WORKING DOCUMENT

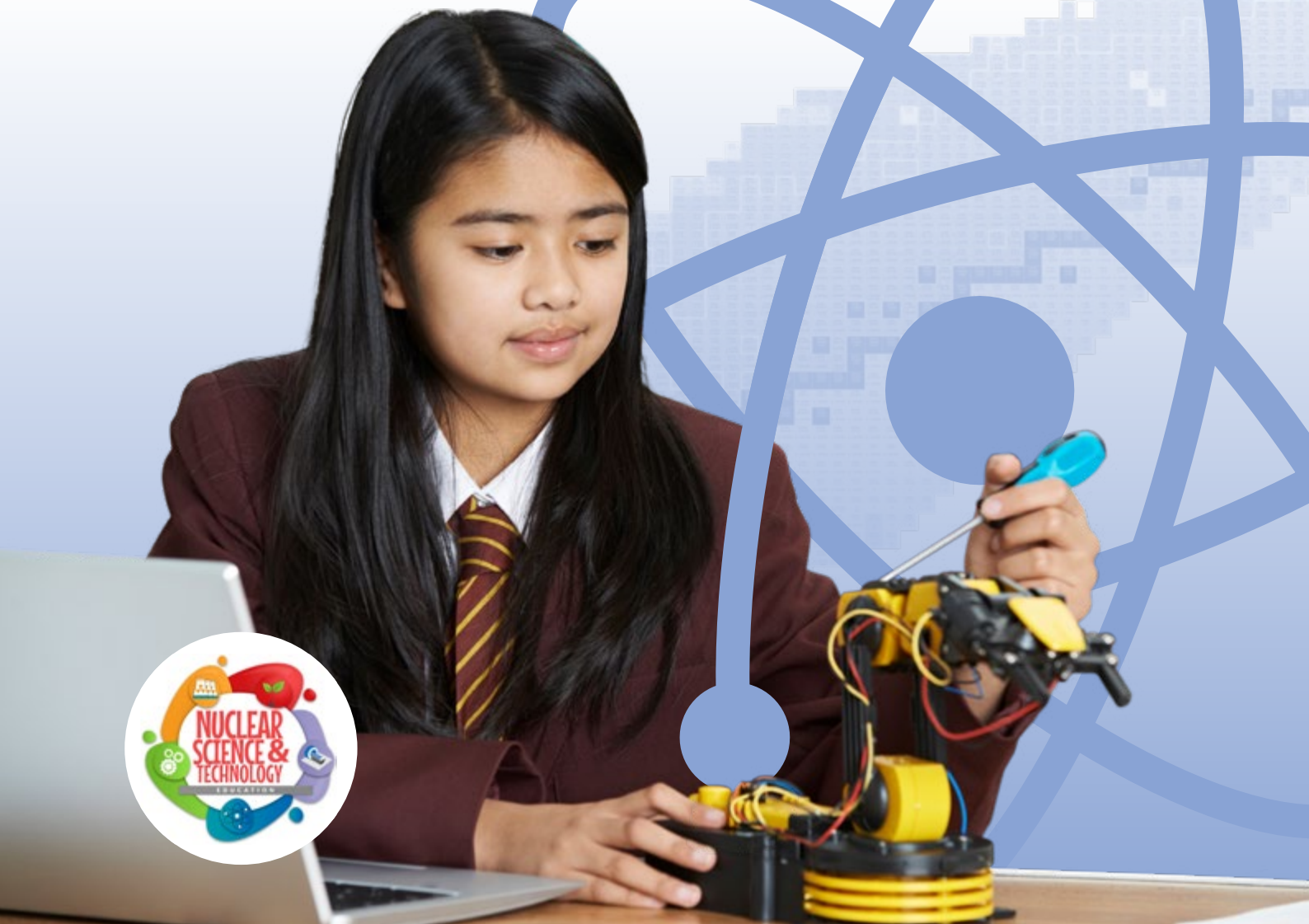
Guidebook series for introducing
Nuclear Science and Technology
at the secondary level education

GUIDEBOOK

3

Co-curriculum development

January 2023



Foreword

The technical cooperation (TC) program is the International Atomic Energy Agency's (IAEA) primary mechanism for transferring nuclear technology to Member States, helping them to address key development priorities in areas such as health and nutrition, food and agriculture, water and the environment, industrial applications, and nuclear knowledge development and management.

The IAEA's technical cooperation programme combines specialized technical and development competencies. The results based programme aims at achieving tangible socioeconomic impact by contributing directly in a cost effective manner to the achievement of the major sustainable development priorities of each country, including relevant nationally identified targets under the Sustainable Development Goals (SDGs).

This important work can be seen through the efforts to enhance education and capacity building for future Nuclear Science and Technology (NST) resources through the TC regional project RAS0065 *'Sustainability and Networking of National Nuclear Institutions in the Asia and the Pacific region'*. This pilot project was the first of its kind in the IAEA program to revitalize NST in schools, specifically to inculcate scientific thinking related to NST among secondary students.

These efforts widened in 2018 with the TC regional project RAS0079 'Educating Secondary Students and Science Teachers on Nuclear Science and Technology,' which aimed to expand and sustain nuclear science and technology information, education and communication among secondary school students and teachers in the region. The target was to reach one million students by training educators through training courses for classroom curriculum and extra-curricular development. From 2018-2021, 8,351 teachers were trained in national courses and 191 teachers were trained through IAEA courses. Ultimately, over 1.6 million students were reached in the Asia and the Pacific region.

The TC project RAS0091 'Supporting Nuclear Science and Technology Education at the Secondary and Tertiary Level' started in 2022 and aims to expand the scope of collaboration to all partners in the region from the NST educational networks and secondary and tertiary level education.

Material developed through RAS0079 was successfully incorporated into secondary level education to support and strengthen continuous learning through enriching teachers and students' knowledge, skills and experiences of NST. These success stories and lessons learnt need proper reporting and documentation, not only as evidence but also to support knowledge sharing. They provide examples of best practice to assist all MS in implementing NST secondary education in a harmonized, consistent and efficient manner. This works in tandem with the IAEA mission to assist MS with scientific advice in nuclear science, education and training, and facilitates the sustainable transfer of knowledge.

The objectives of the guidebook series are to:

- strengthen or enhance existing curriculum programs by increasing capacity, sharing experiences, and forming collaborations and strategic partnerships with national and international partners
- provide a recommended framework for best practice NST secondary education curriculum teaching
- assist MS who are starting to develop and/or link NST to secondary education co-curricular activities to support deeper engagement in STEM with a focus on NST, and
- provide exemplary material that is suitable for teaching and learning for both classroom and outreach activities.

As such, the five (5) key areas proposed below are the basis of each important chapter:

GUIDEBOOK 1 — **Strategic partnership**

This guidebook represents the overarching framework for NST secondary education. It describes the partnerships that MS need to have in place to support good governance and achieve successful implementation. At the same time, linkages with other organizations such as NST-related organizations, stakeholders, academia and professional non-governmental organizations (NGOs) are highlighted as part of their contribution to the project.

GUIDEBOOK 2 — **Linking NST with the school curriculum**

The second book is all about the various approaches that have been taken in developing NST topics to be included in RAS0079 — *Educating Secondary Students and Science Teachers on Nuclear Science and Technology*. It consists of analysis, design and review. It also features the curricula used by various MS in implementing NST as part of a case study that allows others to appraise which of these implemented curriculum suits their country and priority needs. In addition, best practice can be identified, as well as suggested improvements for the inclusion of NST topics in school curricula.

GUIDEBOOK 3 — **Co-curriculum development**

The third book explains the extension activities, programs and learning experiences that are designed to complement the formal curriculum activities and achieve greater engagement from students. These can be in the form of contests, cultural shows, visits and exhibitions.

GUIDEBOOK 4 — **Teaching strategies and learning facilitation tools**

This guidebook details the support from learning materials and instrumentation that is necessary for effective learning. At the same time, lesson exemplars from teachers showcase the development of traditional ways teaching and fact-based learning — which relies on the teacher presenting facts and their own knowledge about the subject — towards inquiry and phenomena-based learning. Inquiry and phenomenon-based learning are learner-centered and demonstrate best practice. These examples seek to inculcate and promote NST learning in effective and interactive ways.

GUIDEBOOK 5 — **Assessment, monitoring and evaluation**

Lastly, the fifth guidebook illustrates the need for many countries to develop appropriate methods to monitor teaching efficiency and assess students' knowledge, attitude and practice with regard to NST education, as well as reviewing the overall curriculum.

Note for the users

As a focal activity of the project, this publication is based on discussions held during workshops and meetings regarding the development of a guidebook series that documents all relevant information crucial for the successful implementation of NST secondary education. The guidebooks are expected to provide guidance to any MS, through their nuclear or education institutions, to initiate or enhance the NST topic/syllabus for students and teachers at the secondary education level. The guidebooks offer lesson plans for curricular and co-curricular activities as well as demonstrating creative ways to deliver knowledge through state-of-the-art pedagogical approaches. The series seeks to leverage the existing curriculum in each country so as to mainstream NST and promote awareness and understanding about its peaceful uses.

This guidebook includes examples of the co-curricular or extra-curricular activities used by teachers from Malaysia, Philippines, Indonesia, Oman and Australia in the delivery of NST in secondary school education.

Co-curricular activities are true and practical experiences engaged in by students. These types of activities enable students to apply the theory they have learned in practice, strengthening and reinforcing their understanding of the curriculum and advancing their abilities and engagement with NST.

Disclaimer

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This work was made possible through the extensive collaboration and contribution of co-authors from participating MS and TCAP. Their contribution to the guidebook series for introducing NST in secondary education is acknowledged and appreciated: Ms Habibah Adnan, Ms Jasmine Albelda, Ms Cassandra Casey, Mr Takeshi Iimoto, Mr David Grabaskas, Mr Adipurwa Muslich, Ms Micah Pacheco, Mr Nirodha Ranasinghe and Mr Sunil Sabharwal.

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Finally, special appreciation goes to the winning and finalist teachers of the 2021 Secondary NST Education Competition who attended the meeting on the development of a Model Curriculum for Secondary Level Education: Ms Corazon V. Mariano, Ms Maribel D. Ganeb, Mr Kuit Vui Ket, Mr Toto Suryo Suprapto, Mr Norman T. Fortun, Ms Asila Al-Mazydi, Mr Marcus Khoo and Mr Sajjad Akhtar.

Contents

List of abbreviations

AELB	Atomic Energy Licensing Board
ANSTO	Australian Nuclear Science and Technology Organization
Argonne	Argonne National Laboratory
BATAN	National Nuclear Energy Agency of Indonesia
BRIN	*Badan Riset dan Inovasi Nasional* National Research and Innovation Agency of Indonesia
DepEd	Department of Education
DOST	Department of Science and Technology
IAEA	International Atomic Energy Agency
MS	Member State
NST	Nuclear science and technology
NST4SS	Nuclear Science and Technology for Secondary Schools
PNRI	Philippine Nuclear Research Institute
RLF-NST	Regional Learning Framework for Nuclear Science and Technology
SMART	System Integrated Modular Advanced ReacTor
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics
UN SDGs	United Nations Sustainable Development Goals

1. Introduction

Co-curricular refers to those activities, programs and learning experiences that supplement or mirror what students learn in the classroom. They are often distinguished by their separation from academic courses, but this is not always the case. Co-curricular activities typically include material that is aligned with the formal curriculum, in comparison to extra-curricular activities, which introduce topics that are outside the designated curriculum. These activities may be compulsory or voluntary, depending on each school system. Regardless, participation helps students with emotional, social skill and overall personality development. The advantages to involvement in co-curricular activities include:

- allowing students to explore strengths and talents outside of academic study
- helping students develop better time-management and organizational skills
- teaching the importance of following through on commitments
- giving students the opportunity to build friendships and participate in group activities outside of the tight circle of the regular classroom
- helping to build confidence and self-esteem
- building skills that are not necessarily taught in the classroom but are still important for the future
- accommodating different types of learners, especially those who learn more effectively through practical application.

In the 21st century, our world has fundamentally changed, particularly in the ways and role of learning and education within a student's day-to-day life. We understand that students may find certain scientific topics, such as NST, less appealing, given that they can often be presented in a less-engaging, technical manner. It is therefore important to develop an understanding of how the scientific approach of NST can provide solutions to many issues in our lives. For example, co-curricular activities focusing on human health, food safety and security can often present engaging and interactive ways of introducing students to NST topics.

One of the objectives of the TC RAS0065 Project — Supporting Sustainability and Networking of National Nuclear Institutions in Asia and the Pacific Region (RAS0065 Project) — is therefore to provide guidance to any MS, through their nuclear or education institutions, to initiate programs for students and teachers (as well as the general public) to generate curiosity, understanding and acceptance about NST, and, as a potential result, prompt secondary students to consider a career in the nuclear sector.

It is important to develop an understanding of how the scientific approach of NST can provide solutions to many issues in our lives.

2. Co-curricular development

The development of activities that support the curriculum is very important and needs to be done in a systematic manner and in accordance with the main curriculum. To be effective and beneficial, school co-curricular activities need to contain some essential components:

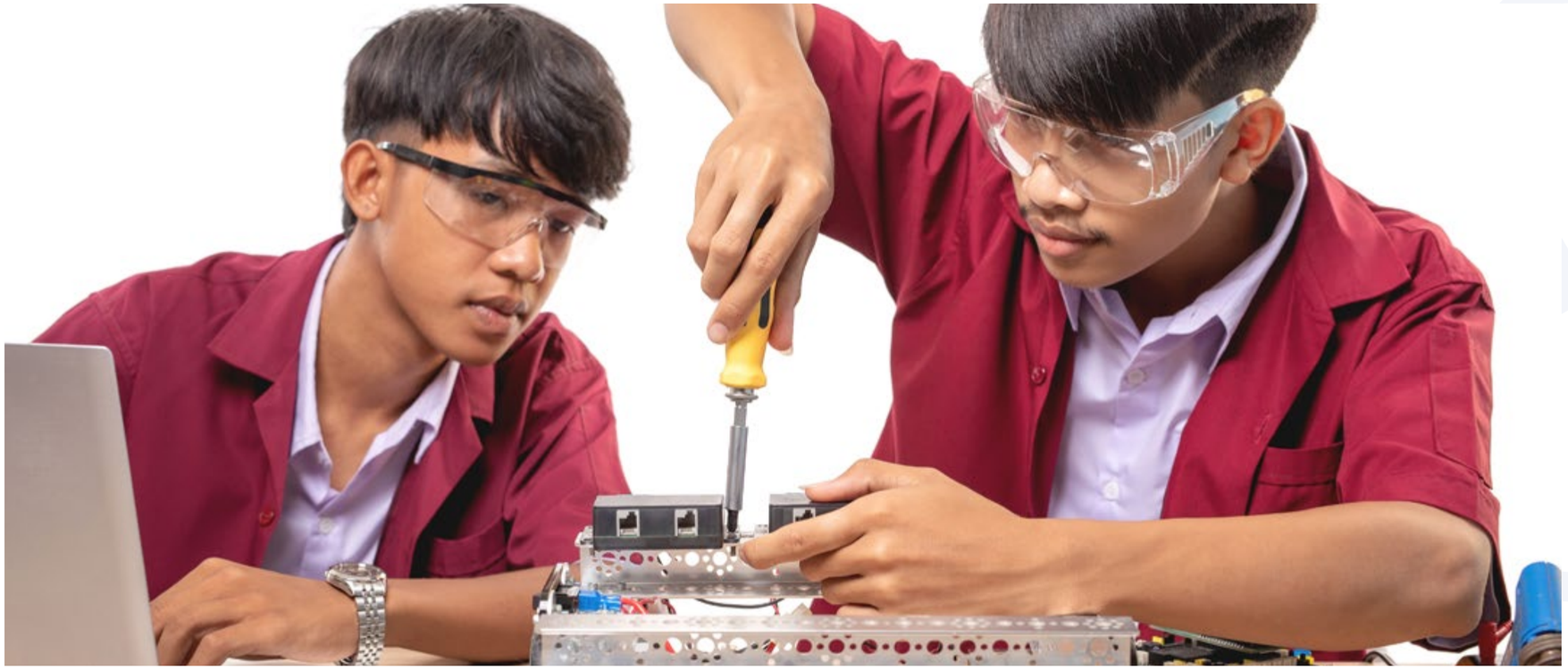
- **Curriculum-aligned content and resources**
  The content and resources of a school outreach program needs to inspire students and instil in them the goals of the school activities. The educational materials, projects, activities, games, exercises and resources need to be aligned with national educational standards and classroom curriculum. Co-curricular content can weave issues and solutions into curriculum in innovative and creative ways, but needs to always be grade specific and age appropriate.
- **Memorable and engaging content**
  The activity needs to engage students in memorable ways and encourage them to retain the lesson. It is recommended that activities be developed so that:
  - students identify with the subject and are inspired
  - they create relevance for NST in the lives of the students and their communities
  - they incorporate multiple learning strategies to support different types of learners
  - they build interactive skills.
- **Developmental focus**
  Emphasis needs to be placed on the development of activities that use age-appropriate topics and skills. Hands-on experience with relevant issues in students' daily lives makes for effective activities.

  With NST, empowerment and ownership need to be reiterated. In terms of voluntary co-curriculum activities, the self-initiative demonstrated by the student should be embraced and encouraged through self-directed activities. In addition, students can become ambassadors (whether formal or informal) and further disseminate the information they have learned, while developing leadership skills and self-confidence.

At the same time, the activities need to acknowledge that students have different learning styles. Activities that support their individual style can further trigger their auditory, visual, kinesthetic or tactile input for learning and increase learning retention. Analyzing one's own particular learning style can be very helpful and beneficial to students and aid their focus, which ultimately will increase educational success.

Finally, collaborative work with other organizations can further add creativity to planned co-curricular activities.

Co-curricular activities can also be important for teacher development. Starting an NST-themed club or organizing an outreach activity (discussed in Section 4) can afford teachers the opportunity to take ownership of a program. Teachers may embrace available training, such as that offered through the IAEA, to expand their expertise on various topics and thus become a resource for their school or municipality. Such skills are a valuable asset for the teacher, supporting their career, improving their motivation, and developing their leadership and management capabilities. In addition, the connections they establish with outside organizations can also present new opportunities for themselves, their students and the school.



Starting an NST-themed club or organizing an outreach activity can afford teachers the opportunity to take ownership of a program.

3. Existing co-curricular activity in MS

Table 1 illustrates the existing co-curricular activities related to NST that have been planned and implemented at the secondary education level.

Table 1.
Co-curricular activities by country

Country	Co-curricular activities
Australia	• ANSTO interactive periodic table of elements using Augmented Reality — available on the free ANSTO AX app. • ANSTO Virtual Reality experience — dive inside the reactor and be shrunk down to the size of an atom. • School Hackathon linked to the national science week program and theme.
Indonesia	• Several schools in Indonesia have made visits or study tours to BATAN/BRIN. • Several schools have been visited by BATAN/BRIN people to introduce NST. • Virtual visits to BATAN/ BRIN are already available for schools that do not allow physical tours.
Malaysia	• "National Science Month" organized by the Ministry of Science, Technology and Innovation with the Ministry of Education — activities include competitions and quizzes. • Nuclear Science and Technology for Secondary Schools (NST4SS) Program — organized by Malaysia Nuclear Agency and Japan Atomic Energy Agency. • STEM Clubs formed in schools. • Various competitions run by various bodies/agencies — mostly STEM-based and not really NST specific.
Oman	• "National STEM Week" organized by the Ministry of Education in cooperation with institutions such as the Peaceful Nuclear Technology Office and Ministry of Foreign Affairs — activities included interactive workshops, competitions and NST exhibitions. • "Oman Science Festival" organized by the Ministry of Education — a booth was assigned to NST where some activities were presented to the visitors to promote the knowledge and techniques related to NST. • Assignment of a special hall in one of the secondary schools in Muscat to be permeant fair specializing in NST education. • Virtual lectures for Grade 10 students conducted by the trained teachers within the RAS0079 Project.
Pakistan	Co-curricular activities have included: • NST Club and NST Society • The Science Expo/National Science Mela 2022 • Outreach programs with the Pakistan Atomic Energy Commission for achieving the SDGs and Pakistan Atomic Energy Cancer Hospitals
Philippines	• Partnership with Local Government Units (LGUs) and other private corporations relating to NST education. • Science Clubs and Research Clubs in schools. • Study tours to PNRI during which students visited the facilities (i.e. reactors and laboratories). • In-school activities such as a photo essay contest, poster making, jingle writing and a logo design contest. • Science and Technology Fairs in schools at Division, Regional and National levels. • "Siyensikula" competition: production of an original video focusing on a science concept — showcasing and improving the students' learning outcomes through the development of engaging multimedia learning materials, focusing on challenging science and technology concepts. • #SciTokperiments — a Tiktok science experiment competition.

One example of an activity that can be used as part of co-curricular experience is the use of a web-game call Minecraft. This is a video game in which players create and break apart various kinds of blocks in a three-dimensional world. Minecraft has created an Education Edition that is a great tool for learning, as it allows students to collaborate with each other on personalised projects while playing in a safe environment. It also features tutorials to support educators. Minecraft can also be used in learning across the curriculum as it has coursework for STEM, History, Language and Arts among other subjects.

One of the finalists in the NST Exhibition competition was a teacher from Malaysia who, together with his students, built and simulated a nuclear power plant based on Minecraft (see Figure 1).

Figure 1.
Minecraft used to create a nuclear reactor.

Below is a list of proposed NST co-curricular topics that are related to Science, Technology, Engineering and Mathematics (STEM), developed from the RAS0065 Project:

Radiation

- non-ionizing and ionizing radiation
- radioactive atoms and radioactive decay
- radiation effects on human body
- radiation doses
- measurement devices
- applications

NST

- applications (health, food and agriculture, industry and research, energy, etc.)
- environment and sustainability
- electricity

In all countries, especially those where nuclear power is being considered or produced, topics such as nuclear energy, nuclear reactors, the fuel cycle and fusion, can be introduced in the context of energy needs and planning, energy sources and the environment.

4. Outreach activities

Teachers are at the center of any education system. Their classroom work and the relationships they form with their students have an impact on society's future. However, it is not entirely the responsibility of teachers to support young people's education. The wider community resources can also have an impact. Through utilizing these resources, outreach activities can become an important pathway for introducing NST topics to students.

Similar to co-curricular activities, outreach refers to activities that support formal or classroom-based education, as well as informal education that occurs outside the classroom. However, the difference is that outreach activities are typically planned and conducted in partnership with outside organizations, such as corporations, organizations, governmental agencies, municipalities, industry or community-based organizations. Partnerships with these organizations can open up new pathways for growth and success, such as access to experts, facilities and resources. This can also support the professional development and networking of teachers who work with students.

In general, outreach activities/programs provide educational institutions with the opportunity to:

i) Improve student outcomes

As mentioned above, not everyone learns in the same way. Diversification in learning pathways improves student outcomes by helping them better understand what they are learning in class. Participation in outreach programs increases material retention by reinforcing lessons in creative and innovative ways. School outreach programs foster learning by helping students make connections between classroom curriculum and real-world impacts.

ii) Promote civic engagement

A school outreach program strengthens the connection between a student and their education, and the world in which they live. It can provide tools for students to understand how forces in society, the economy and politics interconnect and impact their everyday lives. It can also show students how to influence those forces. Programs that instil student awareness of community needs can inspire students to find solutions and work toward change. This is in line with the promotion of NST in achieving the UN SDGs. By promoting civic engagement within the community, outreach programs can demonstrate active citizenship.

iii) Influence behavioral change

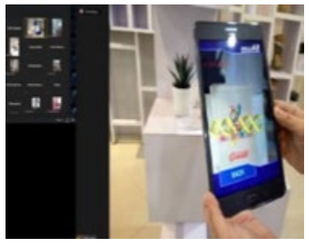
School outreach programs that focus on peer reinforcement and social norming open up spaces for effective behavioral change. With an outreach program, students can learn valuable life skills through shared experiences. This empowers them to make positive changes, not only to themselves, but to act as an agent of change within their families and communities. By providing dynamic learning experiences, a school outreach program affords students the opportunity to make lasting changes for future success.

iv) Educate students on specific issues

School outreach programs have the power to focus on issues and skill-building with innovative learning activities such as NST. They can be tailored to address community needs and skill gaps with curriculum support and innovative learning materials. Outreach programs can increase student learning on specific issues.

Various examples of partnerships with research institutes or ministerial organization to provide outreach activities can be seen in Figure 2 below.

Field trip to a National Science Centre or Museum



Organizing NST talks/forum/lectures/ discussions

Having NST workshops for students

Involvement in organizing a NST Science Fair/Carnival with interactive exhibitions

Science Week/Expo in Pakistan

Figure 2.
Various outreach activities

Other examples of successful outreach programs and activities include:

- Participating in a Campaign Awareness drive about NST in remote areas.
- Participating in a science competition — for example, PNRI conducts the Philippine Nuclear Science Quiz (PNSQ). The PNSQ is a national competition where representatives are drawn from private or public schools from different regions of the country.
- Facility tour to research institute — for example, the Korea Atomic Energy Research Institute (KAERI) has programs for all ages, which include a visit to their R&D facilities. Students aged 12–14 can run two types of experiments: observation of alpha, beta and gamma radiation tracks using a cloud chamber and the measurement of radiation using a detector and standard alpha, beta and gamma radiation sources. They can assemble SMART (System Integrated Modular Advanced ReacTor) paper models and visit robotic and super conductor labs.
- Simple experimentation — As part of the pilot outreach program in Indonesia, 40 students from the third grade of a high school, who were involved in a cloud chamber experiment activity, showed their curiosity in finding visual evidence of radiation. Through this activity, the previously trained teachers successfully introduced the teaching-learning process on radiation topics in a fun and popular way.

Meanwhile, some suggestions to increase outreach activities include:

- Site visit to a related research institute that uses NST, such as the BATAN, Nuclear Power Plant in Indonesia and the Philippine Research Reactor. This needs to be thoroughly planned, as there may be an issue with underage students for facilities where visitors are required to be 18 years old or above.
- Students may also brought to medical and industrial facilities where radioisotopes are being used in manufacturing products and processes.
- Developing partnerships with public and/or private colleges or universities where information on available NST programs or scholarships offered by higher learning institutions can be disseminated to secondary school students.
- Organizing a Nuclear Talk Show which can serve as a platform to provide information about job opportunities and work experiences in NST.
- Mentor-mentee NST Programs with mentors from universities.

The RAS0079 Project envisioned the introduction of NST through classroom activities and outreach activities to at least one (1) million students by 2021. This ambitious goal was overachieved (161%) and the actual number of students reached was 1,611,189. The proportion of students reached through outreach and extra-curricular activities was 31.1% (see Figure 3).

Proportion of the total number of students reached through outreach and extra-curricular activities and classroom activities led by trained teachers

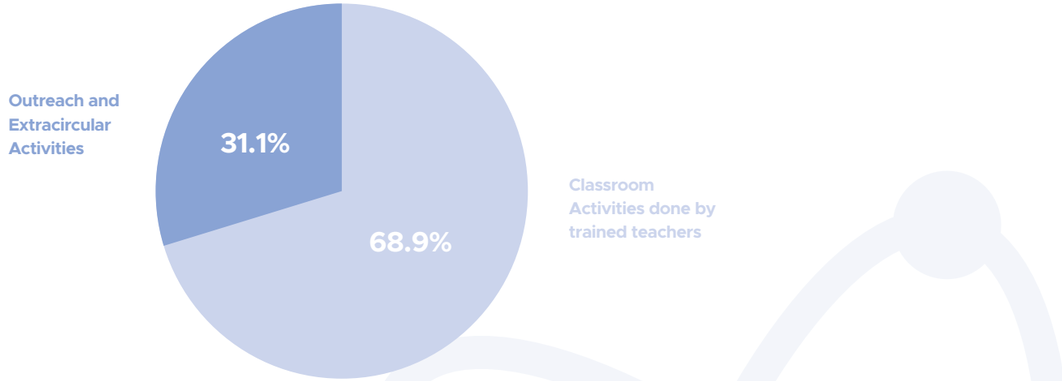


Figure 3.
Proportion of the total number of students reached through outreach and extra-curricular activities and classroom activities led by trained teachers

5. Suggestions to improve co-curricular activities

During a meeting on the development of a Model Curriculum for Secondary Level Education, held in May 2022, one of the key agenda items was a discussion on ways to enhance existing co-curricular activities. Some of the suggestions from the winning and finalist teachers of the 2021 Secondary NST Education Competition (representing four (4) MS — Philippines, Malaysia, Indonesia and Oman) are displayed in Table 2.

Table 2: Suggestions for enhancing co-curricular activities in NST secondary education

Country	Co-curricular activities
Indonesia	• Competitions, such as making posters or designs, photography, debates, painting or drawing stories, about NST using English. • Webinars with NST experts in Indonesia or experts in the Asia-Pacific region, such as Japan, South Korea or the IAEA, where each school has both student and teacher representatives. • Live broadcasts of practicums together at the BATAN/BRIN laboratory. • Live broadcasts of practicums at the IAEA laboratory. • Group discussions between students from the Asia-Pacific region discussing NST issues that occurred in their respective countries.
Malaysia	• Forming an NST Club in schools to specifically promote NST education and activities — working together with other NST Clubs from across the country, or even internationally. • Organising talks for students (by students) on relevant topics and issues regarding NST, perhaps using the partnerships mentioned in Topic 1. • Encouraging industries that benefit from or use NST to "adopt" a school — for site visits, talks and mentor-mentee shadowing programs.
Oman	• Cooperation with the IAEA and its members to participate in NST education activities and events that are held in individual MS countries. • Assignment of a special hall for NST in existing science centers to promote NST among schools. • Enhancing cooperation with higher education institutions to exchange NST knowledge.
Philippines	• Visits from experts in NST. • Organizing Asia and the Pacific Teacher and Student Fellowships and Scientific Visits. • Specific NST Club organization to promote nuclear science in schools.

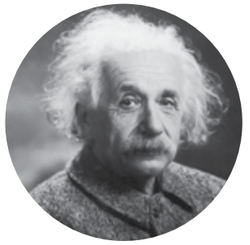
Other suggestion include opportunities for national and regional joint activity. This may include participation in various secondary school level NST contests, competitions, or Olympiads such as the quiz bee, science talk and storytelling. Plus, developing more chances for active engagement in NST-related exhibitions, training and webinars, either through virtual or physical arrangements.

Of particular interest is the suggestion to establish NST Clubs in schools. This could be expanded establishing Clubs at the national and regional levels with membership offered to all secondary students among participating MS. This not only has the advantages of promoting knowledge and creating the opportunity and means to inculcate leadership in students, but also invoves active communication within and between students from various countries. This can help students to function in an increasingly international and culturally diverse environment, and to contribute on a global level.

Conclusion

"It is the supreme art of the teacher to awaken joy in creative expression and knowledge."

Albert Einstein



Theoretical knowledge from the classroom is strengthened when combined with a relevant co-curricular activity. Successful NST co-curricular activities depend on building links between schools and relevant institutions. Bringing NST expertise to engage with students, and allowing students to work on related projects, helps promote interest in the field of NST.

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