Development Directions for Nuclear and Radiation Teaching Materials and Educational Kits Based on a Comparative Analysis of Domestic and International Resources

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1. Introduction

As carbon neutrality and energy security have become major societal priorities, students increasingly need opportunities to understand the scientific principles and environmental and social implications of diverse energy sources. Nuclear energy and radiation, however, involve phenomena that are difficult to observe directly and combine specialized scientific concepts with socially contested issues, making them challenging to teach systematically.

In Korea's 2022 Revised National Curriculum, nuclear-energy-related content has limited continuity across school levels: it is not treated as a core topic at the elementary level, appears only in limited contexts at the middle school level, and is introduced more explicitly in high school Integrated Science [1]. This weak continuity can make it difficult for teachers to organize scientifically accurate, balanced, and age-appropriate instruction. Text-based explanations alone may also lead to fragmented understanding or an excessive emphasis on risk. Instructional materials and hands-on kits are therefore needed to translate abstract concepts into observable, manipulable, and measurable learning experiences.

International resources collectively include lesson plans, student worksheets, experiments, measurement activities, digital content, virtual field trips, career exploration, and teacher training [2-6]. In Korea, KAERI has developed materials and physical models covering radiation fundamentals, research facilities, and advanced nuclear technologies. These resources reflect domestic R&D contexts, but their curriculum alignment, school-level progression, assessment tools, and teacher support require systematic examination.

This study compared domestic and international nuclear and radiation education resources using a common analytical framework, identified the strengths of and areas for improvement in domestic resources, and proposed directions for developing teacher-oriented instructional materials and educational kits for classroom use.

2. Methods

2.1. Materials analyzed

The international sample comprised official school and teacher resources provided by the NRC and ANS in the United States, the Australian Nuclear Science and Technology Organisation (ANSTO), Japan's Radiation Education Site 'Radi,' and the IAEA [2-6]. The resources were purposively selected because they were publicly available, represented different instructional formats, and provided information relevant to school education or teacher support.

The domestic resources reviewed in this study comprised Understanding Radiation, Elements in Everyday Life, the SMART100 small modular reactor model, an export-oriented research reactor model, a proton accelerator model, materials on molten salt reactors and nuclear batteries, the Nuclear Exploration Team activity sheets, the Padongi Nuclear Fuel Pellet materials, and character-based educational kits.

2.2. Analytical framework and procedure

Seven analytical categories were established: (1) target learners and school level, (2) scope of educational content, (3) format and organization, (4) teaching and learning methods, (5) curriculum and subject alignment, (6) links to digital or virtual experiences and career or social contexts, and (7) teacher support and dissemination systems. Each resource was reviewed for explicit evidence within these categories, and recurring similarities and differences were compared. The findings were then synthesized to derive an integrated development model for teacher-oriented instructional materials and educational kits.

3. Results

3.1. Structure and characteristics of domestic resources

Domestic resources were classified into four areas: basic science and radiation, reactors and research facilities, advanced nuclear technologies, and student-centered activities. Understanding Radiation and Elements in Everyday Life explain foundational concepts of atoms, elements, and radiation through everyday examples and visual materials. The SMART100, research reactor, and proton accelerator models present the principal structures and functions of

actual facilities in three dimensions, whereas the materials on molten salt reactors and nuclear batteries extend the scope of content to advanced reactors and space or specialized power systems.

The Nuclear Exploration Team activity sheets, Padongi Nuclear Fuel Pellet materials, and character-based kits combine reading, inquiry, assembly activities, and familiar visual elements to support access and participation among younger learners. A common strength of the domestic resources is their connection of scientific concepts to Korean research facilities and technological examples. Some resources, however, are not sufficiently integrated with school-level learning objectives, curriculum achievement standards, instructional stages, student record sheets, or assessment tools; consequently, additional teacher-led adaptation is required for classroom implementation.

Table I summarizes the four categories of domestic resources and their principal educational characteristics.

Table I. Classification and educational characteristics of domestic nuclear and radiation education resources

Category	Representative resources	Educational characteristics
Basic science and radiation	Understanding Radiation; Elements in Everyday Life	Introduces atoms and radiation through everyday examples and visual materials
Reactors and research facilities	SMART100; export-oriented research reactor; proton accelerator	Visualizes the structures and functions of actual research facilities through models and assembly activities
Advanced nuclear technologies	Molten salt reactor; nuclear battery	Introduces advanced reactors and space or specialized power technologies
Student-centered activities	Nuclear Exploration Team; Padongi Nuclear Fuel Pellet; character-based kits	Supports engagement and accessibility through inquiry, assembly, and character-based activities

3.2. Types and strengths of international resources

The NRC organizes radiation types and applications, nuclear power generation, regulation, learning objectives, explanatory materials, diagrams, and activities into structured classroom units. ANS Navigating Nuclear provides grade-specific lessons for Grades 3-12, including Marvelous Atoms, Exploring Energy, Measuring Radiation, Decoding Decay, and Fission and Fusion, together with projects, career information, and virtual field trips. These U.S. resources integrate authoritative information, inquiry activities, and authentic career and workplace contexts [2,3].

ANSTO connects posters and workbooks with apps, extended reality (XR) content, and teacher professional development. Radi combines cloud-chamber observations, natural radiation measurements, worksheets, and discussion, while the IAEA integrates radiation-detector-based science kits with teacher training [4-6].

Table II summarizes the key characteristics of the international resources and their implications for domestic development.

Table II. Characteristics of international nuclear and radiation education resources and implications for domestic development

Country/ organization	Key characteristics	Implications for domestic development
United States: NRC and ANS	Authoritative content, grade-banded lessons, projects, and virtual field trips	Package lesson plans, worksheets, assessment, authentic contexts, and careers
Australia: ANSTO	Links physical resources with apps, XR, and teacher training	Extend physical kits through QR-, AR-, and XR-based resources
Japan: Radi	Observation, measurement, worksheets, and discussion	Integrate experimental procedures, data recording, and discussion prompts
IAEA	Detector kits integrated with teacher training	Provide safety training before dissemination and sustained follow-up support

3.3. Comparison and complementarity of domestic and international resources

Both domestic and international resources aim to provide accurate information and promote learner participation, but they differ in emphasis. Domestic kits provide physical concreteness and links to actual research by representing facilities and advanced technologies in three dimensions. International resources, by contrast, often integrate grade-level progression, teacher guides, student worksheets, experimental safety procedures, assessment tools, digital extensions, and teacher training into comprehensive instructional packages.

The priority, therefore, is not merely to increase the number of domestic kits but to combine the authentic context of existing models with the systematic instructional design found in international resources. Each kit should be linked to learning objectives and achievement standards, inquiry questions, assembly or measurement procedures, data-recording sheets, discussion prompts, formative assessment, career and sociotechnical contexts, and digital supplements.

Table III compares the complementary strengths of domestic and international resources and presents an integrated development direction.

As summarized in Table III, domestic resources offer contextual authenticity by representing Korean research facilities, advanced reactor systems, accelerators, and

radiation applications through physical models and assembly activities. International resources provide greater instructional coherence through curriculum alignment, school-level progression, teacher guides, student worksheets, measurement activities, assessment tools, digital content, and sustained teacher support. Future resources should combine these strengths by linking physical models to foundational concepts, inquiry and measurement activities, student record sheets, formative assessment, digital content, and social and career contexts.

Table III. Comparison of domestic and international nuclear and radiation education resources

Dimension	Domestic resources	International resources	Integrated development direction
Content	Korean research facilities, advanced technologies, and radiation in everyday life	Foundational concepts, safety, energy, society, and careers	Connect fundamentals, applications, and advanced technologies across school levels
Format	3D models, assembly kits, information resources, and activity sheets	Lesson plans, worksheets, science kits, games, VR, and virtual field trips	Package print resources, physical kits, worksheets, and digital content
Learning methods	Assembly, observation, and inquiry	Measurement, design, projects, discussion, and decision making	Extend assembly into inquiry, measurement, and problem solving
Teacher support	Primarily kit instructions	Teacher guides, assessment, training, examples, and sustained support	Establish teacher training and post-dissemination feedback systems
Primary strength	Authentic context and connection to Korean R&D	Curriculum alignment and classroom usability	Combine authentic context with instructional coherence

4. Development Directions for Teacher-Oriented Instructional Materials and Educational Kits

Based on the comparative analysis, an integrated development model for teacher-oriented nuclear and radiation instructional materials and educational kits is proposed in Fig. 1. The model synthesizes the authentic context of domestic resources, the systematic instructional design of international cases, and curriculum requirements. It comprises three design directions: (1) curriculum alignment and progression across school levels, (2) packaging of instructional materials and kits, and (3) integration of hands-on activities, digital extensions, and teacher support.

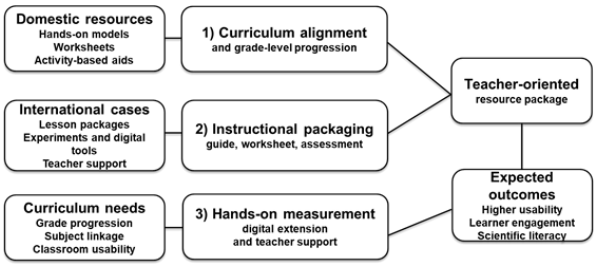


Fig. 1. Integrated development model for teacher-oriented nuclear and radiation instructional materials and educational kits

As illustrated in Fig. 1, future development should move beyond providing isolated models or information resources and instead pursue classroom packages that connect concepts, activities, assessment, and social contexts within a coherent teaching and learning sequence.

4.1. Curriculum alignment and progression across school levels

At the elementary level, atoms, elements, energy, and radiation in everyday life may be introduced through familiar examples and hands-on activities. At the middle school level, nuclear fission, radiation measurement, comparison of energy sources, and safety can be addressed through inquiry activities. At the high school level, radioactive decay, half-life, mass–energy equivalence, reactor systems, and sociotechnical issues can be explored through evidence-based discussion. These topics should be arranged as a spiral progression in which conceptual depth and problem-solving demands increase across school levels.

4.2. Packaging of instructional materials and educational kits

Each kit should specify the target school level and subject, relevant curriculum achievement standards, core concepts, anticipated misconceptions, materials, instructional sequence, student worksheets, safety guidelines, discussion prompts, formative assessment, and extension activities. For example, the SMART100 model could move beyond simple assembly by asking students to infer component functions, compare the system with large commercial nuclear power plants, examine safety features, and evaluate energy options.

4.3. Hands-on measurement and digital extensions

Radiation instructional materials should include activities in which students measure and record radiation levels while varying distance, measurement time, and shielding. Reactor and accelerator models could be linked to QR-based explanatory videos, three-dimensional structural information, augmented reality (AR), virtual reality (VR), and virtual facility tours.
Physical and digital resources should be used as complementary tools that combine concrete observation with indirect experiences of facilities that are difficult to access, rather than as substitutes for one another.

4.4. Sociotechnical issues, careers, and teacher support

Nuclear science and technology should be presented in relation not only to carbon neutrality and energy security but also to applications in medicine, industry, the environment, and space. Students should engage in discussion and design tasks that require them to compare and evaluate multiple forms of evidence. Career materials can connect occupations such as nuclear researchers, reactor operators, radiation safety officers, and medical physicists with their actual duties. Teacher training before and after resource dissemination should address core concepts, risk communication, experimental safety, and digital applications, while a continuing feedback system should collect classroom implementation cases and suggestions for improvement.

5. Conclusions

This study compared domestic and international nuclear and radiation education resources using a common analytical framework and derived directions for developing teacher-oriented instructional materials and educational kits. The analysis showed that domestic resources were strong in physical concreteness, contextual authenticity, and connections to Korean nuclear research facilities and technologies. However, many were provided as standalone models, activity sheets, or information resources and were therefore difficult to apply directly in classrooms without additional instructional design.

International cases tended to organize scientific content, learning objectives, student activities, experiments, assessment, digital extensions, career exploration, and teacher support as integrated instructional packages. Domestic resources should therefore connect existing physical kits with curriculum achievement standards, school-level progression, teacher guides, student worksheets, measurement and inquiry activities, formative assessment, and digital and virtual content. Sociotechnical contexts—including carbon neutrality, energy security, radiation applications, and related careers—should also be incorporated to support both scientific understanding and evidence-based judgment.

Accordingly, teacher-oriented nuclear and radiation education resources should prioritize reconfiguring existing materials into coherent classroom packages rather than simply producing additional kits. This approach may improve accessibility, instructional usability, and learner participation while preserving the technological authenticity of domestic resources. Because this study was limited to a qualitative comparison of selected materials, the proposed model should be tested through classroom implementation and empirical research involving teachers and students.

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