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Report

Fostering Nuclear Science in Schools through Innovative Approaches: IAEA Perspectives

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The industrial and economic growth involving nuclear science and technology (NST) necessitates an increase in the demand for human resource development in the nuclear sector. It is vital to enhance the understanding of students on NST to reach out to the next generation of scientists and engineers. The International Atomic Energy Agency (IAEA) has been strengthening the education of NST in secondary schools to support sustainability of applications of nuclear technology in member states. The implementation of the IAEA Technical Cooperation (TC) project RAS/0/065 during 2012-2016 provided valuable proficiency in successfully introducing NST in secondary schools in the Asia-Pacific region in selected pilot countries. The initiative between 2015-2016 trained 15 teachers through the IAEA fellowship program in turn trained over 1364 other teachers thus creating a critical mass of trained teachers in 4 pilot countries (Malaysia, Indonesia, Philippines and United Arab Emirates) reaching out to a total of 24,717 students in secondary schools in just over one year. The project led to development of education materials, hands-on exercises, as well as co-curricular activities which made nuclear concepts more interesting to students. Countries that implemented the activities have demonstrated the success that can be achieved by the partnership of two sectors – the nuclear sector providing the technical and scientific expertise and the educational sector ensuring the delivery of the topics in the classroom. Encouraged by the success achieved, a new TC project "Educating Secondary Students and Science Teachers on Nuclear Science and Technology, RAS0079" has been initiated in 2018 expanding the project to other member states in the Asia-pacific region. The details of these resources, the activities conducted and their impact as well as planned activities of the new project with a goal to reach one million students during the next four years are presented in this paper.

Key words: Human resource development, nuclear science and technology, NST education, education, secondary school education, WOW factor, cloud chamber, soft skills development

1. Background

Nuclear applications have emerged as an integral part of our day-to-day life in areas related to healthcare, food and agriculture production, industrial processes, better

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management of natural resources, innovative materials needed for various applications and as a clean source of energy[1]. These contributions however have by and large remained unknown to majority of societies and has led to oversight for the growing need of trained nuclear scientists and technologists to realize hitherto unmapped benefits of this technology. The advancement of NST needs continued cadre of scientific manpower to ensure that these benefits maximize the reach in people's lives. Further, the apprehensions and misconceptions related to nuclear and radiation technologies need to be addressed through transparent, balanced, and focused educational activities and programmes that aim to bring about informed understanding and knowledge as well as demystification of nuclear science. The continued availability of qualified personnel is critical to ensuring that benefits of nuclear applications remain available for future generations.

The IAEA dealing with all issues related to nuclear, had at a very early stage appropriately comprehended that education and outreach will be the crucial elements for any vision of the future of nuclear science. The general conference (GC) of the IAEA, at its tenth regular session had passed a resolution recommending close cooperation with UNESCO, particularly in education and training related to nuclear (GC/X/RS/215). In compliance with this, panels of Experts on nuclear science teaching were set and their reports were subsequently published in 1968, 1970 and 1975[2-4]. These reports emphasized that imparting appropriate information about NST to young students represents one of the first key opportunities to help feed the future generation of scientists; as it offers the dual benefits of exposing students to NST at the earliest stages of their education that may inspire them towards science and engineering fields as well as planting the seeds to make a better educated society, more familiar and comfortable with NST. It is in secondary schools that more attention needs to be dedicated to exciting students to consider NST related studies and careers. These efforts might have been an important factor to start in including nuclear sciences as a part of the school curriculum in many countries with advanced nuclear technology programmes as well as enhancing the appeal of NST to students through various outreach programmes.

However, over the years the applications of nuclear sciences in a variety of areas have increased enormously and contribute significantly to the economy of advanced countries like Japan and USA[5, 6]. In the past years, efforts have been made by several countries, especially those with emerging nuclear power programmes, to engage with school student to impart relevant knowledge about nuclear sciences. However, these efforts have typically been conducted as one of events and predominantly as outreach activities with insufficient exposure of nuclear topics in school curricula[7]. This limited exposure has remained one of the factors limiting the interests amongst the young generation in nuclear sciences[8]. Undeniably, these initiatives have provided valuable experience in organizing outreach programmes and enhancing interaction with the school academia and could form the initial basis for implementing a wider programme that could be organized in a structured way across many countries. With this in focus, an IAEA technical cooperation programme was undertaken under a regional project RAS0065 on "Supporting Sustainability and Networking of National Nuclear Institutions in Asia and the Pacific Region" in 2012. The project focused on developing a step-wise guidance on enhancing the students' interest and competencies in nuclear through relevant resources, extracurricular interactive activities and useful examples[9]. This paper provides a glimpse of those resources, the activities conducted and their impact in member states as well as outlines the future planned activities in coming years under the new IAEA technical cooperation project during 2018-2021.

2. The Beginnings

The first workshop in December 2012 identified that approaches contributing to human resources development and outreach varied from country to country and that there was still little synergy between the two areas. As a result, efforts were often duplicated. Some of the identified common issues faced by countries in the region are a public concern for nuclear power, lack of early education to the youth and lack of programmes in schools to provide quality education in science and technology.

A specialist advisory meeting took place in November 2013 for the development of a portfolio of extra-curricular activities for secondary schools on nuclear science and technology, with technical inputs from Australia, Finland, India, Israel, Japan, Republic of Korea, United Kingdom and the USA. Working in close collaboration with experts from these member states, a "Compendium of Resources and Activities for Secondary School Teachers and Students on Nuclear Science and Technology" was compiled capturing a variety of activities and resources that have proven successful in various countries from four continents and could address the needs of other member states. To test the applicability of the material for wider dissemination and improve its final form, a pilot initiative was undertaken to support countries which volunteered for the implementation of extracurricular activities to reach out to students and teachers in nuclear science and technology. The pilot implementation was launched at a workshop in the IAEA Headquarters on October 14, 2014 to four pilot countries of Indonesia, Malaysia, Philippines and the United Arab Emirates. During October 2014

to October 2015 the pilot countries in partnership with ministries, nuclear institutions, school officials, local authorities and the teaching community, implemented the pilot phase of the project. Participating member states identified secondary schools to run the pilot exercise, gathered information on their educational systems via surveys, and shared the information with the wider group of participants. Subsequently, Sri Lanka, Jordan and Thailand adapted some of the activities in their respective schools and started the programme in their countries.

3. Approaches for Enhancing NST Experience in Schools

Based on the discussions held and the experts advise, the following major approaches which needed to be addressed were identified:

- Empowering teachers with appropriate and effective background knowledge and resource material in subjects related to NST;
- Linking nuclear in the day-to-day life of the students with the topics being taught in the class;
- Exciting students through practical, hands-on experience with simple experiments related to nuclear ("WOW factor");
- Developing innovative ideas for enhanced student participation in nuclear through co-curricular or extracurricular activities in nuclear themes;
- Enhancing the soft skills of teachers' competencies in delivering information linked to nuclear in a playful manner; and
- Delivering information related to the wide variety of career opportunities in NST.

These approaches were aimed at ensuring that the scientifically and technically correct, socially pertinent as well as easy to communicate NST content could be developed and delivered by the teachers.

4. Implementation Strategy

The implementation strategy identified through the expert meetings and workshops was divided in two parts:

(i) Planning of the activities with appropriate time horizon and classifying these within short-term, medium-term and long-term frameworks.

(ii) Devising appropriate national activities through which the teachers trained in the project can in turn train other teachers through suitable national activities that could be supported with IAEA experts for a cascade effect.

4.1. Resources and activities that can be utilized or implemented in the short term

- Secondary school curriculum aids and innovative delivery methods of information about nuclear to science and technology teachers;
- Design of simple classroom and outdoor experiments to impart necessary information about NST;
- Innovative ideas for student participation in scientific days with activities such as: essay competition, science quiz, poster and chart competition, and rallies on nuclear themes;
- Site visits to nearby nuclear and other industry facilities;
- Exhibit reports, charts, posters, and photographs at schools;
- Design, organization, and execution of various scientific competitions and programmes for students.

4.2. Resources and activities that can be implemented in the medium term

- Train-the-trainers: The challenge of empowering teachers to deliver appropriate science and technology learning experiences in the classroom to school children will need a cross-discipline and collaborative approach. The aim should be to provide teachers with the best possible chance of acquiring the requisite science content to merge with their pedagogical skills and thus increase their confidence to teach nuclear in the classroom;
- The collaborative approach should involve teachers, educators, and science/engineering academics collaborating together with the experts in the nuclear sector to develop nuclear science and technology resources and to implement them through possible team-teaching within the pre-service teachers' science methods course;
- Development of additional secondary school curriculum/textbooks and innovative delivery of information about nuclear specialties.

4.3. Resources and activities that can be implemented in the long term

- Sustained building of awareness: In the long run, appropriate mechanisms to heighten community awareness are critical to the continued availability of an essential reservoir of qualified personnel for future health and vitality of NST. One way to cultivate this awareness is to establish functional or state-of-the-art public exhibitions or areas dedicated to NST in existing science museums, which can enhance the consciousness and excitement in the minds of general public at large and young minds in particular.

- NST topics can be introduced in national curricula as part of the STEM programmes.

4.4. Execution approaches

In the context of implementation as a regional IAEA project, these activities were planned to be executed through following approaches:

Regional approach

- Training course, seminars, workshops for secondary school science teachers
- Teachers exchange program
- Development and preparation of information, education and communication materials as well as hands-on/practical exercises

National approach

- Events- seminars, workshops, focused group discussion of teachers related to nuclear
- Experts mission to countries to augment the national efforts to locally train other teachers
- Co-curricular activities to engage students in nuclear science topics.

It was realized at a very early stage in the project that national approach will play a crucial role as only a limited number of teachers can be trained in the limited time and resources available for the project. Therefore, considerable emphasis was put in encouraging participating member states to initiate national activities in the project.

5. Implemented Activities

The IAEA support to the implementation of the project was based on a variety of activities and resources documented in the compendium that have been successfully applied in some member states. It was envisaged that these could address the specific needs of other member states through selective implementation of the nationally applicable activities suggested in the pilot countries. The experience gained during the pilot phase was examined to assess the effectiveness of the approaches. Through the national training courses/ workshops conducted by pilot countries, 1364 teachers were trained to provide a critical mass of trained teachers in the region.

5.1. Activities Conducted for the Teachers

5.1.1. Group fellowship training for secondary school teachers

From October 19 – October 29, 2015, the TEES Nuclear Power Institute (NPI) at Texas A&M University hosted a group of nine international educators from Indonesia (2), Malaysia (4) and Philippines (3) as part of the project. The Fellowship which was partially funded through the Argonne National Laboratory, USA, aimed to support nuclear science and technology for secondary schools through a pilot outreach program for educators and students in Indonesia, Malaysia, and the Philippines. The program's mission was to excite, empower, and educate educators about engineering so they can pass on the knowledge and skills learned in their own research experience to their students.

5.1.2. Teachers exchange program

The Philippines hosted the visits of 2 teams of teachers from Indonesia (3) and Malaysia (4) under the Teachers Exchange Program aimed to: (1) provide the visiting teachers a first-hand observation of the implementation of the outreach program in the country, particularly in the two pilot schools in Quezon City and in PNRI; and (2) review and share common concerns in the implementation of the project, especially in tailoring the compendium to the specific and local needs of the different curricula across the participating countries. As part of the capacity building effort by the IAEA, knowhow was shared with the teachers and students participating in the activities of the program. The activities for the visiting teachers included the following: (1) sharing of experiences/best practices to enhance students' learnings and changes introduced or planned in the implementation of the outreach program; (2) discussions and exchange of information with local teachers on the education system and policy, program and career path, curriculum, and ways to improve teacher-learning process; (3) facility tours; (4) observation of pilot classroom lectures and experiments; (5) discussion with PNRI staff and school faculties; (6) participation in the extracurricular activities.

5.1.3. Support teachers on radiation education

The module was piloted by Malaysia, Indonesia, and the Philippines. Scientific visits enhanced the knowledge of teachers in nuclear science and technology. Technical visits to facilities such as cyclotron, laboratories, research reactor and food irradiation centre provided an authentic experience and exposure to the teachers and increased their knowledge and understanding which is very helpful in imparting knowledge to the students.

5.1.4. National training for science teachers

The pilot countries have adopted some teachers training standards provided in the Compendium into existing annual teachers workshop and other activities. The experiences result to further enrichment on non-energy applications materials/topics (agriculture, health, industry and environmental applications) and proposed to be added into the module.

5.2. Activities Conducted for Students: Selected Examples

Informal learning is known to have positive impact on

students' learning, and participation in extracurricular activities often has a positive impact on the academic experience of students in middle and high school. Besides improving academic performance, these activities offer opportunity to learn a variety of skills and provide a sense of commitment to the subject areas. It was therefore obvious that such activities related to nuclear in the schools can enkindle the interest of students in this area. The time-tested modules listed in the compendium were offered to the pilot countries for implementation in their respective countries as per their needs[9]. Following are some of the activities that were conducted during the period.

5.2.1. ANSTO elementals

The Module piloted by Indonesia provided digital teaching material and interactive learning through a fun-popular learning process with opportunity for much broader distribution using website and applications store for smart-phone.

5.2.2. Two-hours radiation education programme for junior high school students

The module from Japan to Support Teachers on Radiation Education was piloted by 3 countries (Malaysia, Philippines & Indonesia). Results showed that the module is compatible and aligned with the science education syllabus in the 3 countries. The Module was found to be an excellent education package because it comes with sub-textbook, movies, slide presentation and experiments offering the opportunity for hands-on learning.

5.2.3. Powerful Opportunities for Women Eager and Ready for Science, Engineering and Technology (POWER SET)

The programme was piloted by the Philippines and the presentation by the experts raised the students' interest. The programme effectively increased female students' participation in science, technology, engineering and math (STEM) related activities recongnizing that being a POWER SET member helps in promoting interest in STEM among other female students.

5.2.4. Science on Saturday

As part of the activities under the nuclear science and technology outreach program for secondary schools, the Philippines adopted the Science on Saturdays (SOS) event from the Compendium of Resources and Activities for Secondary School Teachers and Students on Nuclear Science and Technology (S&T). The SOS is full of extracurricular activities which tap into the creativity and enjoyment of the students to help them appreciate the benefits of nuclear S&T, particularly through science-themed games and competitions. SOS was a sport' and science-themed "Scilympics" featuring outdoor games and relays that require the application of science concepts such as radiation, static electricity, buoyancy, and gravity. Students and teachers also competed for the best posters, slogans, jingles and cheers on the benefits of NST. The feedback received by the participants reflected that students and teachers are more receptive to NST when taught through creative activities and interactive events, additionally promoting friendship and camaraderie among students from other schools.

6. Mid-term Review and Final Project Assessment

A concluding assessment of the project carried out during the final coordination Meeting in 2017 in Indonesia reflected the cascading effect of the project in reaching out to students. The training of fifteen teachers through the IAEA fellowship programme and subsequently through their national capacity building activities trained 1364 additional teachers, creating a critical mass of trained staff in the four pilot countries plus Sri Lanka, Jordan and Thailand, who in turn contributed to disseminating project activities. As such, 24,717 students in secondary schools benefitted from the initiative in just over a year.

Teachers trained through the project successfully developed appropriate lesson and activity plans as a part of their school curricula, and two local reference books were produced in local languages by teachers to effectively communicate appropriate technical knowledge to students.

The assessment also indicated that activities envisaged and implemented were well structured to address various needs of the stakeholders to provide appropriate resources for introducing nuclear sciences in secondary schools in an engaging and effective manner. Structured activities related to class room observation and teaching where the concepts of radiation detection and measurement are explained and demonstrated to high school students through hands on experiments were appreciated by the participants. The concepts of engaging students with nuclear sciences through extracurricular activities such as essay and poster contests, quizzes, creating groups wherein students were mentored by senior students proved to be very effective in generating curiosity and interest of students in science subjects. Furthermore, implementation of these activities played an important role in inspiring teachers and students in nuclear sciences.

The 2017 assessment also noted that innovative, cost effective equipment for classroom demonstrations have been developed for hands-on experiments, including the use of a portable user-friendly gamma detector and a cloud chamber to illustrate natural radiation in the environment. The pilot countries have successfully

adapted programmes from more advanced countries, such as POWERSET, Seminars/Workshops for Teachers & Students in Secondary Schools (SWTSSS), and SOS. Additionally, three Youth Summits were held in Indonesia and the Philippines. The pilot activity has supported the involvement of students from various disciplines and has provided exposure to various aspects of nuclear science and technology.

7. Regional Learning Framework for Nuclear Science and Technology Education

Since the IAEA projects are directed at all the participating member states, it was essential to formulate a broad-based Regional Learning Framework for Nuclear Science and Technology education for Secondary Schools. This must take into consideration that nuclear related subjects might be taught under different subjects in the curricula in different cultural settings, as well at different class levels in different member states. It was therefore essential to bring together representative educators from different countries and experts from nuclear institutions to develop global learning priorities for nuclear science and technology that could be shared with the participating member states for consideration. To meet this important objective, an "International Workshop for Preparation of Standard Education Programmes and Modules on Nuclear Energy and Radiation Applications for Secondary Schools" was organized during 27-31 March 2017 at University of Tokyo, Japan. The workshop was hosted by University of Tokyo and supported by JSPS Grants in Aid for Scientific Research and RADI project operated by Japan Science Foundation (JSF). The meeting provided a clear vision of the fundamental aspects of nuclear science, modules on nuclear energy, radiation application for secondary schools and nuclear risk analysis which should form essential part of school education from Standard 6 to Standard 12 as applicable to the member state keeping in view their respective curricula. This important understanding along with the need to develop soft skills of teachers to deliver these concepts formed the basis of formulating a Nuclear Science and Technology Curriculum Framework (NSTCF) which has become the reference guide for subsequently developing the 2-week teachers training programme which will be discussed in the succeeding section.

8. The New Initiatives: Reaching a Million Students

Encouraged by the success achieved, the pilot countries expressed commitment to propagate the initiative to other schools and have begun to adopt similar initiatives. To sustain the momentum and expand the project to many more countries, member states developed a follow up project, RAS0079, 'Educating Secondary Students and Science Teachers on Nuclear Science and Technology', which was approved as part of the IAEA Technical Cooperation for 2018–2021. The project aims to focus comprehensively on capacity building that is needed to enhance existing educational approaches through training and development opportunities both for teachers and students. The project will address the limitations of outreach by providing in-depth information on NS ensuring that the benefits reach a maximum number of students, while keeping the depth of learning between teacher and student. The mainstay of this initiative was the development of a unique 2-week training course for secondary school science teachers based on the NSTCF, featuring a series of presentations and practical exercises to facilitate sharing experiences by:

(i) Introducing the participants to various learning modules and strategies for the implementation of selected activities, experimental procedures and other resources that are compatible with secondary level curriculum for nuclear sciences.
(ii) Conducting Training activities for teachers to give them necessary insights to the learning experience and their individual plan to integrate such activities into their curriculum.
(iii) Providing necessary soft skills to teachers to introduce nuclear to the students by organizing the content material to be congruent with students' intellectual skills and its application in daily life.

This two-week course introduces participants to the fundamentals of nuclear science and technology while linking the simple concepts being taught to the many applications that change the world around us, especially in areas necessary for sustainable worldwide growth and development. The hands-on experiments, demonstrations and facility visits further enhance the comprehension of teachers in linking nuclear science concepts into their curricula. The first training course was organized during 16-27 April 2018 at - Polytechnic Institute of Nuclear Technology, National Nuclear Energy Agency of Indonesia (BATAN), Yogyakarta, Indonesia and was attended by teachers from 17 member states. The feedback received from the participants and all lessons-learned have been comprehensively compiled and inputs for planning future workshop to ensure that the quality of workshops improve every year[10]. The second similar course is proposed to be held during August 20-31, 2018 at Argonne National Laboratory, Argonne, Illinois, USA. It is envisaged that similar course will be conducted in University of Tokyo, Japan (February 2018), Malaysia (June 2018), ANSTO, Australia (October 2018) and the Philippines (December 2018), after which, the materials

will be compiled into a compendium of resources for teaching nuclear science and technology in secondary schools.

9. Conclusions

In conclusion, the IAEA initiatives have succeeded in generating enthusiasm and excitement in the teaching and students' community in the pilot countries related to nuclear sciences. With the support of partner countries and commitment of participating member states, particularly the formalized partnerships of the nuclear and education sectors for the first time, a critical mass of trained teachers has been generated. The academic and extracurricular activities carried out from Compendium have proved to be comprehensive, simple and effective in generating interest in both teachers and students for nuclear related topics. The successful pilot implementation has greatly strengthened the commitment of the participating countries to adapt and expand the initiatives to more schools. The planned new initiatives under the project RAS0079 during 2018-2019 will help ensure that the goal of reaching nearly a million students are successfully met.

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Conflict of Interest Disclosure

The authors have no conflict of interest. The views presented here are in personal capacity of authors and are not on behalf of the Agency or the Director General.

References

1. Silverman J. Radiation processing: The industrial applications of radiation chemistry. J Chem Edu. 1981;58(2):168–73.
2. IAEA. Report of a Panel on Nuclear Science Teaching held during 15-23 July 1968, Bangkok, Thailand. Vienna: IAEA; 1968. IAEA Technical Reports Series No. 94.
3. IAEA. Report of a Panel on Nuclear Science Teaching II held during 14-23 October 1970, Buenos Aires, Argentina. Vienna: IAEA; 1971. IAEA Technical Reports Series No. 132.
4. IAEA. Report of a Panel on Nuclear Science Teaching III held during 7-11 May 1973, Athens. Vienna: IAEA; 1975. Technology Reports Series No. 162.
5. Yanagisawa K, Kume T, Makuuchi K, Tagawa S, Chino M, Inoue T, *et al*. An Economic Index regarding Market Creation of Products Obtained from Utilization of Radiation and Nuclear Energy (IV) Comparison between Japan and the U.S.A. J Nucl Sci Technol. 2002;39(10):1120–4
6. Tagawa S, Kashiwagi M, Kamada T, Sekiguchi M, Hosobuchi K, Tominaga H, *et al*. Economic Scale of Utilization of Radiation (I): Industry, Comparison between Japan and the U.S.A. J Nucl Sci Technol. 2002;39(9):1002–7
7. Foster DE, Stone CA. Nuclear science summer school for high school students. J Radioanal Nucl. Chem. 1997;219(2)237–39
8. Hirose M, Tsuruta T, Shibata T. Current Status and Future Directions of Nuclear Education in Elementary and Secondary education*-Several Measures for Revitalization- J Nucl Sci Technol. 1999;36(3):219–22
9. IAEA. [Internet]. The Compendium: Resources and Activities for Teaching Nuclear Science and Technology. Vienna: IAEA; 2016 [updated 2016 September 21]. Available from: https://www.iaea.org/newscenter/multimedia/videos/the-compendium-resources-and-activities-for-teaching-nuclear-science-and-technology
10. IAEA. [Internet]. Reaching a Million Students by 2021: IAEA Launches Nuclear Science Education Programme in Asia Pacific. Vienna: IAEA; 2018[updated 2018 July 19]. Available from: https://www.iaea.org/newscenter/news/reaching-a-million-students-by-2021-iaea-launches-nuclear-science-education-programme-in-asia-pacific