Analysis of Changes in Nuclear Energy-Related Keywords in National Curriculum Revisions: Focusing on the 2009, 2015, and 2022 Revised Curricula

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1. Introduction

In South Korea, where energy import dependence reached 93.9% as of 2023, the importance of nuclear energy, aimed at securing sustainable national energy sources and developing future energy sources, is gradually increasing. To maintain or increase nuclear power generation, it is essential to enhance public support and understanding of nuclear energy. In particular, the negative perception of nuclear energy among adolescents, the main players of the future generation, is mostly due to inaccurate information about nuclear energy and radiation. Therefore, elementary and secondary school education is crucial to convey the importance of nuclear energy, which accounts for about 30% of the domestic power generation, to adolescents.

The curriculum reflects social changes and future demands, and is continuously revised based on educational research and evaluation results, while transitioning to student-centered and competency-based education, and considering international trends. At the core of these curriculum revisions are achievement standards. Achievement standards clearly present the content that students should learn in each subject and the level of ability they should reach, and textbooks are structured to effectively achieve these achievement standards.

Nuclear energy education is a field where content and direction are constantly changing according to scientific and technological development, environmental changes, and policy changes. The 2011 Fukushima nuclear accident in Japan and the Moon Jae-in administration's policy stance of phasing out nuclear power from 2019 to 2022 dramatically changed public perception of nuclear energy. In this social change, it is essential to analyze how the achievement standards of nuclear energy education are reflected in the national curriculum.

This study analyzes nuclear energy-related keywords presented in the achievement standards by subject for the 2009, 2015, and 2022 revised curriculum documents. Based on this, we analyze how nuclear energy-related keywords have changed by national curriculum revision period, and explore the meaning of nuclear energy education in the curriculum by analyzing nuclear energy-related keywords by school level and subject. In addition, we intend to analyze the social factors that influenced nuclear energy education when the curriculum was revised.

2. Materials and Methods

Relevant documents from the 2009, 2015, and 2022 revised curricula were collected from the National Curriculum Information Center (NCIC) website. Keywords encompassing essential concepts related to nuclear energy, such as 'nuclear power', 'nuclear fission', 'nuclear energy', 'nuclear power plant', 'radiation' 'radioactivity', and 'nuclear accident', and among others, were selected.

In this study, nuclear energy-related keywords presented in the achievement standards by school level and subject were extracted and analyzed from the 2009, 2015, and 2022 revised curriculum documents. The nuclear energy-related keywords appearing in the achievement standards by subject for each revised curriculum were compared in a context-centered manner, and the relevance to the learning objectives by subject was analyzed. This methodology is effective in verifying whether historical social changes are reflected in the curriculum.

3. Results and Discussion

3.1 Analysis of Keywords Related to Nuclear Energy in Elementary School Curriculum

As a result of analyzing nuclear energy-related keywords presented in the achievement standards by grade and subject in the 2009, 2015, and 2022 revised curriculum documents, as shown in Table I, these keywords did not appear at all. This suggests that the elementary school curriculum does not deal with nuclear energy-related content at all. For reference, in the 2nd national elementary school 6th grade Natural Science curriculum (1963), 'nuclear energy' was first specified as a keyword as one of various energies (hydroelectric, wind, solar energy, nuclear energy). However, since then, there has been no subject in the elementary school national curriculum where nuclear energy-related keywords have appeared.

Table I: Keywords related to nuclear energy in the 2009, 2015, and 2022 revised elementary school curriculum

National Curriculum	School Level	Subject	Keywords
The 2009, 2015, and 2022 Revised National Curriculum	Elementary School	N/A (Not Applicable)	N/A (Not Applicable)

3.2 Analysis of Keywords Related to Nuclear Energy in Middle School Curriculum

Table II presents the analysis results of nuclear energy-related keywords found in the achievement standards of each subject and curriculum within the middle school education course. As shown in Table II, the keywords related to nuclear energy in the 2009, 2015, and 2022 revised middle school Science curricula was 'atomic nucleus', 'proton', and 'neutron'. However, these keywords merely explain the basic components of an atom (atomic nucleus and electrons) at the middle school level, and their direct relevance to nuclear energy is considered weak. Therefore, although nuclear energy relevance is mentioned, the depth of content is insufficient to classify them as core keywords.

For reference, the 2nd national middle school 3rd grade Science Curriculum (1963) specified a number of nuclear energy-related keywords, such as 'atomic energy' among energies ('atomic structure', 'nuclear power, 'nuclear reactor', 'utilization of nuclear power'). However, since then, 'nuclear energy' has never been specified as a keyword in the national middle school curriculum.

On the other hand, as presented in Table II, the analysis of the achievement standards of the 2015 revised middle school Environment curriculum revealed that the keyword was 'nuclear power generation', which involved investigating and discussing issues related to the use of nuclear power generation. This is a notable change in the middle school curriculum that deals with nuclear energy. The 2022 revised middle school Environment curriculum also dealt with the exploration of problems related to nuclear power generation energy use and resource circulation and the analysis of interactions with 'nuclear power generation' as a keyword. This shows that the keyword 'nuclear power generation' consistently appears, emphasizing learning about the risks of nuclear power generation and environmental issues.

3.3 Analysis of Keywords Related to Nuclear Energy in High School Curriculum

Table III presents the analysis results of nuclear energy-related keywords found in the achievement standards of each subject and curriculum within the high

Table II: Keywords related to nuclear energy in the 2009, 2015, and 2022 revised middle school curriculum

National Curriculum	School Level	Subject	Keywords
The 2009 Revised National Curriculum	Middle school	Science	Atomic nucleus
The 2015 Revised National Curriculum		Science	Atomic Nucleus
		Environment	Nuclear power
The 2022 Revised National Curriculum		Science	Proton, Neutron
		Environment	Nuclear power

school education course. As shown in the table, the principle of nuclear power generation and the problem of energy resource depletion was discussed with 'radioactive energy' as a keyword in the 2009 revised high school Integrated Science curriculum.

However, the 2015 revised curriculum used 'nuclear power generation' as a keyword, addressing the analysis of the process of converting nuclear energy into electrical energy, the advantages and disadvantages of nuclear power generation, and environmental evaluation.

Subsequently, the 2022 revised curriculum used 'nuclear energy' as a keyword, adding the analysis of the advantages and disadvantages of nuclear power generation and the social impact on the global environment and humanity, in addition to the analysis of the process of converting nuclear energy into electrical energy. Consequently, it can be seen that nuclear energy education in high school Integrated Science has evolved from a technical perspective to a focus on social and environmental impact analysis as it has changed from the 2009 revised curriculum to the 2015 and 2022 revised curricula.

Additionally, the achievement standards of the 2015 revised high school Integrated Science curriculum discussed the formation process and depletion issues of radioactive energy resources, with radioactive energy as a keyword.

Nuclear energy-related keywords in the high school Physics subject have changed through the revised curricula from 2009 to 2022. In the 2009 revised curriculum, Physics I used 'nuclear fission', 'nuclear reactor', and 'radiation' as keywords, addressing mass change and energy generation, and the types and structures of nuclear reactors. In Advanced Physics, 'nuclear reaction' and 'nuclear fission' were keywords, addressing the basic process and risks of nuclear fission as an energy source, and safety devices in depth. In

Table III: Keywords related to nuclear energy in the 2009, 2015, and 2022 revised high school curriculum

National Curriculum	School Level	Subject	Keywords
The 2009 Revised National Curriculum	High school	Integrated Science	Radioactive energy
		Physics I	Nuclear fission, Nuclear reactor, Radiation,
		Advanced Physics	Nuclear reaction, Nuclear fission
		Physics Experiment	Radioactive material, Radiation measurement, Cloud chamber
		World Geography	Nuclear energy
		Environmental Science	Radioactive material
The 2015 Revised National Curriculum		Integrated Science	Nuclear energy, Nuclear power
		Convergency Science	Radioactive energy
		Physics I	Special theory of relativity
		Environment	Radioactivity leak, Chernobyl nuclear power plant accident, Fukushima nuclear power plant accident, radioactive contamination
The 2022 Revised National Curriculum		Integrated Science	Nuclear energy
		Physics	Special theory of relativity
		Korean Geographical Exploration	Nuclear energy
		History and Culture of Science	Nuclear energy, Nuclear power plant operation extension

Physics Experiment, 'radioactive materials', 'radiation measurement', and 'cloud chamber' were keywords, allowing students to directly experience radiation-related
phenomena through radiation measurement using a Geiger-Müller counter and cloud chamber experiments.

However, in the 2015 revised Physics I curriculum achievement standards, the nuclear energy-related keyword changed to 'special relativity theory', focusing on understanding mass-energy equivalence.

And in the 2022 revised Physics curriculum achievement standards, 'special relativity theory' is the keyword, aiming to explain time dilation and length contraction phenomena (excluding simultaneity relativity and quantitative calculations). Therefore, while the 2009 revised Physics curriculum emphasized the basic principles and experimental aspects of nuclear energy, the 2015 and 2022 revised Physics curricula show a tendency to deepen the theoretical understanding of nuclear energy-related concepts, focusing on special relativity theory. In particular, the 2022 revised Physics curriculum seems to be focusing on explaining time dilation and length contraction phenomena, showing that it emphasizes the theoretical aspect even more.

Furthermore, the analysis of nuclear energy-related keywords in the achievement standards of the 2022 revised high school History and Culture of Science curriculum resulted in terms such as 'nuclear energy' and 'nuclear power plant operation extension'. This shows that it is designed to help students understand the duality of nuclear technology and cultivate balanced judgment. In particular, by investigating social issue cases such as the extension of nuclear power plant operation, it aims to help the public establish a scientific perspective and recognize the importance of balanced value judgment.

As shown in Table III, the analysis of nuclear energy-related keywords in the achievement standards of the high school social studies curriculum by curriculum revealed that the 2009 revised World Geography curriculum achievement standards used 'nuclear energy' as a keyword, recognizing nuclear energy as one of one of the world's major energy resources, and aimed to identify its characteristics, distribution, development, impacts of supply and demand imbalances, and conflicts. It addressed both the aspect of nuclear energy as an energy resource and social issues. However, nuclear energy-related content was not found in the 2015 revised high school social studies curriculum.

On the other hand, the 2022 revised high school Korean Geography Exploration curriculum uses 'nuclear energy' as a keyword, evaluating the current status of nuclear energy in terms of power generation cost, carbon emissions, and energy independence, and investigating the proportion of carbon emissions in the industrial, building, and transportation sectors. It also discusses geographical issues of energy policy, such as location characteristics by power generation type, and equity issues arising from the mismatch between power generation sites and consumption sites. Furthermore, it aims to promote in-depth understanding of nuclear energy by re-examining the importance of nuclear energy as a major energy resource in the carbon-neutral era and structuring learning about various geographical issues. Therefore, it can be seen that each revised curriculum has changed its perspective on nuclear energy and its educational content according to the demands of the times and social changes

Based on the analysis of nuclear energy-related keywords within the Environment subject achievement standards for each curriculum, as presented in Table III, the following distinct trends are observed across the educational curricula.

The Environmental Science subject in the 2009 Revised Curriculum focuses on raising awareness regarding nuclear safety by promoting an in-depth understanding of the effects of 'radioactive materials', a key term, on the human body. Specifically, it is characterized by the scientific analysis of the impact of radioactive materials on human health and the subsequent emphasis on the significance of nuclear safety.

In contrast, the Environment subject in the 2015 revised curriculum emphasizes a critical analysis of the severity of nuclear disasters and their societal repercussions through key words such as 'radioactivity leak', 'Chernobyl nuclear accident', 'Fukushima nuclear accident', and 'radioactive contamination'. In particular, it critically examines issues within disaster response systems, the discriminatory impacts on socially vulnerable groups, and economic losses. Through the Chernobyl and Fukushima nuclear accidents as key case studies, this curriculum aims to foster a profound understanding of the gravity of nuclear disasters and their social ramifications.

3.4 Analysis of Changes in Keywords Related to Nuclear Energy by Curriculum Revision Period Based on Nuclear Issues

The 2009 revised curriculum, preceding the Fukushima nuclear accident, reflects a period before social discussions on nuclear energy had fully commenced. During this time, keywords addressing the basic scientific concepts of nuclear energy, such as 'atomic nucleus', 'radioactive energy', 'nuclear fission', 'nuclear reactor', 'radiation', 'radiation measurement', and 'cloud chamber,' were prominent. In particular, nuclear energy-related content was mainly covered in science and engineering and related subjects such as Physics I, Advanced Physics, Physics Experiment, and Environmental Science.

Discussions on the risks or social impacts of nuclear energy were relatively insufficient. At that time, nuclear energy was strongly perceived as an economical and efficient energy source, and social awareness of the risks of nuclear power generation was lower than it is now. This social atmosphere was reflected in the 2009 revised curriculum, focusing on the understanding of the scientific concepts of nuclear energy.

The Fukushima nuclear accident increased social awareness of the risks of nuclear energy, and this was reflected in the 2015 revised curriculum. During this period, keywords related to the utilization and risks of nuclear energy, such as 'nuclear energy', 'nuclear power generation', 'radioactivity leak', 'Chernobyl nuclear accident', 'Fukushima nuclear accident', and 'radioactive contamination', were added.

The scope of nuclear energy education was expanded as the advantages and disadvantages of nuclear power generation, the impact of radioactive disasters on the environment, and nuclear energy environmental issues were covered in high school Integrated Science and Environment subjects. In the case of high school Physics, I, rather than directly mentioning nuclear energy, the understanding of mass-energy equivalence was indirectly addressed through special relativity theory.

Concerns about the safety of nuclear energy increased after the Fukushima nuclear accident, and social discussions on the risks of nuclear power generation and environmental issues became active. These social changes were reflected in the 2015 revised curriculum, and education was changed in a direction that allows students to recognize the risks of nuclear energy and engage in social discussions.

The Moon Jae-in administration's nuclear phase-out policy further intensified social discussions on nuclear energy, and this was reflected in the 2022 revised curriculum. During this period, keywords related not only to the scientific concepts of nuclear energy but also to energy policies and social issues, such as 'nuclear power generation', 'nuclear energy', 'nuclear power', 'special relativity theory', 'carbon neutrality' and 'nuclear power plant operation extension' appeared.

A multidisciplinary approach to nuclear energy education was emphasized as nuclear energy-related content was also covered in humanities and social studies subjects such as Korean Geography Exploration and History and Culture of Science. It was designed to help students understand the duality of nuclear technology and cultivate balanced judgment. Social discussions on nuclear energy were further intensified under the nuclear phase-out policy stance, and discussions on the importance of nuclear energy as a major energy resource in the carbon-neutral era were also conducted.

4. Conclusions

The results of this study indicate that the 2011 Fukushima nuclear accident in Japan significantly impacted the 2015 revised curriculum. Specifically, the strengthening of content on the risks and safety of nuclear energy, such as 'nuclear power generation,' 'radioactivity,' and 'nuclear accident,' in the 2015 revised curriculum is analyzed as a result of the Fukushima nuclear accident. Consequently, as social concerns about nuclear power generation increased, the curriculum appears to have emphasized efforts to recognize the risks of nuclear energy and ensure safety.

Furthermore, the Moon Jae-in administration's nuclear phase-out policy stance from 2019 to 2022 influenced the 2022 revised curriculum. In other words, the inclusion of content in the 2022 revised curriculum that addresses policy discussions along with the economic and environmental aspects of nuclear energy, such as 'nuclear-based energy supply,' 'carbon-neutral energy policy,' and 'nuclear power plant,' is analyzed as an impact of the nuclear phase-out policy. Therefore, it

appears that exploratory activities on social issues and policy changes, such as energy transition and linkage with eco-friendly policies, rather than nuclear technology itself, have been emphasized.

These research results show that national curriculum revisions are closely related to social issues, and that the educational content on nuclear energy is also continuously changing according to the demands of the times and social changes. In particular, the Fukushima nuclear accident and the nuclear phase-out policy changed social perceptions of nuclear energy and had a significant impact on the curriculum. In future curriculum revisions, it is necessary to further strengthen education that comprehensively addresses not only the scientific understanding of nuclear energy but also its social and ethical aspects.

In particular, there are no nuclear energy-related subjects taught to students in the elementary school science curriculum, and systematic nuclear energy education is not being conducted in the middle school curriculum either. This reality can make it difficult for future generations to make rational judgments based on objective information about nuclear energy. Therefore, it is necessary to provide a basic understanding of nuclear energy from the elementary school stage, and to prepare a systematic nuclear energy curriculum that deals with more in-depth scientific concepts and social issues in the middle school stage.

In addition, at the high school level, it is necessary to provide objective information on the safety and efficiency of nuclear energy and to strengthen science education so that students can develop critical thinking skills. This will enable future generations to make rational judgments about nuclear energy and contribute to the establishment of sustainable energy policies.

REFERENCES

[1] Curriculum Text and Commentary : NCIC National Curriculum Information Center (https://ncic.re.kr/dwn/ogf/inventory.cs)