WORKING DOCUMENT

Guidebook series for introducing
Nuclear Science and Technology
in secondary education

GUIDEBOOK

2

Linking NST with school curriculum

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.

The process by which an instructor or institution produces or accepts a course plan is known as curriculum development. It is critical to a country's educational advancement. It also provides answers and solutions to the world's most important issues and concerns, such as: the environment, politics, socioeconomics, and other poverty, climate change and sustainable development issues. Through TC project RAS0079, NST-related curriculum was able to be designed, reaching out to young secondary school students and improving their NST understanding through structured learning.

This guidebook describes examples that represent the core of education development. Various countries have shared their curriculum examples and allowed others to appraise them. Users can thus compare and contrast these examples in order to identify what is best practice for NST in secondary education among MS, based on their individual country and priority needs.

Disclaimer

The views expressed in this publication are those of the participating IAEA MS under the TC projects RAS0079 and RAS0091. Guidance provided in this manual, describing best practice, represents expert opinion in terms of secondary education but does not constitute recommendations made on the basis of a consensus of MS.

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Contents

List of abbreviations

AELB	Atomic Energy Licensing Board
ANENT	Asian Network for Education in Nuclear Technology
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
JHS	Junior High School
MS	Member State
NST	Nuclear Science Technology
NUTEC	NUclear TEChnology
PNRI	Philippine Nuclear Research Institute
RLF-NST	Recommended Regional Learning Framework for Nuclear Science and Technology
SHS	Senior High School
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics
SS	Social Science
7E	A learning cycle model that can guide students to actively acquire new knowledge — Elicit, Engage, Explore, Explain, Elaborate, Evaluate and Extend
UN SDGs	United Nations Sustainable Development Goals

1. Introduction

A curriculum is a standard-based sequence of planned experiences through which students practice and achieve proficiency in content and applied learning skills. Educators rely on the curriculum for every student's essential needs with regard to teaching and learning. It serves as a road map for teachers and students to follow a path towards evidenced-based academic success.

A curriculum must clearly state the goals, methods, materials and assessments required to support instruction and learning effectively:

Goals

Goals are the standard-based targets or expectations for teaching and learning. Most often, goals are prepared explicitly in the form of a scope and a sequence of skills to be addressed. Goals must encompass the breadth and depth to which a student is expected to learn.

Materials

Materials are the tools needed and selected to successfully implement the methods and achieve the goals of the curriculum. Materials are intentionally and carefully chosen, making sure that they are appropriate to support students' learning. They must reflect inclusivity that will cater to student interests, cultural diversity and world perspectives as well as addressing all types of diverse learners.

Methods

Methods are the instructional decisions, approaches, procedures and routines teachers use to make learning engaging and interesting, thus making the learning meaningful. These pave the way for the facilitation of learning experiences that will promote students' ability to understand and to apply content and skills learned. Methods are differentiated to meet student needs and interests, task demands and learning environment, and therefore they promote learning inclusivity. Methods are continuously adjusted, based on the results of ongoing review of student progress towards meeting goals.

Assessment

Assessment in terms of a curriculum refers to the ongoing process of gathering information about a student's learning. This includes different ways to document what the student knows, understands, and can do with their knowledge and skills. Information from assessments is used to make decisions in choosing the right instructional approaches, teaching materials and academic supports needed to enhance student opportunities and guide future instruction.

When considering these components, it is important to note that all curricula share one goal and that is to help students learn. Therefore, a curriculum should be much more than a guide to lessons and should benefit schools just as much as students, from teachers to administration staff. In addition, curricula can help schools connect with parents and the community around them, and thus a good curriculum must include a solid plan. Anchoring on this premise, the design of the science curriculum has some common guiding principles:

- Science is for everyone. Science and society have a proactive relationship. This means that the quality of life in a certain society increases once science is put into its service. Science education aims to achieve this relationship through teaching scientific literacy that is operational in nature, permeating through all levels of society. Whether or not students pursue a university education, they should leave school with a level of understanding and scientific literacy that will prepare them to be informed and participative citizens who are able to make judgments and decisions regarding science applications that may have social, health or environmental impacts.
- Science is both content and process. Science content and process both work hand-in-hand. Without content, it will be difficult for students to utilize process skills. Likewise, process skills are essential to visualize and advance content learning. Thus, to truly experience science one must take into consideration of both its content and processes.
- School science should emphasize depth, coherence and use of evidence in giving an explanation or making meaning.
- School science should be relevant and useful. By using relatable experiences and day-to-day situations as means of bridging concepts and lessons, science education should be able to engage its learners and encourage them to dive deeper into its concepts and lessons.
- School science should nurture an interest in learning. Learners are inquisitive by nature. They are interested in problems that puzzle them and trigger their mind to think creatively. In addition, they have a natural urge to find solutions. Rather than relying solely on textbooks, lectures and other traditional methods of teaching, teachers are encouraged to use hands-on learning activities that will develop students' interest and make them active learners. The design of the curriculum should focus on inquiry and phenomena-based learning. It is necessary for the curriculum to be organized around problems or phenomena that puzzle students and help motivate them to learn.
- School science should demonstrate a commitment to the development of a culture of science. The classroom is a miniature version of society. That is why it is important that school science be capable of imparting its values to its learners. Excellence, integrity, hard work and discipline are all linked to scientific culture. These values are not only valuable in the field of science but also in other work environments.
- School science should promote a strong link between science and technology, including Indigenous technology. Schools should recognize that science and technology reflect, influence and shape our culture. A science curriculum that is inclusive should recognize the place of science and technology in everyday human affairs. Moreover, it should see the need to integrate science and technology into the civic, personal, social, economic, and values and ethical aspects of life.

These guiding principles can be summarized around these three interlocking components: (1) inquiry skills, (2) scientific attitudes, and (3) content and connections. Being interconnected, these components combine to support the holistic development of a scientifically literate individual.

2. Facing the challenges

The enormous developmental challenges faced by the world today are well known:

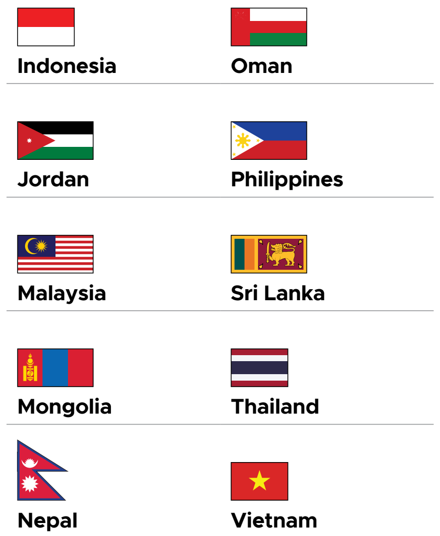
- unprecedented human population growth, with the need to provide food security, healthcare and energy resources to those increasing populations
- the road to recovery following the COVID-19 pandemic
- the associated demand for resources, and
- global climate change.

Society often looks to science to help provide solutions. Scientists are resolute explorers who help us to comprehend phenomena that have yet to be understood and offer solutions that can benefit us all. NST, in particular, has the potential to offer solutions to address those challenges listed above and to positively impact the lives of people. Society needs scientists to continue exploring the unknown for the betterment of our future.

The scientific community believes that science today offers truly amazing challenges and opportunities and that there has never been a better time to do science and yet still fewer students are attracted to study science and technology.

The challenge of attracting more students to study NST is becoming even more critical.

Part of the survey questionnaire given to MS as part of the Status Report of RAS0079 Project involved questions related to curriculum (Figure 1). Ten (10) participating MS responded to the survey:



2. Curriculum

2.1. Are nuclear science and technology concepts part of the basic education curriculum in your country?

YES, in Junior High School level only
When was it implemented? ____________

YES, in Senior High School level only
When was it implemented? ____________

YES, in both Senior High School and Junior High School level
When was it implemented? ____________

NO, not at all

Others, please specify ____________
When was it implemented? ____________

2.2. Please provide any other information about existing, new and/or planned education policies realted to nuclear science education in secondary school of your coutry (if any).

Figure 1.
Questions related to curriculum.

The results of the survey (Figure 2) indicate that the basic education curriculum of three (3) MS — Jordan, Malaysia and Vietnam — already include NST concepts in the science curricula of both the Junior High School (JHS) and Senior High School (SHS) levels. Note: JHS spans Grades 7 to 10. Typically, students in this level are aged between 13–16 years. SHS on the other hand covers Grades 11 to 12. In most cases, students choose an education strand upon entering SHS. Strands in SHS include science, arts and sports, as well as technical and vocational fields, etc. While Jordan and Vietnam have already incorporated NST at the JHS level since their last curriculum reform ten years ago, Malaysia has just begun offering NST in JHS in 2019. The other seven (7) MS — Indonesia, Mongolia, Nepal, Oman, Philippines, Sri Lanka and Thailand — currently cover NST only at SHS level.

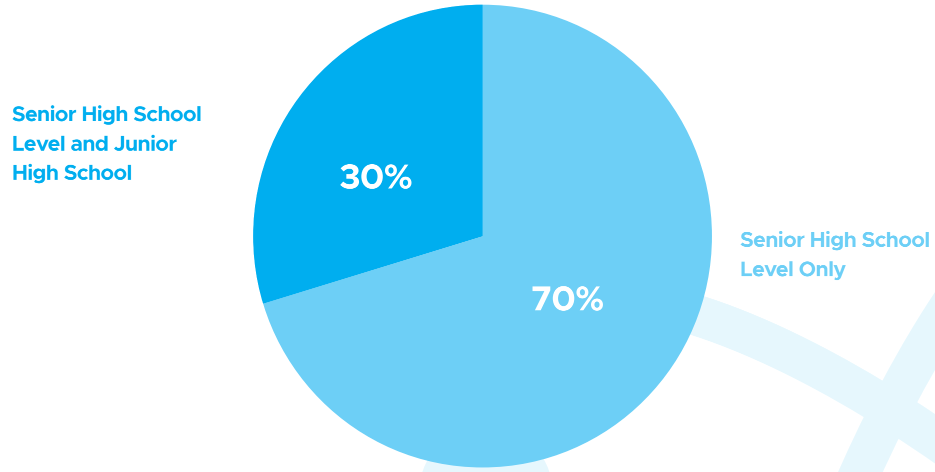


Figure 2.
When are high school students introduced to NST? Only 30% of the participating MS have NST in their basic education curriculum at both JHS (typically 13–16 year olds) and SHS (typically 17–18 year olds) levels. (N=10).

The curriculum determines what is delivered in the classroom and curricular changes are deemed to be adaptive to the ever-changing needs of society. Recognizing the importance of NST in our society, we need to educate our teachers and learners.

3. Finding solutions to the challenges

The IAEA organized a workshop through a TC project (RAS0065 — *Supporting Sustainability and Networking of National Nuclear Institutions in Asia and the Pacific Region*) designed to facilitate an appraisal of current educational programs and to identify types of activities being implemented that could support strengthening the study of science and technology by secondary school students. Encouraged by the responses of those at the meeting, there was further discussion on the desirability of sharing the wide range of individual experiences in terms of implementing academic and extra-curricular activities in schools.

The challenge of empowering teachers to deliver appropriate science and technology learning experiences in the classroom was recognized during an evaluation of RAS0065. As a result, a meeting workshop for MS curriculum developers was held and the RLF-NST was crafted, which serves as a guide to educating teachers under the IAEA TC RAS0079 Project, with the overall objective of expanding and sustaining NST information, education and communication among secondary school students and teachers in the region. The RAS0079 Project, which started in 2018, has continued to pave the way in engaging students in NST, thus ensuring the sustainability of human resources in the region and working towards achieving the UN Sustainable Development Goals (SDGs), especially in health, food availability, energy, and the environment. It contributes directly to nine (9) of the seventeen (17) UN SDGs.

The secondary education curriculum is designed to be a skills-focused program that provides students with a broad and balanced knowledge of key subjects, as well as effective critical thinking and communication skills. Teaching and learning experiences that take place inside the classroom and include linkage of the subject matter with applications "in the real world" results in a student-centric learning practice that augments learning and nurtures personal and social development. In addition, linking NST with the existing syllabus should allow the harnessing of interest among students and promote the development of certain key skills that will permit them to continue their exploration of future fields at both tertiary level education and in the workplace. However, it is necessary to ensure that this linkage neither burdens the teacher nor the students while the objectives of the curriculum are duly achieved.

This guidebook emphasizes how NST in the school curriculum has been implemented by various MS. The similarities and differences within the school science curricula of each MS benchmarks how NST topics are being considered and can be continuously improved so that they remain responsive to time, technology and generational change.

Linking NST with the existing syllabus should allow the harnessing of interest among students and promote the development of certain key skills.

4. Benchmarking of the existing curriculum among MS

Benchmarking the existing curriculum examples below allows for malleability to create and enhance a curriculum with high academic standards for all students. It enables us to comprehend what subjects are being taught and at what grade level, within the framework of the current curriculum in each participating MS. Table 1 shows detailed information.

Table 1.
NST topics based on countries' curricula.

Country	NST topics included in the curriculum
Indonesia	In Indonesia, the NST curriculum has been included in the National Curriculum and is found mostly in Grade 12 during the second semester of Physics. Systematic material used for teaching includes: • nuclei physics • nuclei structure • nuclei reaction • radioactivity • nuclear technology • radiation protection includes time, distance and shielding
Iran	NST topics in school (grade 8-12): • Nuclear structure • Radioactivity and half life • Fission and fusion • Fundamental particle • Applications (Nuclear energy, nuclear medicine, industrial applications, environmental applications)
Jordan	Science curriculum and NST topics include: • radioactivity (Grades 10 and 11) • the concept of energy and its application (Grade 8).
Malaysia	NST education is included in the national Science and Physics curriculum for Grades 10–12. Suggested activities are provided in the curriculum specifications document. For example: an animation on half-life • dice activity to plot a decay curve • videos on nuclear fission and fusion • searching information and presenting on nuclear reactors • making comparisons on the generation of electrical energy from power stations using different fuel sources, and then justifying the use of nuclear energy • debate about the requirements for constructing a power plant in Malaysia. NST is taught explicitly in Science and Physics under the topic "Nuclear energy" (Science, Grade 11) and "Nuclear physics" (Physics, Grade 12).
Mongolia	NST topics in school (Grades 10–12) include: • radiation application • environmental radiation survey
Malaysia	NST education is included in the national Science and Physics curriculum for Grades 10–12. Suggested activities are provided in the curriculum specifications document. For example: an animation on half-life • dice activity to plot a decay curve • videos on nuclear fission and fusion • searching information and presenting on nuclear reactors • making comparisons on the generation of electrical energy from power stations using different fuel sources, and then justifying the use of nuclear energy • debate about the requirements for constructing a power plant in Malaysia. NST is taught explicitly in Science and Physics under the topic "Nuclear energy" (Science, Grade 11) and "Nuclear physics" (Physics, Grade 12).
Oman	In Oman, the basic concept of atoms is introduced starting from Grade 5 in general science courses. Atomic and nuclear energy in post-basic education is mostly introduced in Physics (Grade 12). There is one unit in the Physics curriculum dealing with: • atomic physics and one chapter in nuclear energy • radiation • biological effect of radiation • nuclear binding energy • radioactive decay • nuclear fusion • nuclear fission • nuclear reactor

Country	NST topics included in the curriculum
Pakistan	Pakistan's integration of NST in secondary level curriculum includes: Physics: • Rutherford's scattering experiment and the evidence it provides for the existence and small size of nucleus • Nucleon number (mass number) and atomic number • Element can exist in various isotopic forms each with a different number of neutrons • Mass Spectrograph to demonstrate the existence of isotopes and to measure their relative abundance • Mass defect and calculate binding energy using Einstein's equation • Variation of binding energy per nucleon with the mass number • Spontaneous and random nature of nuclear decay • Half-life • Decay law • Interaction of nuclear radiation with matter • Wilson cloud chamber, Geiger Muller counter and solid state detectors to detect the radiations • Energy and mass conservation in simple reactions and in radioactive decay • Nuclear fission and nuclear fusion • Working principle of nuclear reactor • Various types of nuclear reactors • Nuclear radiation exposure and biological effects of radiation • The use of radiations, for medical diagnosis and therapy • Exposure to ionizing radiation • Use of radioactive tracers in diagnosis • Basic forces of nature • Building blocks of matter based on hadrons, leptons and quarks Chemistry: • Nuclear Chemistry • Physical Chemistry • Atom and Theories related to Structure of atom • Discovery of proton, electron & neutron • Ions, Free radicals • Electronic configuration • Isotopes and its applications • Radiotherapy (Treatment of Cancer) • Traces for Diagnosis and Medicine • Archaeological and Geological Uses • Applications in Power Sector • Chemical Reactions & structure Determination • Bonding • Periodic table • Physical & chemical changes • Atomic Models (Bohr & Rutherford) • Transitions elements • Macromolecules • Chemical industries • Environmental Chemistry
Pakistan *Continued*	Biology: • Level of organization • (subatomic & atomic level, Bio-elements & Molecules) • Microscopy and the Emergence Of Cell Theory • Active transport • Cell cycle, Apoptosis & Necrosis • Tumor, Cancer • Bio-energetics • Oxidation & Reduction reactions • Renewable & Non-renewable energy resources • Respiration • Nutrition (nutrients & minerals) • Blood cancer • Chromosomes and DNA • Energy and Ecosystem • Pollution • Biotechnology • Light the driving Energy (Photon, Absorption Spectrum)
Syria	NST topics for the secondary school curriculum covers: • physical principles • biological effects of radiation • application of NST
Thailand	Ministry of Education secondary level publications include: • national nuclear teaching guideline • nuclear education textbooks. NST topics include: • history of radioactivity discovery • types of radiation • advantages of radioactivity in agriculture, medical treatment, industry and archeology • radiation protection • concepts of fission and fusion • electricity production from nuclear power plants

From Table 1 it can be seen that NST topics from participating MS vary as do their implementation strategies, therefore mapping is necessary.

5. Mapping of important NST topics

Curriculum mapping refers to the process of indexing a curriculum to see its coherence and alignment across lessons, subject areas and grade levels. It also becomes a reflective process that helps teachers understand what has been taught in a class, how it has been taught, and how learning outcomes were assessed.

At this initial stage, based on available data from at least four (4) MS (Philippines, Malaysia, Indonesia and Oman) mapping was conducted to observe what topics of NST were taught to which grade levels (Table 2). This information was gained from the winning and finalist teachers of the 2021 Secondary NST Education Competition during a meeting on the development of a Model Curriculum for Secondary Level Education.

Table 2: Mapping of NST topics according to grade level by country

Topic	Grade					
	7	8	9	10	11	12
Structure of atom	P	P M O Ir		I O		I O Ir
Radiation				P M O		I O Ir
Fission and fusion and their relevance to environment		P		P Ir	P	M I O Ir
Radioactivity in the environment				P M O	P	I O Ir
History of nuclear science				P M Ir		I O Ir
Risk and safety				P M		I O Ir
Applications of NST				P M O	M Ir	M I O Ir
Career paths						P I O

Legend P = Philippines M = Malaysia I = Indonesia O = Oman Ir = Iran

The distribution of topics varied according to grade level and core subject embedded into the curriculum. For example, "Structure of atom" was taught in both Chemistry and Physics but at different grades. The topics "History of nuclear science" and "Risk and safety" were all taught in Physics but at different grades. As for the "Application of NST", it was taught in Physics, Biology and Social Sciences. Meanwhile, topics with more advanced knowledge such as "Fission and fusion and their relevance to the environment" were taught in SHS (Grades 10–12). Lastly, the topic "Career paths" was embedded in Physics, except in Malaysia.

NST topics were also embedded in different subjects for Indonesia, Malaysia, Oman and Philippines respectively, as shown in Figure 3.

Indonesia	Physic, Chemistry, Biology
Iran	Physics, Science, Chemistry
Malaysia	Physics, Science
Oman	Physics, Science
Philippines	Advanced Physics, Consumer Science/Chemistry, Environmental Science, NST as an elective or add on subject offered in Special Science Schools

Figure 3. Comparison NST topics

As result of this mapping of NST topics among MS, the curriculum developers crafted the RLF-NST for secondary schools which serves as a guide for both curriculum developers and teachers in designing and planning learning experiences for their students in relation to NST. The RLF-NST served as the basis for topics discussed as part of the RAS0079 Project both for teachers and trainers.

Table 3. Summary of RLF-NST for secondary schools

	Summary of RLF-NST for secondary schools
1	**Structure of an atom** The student should be able to explain: • the basic components of an atom • basic characteristics including proton, electron, and neutron • the models explaining the atomic structure • isotopes • isomers • the periodic table of elements
2	**Radioactivity in the environment** The student should be able to accurately: • explain radioactive phenomena • differentiate between properties of radioactive emissions • explain natural occurrences of radioactivity • interpret the periodic table of elements • explain how radioactivity is monitor and managed safely
3	**Fission and fusion and their relevance to the environment** The student should be able to accurately: • differentiate between fission and fusion reactions • explain the conversion of mass to energy $E=MC^2$ • explain control of fission and fusion • explain fission and fusion as source of energy.
4	**Radioactivity in the environment** The student should be able to accurately: • explain the natural occurrences of radioactive ores • explain radioactivity in the environment • explain the radioactive decay series
5	**History of nuclear science** The student should be able to accurately: • explain the historical Milestones of Scientists associated with the development of NST • explain early applications — Weapon/health (x-Ray) and who discovered them • explain the establishment and mission of IAEA • understand international agreements
6	**Risk and safety** The student should be able to accurately explain: • biological effects from radiation exposure • principles and concepts in radiation protection/treatment • waste management principles and practices • the impact of nuclear accidents
7	**Applications of NST** The student should be able to accurately explain: • nuclear energy and its benefits in low carbon/low emission solutions • health application and use as diagnostic and therapeutic treatment • how nuclear technologies support a wide range of industries • how nuclear technologies support agriculture • how nuclear research helps to better understand our environment
8	**Career paths** The student should be able to: • show an interest in NST • identify the wide variety of careers available in NST • identify the learning qualifications needed to have NST careers

As the RAS0079 Project continued, the experts recognized the need for the inclusion of other related topics. Understanding the importance of NST in current use and technology, suggestions have been made to include topics such as:

- NST and SDGs
- Instrumentation of technology behind radiation
- Health and medicine purposes
- Agriculture
- Food security, and
- Inclusion of career paths.

Contents

One suggestion put forward to increase student proficiency in science learning was to develop lesson exemplars using the 7E Instructional Model. This model (elicit, engage, explore, explain, elaborate, evaluate and extend) guides students to actively acquire new knowledge and can help them understand the phenomena and problems they encounter, thus increasing student proficiency in science.

In addition, the topics listed below could be integrated into lesson planning in relation to NST. The inclusion of these topics in lessons should enhance student interest and help students in their future decision-making.

- Need for nuclear power
- Nuclear for healthcare
- Ensuring food security with nuclear science
- Radiation in the environment
- Nuclear in everyday life
- Is nuclear safe?
- Teaching nuclear in a playful manner
- Future of nuclear sciences
- Teaching nuclear science with modern technology.

However, it is not enough that the RLF-NST can be readily accessed and used by teachers. In order to teach some NST topics someone must have the relevant content expertise.

A variety of factors that may limit the number of students who might ever consider a career in nuclear science include:

- inappropriate and inaccurate treatment of nuclear topics in primary and secondary curricula
- absence of regularly taught undergraduate courses in NST at tertiary level
- lack of established programs to facilitate the transition of early-career scientists into forefront research activities, and
- lack of post-graduate educational opportunities such as Masters-to-PhD bridging programs to allow for progress in NST careers
- misconceptions of nuclear science and technology.

In an effort to avoid such outcomes, the teachers and would-be trainers involved in RAS0079 were trained on NST topics by experts from the IAEA serving as content experts. As well as content they were given teaching strategies and pedagogies, plus information on organizing and handling extra-curricular activities related to NST. Additionally, the teachers and would-be trainers were shown how to incorporate the “WOW factor”, to make their NST lessons meaningful and engaging. The “WOW factor” refers to the moment an individual becomes aware of new knowledge and is inspired because of the wonder of the discovery, the wonder of delight, the wonder of learning, the wonder of surprise, and the wonder of demystification.

Figure 4. Pictures taken during the RAS0079 training

To access in detail some of the NST topics and possible careers in NST, kindly refer the Asian Network for Education in Nuclear Technology (ANENT) website at **www.anentweb.org**

6. Developing lesson plans

After learning the content of NST and how to teach NST topics using varied strategies the teacher participants of the RAS0079 Project were then ready to craft their lesson plans.

A good lesson plan should consider these questions:
"What should be taught?", **"How should it be taught?"**, and **"How should learning be assessed?"**.

Below are some thoughts to aid teachers in developing a lesson plan.

What is a lesson plan?

- Lesson planning is a way of visualizing a lesson before it is taught.
- It entails "prediction, anticipation, sequencing and simplifying."
- The objective of lesson planning is learning.
- Lesson planning is a hallmark of effective teaching.
- Why plan for instruction?
- Research shows that effective teachers organize and plan their instruction (Misulis 1997; Stronge 2007).
- Daily lesson preparation also encourages reflective practice since it requires teachers to think about and reflect on their instructional practices on a daily basis.

How to plan for instruction?

The instructional process is made up of three (3) steps:

- **i)** planning instruction.
- **ii)** delivery of instruction
- **iii)** assessment of learning.

A well-formulated lesson plan forms the foundation of successful teaching practice as it contributes to successful learning outcomes of the subject in many ways. A deftly planned lesson enhances the teacher's interaction with the students and makes the act of teaching more enjoyable. Table 4 shows the template of a lesson exemplar to be used in the RAS00979 Project as agreed by the experts and participants during meetings and workshops.

Table 4. Lesson exemplar template

Country: ____________				
Members			**Grade Level**	
			Learning Area	
Allotted time	1 Hour			
Standards, topics and references				
GLOBAL COMPETENCY				
Learning Outcomes				
Topic				
References				
Defining success				
Objectives				
Assessment				
Key Points/Concepts				
Instructional flow/Learning cycle				
Daily routine: (please identify the different parts of your daily routine before proceeding to the lesson)				
	Materials needed	Teacher's task	Students' task / activity	Assessment
Elicit (The activities in this section will evoke or draw out a response, or fact, from the students)				
Engage (The activities in this section will stimulate their thinking and help them access prior knowledge as a jumpstart to the present lesson)				
Explore (In this section students will be given time to think, plan, investigate and organize collected information)				
Explain (In this section, students will be involved in an analysis of their exploration. Their understanding is clarified and modified because of reflective activities.)				
Elaborate (This section will give students the opportunity to expand and solidify their understanding of the concept and/or apply it to a real-world situation.)				
Evaluation (This section will provide opportunities for concept check test items and answer key which are aligned to the learning objectives-content and performance standards.)				
Extend (This section gives a situation, then explains the topic in a new context, or integrated to another discipline/societal concern.)				

The sample lesson exemplars that have been developed and the presentations crafted by the participants on NST topics are illustrated in Table 5 and can be accessed via the Asian Network for Education in Nuclear Technology (ANENT) website at www.anentweb.org

Table 5. Example of NST topics developed under the RAS0079 Project

NST topic
History of nuclear science
Structure of atoms
Basic properties and structure of the atom
Periodic table of elements and naturally occurring radiation
Isotopes
Principles of radiation
Types of radiation (alpha, beta and gamma)
Radioactivity decay series
Nuclear reactions
Nuclear fission and fusion
Nuclear power plants and their application
Nuclear Magnetic Resonance (NMR)
Applications (energy, health, industry/agriculture, environment)
Applications of NST in health
Radioactivity in the environment
Risk and safety: Biological effects from radiation exposure
Concepts in radiation protection
Principles of radiation protection
Radiation control and handling
Radioactive material transport and accidents
Career paths in NST

As education involves a dynamic process, improving lessons becomes important in tandem with the progression and advancement of NST. Table 6 shows the suggestions made by MS to further enhance the lesson development of NST topics and activities which could be useful to the other MS embarking on the same mission.

Additionally, the role of the teachers in spreading the good news about NST is undeniable. To do this, teachers must be creative and innovative in delivering NST topics through whatever learning platform or modality.

Table 6. Suggestions on how to link NST topics in the school curriculum

Country	Suggestions
Indonesia	• Commitment from teachers to teach NST material. • Collaboration between Physics, Biology and Chemistry when teaching NST, so that the knowledge and benefits of NST can be seen as a whole and students' interest and understanding of NST will increase. • Teachers must have literacy with regard to NST topics updated by the IAEA or BATAN/BRIN, so that their NST knowledge is always up to date. • The teacher must include the latest world issues (such as Fukushima in Japan, the energy and coal crisis in Indonesia, and the war in Russia and Ukraine) related to NST in the lesson plan. • Radiation measuring instruments such as the Geiger Muller, developed in the form of an app such as a decibel meter measuring instrument, should be used.
Iran	• Linking schools and research centers • Developing the science and technology parks
Jordan	• Train more teachers on importance of nuclear energy. • Cooperation between the Curriculum Department and the Jordan Atomic Energy Commission.
Malaysia	• Teaching should include the roles of organizations and bodies that are directly involved in nuclear energy and NST education (IAEA, Malaysia Nuclear Agency etc.). • Build specific curriculum-centered modules that aid teachers in conducting NST education more effectively — similar to the programs outlined in NST4SS. • Include the use of technology such as Augmented Reality, simulations, mobile apps in NST education.
Oman	• Lessons must be suitable for direct, face-to-face, and indirect online teaching. (This includes materials and topics that can be presented on approved educational platforms such as videos, presentations and interactive activities). • Activate cooperation between science teachers from different disciplines to teach topics related to the sciences of nuclear techniques, so they can enrich each other with scientific material — ideas and suggestions. • Activate competitions within and between schools about projects and research involving both teachers and students. • Participate in conferences and virtual meetings between teachers of our different countries to develop ideas and appropriate alternatives to scientific subjects in the curriculum, as well as ways of presenting, arranging and linking them together to make it easier for students to understand and assimilate.
Philippines	• Map the list of NST topics in the Regional Framework to the existing curriculum to identify the point of entry of NST topics. • Integrate NST topics into the current curriculum. • If there will be an update of the curriculum, include the PNRI in the development of the curriculum guide. • Train teachers to be experts in teaching NST topics.
Sri Lanka	• Develop a NST elective module for Grade 11. • Upgrade the e-module on NST
Syria	• Enhance the NST syllabus. • Establish a NST reference book for secondary school education. • Establish transportable scientific labs to perform experiments in schools.
Thailand	• Develop a variety of attractive teaching materials and equipment for NST topics.
Vietnam	• Strengthen international cooperation in education and training of teachers in NST. • Upgrade and improve equipment and laboratories for NST.

7. Proposed enhancement of the RLF-NST

As we continue to build the pipeline to ensure the future of NST - a strong NST education must be done. We need to further enhance NST topics to be included in the Recommended Regional Learning Framework for Nuclear Science and Technology (RLF-NST) for Secondary Schools that will serve as a guide to our teachers in planning their NST lessons. There is a need to excite our students to consider nuclear science and technology as their future careers. It can be seen in Table 7 the suggested NST topics and the grade level it will be implemented by the corresponding MS.

Table 7. Proposed additional NST topics to be included in the RLF-NST

Suggested topic	Country				
	Indonesia	**Iran**	**Malaysia**	**Oman**	**Philippines**
Nuclear and SDG's		Grade 8 in Science		Grade 9 Science	
Instrumentation of technology behind radiation		Grade 12		Grade 10/ Grade 12	Grade 10
Health and medicine purposes		Grade 10-11	Form 3 (Grade 10)	Grade 12	Grade 10
Agriculture		Grade 10-11	Form 3 (Grade 10)	Grade 10	Grade 10
Food security		Grade 10-11	Form 3 (Grade 10)	Grade 10	Grade 10
Inclusion of career path in 7E's	*Cross-curriculum or integration across disciplines*				
Currents issues or situations that are related to NST		Grade 9 in science	Form 4 / Form 5 (SS)	Grade 12	
Balance discussion about the advantages and trade-offs of NST			Form 4 / Form 5 (SS)	Grade 12	
NST and environment and climate change		Grade 10			

The RLF-NST topics should be updated, making them even more responsive and an essential foundation on which teaching and learning experiences for NST must be based. Progress is essential to allow learning to take place. Be part of your mission to not only spread NST education but to make an interest in the sciences a prominent and lasting feature wherever it is offered. Spread the good news of Nuclear Science and Technology in improving human life.

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"Education is the most powerful weapon which you can use to change the world."

Nelson Mandela

Education shouldn't be seen merely as a way to fulfil school requirements; rather, it should be seen as a way to completely grasp the world in which live and work. With the rapid advancement of NST, sufficient linkages to school curricula as part of early learning will equip nations with the appropriate resources for NST competence and technological advancement.

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Guidebook 2

Linking NST with school curriculum

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