Development of a Radiation Education Supplementary Resource for K–12 Teachers

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1. Introduction

Radiation supports medicine, industry, agriculture, environmental analysis, cultural heritage, and materials research. Yet its invisibility and association with exposure and nuclear accidents can foster risk-centered perceptions. School education should therefore present its principles, effects, protection, and applications in a balanced, evidence-based context [1].

Analysis of K–12 textbooks developed under Korea's 2022 revised national curriculum [2] found no direct coverage of radiation concepts, effects, safety, or applications. Students may therefore rely on fragmented media or accident-related information and confuse radiation, radioactivity, radioactive material, and exposure. Reliable teacher resources are needed for balanced, age-appropriate instruction.

In response, KAERI's Nuclear Training and Education Center developed Radiation in Everyday Life: Scientific Inquiry and Understanding [3]. This paper describes its rationale, development, structure, instructional features, applications, and future tasks.

2. Methods

2.1. Educational Needs Analysis

Radiation education requires scientific literacy and risk communication. Students may confuse radiation, radioactivity, and radioactive material, while Bq, Gy, and Sv remain abstract without familiar examples. Teachers must address misconceptions about natural radiation, exposure effects, and dose limits while explaining low-dose uncertainty, justification, optimization, and medical benefit–risk comparisons [1]. International initiatives have likewise emphasized teacher training and instructional resources for secondary-school nuclear science education [4].

The resource therefore combines age-appropriate analogies, everyday cases, guiding questions, inquiry tasks, discussion topics, and teaching cautions. Its modular design supports selective use in classes, experiential activities, science clubs, career education, and special programs.

2.2. Development Procedure

Development followed four stages: (1) review of core concepts and instructional needs; (2) framework design and drafting by KAERI education and radiation specialists; (3) review by radiation experts and secondary-school teachers for accuracy, terminology, applicability, figures, and activities; and (4) revision of content level, units, terminology, illustrations, and activity procedures.

The final resource, Radiation in Everyday Life: Scientific Inquiry and Understanding, uses a friendly researcher character and science imagery on its cover (Fig. 1) to make radiation more approachable and highlight inquiry-based learning.



Fig. 1. Cover of the supplementary teacher resource, Radiation in Everyday Life: Scientific Inquiry and Understanding.

2.3. Content Selection and Organization Criteria

The organization emphasized not only what learners should know but also how they should judge radiation-related information. Radioactivity, absorbed dose, and equivalent or effective dose were explicitly distinguished, and biological effects were connected to radiation type, energy, tissue, exposure pathway, and purpose. Radiation protection was presented not as a set of fear-inducing prohibitions but as a rational process for reducing unnecessary exposure through time, distance, shielding, justification, and optimization [1].

Table I summarizes the five design principles applied throughout the development of the resource: context-centered learning, scientific balance, concept hierarchy, inquiry orientation, and classroom usability. These principles were established to connect abstract radiation concepts with familiar experiences while maintaining scientific accuracy. In particular, the resource progresses from everyday contexts to basic concepts, measurement, effects, protection, and applications. Inquiry activities, teaching notes, worksheets, visual

materials, and QR-based resources were incorporated to support direct classroom use.

Table I: Design principles of the teacher resource

Principle	Implementation	Examples
Context-centered	Begin with everyday questions and extend to scientific concepts	Food, air travel, medical imaging, security screening
Scientific balance	Present benefits, potential harm, and protection together	Natural/artificial radiation, medical benefit, protection
Concept hierarchy	Move from basic concepts to measurement, effects, and use	Atom → radiation → measurement → effects → protection → use
Inquiry orientation	Include observation, calculation, data analysis, and discussion	K-40 activity, distance and shielding investigations
Classroom usability	Provide teaching notes, visuals, worksheets, and QR resources	Unit questions, activity guidance, digital materials

3. Results

3.1. Content Framework

As summarized in Table II, the resource is organized into five interconnected content domains: radiation around us, fundamentals, measurement, effects and protection, and applications. The domains were arranged as a progressive learning sequence in which students first encounter radiation through familiar situations, develop basic conceptual understanding, examine evidence through measurement, understand biological effects and protection, and finally consider the social value and responsible use of radiation technology.

The first domain introduces radiation in everyday life through K-40 in plants and food, medical CT, X-ray non-destructive testing, neutron imaging, and C-14 dating. Its educational focus is to increase familiarity with radiation and motivate further learning. The second domain covers atomic structure, isotopes, distinctions among radiation, radioactivity, and radioactive materials, emission mechanisms, and radiation properties, thereby supporting conceptual understanding.

The third domain explains detectors, detection principles, measurement methods, and radiation units. It is intended to help students recognize that radiation-related judgments should be based on measurement and evidence. The fourth domain addresses biological effects, deterministic and stochastic effects, safety standards, and protection principles, with an emphasis on risk understanding and safe behavior. The fifth domain presents applications in medicine, industry, agriculture, the environment, cultural heritage, and scientific research, allowing students to examine the societal value of radiation technology.

Table II therefore functions not merely as a list of chapters but as an instructional progression from familiarity and conceptual understanding to evidence-based inquiry, risk understanding, safety, and the evaluation of technological value.

Table II: Content domains and instructional focus

Domain	Main Content	Educational Focus
I. Radiation around us	Natural/artificial radiation; daily-life cases	Familiarity and motivation
II. Fundamentals	Atoms, isotopes, decay, types, properties	Conceptual understanding
III. Measurement	Detection principles, devices, units	Evidence-based inquiry
IV. Effects and protection	Biological effects, standards, ALARA	Risk understanding and safety
V. Applications	Medicine, industry, agriculture, environment, research	Societal value of technology

3.2. Linking Everyday Contexts to Scientific Concepts

The resource begins with the question, “Where is radiation found?” The example of K-40 in plants and food demonstrates that natural radionuclides exist in living organisms and are not limited to nuclear facilities. X-ray and CT images, investigations of objects inside cultural artifacts, neutron imaging of water transport in plants, and C-14 dating connect penetration, interaction with matter, and half-life to real problem solving.

The natural radiation unit distinguishes exposure from cosmic rays, terrestrial materials, radon, and food. Dose comparisons involving K-40 in bananas, air travel, and medical examinations are used to develop unit conversion and scale awareness. Teachers are cautioned that such comparisons are explanatory aids rather than simple equivalences because meaning varies with exposure route, irradiated tissue, dose rate, and purpose [1,5].

3.3. Inquiry and Discussion Activities

The inquiry activities combine investigations, calculations, and model-based tasks that can be conducted without specialized laboratory equipment with optional observations at science museums or research institutions. In one activity, students record breakfast foods and quantities, use activity concentrations to estimate ingested K-40, and recognize

that naturally occurring radionuclides are routinely present in the body.

Additional activities compare detector readings as source distance, measurement time, or shielding material changes. These tasks support quantitative understanding of protection principles.

3.4. Educational Features and Applications

3.4.1. Scientific Accuracy and Learner Accessibility

Excessive technical detail can make radiation education inaccessible, whereas oversimplification may create conceptual errors. The resource retains scientific distinctions in nuclide notation, half-life, decay modes, detector principles, dose units, and protection while using visual and linguistic scaffolds. Examples include comparing radioactive material–radioactivity–radiation with a lamp–light-emitting capacity–light relationship, using variations in clover leaves to explain isotopes, and comparing a stadium and an ant to illustrate the relative scales of atoms and nuclei.

Each unit includes teaching points, questions, short information boxes, and experimental or survey tasks. Historical episodes involving Röntgen, Becquerel, Marie Curie, and Rutherford show that scientific knowledge develops through observation, experimentation, debate, and revision rather than through the simple accumulation of facts.

3.4.2. Balanced Risk Communication

Effective risk communication does not reduce radiation to a binary judgment of “safe” or “dangerous.” It asks what type of radiation is involved, by which pathway and at what level exposure occurs, whether the exposure has a justified purpose, and how unnecessary exposure can be reduced. The resource distinguishes natural and artificial radiation and explains why natural background and medical exposure are treated separately from the public dose limit. In medicine, justification and optimization are emphasized: an examination should provide a sufficient clinical benefit and should be performed under appropriate conditions without unnecessary repetition [1].

Scientific uncertainty, particularly for health effects at low doses, is presented without unwarranted certainty. Teachers are encouraged to explain that protection standards incorporate uncertainty conservatively and to guide students in checking source credibility, units, comparison criteria, and context when evaluating claims encountered online or in the media.

3.4.3. Applications by School Level

At the elementary level, emphasis should be placed on the basic ideas that radiation exists in nature, X-rays can reveal internal structures, and radiation should be used safely when needed. Middle-school instruction can introduce atoms and isotopes, alpha, beta, and gamma radiation, penetration and shielding, and the meaning of measurement through simple calculations and data analysis. High-school activities can extend to radioactive decay, half-life, dose quantities, biological effects, justification and optimization, and evidence-based discussion of social issues.

3.5. Limitations and Future Work

This paper describes a development case and does not provide empirical evidence of classroom learning effects. Because a single resource covers all K–12 levels, difficulty levels and lesson sequences are not yet fully differentiated. Future work should develop school-level modules, lesson plans, student worksheets, formative assessment items, and digital content. Pilot instruction should evaluate conceptual understanding, risk perception, scientific attitudes, and teacher usability. Digital detectors, virtual experiments, and augmented-reality content may also make invisible radiation phenomena more intuitive.

4. Conclusions

The supplementary resource integrates radiation-related content that was absent from the analyzed 2022 revised curriculum textbooks into a coherent sequence of everyday contexts, scientific principles, measurement, biological effects, safety management, and social applications. Its major contributions are the balanced treatment of benefits and risks, the explicit distinction among key concepts and dose quantities, and the connection of protection principles with inquiry activities.

The resource aims not to promote a predetermined attitude toward radiation but to strengthen scientific literacy and risk communication competence. By collecting, comparing, and interpreting evidence, students can assess information sources, exposure conditions, benefits, risks, and uncertainties. With further school-level differentiation and empirical evaluation, radiation education can develop into a form of citizenship education that supports safe and responsible decisions about science and technology.

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