Strategic Academic Cooperation with Resource Universities in Developing Countries through Laboratory-Based Education in Engineering Field

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Abstract

This paper demonstrates the effectiveness of academic cooperation in the engineering higher education that introduces Laboratory-Based Education (LBE) at a resource university in developing countries, involving local universities in the target country. Nurturing human resources equipped with ability to use advanced knowledge and generate new ideas is indispensable for technological progress and hence for achieving the Sustainable Development Goals (SDGs) in terms of accelerating economic growth and eliminating disparity between central and peripheral areas.

LBE, Japanese-style engineering education, involves 4th grade undergraduate students and postgraduate students in research activities at his/her supervisor's laboratory. LBE simultaneously strengthen research capability of faculty staff and nurture capable human resources through research in laboratories. A laboratory means a research team, not a room for experiments. Participation of faculty staff of local universities in LBE at a resource university is thus the key of the strategy that this paper presents.

Verification of the proposed approach is based on the results of a technical cooperation project in Indonesia. The author participated in the project as an expert for LBE. The processes and outputs of the project suggested positive impact of the proposed approach for improving engineering education of local universities besides strengthening research capability of the resource university.

1. Introduction

Expectation on higher education institutions' contribution to society expanded after the World Declaration on Higher Education for the Twenty-first Century was adopted in 1998. Recently it is even larger in terms of achieving the Sustainable Development Goals (SDGs). Considering that economic growth is one of the core elements for achieving the SDGs and should be harmonized with social inclusion and environmental protection, universities' mission is to provide industries with capable human resources and new technology. However, many of universities in developing countries, although faculty members often obtain doctoral degrees in developed countries, do not have enough capacity to fulfill this significant role.

Another pillar of the SDGs is to make no one left behind. From the viewpoint of education, all countries are required to secure access to quality education for every individual. With this regard, gaps between prestigious universities in central areas and local universities, which are serious in terms of both hard and soft infrastructure in most developing countries, should be reduced. Upgrading quality of education at local universities also contributes to development of local industries and hence to reduction of income disparity between central and peripheral areas. International cooperation for strengthening research capability of resource universities and upgrading education quality of remote universities in developing countries is therefore anticipated as part of effort to achieve the SDGs.

Laboratory-Based Education (LBE) is a form of engineering education that most Japanese universities introduces. The essence of LBE is to conduct research and education holistically in a laboratory; postgraduate students and 4th grade undergraduate students are members of his/her supervisor's laboratory and take part in research projects of the laboratory. For students, a laboratory is a family place where he/she spends most of the daytime besides attending classes. Senior students are expected to assist juniors in carrying out their research task. Japanese LBE originates from the imperial college established at the beginning of Japan's modernization at the end of the 19th century. Based on the long history of LBE in Japan, Japan International Cooperation Agency (JICA) has been cooperating with universities in developing countries with the purpose of enhancing research capability mainly through introducing LBE to master's programs in engineering fields.

The author aims to verify the holistic approach to simultaneously enhancing capability of both resource and local universities in developing countries,

through analyzing processes and results of a JICA technical cooperation project implemented by Indonesian universities. As the result of detailed analysis on how LBE contributes to the capacity building of both resource and local universities in terms of research and education, this paper explains that participation of faculty staff of local universities in LBE at a resource university is the key strategy of the approach. The author participated in this project as a Japanese expert for LBE.

The project was designed from the viewpoint of development of local industries and communities through enhancing higher education in the engineering field. Taking into consideration the huge disparity in living standards between Western Java and other areas in Indonesia, this research will, in the longer term, contributes to the achievement of SDGs through industrial development.

Finally, the author considers the way forward to sustaining international higher education cooperation with the purpose of ensuring universities' contribution to the SDGs.

2. Human resources development for technological progress

2.1. Social capacity for absorbing advanced technology and creating new ideas

Catch-up-industrialization is a pattern that latecomers commonly adopt for reducing the gap with developed countries in national wealth [1]. Advanced technology, however, would not simultaneously spread to backward regions; developing countries are required to have the capacity to assimilate advanced technology, namely the ability to acquire the technological knowledge that developed countries use for producing advanced capital goods, not the skill to operate sophisticated equipment [2]. Furthermore, from the viewpoint of the SDGs, economic growth must be sustainable. Based on the understanding that technological progress is the driving force of economic growth and that new technology for adding more value to the goods requires new ideas, lack of access to advanced ideas should be the core issue of persistent poverty [3]. Backward countries therefore have to obtain social capacity not only to absorb advanced technologies but also to create new ideas of their own.

With regard to the social capacity necessary for technological catching-up and development, studies on past experiences such as Japan's rapid economic growth after the inauguration of the Meiji Restoration in 1867 [4, 5] recognizes human capital as its crucial component. Considering that substance of technology is technical information and must be interpreted as usable recipes for local societies so that they can enjoy latecomer's advantage, knowledge and theoretical understanding of basic science and technology should be indispensable as ability of human capital. For example, the role of university-educated engineers in the initial establishment of steel industry in Korea at the end of 1960s was to understand the technical documents that Japanese steel companies prepared for Korean engineers, to absorb the total production system of the most updated Japanese steel plant and to maintain the first steel mill in Pohang by themselves [6]. Capacity that enabled POSCO' rapid growth in 1980s is understood as organizational ability to utilize human resources and internalize innovations [7]; this analysis also indicates that existence of human resources who have ability to lead innovations is the fundamental for growth.

2.2. Role of engineering higher education in developing countries

Studies on the social capacity and the example of Korea suggest that higher education in the engineering field is responsible for nurturing human resources who have ability to understand and use advanced ideas for generating economic value. Additionally, to meet the SDGs' request, universities must equip students with ability to harmonize technical knowledge with the concept of leaving no one behind and protecting environment including natural resources preservation.

In this context, many of universities in developing countries do not have enough capability to carry out their mission due to the lack of research capability. Research is to find something new or, especially in the engineering field, to make an invention no matter how small it is. In developed countries, research makes the basis for education; faculty members are fundamentally researchers, not teachers who only give lectures. There are many reasons why faculty members do not conduct research in developing countries: they are busy giving lectures day and night or working for several institutions to earn living: there is no research equipment in the laboratory: research grants are scarce: postgraduate students are mostly working students and prefer getting degree without research, especially in the case of master's degree.

In the past, prominent university leaders tried to transform their institutions to research-based. Many young lecturers who obtained Ph.D. degrees abroad were eager to continue research. Despite these movements, very few universities were successful in introducing research culture. We know that no economic value would be generated without research; enhancing engineering education through promoting research activities has been hence an urgent issue for developing countries.

3. Advantage of LBE

LBE is implemented at laboratories through giving research assignment to postgraduate students. A laboratory is relevant to a research team, led by a principal investigator (PI), consisting of faculty members, post-doctoral fellows, postgraduate students and 4th grade or final year undergraduate students. Structure of each laboratory is hierarchical; senior students assist juniors in understanding research and producing theses, while the PI is responsible for the whole education and research conducted in his/her laboratory. All postgraduate students belong to one of the laboratories at graduate school they enroll in and thus have a place to work. Students do not make a contract with the PI, their thesis advisor, but have research tasks and stay working in the laboratory. Apart from the laboratory life, students have to attend classes and earn credits following the curricula they pursue. Some subjects are equivalent to research tasks in the laboratory such as research discussions and thesis writing. LBE is hence feasible regardless of curricula and does not affect syllabi or class schedule.

Outputs of LBE are theses/dissertations, research papers, intellectual property rights and human resources who have potential research capability and ability to provide practical problem solutions. Consequently, quality of LBE is evaluated by other PIs of the relevant university, academia and industries.

Advantage of introducing LBE at universities in developing countries is that it naturally pushes faculty members to conduct research and produce ideas, simultaneously nurturing students' research capability. The largest hindrance to the LBE implementation in developing countries should be lack of research culture or low motivation to conduct quality research as part of faculty's responsibility.

4. Approach and method

4.1. Introduction of LBE at a resource university

Institut Teknologi Sepuluh Nopember (ITS) is a higher education institution located in Surabaya, East Java Province of Indonesia. In Indonesia, an archipelagic country, Information and Communication Technology (ICT) has been recognized as an important engineering field from the viewpoint of socio-economic development of remote areas including the eastern part of Indonesia (EPI). The Government of Indonesia, aiming to accelerate socio-economic development of remote areas, expected ITS to be a resource university for higher education in EPI, especially in the field of ICT. ITS hence had a mission to strengthen research capability and contribute to the development of EPI through human resources development. In this context, the Government of Indonesia requested Japan to provide technical cooperation with the purpose of enhancing ITS's research and education capability in the field of ICT. Technical cooperation was thus designed to introduce LBE at ITS.

When introducing LBE to master's programs of universities in developing countries where research is not much conducted, establishment of laboratories, or research teams in other words, that include postgraduate students is a primary and crucial requirement. In this regard, besides the low motivation of faculty members, circumstances such as lack of financial resources, insufficient research equipment and small number of fulltime postgraduate students should also hinder the initial implementation.

When JICA launched a four-year technical cooperation project at ITS in 2006, master's students of ITS were supervised by faculty members of the division they belong to but did not have any specific thesis advisor even at the beginning of the 2nd year. It is partly because many of master's students had a job and preferred to obtain a master's degree by course work. There was also a discouraging situation where students often had to bear the cost for research such as assembling parts and consumables. Few faculty members had experiences of publishing research articles in international academic journals after finishing study abroad. Consulting work for private firms was popular among lecturers and considered as part of research, even though it did not produce any invention.

The project approach for introducing LBE at ITS was to lessen hindrance to research activities by providing small research grants for implementing LBE, especially for motivated faculty members. The 1st phase of the project supported joint research with Japanese researchers; research grants for introducing LBE was the tool for strengthening research capability of ITS faculty at the same time. The key issue is to give purposely-designed requisites for applicants; the project limited applicants to faculty members who can lead a research team that includes one or more master's students, namely PIs of LBE teams. Grantees are requested to co-author and publish research articles with master's students. Although there were almost no faculty who conducted research with his/her master's students before the 1st phase project, more than 30 proposals were submitted to the 1st call for proposals in 2006, among which 3 were selected as model laboratories for the first LBE implementation.

Additionally, in the 2nd phase from 2012, the project adopted a policy of ICT for all. This is based on the idea that ICT is a fundamental technology for all fields of study; for example, the project accepted proposals from chemical engineering as far as the

research includes utilization of ICT such as digital analysis, censoring, and so forth. This policy encouraged ITS to invite all faculty staff to implement LBE as the ITS standard.

During the project period of 9 years from April 2006 to December 2014 with a 2-year interval between 1st and 2nd phases, the project supported 38 LBE teams. Consequently, ITS established and certified 51 LBE teams in total covering all engineering departments through project implementation.

4.2. Academic cooperation with local universities

The Government of Indonesia was seriously concerned with expanding digital gaps between the Java and other islands. Following the government's policy, the Directorate General of Higher Education (DGHE) of then Ministry of Education and Culture launched the Indonesia Higher Education Network (INHERENT) in 2006 in order to connected remote universities with DGHE and major universities in Java Island. ITS was assigned as a hub university for connection with EPI universities. The timely settlement of communication network and ITS's role worked as strong background of the project.

There was another issue that provided the project with positive circumstances; ITS had experiences of receiving faculty members of universities in EPI as postgraduate students and had nurtured culture for fostering remote universities prior to the project. This situation also comes from the policy of the Government of Indonesia; the government has been offering scholarships for lecturers of EPI universities to pursue master's and/or doctoral study at resource universities inside Indonesia including ITS. ITS was therefore originally motivated to make good cooperation with EPI universities as an expected resource university. In addition, ITS thus had sort of human network with many of state and private universities in EPI. Finally, the scholarship was indispensable for involving full-time master's students, namely lecturers of EPI, in the LBE activities at ITS.

In order to carry out simultaneous strengthening of both resource and local universities, the project needed to involve lecturers of EPI universities in the LBE activities of ITS. It was however difficult to make their participation requisite for the grant application during the 1st phase project. Establishing LBE teams that involve any master's students of ITS was the first priority. In spite of such conditions, considerable number of postgraduate students who were EPI lecturers eventually joined granted LBE teams. Master's students from EPI universities are full-time students supported by the government scholarships and hence ideal as LBE team members. ITS accordingly selected four official partner universities among those that were sending faculty members in the granted LBE teams.

Some LBE teams invited faculty members of EPI universities who are not postgraduate students of ITS but in-service lecturers in EPI to join the research with Japanese researchers. Table 1 shows the structure of LBE teams who conducted joint research with Japanese researchers during the 1st phase.

Table 1. Structure of LBE teams (1st phase)

Batch (Number of teams)	ITS		EPI University	
	Faculty member	Student	EPI	ITS Student
1 (3)	21	1	1	9
2 (4)	18	0	0	11
3 (7)	32	20	5	46
Total	71	21	6	57

(Source) Prepared by the author based on the project data.

In the 2nd phase, research grants were provided for joint research by ITS and EPI universities; a few Japanese researchers were assigned as LBE advisors. Accordingly, the project made it requisite for application that applicants include one or more faculty members of EPI universities in his/her LBE team, either as in-service lecturers of EPI universities or as postgraduate students of ITS.

This advanced arrangement is based on the progress of the academic cooperation during the 1st phase, which is featured by establishment of the Forum for Integrated Development of 11 Universities (FIND-11) in 2010 through the initiative of ITS. FIND-11 presents expanded partnership based on the activities with four partner universities. FIND-11 has been upgraded to the Eastern Part of Indonesia University Network (EPI-UNET), consisting of 23 EPI universities, in 2012. Participation of EPI researchers in the 2nd phase project, either as in-service lecturers or ITS students, are as shown in Table 2.

Table 2. Participation of EPI universities in LBE (2nd phase)

Batch (Number of LBE teams)	Partner and EPI-UNET Member		Other EPI University	
	in-service	ITS Student	in-service	ITS Student
1 (7)	10	8	6	8
2 (7)	12	2	2	15
3 (10)	22	7	4	13
Total	44	17	12	36

(Source) Prepared by the author based on the project data.

The project actively utilized ICT as collaboration tool with EPI universities besides the common research concerns. One is for communications with

counterparts at far sites, such as e-seminars for sharing research results of LBE teams with researchers and students in EPI, e-lectures by ITS faculty members for students in EPI and so forth. Another is for e-Learning. Naturally, e-Learning by itself helps students and lecturers of remote areas since it makes education materials of resource universities available at local classes. Additionally, the project utilized e-Learning as collaboration agenda; preparing specific e-Learning programs for a partner university requires strong communication paths and collaborative activities based on mutual reliance. As part of the project activities, ITS and Universitas Sam Ratulangi (UNSRAT) started from discussions on what kind of program should be jointly prepared and provided, designed the syllabi, prepared materials for both digital and face-to-face classes and quizzes for everyday self-study, decided evaluation methods, and jointly provided several subjects during the 1st phase.

5. Results

5.1. Outputs of LBE

Enhancement of research capability should primarily be inferred from increased numbers of reseserch articles published in international academic journals. Publication of papers, co-authored by master's students and faculty members, indicates that students should have acquired potential capability to conduct research.

During the 1st phase period, 14 LBE teams in total presented 67 papers, whose first author was a master student, at international conferences. In the 2nd phase of the project, as Table 3 shows, the average number of co-authored articles of ITS appears largely increased. The first author of these papers was frequently a master's student.

Table 3. Number of co-authored papers published in international conference/journal by ITS

Year	Granted laboratories (Average/lab/year)	51 certified LBE laboratories (Average/lab/year)
2012	5 (0.71)	32 (0.53)
2013	66 (2.75)	86 (1.69)
2014	(45) (n/a)	(53) (n/a)

(Note) The number of granted laboratories is 7 in 2012 and 24 in 2013 and 2014.
Data of 2014 is as of September 2014.
(Source) Prepared by the author based on the project data.

On the other hand, the number of international journal publications by granted laboratories grew at a considerably slow pace during the 1st phase project period; however, as Table 4 shows, the growth sharply speeded up after the 2-year interval. The total number of publications in international journals and patent application by all faculty members at ITS also elevated prominently after the 1st phase is closed.

Table 4. Number of international journal publications and patent applications by ITS

Year	Publication in international journal		Patent application	
	Granted laboratories	ITS total	Granted laboratories	ITS total
2007	0	27	2	11
2008	1	42	1	4
2009	2	95	7	14
2010	(1)	121	(-)	16
2011	-	-	-	2
2012	6	381	8	53
2013	39	379	6	35
2014	(47)	759	(8)	91

(Note) Research grants were provided as follows:
1st phase
Batch 1 (3 teams) August 2006-July 2007
Batch 2 (4 teams) August 2007-July 2008
Batch 3 (7 teams) August 2008-July 2009
2nd phase
Batch 1 (7 teams) July 2012-June 2013
Batch 2 (7 teams) February-November 2013
Batch 3 (10 teams) July 2013-June 2014
Granted laboratories' data in 2010 is as of March 2010 and in 2014 is as of September 2014.
(Source) Prepared by the author based on the project data.

5.2. Establishment of academic network with local universities

One of the visible outputs of the academic collaboration is establishment of the EPI-UNET of Figure 1. As described in 4.2., ITS voluntary led this initiative based on the project activities and has been providing the member universities with small research grants. EPI-UNET is now documented as part of ITS's official development strategy.

Figure 1. Major member universities of EPI-UNET
(Source) *Rencana Strategis Penelitian Institut Teknology Sepuluh Nopember 2016-2020*, p.20

In terms of capacity building of faculty staff in EPI, 52 co-authored research articles were internationally published by 14 granted LBE teams during the 1st phase project period and 38 by 24 granted LBE teams during the 2nd phase. Table 5 shows the growth of papers, co-authored by ITS and EPI members of 51 certified LBE teams and nationally and internationally published, during the 2nd phase.

Table 5. Number of co-authored papers with EPI faculty members by 51 LBE teams (2nd phase)

	2011	2012	2013	2014
Publication in journal and conference (international/national)	10	11	25	44

(Note) Co-authors of EPI universities are either in-service lecturers or those who are studying as postgraduate students at ITS.
(Source) Prepared by the author based on the project data.

6. Evaluation of LBE introduction and academic cooperation

6.1. LBE at a resource university

The increased number of international research papers co-authored by master's students and faculty members at ITS concededly proves that master's students of ITS took an active role in the research of his/her supervisor's laboratory; authorship of a research article is the evidence of considerable contribution to the research outputs. In the laboratory, different from earning credits by attending classes and/or receiving skill training for vocational purposes, students should have understood his/her research task as part of PI's research project, made logical thinking and took practical actions in order to carry out the research task.

Considering that there was no research duty for master's students before the technical cooperation, the result strongly supports the hypothesis that introduction of LBE nurtures potential research capability of master's students at universities in developing countries, enabling them to solve practical problems.

On the other hand, the enhancement of international journal publication by faculty members of granted laboratories was relatively gradual. Taking into consideration that there was no research team before the technical cooperation project, the increased number of co-authored papers however suggests that faculty members conducted research with colleagues and students; the fundamental idea that research is the basis for education, in other word faculty members are researchers, is sinking in.

Successful model activities also encouraged surrounding faculty staff to follow what LBE teams were doing, though many of them were originally reluctant to get involved in additional work without additional salary. LBE at model laboratories eventually nurtured research culture at all departments of ITS through visible outputs such as international publications.

Patent application, which must be done before any publication of research outputs, was sometimes difficult in conflict with the priority of paper publication. Complicated and unfamiliar procedures also discouraged faculty members to embark in patent application, even though ITS put much effort in preparing better environment for faculty members such as providing guidelines and strengthening functions of relevant campus-organizations. Notwithstanding this situation, as the result shows, awareness of the significance and necessity of intellectual property rights management rose up, almost from scratch at ITS. Universities must produce new ideas through research, while technologies must bring forth value-added goods in order to contribute to economic growth. Inclusion of patent application besides paper publication is therefore one of the crucial issues in introducing LBE.

As to the driving force of LBE introduction, it is understandable that provision of research grants worked as incentives for faculty members to tackle the additional tasks At the same time, some internal factors were also critical for enabling LBE despite the difficult situation; the issue is directorates' strong motivation to upgrade their institution to an established research university. ITS organizationally supported the project activities through allocating small budget exclusively for LBE teams, awarding PIs who made excellent progress in LBE, selecting promising research proposals as targets for financial and technical assistance in patent application, and so forth. Such policies and actions strongly pushed forward LBE.

6.2. Academic cooperation with local universities through LBE

From the viewpoint of simultaneous capacity building of both resource and local universities in developing countries, impact of LBE implementation at ITS, as described in 6.1, naturally supports this approach, since many of postgraduate students of ITS were faculty members of EPI universities. Educational effects of LBE should be evaluated in a longer-term and it may take long to nurture research culture in EPI; the holistic approach of the project however resulted in potential research capability of total 123 lecturers of EPI universities.

Additionally, LBE requires postgraduate students to make frequent research discussion with team members and to logically defend their research result against severe comments by seniors at regular

meetings of the laboratory. They also have to follow rules and role-sharing assignments of the team, once he/she becomes a member of an LBE team. Most importantly, students learned that working hard for better research outputs would bring fruit such as international journal publication. This environment should have invisibly transformed their way of thinking from traditional to international style. Communication skills also should have improved. It may also need time to disseminate this working culture in EPI; however, those who have been exposed to international atmosphere might work as transmitters in EPI.

Finally, it is well known, especially in science and engineering fields, that supervisor-supervisee relationship goes on even after the student has left the laboratory: faculty members in EPI universities should keep in touch with their supervisors, namely the PI of the laboratory, to which he/she had once belonged. This partnership should help remote universities collaborate with the resource university and continuously upgrade education and research in EPI. Involving lecturers of local universities in LBE teams of the resource university also has an impact in this way.

As described in the previous chapters, human capital that has ability to interpret advanced technical information as local recipes is crucial for industrial catching-up of late-coming countries; technological assimilation needs well-founded intelligent actions. Besides acquiring knowledge on basic science and technology in the classroom, LBE enables students, supposing that considerable number of lecturers of local universities are included, to utilize the knowledge for practical purposes including problem solution and, after reaching a certain level, value creation. This makes the fundamentals of industrialization of developing countries and simultaneously upgrades the quality of engineering education in local areas with the prospect of reducing disparity between central and peripheral areas. LBE is thereby advantageous for achieving the SDGs.

7. Conclusion

This research has firstly clarified that LBE introduction at the master's level in the engineering field helps universities in developing countries carry out their mission; universities must provide industries with capable human resources and new technology. Taking into considering the current situation of local universities in developing countries, strong resource universities should make a commitment to fulfill this mission. Secondly, the research results supported the hypothesis regarding effectiveness of the holistic approach to simultaneously enhancing capability of both resource and local universities in developing countries.

From the practical aspect, the research also presented some lessons for deploying the holistic approach in developing countries. The project design was relevant to the social needs that request ITS to strengthen its research and education besides establishing substantial academic network with universities in EPI. The project thereby laid duties on PIs of granted LBE teams to involve postgraduate students who are lecturers of universities in EPI as their research team members. Consequently ITS established EPI-UNET and, at the same time, enhanced capability of faculty members of ITS itself and local universities. Government policies and arrangements for supporting local universities to improve education and research are also vital for active participation of both resource and local universities. As for the LBE implementation, the research demonstrates effects of strong motivation to become a prestigious research university. The analysis also indicates impact of good practices by successful models in terms of disseminating LBE inside and outside the resource university.

There are also remaining issues. First, considering that research is the basis for education, self-sustaining enhancement of research capacity of faculty members is imperative in order to assure the quality of LBE. Especially at a resource university, quality of LBE affects nationwide superiority of human resources and thus their contribution to socio-economic development. With this regard, sustaining partnership between a resource university and local universities should be more difficult, compared to keeping collaboration between the resource university and its international partners; both resource and local universities lack financial resources for research and sometimes motivation for improvement.

Second, assuming that quality research is done at universities, from the viewpoint of universities' mission to contribute to industrial development, industry-university collaboration for creating new value is still limited. This is partly due to the low motivation of industries in developing countries for technological innovation, which is an external condition for academic institutions. At the same time, universities' awareness of mutuall-beneficial collaboration with industries is not strong enough or even weak. Awareness raising should also be elaborated for actualizing sustainable industry-university collaboration, especially collaboration for value creation. Driving force of economic growth is continuous technological progress in production. Research output, namely new technology, must be utilized for industrial development.

Accelerating sustainable LBE implementation for research and development along with productive industry-university collaboration is a challenging yet crucial issue of higher education in developing countries. International education cooperation for

this purpose should therefore contribute to the achievement of SDGs.

The ideas and opinions expressed in this paper are entirely those of the author and should not be attributed in any manner to the organization that the author belongs to.

8. References

[1] A. Suehiro (Translated by Tom Gill), *Catch-Up Industrialization The Trajectory and Prospect of East Asian Economics*, NUS Press, Singapore, 2008.

[2] R. Solo, "The Capacity to assimilate an advanced technology", *American Economic Review,* Vol. 56, American Economic Association, Pittsburg, Pennsylvania, U.S.A., 1966 pp. 91-97.

[3] Romer, P., "Idea gaps and object gaps in economic development", *Journal of Monetary Economics* 32, Elsevier, Amsterdam, The Netherlands, 1993, PP. 543-573.

[4] Kuznets, S, "Notes on Japan's Economic Growth: The Japanese Experience since the Meiji Era", *Proceedings of the Conference of the Japan Economic Research Center*, R. D. Irwin. Inc., Chicago, Illinoi, U.S.A., 1968, pp. 385-422.

[5] Minami, R., *The Economic Development of Japan A Quantitative Study*, Palgrave Macmillan, London, U.K., 1986.

[6] Nakano, K., "The role of university-educated engineers in technology transfer - a case study on the establishment of Pohang Iron and Steel Company through interviews to Japanese engineers", *Journal of International Development Studies*, Japan Society for International Development, Tokyo, Japan, 2016, pp.193-207.

[7] Song, S., "Historical Development of Technological Capabilities in POSCO", *Case Study on Technological Innovation of Korean Firms,* Science and Technology Policy Institute, Seoul, Korea, 2002, pp. 97-131.

