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International Training Program for Geothermal Energy Development in Japan

Ryuichi Itoi[1], Hiroto Kamiishi[2], Daisuke Iijima[2], Eiji Wakamatsu[2]

1 Kyushu University, Fukuoka, Japan , 2 Japan International Cooperation Agency (JICA), Tokyo, Japan

itoi@mine.kyushu-u.ac.jp

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ABSTRACT

Japan International Cooperation Agency (JICA), an implementing agency of Japan's Official Development Assistance (ODA), is providing various training programs in the field of geothermal energy. As geothermal development in developing countries has become more active in recent years, a shortage of geothermal experts in each country has increasingly become a serious problem for a steady progress of development. In order to solve this problem and to contribute to geothermal development in developing countries, JICA started new capacity building programs of short and long terms since 2014. The short-term program consists of three courses started in 2016 and the long-term program for master and doctoral courses started in 2014. The programs aim to support and help geothermal energy development in developing countries through human capacity building. The short-term training programs consists of three courses: (a) six months course for geothermal resource engineers, (b) six weeks course for drilling managers, and (c) two weeks course for executives. In the last three years from 2016 to 2018, a total of 82 participants completed the courses: 25 participants from 9 countries in the executive course, 18 from 8 countries in the drilling manager course and 39 from 10 countries in the geothermal resource engineers course. These courses have been carried out with cooperation of 36 organizations being comprised of universities, private companies and national and public institutions. Long term programs consist of two programs that provide participants with opportunities to obtain masters and doctoral degrees: (a) Kizuna program, (b) African Business Education program ("ABE Initiative"). These long-term training programs are carried out in collaboration with universities, private sector, research institutions, and governmental organizations in Japan.

1. INTRODUCTION

Since the 1970s, the Japanese government has been supporting geothermal development in developing countries that have geothermal potentials through various activities; technical support, financial loans and capacity development. Regarding capacity building in the geothermal sector, Japan has a long history from as early as 1970 when the geothermal training program started at Kyushu University in collaboration with UNESCO and the Japanese government (Fukuda et al., 2000). Around the same time, several programs were started by Iceland, New Zealand, and Italy. Kyushu University's course lasted for 32 years until 2001. New Zealand also stopped their Geothermal Diploma Course in 2002, but restarted it as a six months program in 2007 (Zarrouk, 2017). The United Nations University Geothermal Training Program (UNU-GP) in Iceland is the only one running continuously from its start in 1978 until now (Georgsson et al., 2015).

As geothermal development in developing countries has become more active in recent years, a shortage of geothermal experts in each country has increasingly become a serious problem for a steady progress of development. This is widely recognized in the global geothermal community. In order to solve this problem and to contribute to geothermal development in developing countries, JICA has started new capacity building programs of short and long terms. The short-term program consists of three courses started in 2016 and the long-term program for master and doctoral courses started in 2014 (Itoi et al., 2018). This paper explains the present status of these geothermal capacity building programs.

2. SHORT TERM PROGRAM

The short-term program consists of three courses, and they are: 1) Geothermal Resource Engineers (GRE), 2) Geothermal Drilling Management (GDM), and 3) Geothermal Policy and Strategy Program for Executives (Executives). These courses were started in 2016 and are prepared for assigned countries in Asia, Latin America and the Carribean, Africa, and other regions with geothermal resource potential. As JICA's program is on the basis of government cooperation, application and nomination of candidate of respective countries can be made only through relevant governmental organization of the country. Candidates for the course should be currently engaged in geothermal development and have more than 1 to 3 years of work experience depending on the course. Information on these courses called General Information (GI) can be obtained at the JICA office of the respective country. Expenses for the courses including international travel fee, daily allowance, accommodation fee, field trip are covered by JICA. The following sections explain a brief overview of each course.

Figure 1 presents the number of participants that have attended the three courses. The total number of participants for three courses by 2019 is 107. This excludes that for Executive course in 2019, as the application process has not yet started.

Figure 2 shows the total number of participants by country for the three courses by 2019 except the Executive course. The largest number is Djibouti (27) followed by Kenya (20) and Ethiopia (17). More than half of the participants are from African countries.

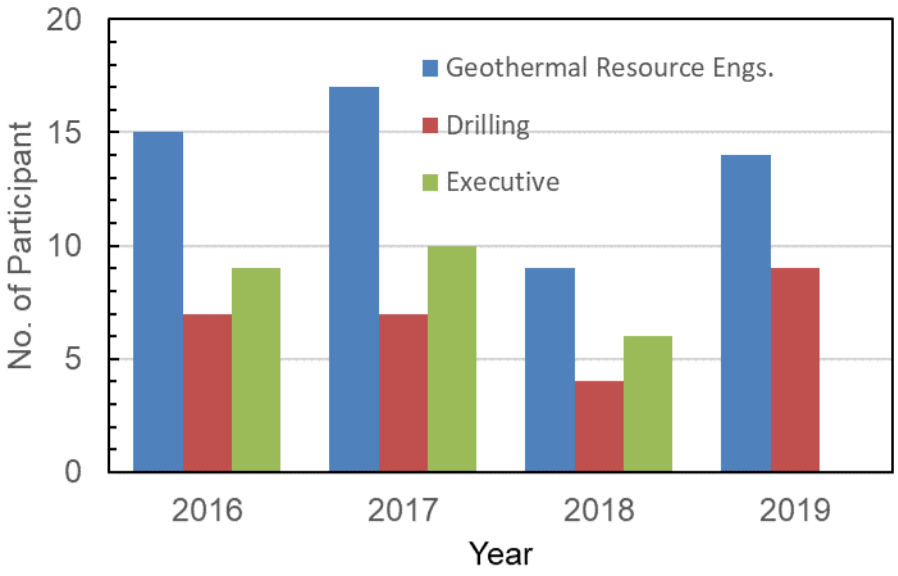

Figure 1: Number of participants for the short term program (Geothermal Resource Engineers, Geothermal Drilling Management and Geothermal Policy and Strategy Program for Executives) from the year 2016 to 2019.

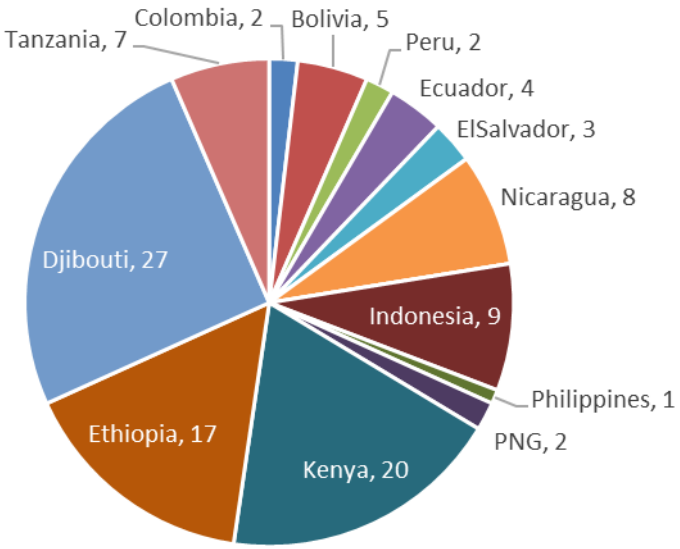

Figure 2: Number of participants for three courses by country. The largest number is Djibouti followed by Kenya and Ethiopia.

2.1 Geothermal Resource Engineers (GRE)

This course is prepared for university graduate level engineers with a few years of practical experience in the geothermal industry to learn a wide range of subjects related to geothermal development from geology, geochemistry, exploration geophysics, reservoir engineering, environmental chemistry and sustainable development. Duration of the course is six months. The course generally starts in early June and finishes in the middle of December. First three months are mainly classroom lectures and exercises followed by three months of individual project study. Lectures and project studies are carried out at Kyushu University. In 2018, lecturers came from 17 organizations. The organizations were universities including Kyushu University, private companies, national institutes and public organizations. During the course, field trips are carried out three times: twice in Kyushu and once to Tokyo and Tohoku region, which is in northern part of Japan.

Three months of the latter part of the course is assigned for project study. Participants are requested beforehand to select one out of six specific study categories. At the same time, they are recommended to bring their own data from their country for their study work. If the data are not available, they can use existing field data in Japan or carry out field work in Kyushu and collect samples for their study.

The maximum number of participants for the course is 18 per year. The total number of participants from 2016 to 2019 was 41, but two participants returned home before finishing the course, one each in 2016 and 2017. Thus, 25 participants have completed the course and 14 participants from 6 countries are now taking the 2019 course.

During the course, participants are required to make three presentations: (a) on the situation of geothermal energy resource and its development in their countries, (b) on the results of the project study in a seminar, and (c) on an Action Plan at the end of the course. An Action Plan is a future plan of each participant's activity after going back to their country and organization.

Upon completion of the course, a certificate both from Kyushu University and JICA will be handed to each participant at the closing ceremony. Figure 3 is a picture taken after the closing ceremony in 2017. In the following subsections, the course content of GRE is described in detail.

Figure 3: Group photo of participants of the Geothermal Resource Engineers course and staff of Kyushu University at the closing ceremony in December, 2017.

2.1.1 Lectures

Lectures are given in the classroom of the university during the first three months from June to early September, and are divided into 11 groups. They are:

1) **General topics** consisting of 8 subjects: (1) Energy demand and supply in the world, (2) Geothermal systems, (3) World geothermal development, (4) Exploration geophysics for geothermal development, (5) Introduction to geochemistry of geothermal fluids, (6) Introduction to geothermal geology, (7) Geothermal development planning, (8) JICA's support for geothermal development

2) **Geology** consists of 4 subjects: (1) Geothermal geology for alteration mineral, (2) Geothermal geology for fluid inclusion, (3) Exercises for X-ray diffraction (XRD), and (4) Microscope observation.

3) **Geochemistry** consists of 6 subjects: (1) Fluid geochemistry, (2) Gas geochemistry, (3) Chemistry of silica, (4) Isotope geochemistry, (5) Chemistry of wellbore fluid, and (6) Exercise on chemical analysis.

4) **Exploration geophysics** consists of 7 subjects: (1) Geophysical exploration for geothermal development, (2) Gravity survey and monitoring, (3) Magnetotelluric (MT) survey, (4) Seismic exploration, (5) Microseismic monitoring, (6) Magnetic survey, and (7) Remote sensing.

5) **Drilling and logging** consists of 2 subjects: (1) Drilling technology and (2) Geothermal well logging.

6) **Surface facilities** consists of 2 subjects: (1) Geothermal power generation, (2) Operation and maintenance of geothermal power plant.

7) **Reservoir and production engineering** consists of 5 subjects: (1) Liquid-dominated system, (2) Vapor-dominated system, (3) Reservoir simulation, (4) Tracer test, (5) Wellbore flow, and (6) Well testing.

8) **Direct use** consists of 2 subjects: (1) Ground source heat pump system, and (2) Direct utilization.

9) **Social science** consists of 5 subjects: (1) Economic aspects of geothermal development, (2) Geothermal energy policy, (3) Social acceptance of geothermal development, (4) Social environment, (5) Environmental impact assessment .

10) **Basic engineering** consists of 4 subjects: (1) Thermodynamics, (2) Exergy analysis, (3) Corrosion, (4) Data analysis with Excel.

11) **New technology** consists of 2 subjects: (1) Enhanced geothermal system (EGS) and (2) Supercritical geothermal resources

Lectures are usually one day for each subject: 3 hours in the morning and another 3 hours in the afternoon. Some lecturers use a part of the afternoon session for exercise to confirm comprehension of the lecture subject.

2.1.2 Field trip

Field trips are organized to geothermal fields, geothermal power plants, turbine manufacturer shop, renewable energy utilization sites, and university facilities. This is for the participant to have a deeper practical understanding of geothermal in general as well as present status and issues of geothermal activities in Japan. There are three field trips during the course.

1) Hatchobaru and Beppu areas in Kyushu region
This is the first trip and is designed for participants to understand geothermal energy and its utilization after participating in the first two weeks of introductory lectures on geothermal energy. This is because some participants do not have geothermal power plants in their country and need to understand its system. The trip will take them to the Hatchobaru geothermal power plant of double flash type and the Takigami or Sugawara binary power plant. We also visit the Komatsuike fumarole near Hatchobaru to observe surface manifestations and for demonstration of gas and water sampling. Then, they will visit Beppu for microscale binary geothermal power plant, fumaroles, and hot spring steam utilization facilities for tourist attractions.

2) Tokyo and Tohoku region
Participants will make presentations on the present status of geothermal energy development of their country and geothermal energy potential at JICA headquarters in Tokyo. This is followed by a visit to the turbine factory of Toshiba or Fuji Electric Co. in the metropolitan area. Tohoku is one of the main geothermal areas in Japan. The participants will visit Matsukawa geothermal power plant to observe dry-steam type production and Sumikawa geothermal power plant to observe water-dominated type production. A visit to Geothermal Engineering Co. at Morioka provides a good opportunity for participants to observe water and gas analysis equipment, logging tools, and drilling rigs. Kuzumaki town, located in the northern part of Iwate prefecture, has been developing various type of renewable energy sources found in the town for their own use and exporting excess electricity out of the town. Participants will develop understanding local energy production and consumption system by visiting a wind power mill, biogas power plant, and solar PV generation plant in the town.

3) Nagasaki and Unzen geothermal area in Kyushu region
Three days trip to western Kyushu leads to YBM Co. that manufactures small scale drilling rig, Institute of Ocean Energy, Saga University, and to observe ocean thermal energy conversion system for power generation. Then, they will visit Mitsubishi-Hitachi Power Systems Co. at Nagasaki to observe production of geothermal steam turbines. The Obama hot spring resort in Shimabara peninsula uses hot springs to power geothermal power plants with many hotels generating up to 135 kW with small scale power generation. Other than geothermal energy related places, participants also visit the atomic bomb memorial museum in Nagaski, and the natural disaster memorial museum of Unzen volcano.

Other than these trips, participants also have a chance to visit Kyushu University facilities such as the hydrogen station at HYDROGENIUS, research center for hydrogen use, and high voltage transmission electron microscope at Ultramicroscopy Research Center of Kyushu University.

2.1.3 Project study

Project study (PS) is carried out for three months in the latter part of the course. Participants are requested to select one category for his/her PS upon submitting application. The categories are divided into six and they are: (1) Geothermics, (2) Geology, (3) Exploration geophysics, (4) Geochemistry, (5) Reservoir and production engineering, and (6) Energy and exergy analysis. The project study will depend on the capacity of research laboratories in the Department of Earth Resources Engineering, the main organization in charge of running the course. Brief explanations on each category are provided in the GI sent to applicants through the JICA office of respective countries. At the same time, participants are requested to bring samples or field data for analysis to be used for their project study. Soon after the course starts, Kyushu University's course leader conducts an interview with each participant on his/her project study to discuss study topics and the category they selected, and availability of samples or data. During the interview participants are sometimes advised to modify or change study topics to a more appropriate category. For example in 2017, two participants changed their topics, but other 14 remained with the original selection of study category. Table 1 summarizes number of participants assigned to research categories of PS in the last three years.

Table 1 Number of participants assigned to categories of project study in the last three years.

	2016	2017	2018	Total
1. Geology	3	3	2	8
2. Geothermics	2	1	1	5
3. Geophysics	3	4	0	7
4. Geochemistry	3	2	0	5
5. Reservoir	3	4	3	10
6. Exergy	0	2	3	5
Total	14	16	9	39

When PS starts in September, each participant is assigned to a research laboratory in the department. Both faculty members and graduate students in the respective laboratory provide support and guidance for the participants to start conducting their study. In some cases, there are graduate students from the participant's country. The graduate students can introduce the participants to the laboratory facilities and guide them on how to use them. Research laboratories and faculty member offices are located in the same building as the course, so the participants have easy access to the laboratories.

Project studies in 2017 and 2018 are briefly introduced as follows.

1) Geology
   A field survey of altered zones in the Otake and Hachobaru geothermal field in Kyushu, and XRD analysis of altered minerals was conducted to understand alteration structures (Participants from Ethiopia and Djibouti).

2) Geochemistry
   Hot spring water and fumarolic gas were collected in the Unzen geothermal area in Kyushu, and basic sampling techniques and sample treatment methods were trained in the field. Chemical analysis of samples was carried out using university equipment (atomic absorption spectroscopy (AAS), ion cromatograpy, inductively coupled plasma mass spectrometry (ICP-MS), gas cromatography). The results were then evaluated and analyzed to understand the characteristics and origin of the geothermal fluid (Ecuador and Tanzania).

3) Geophysical prospecting
   The resistivity structure was clarified by two-dimensional analysis using the MT survey result carried out in the home country (Indonesia, Ethiopia, and Kenya).

4) Geothermics
   The remote sensing data were analyzed for delineation for potential area (Indonesia, Kenya). Gravity data from participant country were analyzed for Bouguer anomaly map and delineate fault area by inversion analysis (Djibouti, Bolivia).

5) Reservoir and production engineering
   Processing and analysis of well pressure test data were carried out to estimate values of reservoir parameters (Ethiopia, Kenya). Data will also be extracted from published papers and reports to conduct a series of reservoir studies, including the development of a conceptual model of the reservoir, development of a grid model, and a natural state simulation using a numerical simulator (Bolivia, El Salvador and Kenya).

6) Energy and exergy analysis:
   Flow diagram of energy and exergy in geothermal power plant were compared among systems of single flash, double flash, binary, and hybrid power plants (Kenya, Nicaragua).

Reports of PS are published in the annual Geothermal and Volcanological Research Report of Kyushu University after proofreading for grammar and revising the content as necessary. At the end of the course, each participant must write a report on their study results. At the same time, they present their results and findings in a presentation session of the course for 15 minutes followed by Q&A.

2.1.4 Management of the course

The course is run by Kyushu University (KU) and JICA Kyushu. Kyushu University is in charge of planning and managing activities during the course such as lecture, field trip, project study. JICA Kyushu is in charge of applicant recruitment, participant acceptance, arrangement of trip to and from Japan, and accommodation. Kyushu University receives a running fee from JICA Kyushu on the basis of the contract between KU and JICA. This fee covers all the activities related to university and salary of two coordinators and a secretary. Program staff consists of course leader, Prof. Yasuhiro FUJIMITSU, two program coordinators, Prof. Emeritus Ryuichi ITOI and Dr. Tatsuto INO, and a secretary, Ms. Eri INOU. The department office and faculty office also support the program. Organizing committee meetings are held occasionally to discuss course content, accommodation, revision of lecture subjects and project study. Members of the committee are comprised of program staff and Associate Profs. Jun NISHIJIMA and Tatsuya WAKEYAMA, and Research Associate Mitsuo MATSUMOTO of the department. The committee also have meetings with JICA Kyushu on running the course.

2.2 Geothermal Drilling Management (GDM)

This program is designed to train drilling managers for planning, managing, and supervising drilling activities. The aim of the program is to provide the current and future drilling managers with the tools to effectively plan and manage a drilling project. In many countries with geothermal potential, the implementing organizations must procure equipment and materials, drilling contractors and other services. Geothermal drilling is a highly complex task involving various contracts. It also requires adequate knowledge and experience of geothermal development, drilling management, drilling technology, logistics, and contract management.

During the six (6) weeks course starting in early July to August, the participants will participate in lectures and site visits to geothermal drilling sites, and warehouses for drilling rigs. They will also visit manufacturing factories of drilling rigs, valves, and steam turbines to obtain first-hand knowledge of the whole value chain of geothermal drilling.

One of the highlights of the course is a lecture on a detailed analysis of actual drilling accidents that occurred in Japan that was produced especially for this training program. In the lecture, participants can discuss with lecturers on how to mitigate these incidents from happening. The program is implemented by Kitakyushu International Techno-cooperative Association (KITA) under administration of JICA Kyushu.

The number of participant acceptable is eight (8) per year. The total number of participants for the four years from 2016 to 2019 has been 27.

2.3 Geothermal Policy and Strategy Program for Executives (Executives)

To promote geothermal energy development, government officials of ministries and management level persons of geothermal development organizations need to understand the basics of the technology, its development risks, its economics, policy, legal structures, etc. This two-week course provides an opportunity for participants to learn geothermal law, economic evaluation model of geothermal development on the basis of engineering economy, and case studies on comparative analysis between public and private investments. Participants discuss issues such as the role of public and private sectors for geothermal development, and how to attract private investment. Japanese executives of the private sector, government and academic organizations join the discussion. A network among participants and Japanese executives can also be developed during the course. The program is implemented by JICA Kyushu with support of West Japan Engineering Consultants Inc. (WEST JEC) for the courses from 2016 to 2018. From 2019 Kitakyushu International Techno-cooperative Association (KITA) will implement the course under administration of JICA Kyushu.

Seat number of participants acceptable was twelve (12) per year. The number of participants for the last three years from 2016 to 2018 has been 25.

3. LONG TERM PROGRAM

In 2014, JICA started a long-term program for capacity building in the field of mining and earth resources called the Kizuna Program[1] *Kizuna* means "bond" in Japanese. Many developing countries are rich in minerals, oil and gas, coal and geothermal energy resources. In order to develop these resources in a sustainable manner, engineers and governmental officials need to have the necessary knowledge and experience on their development. The aim of the program is to: 1) develop human resources for earth resources, and 2) develop human resources network, or *Kizuna*, among developing countries and Japan. The program started in 2014 with collaboration of Japanese universities that have departments specialized in education and research in earth resources and mining. They are Kyushu University (KU), Hokkaido University, Akita University, Tohoku University (TU), Tokyo University and Waseda University. This program covers not only geothermal but also oil and gas, coal and metal mining.

Target countries for the Kizuna Program's geothermal sector are ones with geothermal potential. So far, the program has accepted students from Rwanda, Kenya, Ethiopia, Tanzania, Djibouti, El Salvador, and Indonesia. Eligible applicants of these countries are employees of governmental organization such as geological survey, public corporation and academic staff of universities. A brochure of the Kizuna Program can be found at the JICA website[1] (JICA, 2019).

Students are enrolled in the graduate school at respective universities and supervised by professors of related fields for their research project. JICA organises site visits in Japan during the program to geothermal power plants and manufacturing companies of geothermal turbines, and assists participants to participate in a short-term internship at relevant private companies. These programs provide opportunities for students to enhance their knowledge obtained during the program in actual application. The program financially supports field work in the participants' home countries as part of their research project for masters or doctor thesis. Her/his supervisor will accompany the field work (also supported by JICA). JICA's support includes travel expense of student and supervisor.

The total number of students allocated for geothermal sector in the program is expected to be 50 for 10 years from 17 countries. In 2019 as of May 1st, there are six (6) master course students in KU and two (2) doctoral students in KU as shown in Fig. 4. Seven (7) master course students have already completed their program after finishing their defense by March 2019: three (3) from Rwanda, two (2) from Ethiopia, one (1) from Kenya and one (1) from Tanzania. They have already gone back to their home countries after completing their master programs.

Many Kizuna students are former participants of the GRE course. Among KU's Kizuna students, three (3) master course students and one (1) doctor course student have completed the GRE course, gone back to their home institutions, and returned to Japan after being admitted to the program. One master course student already finished his defense and completed the program in March 2019. The GRE course can motivate its participants to pursue higher educational degrees such as master and doctor by applying to the Kizuna Program for their future.

There are graduate students at KU under different JICA program): two master students both from Uganda and one PhD student from Kenya.

Dr. Isaac Kiplono KANDA of KU from Kenya and Dr. Alvaro Josue AMAYA AREVALO of TU from El Salvador received PhD degree in March 2019, and Mr. Carlos Osmin POCASANGRE JIMENEZ of KU from El Salvador will receive PhD degree in September 2019.

[1] https://www.jica.go.jp/english/publications/brochures/c8h0vm0000avs7w2-att/japan_brand_09.pdf

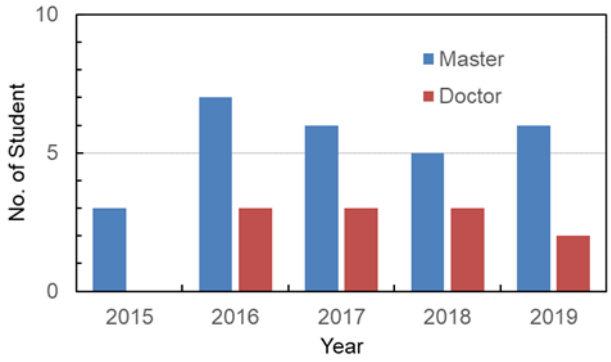

Figure 4: Number of students that are enrolled in the masters and doctor courses in the Kizuna Program.

4. SUMMARY

JICA started capacity development programs in the geothermal energy sector in 2014 for long-term courses and in 2016 for short-term courses. By the end of 2019, about 110 participants would finish the short term programs and 10 graduate students (three PhD and seven master) completed their programs. The short-term course of 6 months provides a good opportunity for participants to invoke incentives for pursuing higher education degrees such as PhD and master.

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