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Report

Synergy for Nuclear/Radiation Asian Teacher/Student Development: Experts Activities and Development for NS&T HRD Focusing on Secondary School Levels in Asia Pacific Region — Case of Japan

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International Atomic Energy Agency (IAEA) RAS0065/0079 (2012-2021) Technical Cooperation Programme (TCP) relating secondary school education on nuclear science and technology (NS&T) in Asia and Pacific region became a trigger to organize Team JAPAN. This team consists of several Japanese experts to support the activities and develop several educational tools and modules with "WOW factor" using the STEAM (Science, Technology, Engineering, Arts and Mathematics) education concept. This article shows the overviews of Japan Nuclear Human Resource Development (JN-HRD) Network which plays an important role of human resource development and supports the activities of Team JAPAN, and RADI which is an information web-platform for radiation education. In addition, the latest status of the national curriculum guideline of Japan on radiation education and representative examples of Japanese HRD activities for secondary school level. Furthermore, future scope from the eyes of Team JAPAN including issues to be solved and messages to stakeholders are mentioned. The TCP has provided big opportunities for the participating organizations and individuals from expert countries including Japan to brush up our abilities, skills and experience. Team JAPAN continues its activities with the cooperation with experts, teachers, and other stakeholders in the world.

Key words: human resource development, radiation education, NS&T education, secondary school education, STEAM, WOW factor

1. Introduction

International Atomic Energy Agency (IAEA) RAS0065/0079 Technical Cooperation Programme (TCP)[1)] relating secondary school education on nuclear science and technology (NS&T) in Asia and Pacific region became a trigger to organize Team JAPAN. This

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team consists of several Japanese experts to support the activities and develop several educational tools and modules for them with "WOW factor" (surprise, excitement, discovery, etc.) using the STEAM (Science, Technology, Engineering, Arts and Mathematics) education concept. Here, this article shows the overviews of (1) Japan Nuclear Human Resource Development (JN-HRD) Network which plays an important role of HRD both in Japan and worldwide and supports the activities of Team JAPAN, and (2) RADI which is an information web-platform for radiation education. In addition, the latest status of the national curriculum guideline of Japan on radiation education and representative examples of HRD activities for secondary school level described in the Compendium[2, 3] of IAEA are introduced. Furthermore, future scope from the eyes of Team JAPAN including issues to be solved and messages to stakeholders are mentioned.

2. Organizations and experts

2.1. JN-HRD Network

The network, established in 2010, consists of 77 organizations as of May 1, 2018, which are educational institutes, electric power companies, nuclear energy related companies, research institutes and society, nuclear energy related organizations, national government organizations, prefecture government organizations, and city government office in Japan. Its mission is described as the following in the website of JN-HRD Network[4].

"Global momentum toward the restoration and expansion of nuclear energy has become more evident due to several factors, such as issues related to stable supply of energy and environment concerns that are symbolized by global warming. Under this circumstance, it is urgently necessary to develop human resources to fulfill the increasing needs of new-build domestic and foreign nuclear facilities. Consequently, Japan is required to engage actively in human resources development that supports nuclear energy foundation and nuclear businesses in the future in all of the nuclear related organizations, in industries, educational institutions such as colleges and universities, research institutes and government.

Overseas, the nuclear human resource development has become a national commitment for some countries. With regards to implementation of nuclear human resource development in Japan, it is highly important to work together to construct a framework of nuclear human resource development nationwide not only with efforts of each relevant institution and individual cooperation, but also through mutual collaboration of all relevant organizations among industry, academia and government.

Given this situation, the national government (Cabinet Office, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Ministry of Economy, Trade and Industry (METI) and Ministry of Foreign Affairs (MOFA)) urges to establish "Nuclear Human Resource Development Network" based on mutual collaboration of all relevant institutions/organizations in Japan, with each of them coming together to promote various activities and projects on nuclear human resource development efficiently and effectively. Through these activities, it is aimed to bring the expansion and improvement of a social base involved in nuclear, to promote interests in nuclear among young students and to secure human resources which support the future nuclear field in Japan. And for the young researchers and engineers in the nuclear field, these activities should contribute in training them to have high quality with an international perspective to work for the world. Furthermore, in cooperation with IAEA, human resource development in NPP introducing countries shall be pursued."

In addition, we can see the overview of the activities of JN-HRD Network as follows.

"The network conducts new inter-organ activities as well as sharing information of the existing independent activities and having mutual cooperation among the participating organizations related to nuclear human resource development. Main activities are shown below.

- Establishment of cooperative partnerships with related organizations at home and abroad
- Mutual support for participating organizations in the network
- National and international public relations
  - ✓ Building international network
  - ✓ Japan nuclear human resource development network is building cooperative relationships with international nuclear human resource development networks, by promoting mutual understanding and sharing information with international nuclear human resources development organizations, such as International Atomic Energy Agency (IAEA) and European Nuclear Education Network (ENEN).
  - ✓ Cooperation Agreement between IAEA and JN-HRD
- Planning and operation of inter-organ human resource development activities
- Support and cooperation on nuclear human resource development for overseas, especially for NPP newly introducing countries
- Others (human resource development related activities)."

2.2. Team JAPAN for IAEA RAS 0065/0079 TCP

Team JAPAN has been organized to support the activities of TCP in Asia and Pacific region. Prof. and Dr. Takeshi IIMOTO of The University of Tokyo, who is an expert of radiation protection and also the national committee chair at that time for the promotion of radiation education mainly in secondary schools, was recommended as the key person in the related activities of Japan by the office of JN-HRD Network through MOFA to IAEA. He has been developing the team consisting of mixed members of highly talented Japanese young and middle-aged generations, with the full use of his own human relations. Their specified fields are radiation protection, radiation measurements, radiation bioscience, radioactive waste management, radiation education, cloud chamber development, energy literacy development, nuclear information outreach, etc. As seen in the Compendium[2, 3] of TCP, Team Japan's activities, has mainly focused on radiation education for the secondary school level and been financially and effortfully supported by several organizations. One of the strongest supporters to Team JAPAN is RADI shown in the next section. Some of activities of Team JAPAN and the message to the pilot countries of TCP from Japan are based on the RADI's information and experiences.

2.3. RADI, Information Web-platform for Radiation Education

Since 2012, a radiation education supporting website called "RADI"[5] has been operated as a voluntary project by Japan Science Foundation (JSF). This is an information web-platform mainly targeting science teachers to educate radiation basics in schools. The main aim of RADI is to help these teachers in their work without adding to their challenging and busy schedules. In addition, RADI are aiming to add a 'WOW factor' that will intrigue students and encourage them to pursue careers in STEAM. The RADI's activity based on the operation of the website consists of lending simple radiation survey-meters to schools, development of teaching materials or instruments for radiation education. Its operation strategy is discussed and determined by the Radiation Education Promotion Committee which was specially organized for RADI, consisting six committee members, who are a former Minister of MEXT, a president of All Japan Lower Secondary School Education Association, and the national chief inspector of MEXT, and three radiation experts of radiation protection, radiation bioscience and medical application of radiation.

More specifically, RADI presents reports of radiation education workshop, effective materials such as movies, photos, illustrations, handout documents, education plans, guidance documents, Q&A collection from teachers and students such as radiation related units, biological effect of radiation, newsletter, column of representative experts and teachers, website link collection, glossary on radiation, and so on. By inputting simple information needed through the web to be registered as a RADI member, everyone can use all the effective contents for free. The number of registered member of RADI is 2,488 as of the end of FY 2017. Some of the contents have been translated or subtitled in English.

For example, effective materials, education plan, etc. for radiation classes are extremely practical for direct application of the school teachers. These are also useful and valuable for experts who have opportunities to deliver their classes to schools according to the audience's age and learning progress because they can obtain the on-site live voices and real experiences. Movie collections are prepared for the direct use in school classes of 45 to 50 minutes, each story is within about 5 to 30 minutes (max). As the representative movies used in IAEA TCP are;

- Let's Try Radiation Experiments! (5 minutes each)
  1. Cloud Chamber - Let's See the Tracks of Radiation; Guidance movie to observe radiation tracks using a cloud chamber. Introducing points to keep in mind what materials are needed and how to fabricate them to assemble a cloud chamber
  2. Measurement of Environmental Radiation; Guidance movie to investigate environmental radiation with a simple survey meter. Introduction of operation procedure of the instrument and examples of measurement results and their explanation.
- Various Radiation Applications (30 minutes); Movie to encourage understanding of various radiation application in the daily life. Lower secondary level students report representative cases. Information exchange between students and a radiation expert in quiz. This movie was recommended by MEXT for the school use in 2010.
- Radiation Course for Sufficient Understanding (20 minutes); Explanation of radiation basics following the science textbooks of lower level secondary schools. A radiation expert answers representative questions from students.

3. National curriculum guideline on radiation education

Contents on "Radiation" were added into the national curriculum guideline of science for the lower secondary school level, which became full-scale operation from April of 2012. The education content, at the site of compulsory education for the first time in about 30 years, is "to mention the nature and the application of radiation" in the field of "science technology and human" in the scope of "energy resources" at the age of 15 years old. In

addition, due to the Great East Japan Earthquake, TEPCO Fukushima Dai-ichi Nuclear Power Plant accident in 2011, various disruptions and confusion of radiation basis occurred in all over Japan, and the necessity of radiation education and the importance of radiation literacy building were strongly pointed out again.

Under the status above, in the education category of "static electricity and current", the next guideline[6], which was announced in July of 2017 and will be fully operated from April of 2021, instructed teachers to mention that "the current is related to the flow of electrons", and requested them "to mention the nature and application of radiation in relation to the vacuum discharge." Specifically, "let the students understand the existence of electrons by the observation of vacuum discharge in a Crookes tube, etc. Furthermore, let the students understand that the flow of electrons is related to the current." "X ray should be mentioned in relation to the vacuum discharge. Existence of other types of radiation other than X ray who penetrate materials should be mentioned. It should also be mentioned that these radiations are applied in medical, manufacturing, etc." These are additionally inserted in the subject of science at the age of 14 years old.

Furthermore, the new curriculum guideline strongly recommended the use of ICT (Information and Communication Technology) in school education. It is worth noting that three categories of "Utilization of ICT by teachers for preparing and evaluating teaching guidance", "Use of ICT by teachers in classes" and "Utilizing ICT by students" were shown as examples of its application. The authors believe that this viewpoint is expected not only in Japan but also in the whole world. Some of the activities and developments by Team JAPAN in TCP shown in Chapter 4 are strongly linked to strengthening the ICT education in the future.

4. Example HRD activities for secondary school level[7]

Team JAPAN introduced the following examples as HRD activities for the Compendium[2, 3] of IAEA TCP, and gained great interest from the IAEA Secretariat of TCP and members of the participating Asia & Pacific countries.

- National editing project on the supplementary textbooks of radiation basics issued after TEPCO Fukushima Dai-ichi Nuclear Power Plant accident and its experience[8]
- Operation of Information Web-platform for Radiation Education "RADI" started from 2010, which was shown in Section 2.3
- Lending business of the "Hakaru-kun" national project[9] for schools for more than a quarter of a century, a simple radiation survey meter developed for radiation education
- Two-Hour Radiation Education Module on radiation basics with WOW factor, which was applied in several pilot countries in TCP as mentioned in the next
- HRD programs using a nuclear research reactor such as Kindai University, Kyoto University and JAEA
- MEXT Project to financially, scientifically and technically support research activities by upper secondary school students on nuclear energy and radiation based on their own interests and plans
- Flameworks and activities of HRD, for examples, JN-HRD Network[4] and Forum of Nuclear Cooperation in Asia (FNCA)[10]

Among the four pilot countries selected at the beginning of TCP, three countries (The Philippines, Indonesia, Malaysia), excluding UAE who joined TCP as a voluntary activity, tried the Japanese "Two-Hour Radiation Education Module" in their pilot phase. This module consists of a lecture on basis of radiation and the following two experiments, (1) radiation observation with a cloud chamber and (2) natural environmental survey with a simple radiation dose-rate meter.

The history of radiation education programs established by stakeholders in Japan, the high quality of related teaching materials and the ease of approach in the field are all highly appreciated by them in the international community. Thailand, Sri Lanka and Jordan who joined TCP as additional pilot countries also succeeded in introducing this 2-hour program in their pilot activities. In some pilot countries, this radiation education program was combined with S.O.S (Science on Saturday) or POWER SET (Powerful Opportunities for Women Eager and Ready for Science, Engineering and Technology) suggested by USA. With respect to the introduction of the WOW factor into the educational program, it will be spreading to stakeholders and being accepted in the region.

Through the IAEA TCP activities, Team JAPAN has been continuously developing several educational tools[11] based on requests from the pilot countries. For example, (a) a new cloud chamber of Peltier cooling type, (b) small radiation survey meter for school education called KIND-Pro and KIND-mini as results of reduction of cost/size/weight of existing ones, (c) an air-type GM counter designed for students' self-made, (d) radioactive sources using naturally occurring radioactive materials (NORM) for use of outside of controlled area in a radiation facility, and (e) introduction movies to attract students' interest on the existence, science and application of radiation, etc. have been developed and are still under the study.

In order to strengthen and accelerate the movement

above, Team JAPAN has hosted some international meetings and collaborated with experts of other countries. For example,

- International Symposium (Tokyo Symposium 2016), held in Tokyo on Dec. 6, 2016 "Today and Future on Radiation Education by International Viewpoint - Improvement of Risk Literacy Based on STEM Education", inviting two lecturers from the Asian education sector.
- International Workshop (Tokyo WS 2017), held from Mar. 27 to 30, 2017, for the Preparation of Standard Education Programmes and Modules on Nuclear Energy and Radiation Application for Secondary Schools, inviting 5 regional experts from Asia and 4 from IAEA, USA and Australia.
- Starting Research Collaboration on developing STEAM education in NS&T between Texas A&M University and The University of Tokyo.
- Series presentations in AOCRP-5[12]. (5th Asian and Oceanic Congress on Radiation Protection, Regional congress of IRPA), held in May, 2018, designed and lead by The University of Tokyo, as follows.

  Special Oral Session

  "International Cooperation on HRD -Synergy for Nuclear Science and Technology: PHIL, AUS, USA, and JPN Synergize for Nuclear/Radiation Asian Teacher/Student Development"

  1) Activities Under the International Atomic Energy Agency- Technical Cooperation Project (IAEA-TCP) 2012-2017; Rhodora LEONIN (PNRI, Philippines)
  2) ANSTO's Challenges on HRD and Education for Nuclear Science and Technology; Cassandra CASEY (ANSTO, Australia)
  3) Outreach to Students and Teachers - Human Resource Development Valerie G. SEGOVIA (TAMU, USA)
  4) Development of Radiation Education Tools Based on Feedback from Asian Countries' Activities; Takeshi IIMOTO (UTokyo, Japan)

5. Future scope and Conclusion

5.1. Issues to Be Solved

Common international technical cooperation programs tend to be one-way activities. Team JAPAN utilizes feedback from pilot countries in their activities to develop new educational tools and modules at the same time of sharing their experiences with pilot countries. This is a two-way activity. This point is a major feature of our activities. Several pilot countries not only introduce what they learned from developed countries on NS&T but also evolve tools and modules that are suited to their own history, culture, environment and purpose of education.

In some countries, it may be very difficult to obtain ethanol for religious reasons, which is essential for cloud chamber experiments. In addition, as long as both the radioactivity concentration and the quantity handled are increased, NORM might be required to be controlled by a similar treatment as artificial radioactive sources based on the IAEA basic safety standards[13]. This is one of the example issues to be solved from the viewpoint of radiation protection; how to use the NORM sources in schools. Features of NORM sources for education are, (a) > 1Bq/g U-Th or > 10Bq/g ^{40}K, (b) < 1mSv/a, (c) used as radiation sources. This could be considered in planned exposure situation, not in existing exposure situation. Whether the sources can be exempted or not, this is relating to the future scope of IAEA Safety Standards. At the moment, NORM sources that can be used anywhere could always not be used as ever in the future. How to obtain and to safely handle educational tools and radioactive sources appropriate for schools will be one of the important subjects for future study. The stakeholders should share knowledge, skills and experiences to overcome problems to be addressed.

5.2. Messages to Stakeholders

A lot of skilled experts to support schools and teachers are needed. "Skilled" means here not only on the level of knowledge on radiation or experience of radiation application, but also on the teaching experience and communication ability. Let's select adequate and attractive candidates and start to train them as soon as possible. Let's prepare education materials (handouts, PPT materials, work sheets, experimental tools etc.) and their instruction documents for teachers, and distribute them, which can be directly used by teachers in their classrooms.

Showing and opening real radiation/nuclear sites to teachers and/or students is one of the best experiences for them to be interested in radiation with WOW factor. Let's establish the systematic framework to accept them into each facility, institute or university.

It is very difficult to educate high-level science contents to teachers and students. Radiation risk is one of the most difficult items in radiation education. Not only radiation experts, but also risk communicators or social scientists should also join the discussion to prepare the education materials.

It is important to clarify the purpose of radiation education in each country. Education system, strategy and vector would be established based on this information. Based on the purpose of radiation education shown by the government, the education agency should prepare the national standard text book of radiation for school education. The agency should determine the adequate contents and range by the physical viewpoint of radiation

education. In addition, social science viewpoint on radiation, for example on a part of the story of radiation risk, is also important. However, this area needs careful discussion among well-arranged experts to prepare and write the national standard text book. Occasionally the transparency of process and reason of selection of experts editing it could be an important point to be discussed in public.

National framework or system to support teachers is strongly needed to perform attractive radiation education. Radiation experiment in classroom costs. Teachers and schools need funds. Information web platform is also effective. Instruction movies, e-learning systems, teaching materials, model education programs, etc, could be cost-freely shared among teachers and experts through this website.

Simplified radiation survey-meter is effective for radiation education with WOW factor. It is recommended the related agency would establish nation-wide distributing system of survey-meter to all schools by cooperated with institutes or universities. This activity must include the development challenge of their own simplified radiation survey-meter not only for student education but also for public understandings.

It is recommended that Ministry of Education or appropriate organization would trace the career pathway of the trained students after the graduation as well as of the trained teachers. This data will provide useful feedback to effectively continue the HRD activity of IAEA TCP.

IAEA TCP has also provided big opportunities for the participating organizations and individuals from expert countries to brush up our abilities, skills and experience. Team JAPAN continues its activities with the cooperation with experts, teachers, and other stakeholders in the world.

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The activity of Team JAPAN is mainly based on the results and experiences of NS&T education and radiation education history over the years in Japan. This is one of the common fruits by all those related. JN-HRD Network and RADI have strongly supported the activity of Team Japan in TCP, especially Profs. Kazuhiko Kudo of Kyushu University and Mitsuru Uesaka of The University of Tokyo, Ms Keiko Kito, Yuko Kono, and Yuko Ikuta of the officers of JN-HRD Network. Here the authors express their deep appreciation to all stakeholders and related organizations.

Conflict of Interest Disclosure

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The authors declare that they have no conflict of interest.

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