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Examining the effectiveness of initial response training program for nuclear emergency preparedness

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ABSTRACT

Background: Although nuclear technology has various beneficial, it also has a variety of risks. In particular, initial response is very import to respond to risks. Therefore, the program to increase initial response proficiency can be regarded as very essential. The Republic of Korea annually conducts more than 10 nuclear emergency response training programs, and specialized training courses for initial response are conducted twice several times a year. ***Materials and Methods:*** The participants of the initial response training program were evaluated by senior professionals who had over 10 years of experience. The DISASTER Paradigm developed by the National Disaster Life Support Program was used as an index for evaluation. The purpose of evaluation was to identify issues in the current training program through evaluation results over a period of three years. The difference-in-differences method was used to quantitatively analyze the evaluation results. ***Results:*** Five indicators of the DISASTER Paradigm demonstrated that personnel skills improved through training. However, three indicators showed that skill levels decreased despite continued training. ***Conclusion:*** According to the results, the treatment of radioactive waste (T), evacuation (E), and triage of radiation exposure (R) indicators showed a decrease in the proficiency level, which were difficult to demonstrate in the real world because of the specificity of radiation. Accordingly, program contents corresponding to T, E, and R indicators must be revised using tools that can accurately portray the specificity of radiation.

Keywords: *Nuclear emergency, initial response training, difference-in-differences method.*

INTRODUCTION

Nuclear and radiation technology, which is one of the major sources of energy, is useful in medicine, non-destructive testing, well logging, and agriculture. Consequently, this technology is extremely crucial for national development and prosperity [1–3]. However, nuclear accidents have the posibility of widespread of adverse effects. In particular, radiation causes biological effects and psychological fluctuations in the human body [4–5]. Thus, a highly skilled expert must provide an early response during the occurrence of such accidents. Countries that are improving their nuclear technology and utilizing it in various fields are establishing nuclear emergency response planning programs in accordance with the international standards recommended by

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the International Atomic Energy Agency [6–7]. As part of nuclear emergency preparedness, training programs have been implemented to improve the proficiency levels of agents. Several proficiency training programs have been implemented in the Republic of Korea [8]. Among these programs, the initial response training program is the region of interest (ROI) of this research. For this purpose, a special team was established, and its members intensively participated in training programs for the improvement in proficiency levels concerning initial response. This study analyzes the efficacy of initial response training programs in improving personnel skills to respond to a nuclear accident. Accordingly, this study assesses the limitations of the current initial response training program and suggests directions for overcoming these limitations.

MATERIALS AND METHODS

Initial response training program

The Republic of Korea annually implements more than 10 nuclear emergency response training programs. Furthermore, several times of these training sessions focus on initial response training. Table 1 presents the types of training programs for nuclear emergency preparedness.

Minimizing the widespread impact of accidents through an accurate and prompt response during the early phases of a nuclear emergency is essential. In this study, "H" in table 1, which corresponds to the training during the early phase of a nuclear emergency, is designated as the ROI.

Difference-in-differences method

Government programs are implemented through the investment of public funds, which comprise social agreements and taxes collected from the citizens. Therefore, the public has the right to know if the program implemented by the government is efficient in accomplishing its intended purpose. Accordingly, the efficacy of the implemented program must be evaluated for public awareness. The evaluation results can be used as a foundation for making decisions concerning the effectiveness of the program or the continuation or discontinuation of its implementation. We used the difference-in-differences (DID) method, a frequently used research method in the social sciences, to evaluate the efficacy of the programs that have been implemented by the government. This method helped identify the contributions of the program toward achieving the goal because DID can deduce changes caused by external factors in addition to the effects of the program [6]. Four factors were identified in this study: the response proficiency of the special team member before the implementation of the initial response training program, response proficiency of the special team member after the program implementation, non-special team member's response proficiency before the program implementation, and the non-special team member's response proficiency after the program implementation. The equation shown in table 2 was considered for the use of these four factors in the DID method.

In table 2, E0 indicates the proficiency level prior to program execution; E1 indicates the inhomogeneity between the two groups; d0 indicates the difference in proficiency levels due to inhomogeneity; dE indicates the rate of change in proficiency due to the program; and dE represents the observation target of this study.

Quasi-experimental design

The quasi-experimental design is frequently used in the social sciences, particularly the policy evaluation method. Through this method, participants can be easily obtained for experimental studies conducted in real-life settings. The reliability of the results of the social scientific experiment is high compared to that of the experimental design, as a quasi-experimental design is less likely to deviate from the selected group (experimental and control groups). However, the social scientific experiment has disadvantages, as it is not performed using a statistical random technique. Thus, a homogeneous group may be established. The quasi-experimental design was found to have a weak internal validity. Internal validity is one of

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the most fundamental properties of scientific studies and an essential concept in reasoning about evidence in more general terms [10]. Despite its weak internal validity, the method can have high external validity and block the Hawthorne effect, a tendency for people to modify their behavior that results from their awareness of being observed [11]. External validity is an important property of any study because general conclusions are a goal in research [12].

DISASTER paradigm

The DISASTER Paradigm was developed by the National Disaster Life Support Program to evaluate the effectiveness of the training program in improving the proficiency levels of agents. The details of the DISASTER Paradigm are summarized in table 3.

Table 1. Types of training programs for nuclear emergency preparedness.

Classification of Training Program	Contents
A	A training program for improving the proficiency in all response options available to the government
B	A training program for increasing the proficiency of responding systems of the government, civilian, and armed forces
C	Training programs for improving the ability of nuclear business operators to respond to nuclear emergency
D	Training programs for improving the proficiency in specific areas, such as radiation protection and radiation emergency medicine field
E	A training program for improving the response to complex emergency situations that can occur simultaneously with the nuclear emergency
F	Training programs for improving proficiency in response to nuclear emergency in neighboring countries (Event corresponding to Emergency Preparedness Category 5)
G	A training program for improving the proficiency of responding to the use of malicious nuclear technology for terrorism purposes (Event corresponding to Emergency Preparedness Category 4)
H	A training program for improving the proficiency of responding quickly and accurately to accidents in the early phases of nuclear emergency

Table 2. Difference-in-differences equation [9].

		Experimental Group	Control Group
Program Execution	Before	E0+E1	E0
	After	E0+E1+d0+dE	E0+d0
Rate of Change		d0+dE	d0
Effectiveness		dE	

Table 3. DISASTER Paradigm [13].

	Indicator	Contents of Details
D	Detection	Ability to identify accident information
		Cognitive abilities of accidents and field conditions
I	Incident Management	Ability to quickly switch to a response system
		Establishment of on-site emergency operating system and ability to perform roles
S	Safety and Security	Ability to maintain control over patients, ability to carry out on-site management
		Ability to ensure the safety of injured persons in disaster situation
A	Assess of Hazards	Ability to assess the risk factors that may arise in responding to emergency
		Ability to operate equipment for emergency
S	Support	Ability to collaborate with designated emergency institutions
		Ability to use the walkie and radio communication
T	Triage and Treatment	Ability of medical triage for injured persons
		Ability of radiological triage for radiation injured persons
E	Evacuation	Ability to evacuate to areas for minimizing radioactive contamination and exposure
		Ability to proceed with evacuation procedures in areas where there is no residence
R	Recovery	Ability to manage and dispose of radioactive waste
		Ability to be quickly normalized by routine work

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RESULTS

To utilize the methodologies and tools introduced in the previous chapters, we have compiled raw data on the proficiency of response agents. The proficiency change data for 2016–2017 are summarized in table 4, and the proficiency change data for 2017–2018 are summarized in table 5.

Table 4. 2016–2017 data for DID calculation.

	D	I	S	A	S	T	E	R
E0+E1+d0+dE	793	711	702	734	729	750	704	694
E0+E1	418	401	379	403	427	452	425	473
d0+dE	375	310	323	331	302	298	279	221
E0+d0	705	673	601	563	621	601	547	501
E0	386	394	342	278	357	352	285	377
d0	319	279	259	285	264	249	262	124
dE	56	31	64	46	38	49	17	97

Table 5. 2017–2018 data for DID calculation.

	D	I	S	A	S	T	E	R
E0+E1+d0+dE	810	732	711	740	731	761	723	702
E0+E1	435	422	388	409	429	463	444	481
d0+dE	375	310	323	331	302	298	279	221
E0+d0	710	701	621	632	630	617	609	523
E0	391	422	390	357	376	357	340	352
d0	319	279	231	275	254	260	269	171
dE	65	65	92	56	48	38	10	50

E0 + E1 + d0 + dE can be expressed as the proficiency data for the group affected by the target program. Conversely, E0 + d0 can be expressed as the proficiency data for groups not affected by the target program. The difference in the proficiency of the experimental group before and after the program can be expressed as d0 + dE. The difference in proficiency of the control group before and after the program execution can be expressed as d0. By subtracting the data from both groups, we can derive the net validity of the program or dE. This calculation method is summarized in table 6 for each index of DISASTER Paradigm.

Table 5. 2017–2018 data for DID calculation.

DISASTER Paradigm		Pure Effectiveness by Program (Calculated by the DID Method)	
		2016–2017	2017–2018
D	Detection	56	65
I	Incident Management	31	65
S	Safety and Security	64	92
A	Assess Hazards	46	56
S	Support	38	48
T	Triage and Treatment	49	38
E	Evacuation	17	10
R	Recovery	97	50

DISCUSSION

Figure 1 (D-Detection) shows a change in the ability to accurately analyze nuclear emergency. This (D-Detection) increased in proficiency level through the process of learning the classified nuclear emergency in the training program. In particular, (D-Detection) assessed whether agents could accurately interpret a hypothetical nuclear emergency scenario. As a result, as shown in figure 1, the training of agents increased their proficiency level.

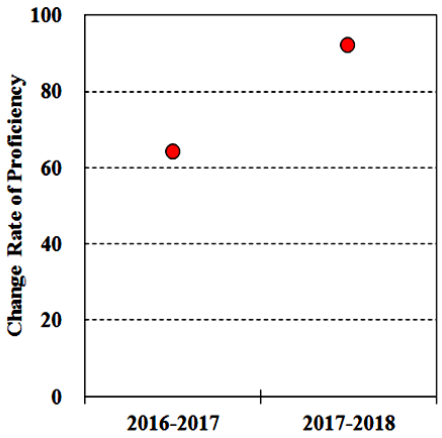


Figure 1. D (Detection) of the DISASTER Paradigm.

Figure 2 (I-Incident) shows a change in the ability to quickly switch to a system for responding to a nuclear emergency in normal

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situations and to operate the converted system. It was planned to increase the proficiency of agents through the process of actually deploying and operating on-site equipment in the training program. As a result, as shown in figure 2, the training of agents increased their proficiency level.

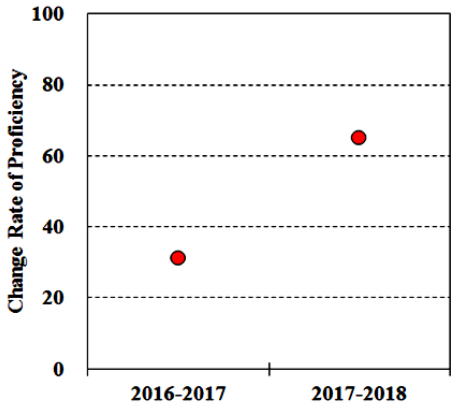


Figure 2. I (Incident) of the DISASTER Paradigm.

Figure 3 (S-Safety) shows a change in the ability of agents to ensure the safety of patients caused by an accident. It was planned to increase the proficiency of agents through the training of contents related to disaster medicine in the training program. As a result, as shown in figure 3, the training of agents increased their proficiency level.

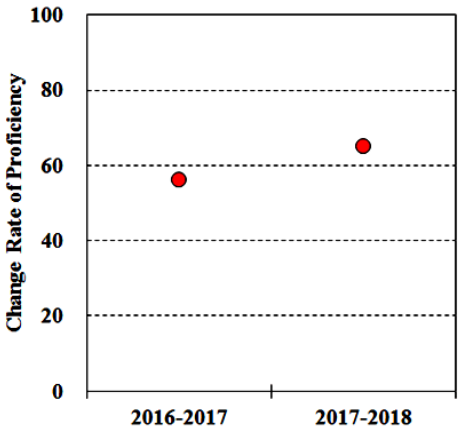


Figure 3. S (Safety) of the DISASTER Paradigm.

Figure 4 (A-Assessment) shows a change in the ability to identify the hazards at the site of the nuclear emergency and to operate the response equipment appropriately. It plans to increase the proficiency of agents through the education process that analyzes various disaster cases in addition to nuclear emergency cases. As a result, as shown in figure 4, the training of agents increased their proficiency level.

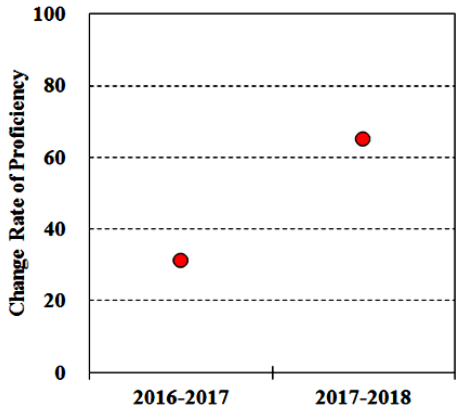


Figure 4. A (Assessment) of the DISASTER Paradigm.

Figure 5 (E-Evacuation) shows a change in the ability of agents to engage in remote communication and collaboration between various organizations to respond to nuclear emergency. This program was designed to increase the proficiency through the training process of inviting agents from other organizations to implement collaboration. As a result, as shown in figure 5, the training of agents increased their proficiency level.

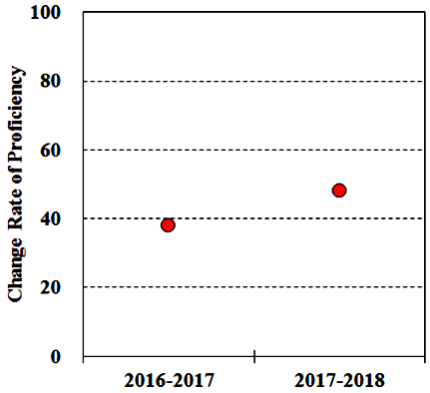


Figure 5. S (Support) of the DISASTER Paradigm.

Figure 6 (T-Triage) shows a change in the ability to classify and treat injuries caused by nuclear emergency. This (T-Triage) includes radiological triage and medical triage. In the case of medical triage, sufficient training could be

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conducted using educational tools like other medical facilities. Radiological triages, on the other hand, could not be practiced through descriptions similar to nuclear emergency in the real world of peace because of the specificity of radiation. As a result, as shown in figure 6, the training program did not increase the proficiency of agents.

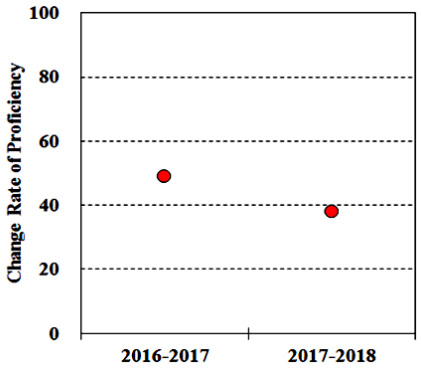


Figure 6. T (Triage) of the DISASTER Paradigm.

Figure 7 (E-Evacuation) shows the change in evacuating ability escaping from the radioactive contamination area. This (E-Evacuation) includes the ability to manage radiation exposure doses, especially in radioactive contamination area it also includes the ability to measure radioactive contamination on a wide range of lands, facilities and human bodies. This is the skill of specific behavior in a particular situation. And because of the specificity of radiation, it is impossible to describe the same situation as nuclear emergency in the real world of peace. As a result, as shown in figure 7, the training program did not increase the proficiency of agents.

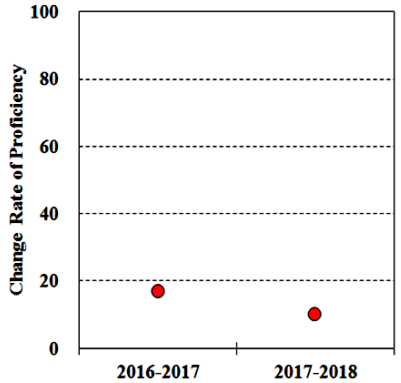


Figure 7. E (Evacuation) of the DISASTER Paradigm.

Figure 8 (R-Recovery) shows the change in capacity after the end of response to nuclear emergency, such as assessment, management and disposal of radioactive waste. In particular, there is a diversity and unpredictability of nuclear emergency situations. And, like figures 6 and 7, this includes the specificity of radiation and the proficiency of specific behavior in particular situation. Therefore, as shown in figure 8, the training program did not increase the proficiency of agents.

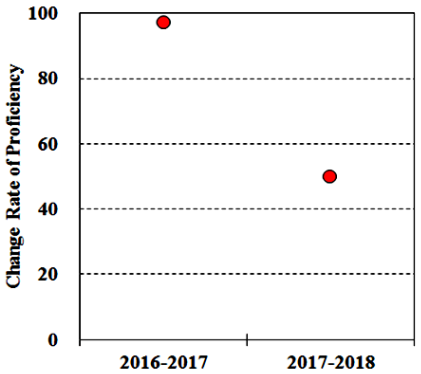


Figure 8. R (Recovery) of the DISASTER Paradigm.

The DID calculation results show that the top five indicators D, I, S, A, and S have achieved the purpose of the program. However, the bottom three indicators or T, E, and R indicate that the program did not achieve its goal. The characteristics of T, E, and R were proficiency in specific behaviors for special situations that are difficult to describe in the real world of peace.

CONCLUSION

The results of the present study suggest that the D, I, S, A, and S indicators were effective in training personnel and improving the proficiency levels of agents. The program contents of the five proven indicators were relatively easy in terms of determining the description of a nuclear emergency situation in the real world. However, the T, E, and R indicators showed a decrease in the proficiency level of agents. This result indicates that revisions are required to address the problems and limitations in the learning content of the T,

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E, and R indicators. These three indicators were difficult to reproduce in the real world during peacetime because of the specificity of radiation. Thus, innovative tools are essential to accurately describe the specificity of radiation in the real world. Artificial reality (AR) and virtual reality (VR) technologies are currently being used to increase the proficiency of stakeholders in safety -related fields [14]. Currently, during the Fourth Industrial Revolution, various fields are introducing new AR and VR technologies to improve the proficiency of specific behaviors in special situations. In the medical field, particularly in the field of ophthalmology, which requires a high level of proficiency for specific behaviors, the improvement of proficiency using VR technology has been demonstrated [15]. In mastoidectomy operations, which require a high level of specific behavioral skill in the medical field, the effectiveness of VR technology has been demonstrated [16]. VR technology has already proved to be substantially useful in improving the proficiency of specific behaviors for escaping from narrow areas in special situations such as fires in certain areas such as mines [17]. Therefore, this study recommends verifying the feasibility of using AR and VR technologies as part of the initial response training program for nuclear emergency preparedness for a follow-up study.

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***Conflicts of interest*: Declared none.**

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