technological capability and competitiveness of the country (Yim, n.d.).

Today, R&D efforts are geared toward a knowledge-based economy that aims to bring the nation among the ranks of the world's most advanced economies. Currently, Korea has the 21st Century Frontier R&D Program, the Creative Research Initiative, the National Research Laboratory, the Biotechnology Development, the Nanotechnology Development Program, the Space and Aeronautics, among others.

5.3. Role of Higher Education and Graduate Education in Innovation Systems

Higher education institutions (HEI) play a central role in the innovation system of countries, and this is because universities, aside from providing education to the youth, are tasked to conduct research. Looking back at the theoretical discussions in this paper, much R&D is needed to develop knowledge capital, which in effect, is a requirement for developing innovations. To each become a "world-class university", these schools must have research-oriented institutions above all else (Kearney, 2009). This requirement should apply as well to developing countries, because even they need research capacity or access to research so as to progress.

A *knowledge society* is created by a society that is nurtured by diversity and its capacities, fosters the sharing of knowledge, and offers a wider and richer array of methodologies for the development of countries. Higher education directly influences the capacity of the country's innovation system and is "characterized by its top graduates, cutting-edge research, and vigorous technology transfer" (Kearney, 2009). The concentration of talent, abundance of resources, and favorable governance are what drive excellence in graduate education and research output (Bienenstock, 2006), which in turn, translates to better knowledge generation, and then to better innovation.

The production of knowledge has evolved from a disciplinary, scientific approach (mode 1), to a more interdisciplinary, applied approach dubbed as "Mode 2 of knowledge production" (Martin 2010; Gibbons, *et al*. 1994). This gives rise to universities whose role is geared toward regional development (Gunasekara, 2004). That is, such universities' objective goes beyond community service, regional development, and regional engagement, to encompass regional innovation organization and academic entrepreneurship as well (Knoll, *et al*. 2012). In fact, this has been believed to go beyond education and research. In Mode 2 of knowledge production, universities are able to bring benefits to firms. For example, such universities are able to provide innovative outcomes as collaborative partners in various activities (Howells, *et al*., 2012).

Uyarra (2010) enumerates five roles of universities as contributor to regional development: (1) A knowledge factory that produces and transfers knowledge as well as the pool of human capital; (2) A relational university that provides a central point of reference for cooperation among regional firms and other actors; (3) A potential center of academic entrepreneurship that helps facilitate entrepreneurship within the region and provide newer firms with know-how; (4) A systemic player that helps overcome barriers to thinking creatively as well as weed out persistent but outdated views that restrict regional cooperation; and (5) an engaged university with a regional identity that seeks supporters of development in the region.

6. Other Regional Initiatives Towards the Development of Higher Education

6.1. Role of AFAS in Developing Higher Education

The ASEAN Framework Agreement on Services (AFAS) was signed by ASEAN members in 1995 to facilitate the free flow of services within the region by 2015. The AFAS aims to achieve liberalization through the removal of existing (and prohibition of new) discriminatory measures and market access limitations (ASEAN, 2012). These limitations that will be liberalized may pertain to the number of service suppliers, total value of services transactions and assets, total number or quantity of services operations, number of employees, types of legal entities, and foreign equity participation (Dee, 2013). The agreement requires all member-states to cooperate in establishing or improving infrastructure, joint production, marketing and purchasing arrangements, R&D, and the exchange of information. Also, each member-state needs to mutually recognize the education and experience, requirements, licenses and certifications granted by other member-states (ASEAN, 2012).

One of the target sectors for liberalization under AFAS is the education services. Ishido (2011) computed the Hoekman index for education services of the ASEAN given the commitments made by ASEAN member states in AFAS. The Hoekman index is simply the average of eight values. That is, four modes each for both market access and national treatment. These eight values represent the degree of liberalization in the market: "N" = 1 if sectors have no more limitations and are bound, "L" = 0.5 if there are still limitations/restrictions but bound, and "U" = 0 if unbound.

Table 15: Hoekman Indices for Education Services Sub-sectors Covered by AFAS

Country	Primary Education	Secondary Education	Higher Education	Adult Education	Other Education	Country Average *
Brunei Darussalam	0.56	0.56	0	0.56	0.56	0.448
Cambodia	0	0	0.75	0.75	0.75	0.45
Indonesia	0	0.63	0.63	0.56	0.56	0.476
Lao PDR	0.56	0.56	0.56	0.56	0.56	0.56
Malaysia	0.44	0.44	0.19	0.44	0.44	0.39
Myanmar	0	0	0.63	0.63	0.63	0.378
Philippines	0	0	0	0	0	0
Singapore	0	0	0	0.75	0	0.15
Thailand	0.63	0.81	0.63	0.63	0	0.54
Vietnam	0	0.25	0.5	0.5	0.5	0.35
ASEAN Average	0.22	0.33	0.39	0.54	0.4	0.376

Note: *Country average for education services. Computed by authors, but data taken from Ishido (2011).
Source: Ishido (2011).

Table 15 presents the Hoekman indices for the five education services sub-sectors in the ASEAN. It can be observed that the sub-sector with the deepest degree of liberalization is adult education, followed by other education and higher education. However, the average index for higher education is 0.39, indicating that the degree of commitment is not deep. Furthermore, Brunei, the Philippines, and Singapore have not made any commitment for higher education at all. The highest degree of commitment to higher education comes from Cambodia (0.75), followed by Indonesia, Myanmar, and Thailand (0.63), and Laos (0.56).

The degree of liberalization for primary and secondary education is not very high. In fact, relatively few committed at all. The highest index belongs to Thailand with 0.81 in secondary education and 0.63 for primary education, followed by Indonesia with 0.63 for secondary education, and Brunei and Laos (0.56) for primary education.

The degree of liberalization is deepest for adult education wherein all member states except the Philippines have relatively high commitment. Noticeably, the Philippines (with a sector average of 0) and Singapore (with a sector average of 0.15) barely committed to the liberalization of education services, whereas the rest committed to three to five sub-sectors. The most committed to the liberalization of education services is Laos (0.56), followed by Thailand (0.54), Indonesia (0.476), Cambodia (0.45), and Brunei (0.448). The average for the education services sector of the ASEAN is 0.376. This reflects that the degree of liberalization of the education services sector still needs to be developed.

Sectors such as business, communication, construction and engineering, distribution, and tourism and travel are more liberalized as compared to others. Ishido (2011) finds that ASEAN countries have not committed much based on the grand mean of Hoekman indices of 0.33 for all sub-sectors and all member-states (Ishido, 2011).

Education services is a sector that builds social infrastructure (Dee, 2013), and its development is vital to the progress of any nation. The liberalization of this sector ensures the quality, affordability, and availability of education to all segments of society. Dee explains that when frameworks for quality assurance and accreditation are underdeveloped, barriers may tighten, which in turn may hinder trade liberalization.

6.2. Role of Other Multilateral Institutions in Developing Higher Education

Aside from AFAS, multilateral institutions such as the Southeast Asian Ministers of Education Organization (SEAMEO) and the Asia Professional Education Network (APEN) play vital roles in developing higher education in the ASEAN.

The SEAMEO was established in 1965 by the governments of the Southeast Asian countries to foster regional cooperation in education, science, and culture (SEAMEO, n.d.). It aims

> "…to enhance regional understanding, cooperation and unity of purpose among member-countries for a better quality of life through the establishment of networks and partnerships, the provision of fora among policy makers and experts, and the promotion of sustainable human resource development."

Among SEAMEO's strategic goals are

1) to develop regional centers of excellence;
2) to provide programs that address national and regional issues under SEAMEO's thrust;
3) to strengthen organizations to manage the effects of globalization;
4) to ensure continued financial viability;
5) to promote R&D in education, science and culture and improve the dissemination of R&D;
6) to encourage and enhance collaborations among members
7) to be ASEAN's partner in the advancement of education, science, and culture;
8) to facilitate the harmonization of education standards; and
9) to be the leader in the advancement of education, science and culture.

SEAMEO provides training programs and human resource development programs through the 15 specialist institutions in eight of the 11 member-countries. These specialist institutions provide regional leadership, human resource development, and expertise in learning, health, environment, agriculture, and natural resources (SEAMEO). Training covers the following areas:

1) Agriculture and Rural Development;
2) Culture and History, which includes Culture Development, Archaeology and Fine Arts, and History and Tradition;

3) Education, which includes Higher Education, Language Education, School Management, Innovative Education and Information and Communications Technology (ICT) for Education, Open and Distance Education, Science and Mathematics Education, Vocational and Technical Education;
4) Tropical Biology and Natural Resources; and
5) Tropical Medicine, Public Health and Nutrition.

The SEAMEO Regional Centre for Higher Education and Development (SEAMEO RIHED) is located in Thailand and offers courses in Higher Education/University Governance and Management, Harmonization on Higher Education in Southeast Asia, and Quality Assurance in Higher Education.

Meanwhile, the SEAMEO Regional Centre for Vocational and Technical Education and Training (SEAMEO VOCTECH) is located in Brunei Darussalam, and offers courses in Curriculum Design and Development for Vocational and Technical Education and Training (VTET), Management for VTET, Refresher Programmes for VTET Teachers and Instructors, Incorporating ICT in education and learning, and Research and Development for VTET.

The APEN, on the other hand, was established to enhance the nexus of collaboration among organizations through project-based learning (PBL). The aim here is to produce global professionals who can contribute to the development of Asian society through industrialization (APEN, n.d.). These PBL programs have specific training projects characterized by well-designed education processes, clearly defined learning targets, and proper assessment systems, as carried out by students in their curricula. The APEN programs include creating dialogues among policymakers and training entities and education institutions (such as the 2013 Saudi Arabian Mission of directors of the vocational training entities organized by the Japan International Cooperation Center (JICE), as well as the dialogue with Institute for Small-Scale Industries). APEN was founded by Shanghai Jiao Tong University (China), Advanced Institute of Industrial Technology (Japan), Pohang University of Science and Technology (Korea), and the University of Engineering and Technology, Vietnam National University, Hanoi (Vietnam) in June 2011. Soon after, the Institute of Technology of Cambodia (Cambodia), the Institut Teknologi Bandung (Indonesia), Thammasat University (Thailand), Universiti Teknology

Malaysia (Malaysia), and the National University of Laos (Laos) became APEN members as well (APEN, n.d.).

7. Emerging Engineering Education for the 21st Century

An integral part of the innovation system is the higher education system of the country. Since the production of engineers and other scientists are critical in the creation of innovative products and services, it is important to know what types of engineers are needed in the 21st century taking into consideration the tight global competition, need to innovate, changing learning styles of the youth as well as demand for human resources in a highly globalized environment. The earlier section of this paper reviewed the regional cooperative efforts in engineering education. This section now focuses on the emerging trends in engineering education for the 21st century.

7.1. Role of Global Competition

Globalization has induced rapid integration of the world: reduced barriers to trade, investment and factor mobility, as well as the establishment of a worldwide network of capital, technology and information through enhanced competition, stronger interconnection and greater interdependence (Tullao, 2002). The enhanced competition has greatly affected the production and distribution structure of the global economy; hence, it has changed consumers' demand and the producers' capacity along the their production frontier and eventually, beyond the country's comparative advantage. After a country shifts from an agriculture base to service and exports, then to industry, it proceeds toward a knowledge-based economy (Tullao, 2012; 2002), which is now hinged on innovation and technology to grow. Because of greater global competition, countries are forced to increase their dependence on skilled professionals, technical innovations and knowledge, rather than on traditional factors of production. However, this need to cope with globalization is not limited to the country level, but applies to the individual level as well.

The liberalization of "the educational sector is reinforced by the globalization of professions and the entry of economies into international commercial agreements (Tullao, 2002)." With greater interconnection, countries may now request the entry of certain professionals from other countries, although this implies that such professionals and workers need to have the skills needed by host-countries to remain competitive in this global market. This means more demand for academic degrees from higher educational institutions and stringent retraining in post-graduate programs through continued education (Tullao, 2002). As expected, this has induced educational institutions to restructure their curricula to fit the needs of the continually-globalizing market. With its central role in developing innovations, engineering education has evolved to cater to this call, going beyond the learning of technical skills and delving more into analytical, managerial, and interpersonal abilities.

7.2. Role of Innovation in Shaping the Engineering Curriculum

Engineers are value creators who transform ideas and inventions into innovations that give value to customers and result in sustainable profit for the enterprise (Wnek and Williamson, 2010). Engineers use their technical capabilities, analytical thinking and scientific principles to create such value. To innovate, they also need to consider a broad set of issues (such as markets, customers, intellectual property protection, financing and sustainability) and should acquire a broad set of skills (such as communication, teamwork, project management, and the ability to spot emerging opportunities). Most undergraduate engineering curricula rarely integrate these skills requirements and tend to focus on technical aspects only. As a result, many engineers with strong analytical skills find themselves competing with one another on the cost of those needed skills. It is now necessary for them to develop personal skills if they are to thrive in the global economy (Wnek and Williamson, 2010).

Allenby (n.d.) lists the types of engineers. "I-types" are deep specialists in one area and are the easiest to produce given the current curriculum and traditional methods of engineering around the world. They have high analytical and technical competencies that rely heavily on the mathematical and scientific rigors of the curriculum. They are produced more commonly by schools but are criticized because they are allegedly taught using “dangerously obsolete ideas about how viable such an education is in a highly competitive world” (Allenby, n.d.). They are easier to outsource to the least expensive regions.

“T-types” are specialists in one area but possess working knowledge and expertise, and have the skills in interdisciplinary communication. Meanwhile, the “H-type” is a specialist in two areas. There is also the “π-type”, which is a specialist in two areas but has the ability to work in and communicate across various disciplines. By far, T, H and π types are more productive than I-types and have a stronger capacity to produce innovation given the demands of industries. However, the production of these types takes a lot more time and as mentioned previously, will require development of personal and soft skills.

Amidst globalization, a “new economy engineer” is needed to create value (Wnek, 2013). All engineers have the same set of analytical and technical competencies; to remain competitive and innovate, they need to be able to analyze and think critically, communicate and translate ideas into the language of different constituencies, and to perceive emerging opportunities by connecting disparate ideas from different disciplines into new ways and synthesizing these into new, value-added products and services (Wnek 2013; Wnek and Williamson, 2010). These additional skills---technology opportunity identification and assessment, ability to transform interesting inventions into innovations, clear oral and written communication, ethical leadership, and teamwork with members that have no technical background in engineering---are needed to leverage their core analytical and technical skills (Wnek and Williamson, 2010). This suggests a restructuring of engineering education as a whole to adjust to the environment and the new ways that students are learning (Wnek and Williamson, 2010; Allenby, n.d.).

7.3. Role of the Changes in the Way Students are Learning

Developments in ICT have enabled the exponential expansion of knowledge, making it accessible from nearly any point in the world (Tullao, 2002; Allenby, n.d.). In this sense, memorization of facts may no longer be needed. This does not imply, though, that facts are no longer important. The point here is that beyond memorizing, facts should first be understood in terms of how they work and how these are related to concepts in various disciplines. The student needs to be able to use these concepts to assemble patterns and knowledge responsive to particular questions (Allenby, n.d.). Furthermore, with rapid globalization, students need to be technically competent as well as understand environmental and social contexts within which much of today's innovation and invention revolves around (Wnek and Williamson, 2010; Allenby, n.d.).

7.4. Requirements of a Highly Globalized Environment

Because of global competition, the need to innovate, and the changes in the way that students are learning, students and universities have to prepare to change so as to meet the requirements of this highly globalized environment. Cogburn (n.d.) enumerates a set of skills needed to respond to the impacts of the many forces of globalization on the education sector.

First, students and universities must shift their learning emphasis from mere transmission of information to comprehension of abstract concepts. This is a necessary tool for students to gain critical thinking and the ability to explain events, solve problems, gather appropriate information and make intelligent decisions based on the information gathered.

Second, a holistic approach where information from various disciplines is integrated will provide a fuller understanding of the increasingly complex system of the world. This entails understanding ecosystems, communications networks, and systematic thinking. This challenges all to synthesize information from various sources of knowledge.

Third, the ability to manipulate symbols will help students deal with the rapid developments globally. Reflection, critical thinking and analysis are skills essential in manipulating political, legal, business, social, financial, and historical concepts, recognizing and understanding their issues, and relating them to the various units of society.

Fourth, the ability to acquire and utilize knowledge is essential in research. Educational institutions no longer monopolize the sources of information and are therefore tasked to manage the knowledge and information that need to be transmitted to students. Students, in turn, need to learn how to research and gather the appropriate information themselves.

Fifth, the ability to work in teams---particularly teams comprised of multiple cultures and nationalities---is essential for innovation, especially since most innovation comes from interdisciplinary ventures. Despite the vast pool of knowledge and information available, solutions are more easily obtained when one works in teams and cooperates in the interest of utilizing each other's expertise. These teams, though, should not be limited to members of the same discipline. These have to be dynamic and comprised of members from different disciplines so that students may learn to understand issues and craft solutions based on other perspectives as well. This develops communication, negotiation, persuasion, leadership, organization, and ultimately, management skills.

Working with people from different cultures and nationalities and working together despite significant differences teach students relational skills. Learning these days also need not be limited by distance, because the advancements in ICT have enhanced people connectivity.

Thus, to foster R&D and innovation, educational institutions and the engineers of the 21st century need not only focus on technical engineering know-how. They must also develop professional competence, communication skills, critical thinking, global mindset, multidisciplinary and interdisciplinary collaboration, and an understanding beyond the available knowledge.

8. Some Key Policy Issues

As mentioned in the introductory note of this study, investment in education, research and development and the liberalization of immigration policies will definitely help shape the innovation and creativity environment of the region in the near future. Innovations and creativity will shape the competitiveness of ASEAN companies and help deepen interconnections among the economic clusters in agriculture, manufacturing and services. But in the bid to develop this base for innovation and creativity, there remains several challenges and issues that have to be addressed, including: the optimal mix of investment in education, the required investment in R&D, re-engineering the engineering education for the 21st century, the role of innovation in the instructional and research activities in engineering education, and the optimal partnering with the private and external sectors.

8.1. How to Invest in Education?

The need to expand human capital so as to enhance economic growth is recognized in various literatures. However, if the goal is to expand its innovation and creativity base, investment in education will be saddled with numerous issues. There are three main issues to be addressed:

1) The availability of resources to finance education;
2) The manner of financing various types of education; and
3) The institutional requirements for graduate education and research.

The first issue is crucial since education covers three primary components: basic education, technical training and collegiate education, and graduate education and research. Basic education is a primarily a socialization process oriented toward acquiring literacy, numeracy skills, and socio-cultural and civic awareness. Technical training and collegiate courses are primarily meant for employment.

It is therefore graduate education and research that may have greater contribution to advancing innovation and creativity since it is focused on expanding the frontier of knowledge.

However, given the limited resources of the economies, expanding population, the cost of higher education as well as research, are the resources sufficient enough to fund these types of education? While distinct in orientation, these types of educational investments are not mutually exclusive but mostly complimentary. Although basic education is a public good and generates social benefits, it is needed to produce good inputs for skills training in technical schools, colleges, and universities. The same is true for tertiary education. Good graduates of collegiate programs are needed to produce good graduate-level students, who will ultimately be the scientists and skilled professionals of the future. A good graduate education can translate into better future teachers, instructors, professors and researchers for basic, technical, and collegiate courses as well as universities.

Given the limited government budget, the need to respond to all these types of educational programs, and the existence of distortions, there must be an optimal way for the government to allocate its resources for education. Basic education must be funded by the government because of its huge social benefits. Collegiate education, meanwhile, can be channeled to the private sector since graduates are able to internalize the private benefits to education in terms of higher productivity and higher earnings in the future. Although the returns to technical education can likewise be internalized, there is a distortion in the demand for technical education. The existence of a social aversion to technical education results in an under-investment in technical education. Because of this, individuals and their families are not aware of the extent of the private returns to technical training. In such a case, the government can intervene by supporting technical education. For equity reasons, the government can grant vouchers and scholarships to capable but financially-challenged individuals for tertiary education. For graduate education and research, there should be a massive government support in key fields such as science, engineering, and technology, and teacher education for those who will be the instructors and professors in collegiate and technical programs.

Aside from public-private partnership in financing education, there is need for cooperation with some of the key researchers and scientists outside the country. This will strengthen the institutions of graduate education and research. Given the level of economic and scientific development in sciences and technology, many middle-income countries in the region may not be able to invest heavily in R&D and even in highly specialized higher education. Thus, there is a need for regional cooperation among the key research institutes and universities in the ASEAN region so as to further expand, deepen and strengthen the research capabilities across its member-countries.

The AUN-SEED-Net is a best practice that can be replicated in other S&T fields. The mechanism for research cooperation under SEAMEO and APEN can also be harnessed to develop the research capacity of the region. Meanwhile, liberalizing the education sub-sector under AFAS can help develop the higher education system in the region.

Earlier, a section of this paper discussing the optimal mix of investment in education had focused on the supply side. However, the demand aspect of the country's manpower requirement is equally important since a nation's level of economic development is intimately linked with the technological and manpower requirements. It may be wasteful for a low-income country using traditional technology to focus on the training of highly sophisticated engineers and scientists. Similarly, technical and vocational education may not be as important compared with higher education in a mature economy that is trying to innovate on its products and services. Although there is a need to match supply and demand of manpower at every stage of economic development, such coordination is saddled with difficulties. One of these difficulties may be due to the distortion.

8.2. What to Invest in Research and Development?

As mentioned earlier, allowing the entry of scientists and highly skilled professionals can create the base for innovation and creativity in the region. This may substitute the long and expensive investment in R&D. But entry of foreign experts will depend on incentives for moving/migrating, including liberal immigration policies, attractive compensation and incentive system as well as the presence of an R&D infrastructure. The first two requirements can be easily addressed through government policies and interventions. An acceptable level of acceptance R&D infrastructure will require the presence of several research institutes, research universities, a certain threshold number of scientists and engineers and technicians who are actively doing research and publishing in international academic journals. However, this presence of an *existing* R&D infrastructure may be more difficult to attain as evidenced by the weak national innovations systems in several ASEAN countries, the dearth of scientists in the region, the lack of a research culture in many universities, and limited number of published articles in international refereed journals.

Thus, an alternative is for the countries to join forces in building the R&D infrastructure for both the region as well as their individual economies. As mentioned earlier, the AUN-SEED-Net is a model that should be pursued and promoted as a building block toward an ASEAN R&D infrastructure. The best practices of the various centers under SEAMEO can also be incorporated in this research infrastructure.

There, too, is a need to plan the investment in education. Too much investment in research and graduate education without the corresponding demand for it may lead to unemployment among the educated or worse, brain drain. The case of India---as well as South Korea and Taiwan---are good case studies on how they invested heavily in the production of highly skilled professionals, including scientists. Although South Korea and Taiwan had experienced some form of brain drain in the 1960s, their highly skilled professionals eventually returned when their home R&D infrastructure became available.

Financing of R&D can shape the type of innovation system that the country will develop. If it is left solely to the private sector, it may lead to an underinvestment since the innovations undertaken by the private sector are primarily for monetary returns. Also, the positive externalities associated with R&D, which are enormous, might be ignored by the private sector. In such a backdrop, government intervention may be needed to reap these social benefits. In developing the innovation framework or system for the country, there should an understanding on the role of the private sector and public sector. One should not compete with the other given the limited resources and the huge cost of R&D. The ideal dynamics should be one of cooperation and reciprocity, with the aim of raising the standards in research.

In addition, venture capital is crucial in developing innovative products and services that are the results of the research from government and university research institutes. The public-private link in R&D should be well mapped out.

Another important issue on R&D investment is the nature of research and development that should be pursued. Should it address the pressing problems of the country or should it contribute to the expansion of knowledge? Relatedly, should university researchers pursue practical research? Or play the publications/citations game? Should R&D address the interests of business companies or the interests of society-at-large? These choices will depend not only on the importance of these concerns but also on how these are being financed. Again, an optimal mix of public-private financing will make these questions easier to answer.

8.3. The Balance of Technical Competence and People Skills: A New Perspective in Engineering Education

In this paper's earlier discussion on the emerging engineering education in the future, the various types of engineers were identified: "I-types" (specialists in one area); "T-types" (specialists in one area but have the ability for interdisciplinary communication); "H-types" (specialists in two areas); and the "π-types" (specialists in two areas but have the ability to work in and communicate across various disciplines). The T, H and π types are more productive than the I-types and have stronger capacity to produce innovation given the demands of industries amidst globalization. However, the production of these types takes a lot more time and will require improvement of one's personal and soft skills.

There is a need to revisit the manner of teaching in the 21st century. This involves understanding how students learn, given their diverse interests and the ease with which information is easily accessible through personal electronic devices. The role of the professor is not to inform students but primarily to guide them to think critically, communicate effectively and understand the connections between concepts and real global issues. The objective of engineering education is not only to acquire technical competence but to understand and solve real problems as well as contribute to their solution. More than professional competence, therefore, there is a need to emphasize personal qualities, communication skills, critical thinking. Beyond analysis, there should be synthesis and teamwork. Beyond technical competence is the ability to resolve key issues at hand.

8.4. Innovation Perspective: A New Wave for Instruction and Research for the 21st Century

Innovation is meant to add monetary value to an invention or creation. This is quite a departure from the perspective that research means basic research for the extension of the frontiers of knowledge. Although basic research is important, applied research and research for commercialization are likewise legitimate since they address current societal problems. In this highly globalized environment, there is the need to be competitive. One way to be so is to make innovation the thrust for research. To add value to the products of research and inventions means improving products, processes and systems in production and distribution.

Aside from shaping research, innovation should likewise influence the way engineering education are delivered. Currently, engineering education in many universities in the region stresses technical competence. If the objective is to create innovative products and services, this technological competence must be translated into something that will be consumed, and used in production. Engineering education must be reinvented so that it gives students the skills to solve key engineering problems and at the same time.

The difficulty in re-engineering the engineering education lies in the way universities in the region are structured. There is prominence of disciplinal governance. What is needed instead is multi-disciplinal or inter-disciplinal governance. This can be attained in research institutes to great extent and not in rigid disciplinal departments.

A multi-disciplinal perspective is just the physical association of experts in various disciplines in the teaching of engineering. An inter-disciplinal approach, on the other hand, may require some form of transformation in the professor that may lead to disciplinal cross breeding. This may not lead to hard-core discipline but may answer the quest for innovation in a competitive global market.

8.5. Regional Cooperation and Private Public Partnership

Regional cooperation is meant primarily to address regional public goods. However, in the case of R&D across regions, it may not be the region's public good that is the first priority in all parties' minds. In fact, it can be argued that external partners may not be interested in helping countries build their R&D infrastructure and base for innovation and creativity, since strengthening these target nations' capability may in fact strengthen the competitiveness of the external partners' future competitor.

If countries will require external partners to promote R&D, there must be more than mere altruistic motivation that drives partners from developed countries to participate in the cooperative scheme. Aside from financial support, the institutional infrastructure should be operational and has some degree of international acceptance to allow for greater cooperation.

Private and public partnership, on the other hand, is meant to address the limited resources of the government as well as to address the numerous distortions in the market. The government alone cannot build the R&D infrastructure. This is where the private sector comes in. Investments in education and R&D qualify for private-public partnership. The assignment of roles will be determined by private returns, social benefits, and other positive externalities. Government can push for activities and programs that have huge social benefits and whose cost cannot be internalized. Private sector should be assigned to programs that have huge private benefits that can be internalized.

The private sector can also be enticed to undertake these programs if there is an appropriate environment, incentive system and regulatory framework that will entice them to participate. Otherwise, their participation will not be optimal.

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