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Paper:

Development of Tsunami Disaster Risk Reduction Education Program for Children with No Experience of Earthquake Disaster – Practice and Verification at Shichigahama Town, Miyagi Prefecture

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In this study, we developed a tsunami disaster risk reduction (DRR) education program for children with little or no memory/experience of the Great East Japan Earthquake. The objective was to strengthen their disaster response capacity and enable them to think and act to protect their lives from tsunami disasters. The development of this program employed the ADDIE model of Instructional Design in learning theory. Based on the GIGA school concept promoted by Japan, information and communications technology (ICT)-based education and DRR education were integrated into the program from a geographical perspective. Using the ICT-based teaching materials, YOU@RISK Tsunami Disaster Edition, empirical learning was introduced. The town of Shichigahama in Miyagi Prefecture, which was devastated by the tsunami during the Great East Japan Earthquake, was selected as the study target. The study implemented and verified the program with local elementary school students to assess its effectiveness.

Keywords: Great East Japan Earthquake, tsunami, disaster risk reduction education, instructional design (ID), ICT education

1. Introduction

1.1. Great East Japan Earthquake and the Resulting Damage

On March 11, 2011, Tohoku Offshore Earthquake recorded a magnitude of 9.0 and became the greatest earthquake ever recorded in Japan. The earthquake resulted in a giant tsunami, which wrought devastation and damage over an extensive area around the Pacific Coast in Eastern Japan. This composite disaster, which included an earthquake, a tsunami, and a nuclear plant accident, was called the Great East Japan Earthquake and Tsunami Disaster and adversely impacted the lives of the Japanese people [1, 2].

While various measures of disaster reconstruction, including physical infrastructure and social programs, have been promulgated in Japan, the tenth year of the disaster marks a turning point as we enter a new phase of reconstruction and renewal [3]. Meanwhile, in the disaster-affected areas, children, who have no memory/experience of the disaster, have reached school age. Thus, the "transmission of disaster," through which the lessons culled from past earthquake disasters are handed down to the children who make up the next generation of citizens, and the strengthening of disaster risk reduction (DRR) education, will equip these children with the knowledge to make appropriate decisions and proactively act during disasters [4–6]. To learn from past disasters and be prepared for future disasters, it is necessary to promulgate DRR education that would incorporate new perspectives of "soft" measures that are important for disaster reconstruction and renewal.

1.2. Current Status and Issues of Tsunami DRR Education

Following the Great East Japan Earthquake, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) compiled the "Expert Committee on DRR Education and Disaster Risk Management in Response to the Great East Japan Earthquake (Final Report)" [7]. The report put forth "the attitude of acting proactively" as a general direction for DRR education in schools. Learning from the earthquake disaster, the report noted the importance of tsunami DRR education, whereby students are taught to use tsunami hazard maps to estimate inundation levels and undertake evacuation actions in various scenarios according to local disaster features. Furthermore, the document "Deploying DRR education to nurture the 'zest for life'" [8] presented practical cases of and teaching ma-

terial about tsunami disasters.

In DRR education in the Tohoku region, which was hit by the tsunami caused by the Great East Japan Earthquake, it was noted that tsunami preparedness education, based on the idea of "tsunami-tendenko," also known as the "miracle of Kamaishi," greatly contributed to the reduction of human suffering. The Iwate Prefecture Board of Education presented, on its portal, practical cases of DRR education that followed the notion of "tsunami-tendenko" [9]. The Miyagi Prefecture, which was also affected by the tsunami, published the DRR education supplementary reading, "Mirai eno Kizuna" (Link to the Future) [10] in 2013, based on the "Miyagi Basic Guidelines for School Safety (2012)," which was based on the lessons of the earthquake disaster and presented examples of DRR education teaching material for learning about tsunami disasters. Similarly, the adjacent prefecture, Fukushima, published "DRR Education Instruction Resources – Fukushima Prefecture DRR Education to Nurture the Strength to Survive (3rd edition)" in 2016 and presented practical cases of tsunami DRR education on its website [11]. While the affected areas have practiced DRR education, using the guidelines and supplementary reading material prepared by the national and prefectural governments, there remain certain aspects of the tsunami disaster that have not received due coverage in school education due to the magnitude of devastation and loss of human lives caused by the Great East Japan Earthquake [12]. In addition, the teaching material provided to the schools mostly consists of content premised on classroom-type instruction in which students take a passive role. However, there are a few teaching materials that incorporate "proactive, dialogue-based, deep learning" (active learning), as recommended in the new government course guidelines [13, 14].

1.3. DRR Education that Utilizes Information and Communications Technology (ICT)

As natural disasters continue to occur with increasing frequency and severity, Japan's expectations for using ICT in DRR and disaster mitigation are high.

The MEXT has set a goal to develop education using ICT (ICT education) in all educational settings in Japan by promoting the GIGA School Concept [15]. As a specific measure, the MEXT is promoting the development of a learning environment where every student in Japan can use an information terminal (e.g., a tablet) at school. The creation of classes using tablets calls for the proactive use of ICT material for developing children's ability to think independently and solve problems on their own initiative. Furthermore, to enhance ICT education at schools, various types of support for schools that practice ICT education are being promoted, such as the creation of the "Guide to the Informatization of Education: Supplementary Edition" [16] and the establishment of a portal [17] to support ICT education. Yet, when we review the progress under the GIGA School Concept, we find that, although the distribution of information terminals is increasing, the development or application of digital material for DRR education or the environment for practical case presentation as a valid means to promote DRR education, has not been established.

Meanwhile, the Geography Education Subcommittee, Science Council of Japan, has proposed the need for ICT education, using geographical information system (GIS) at the compulsory education level [18]. This proposal points out that the ability to accurately read geographical spatial information is necessary and is directly connected with nurturing the "zest for life" necessary to protect one's life during disasters. In addition, it points out that the use of information terminals for education is suitable for learning environments where the students learn proactively and collectively and stresses the importance of ICT education in elementary and secondary education [19].

This indicates that the learning opportunities provided by ICT will continue to increase due to the GIGA School Concept being promulgated as a national policy. Therefore, it will be necessary to address DRR education implementation, which is not recognized as a curriculum subject in connection to ICT education.

Recent examples of ICT application in DRR education include studies on the practice of tsunami evacuation drills based on the use of tablets or portable terminals [20, 21], the use of ICT in DRR map-making [22], and the development of disaster-related video contents that can be viewed on online terminals [23]. In addition, some studies utilize ICT, such as a system that gives the user a simulated experience of tsunami disasters using virtual reality [24]. Yet, most of these studies deal with learning situations in which the user captures photos or videos, plays back videos, or searches for information online. There have been very few learning materials or studies in Japan that employ ICT for DRR education by using maps to acquire a spatial understanding of the disaster risks or connect such an understanding of evacuation behavior.

1.4. Objective of this Study

In Japan, the GIGA School Concept, promoted by the MEXT, is creating a learning environment where every student has access to an information terminal.

In this study, we developed a tsunami preparedness education program for Shichigahama Town, Miyagi County, Miyagi Prefecture, which was hit by a tsunami following the Great East Japan Earthquake. The program targets children with limited memories/experiences of the disaster and is based on the issues of DRR education in tsunami-affected areas. It is a learning program that educates children about the risks of an earthquake-related tsunami and imparts disaster response skills to enable children to make decisions and evacuate in the event of a tsunami. In addition, to introduce ICT education, using tablets, which are the information terminals prepared under the GIGA School Concept, to DRR education, the present study incorporated learning using "YOU@RISK:

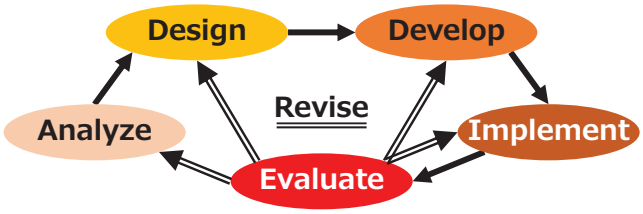


Fig. 1. ADDIE model.

Fig. 2. Tsunami damage (due to Great East Japan Earthquake, source: Record of Earthquake Disaster in Shichigahama Town).

Tsunami Disaster Version (developed by the National Research Institute for Earth Science and Disaster Resilience [NIED]),” an ICT teaching material that links map information with tsunami disasters.

Based on the knowledge and skills acquired in these studies, through hands-on learning in “community walking” with the residents, students can spatially perceive the natural environment and tsunami hazards in their immediate area, understand the tsunami damage and the vulnerability of the area, and increase their awareness of preparedness for tsunami hazards.

In the development of this program, we adopted the ADDIE model of Instructional Design (ID) as the learning theory. We evaluated the program’s effectiveness via implementation and testing with children who had never experienced a tsunami. Furthermore, to examine the scope of DRR education using YOU@RISK: Tsunami Disaster Version, we verified the program’s application with children of different grades. Through the development of the program, in this study, we aim to standardize teaching methods for tsunami preparedness education, which has been a concern at schools in areas at risk of a tsunami.

2. Study Method

2.1. Development and Evaluation of the Educational Program Based on the ID Theory

The tsunami DRR educational program was developed by applying the ADDIE model of ID theory. ID is a learning theory used in education, psychology, and educational technology and is defined as the “model or research field that combines methods to increase the effectiveness, efficiency, and appeal of educational activities, or the process of realizing a learning environment, such as instructional materials and classroom lectures, based on the application of this research” [25]. The ADDIE model’s five-step process – Analyze, Design, Develop, Implement, and Evaluate – can be used to design and develop effective educational programs [26] (**Fig. 1**).

Our tsunami preparedness education program was developed based on each step of the ADDIE model. A single cycle consisted of the following: (1) analysis of the needs for tsunami preparedness education and establishment of research targets and learning objectives, (2) design of syllabus and examination of the implementation plan at target schools and the learning methods, (3) development of teaching materials, such as lesson plans, worksheets, supplementary materials, and evaluation sheets, (4) implementation of the program at the schools included in the study, and (5) evaluation (self-evaluation) by children, qualitative survey of teachers, and measurement of effectiveness. In this study, the steps from (1) analysis to (3) development of ADDIE were repeated, and followed by (4) implementation and (5) evaluation.

To evaluate the validity of the developed tsunami DRR educational program, its effectiveness was measured by encouraging the learners (students) to self-evaluate their achievement levels of the learning objectives. Based on the definition of ID, researcher Robert M. Gagné stated, “program evaluation is expressed solely by the evaluation of the learner’s performance” [27]. This measure of effectiveness is a commonly used method to evaluate educational programs developed using ID theory.

Several studies have employed the ID theory. For example, Kimura et al. [28] developed a disaster education program based on the experience of local historical disasters. Higashino and Yoshimoto [29] developed e-learning materials for elementary school teachers. Ikeda et al. [30] developed DRR education programs in response to heavy rainfall disasters. In academic research, outside the field of ID education, Umeno and Asada [31] developed an educational program for large-scale disaster training in medical institutions, Ogasawara [32] developed a learning support program for a company using ID theory, and Ishii et al. [33] developed a technical management education program in an engineering course. In recent years in Japan, ID theory has become potentially applicable to a wide range of fields of academic research.

2.2. Areas and Schools Targeted by this Study

Shichigahama Town, Miyagi County, located along the Pacific coast between the northern and southern borders of Miyagi Prefecture, is adjacent to the cities of Sendai, Shiogama, and Tagajo, and consists of seven settlements along the coastline, which is surrounded on three sides by the sea. The topography is characterized by rocky uplands and coastal plains, with no rivers, and the low-lying areas are dotted by inland sea lakes and oxbow lakes.

While Shichigahama was subjected to maximum seismic intensity in the upper five during the Great East Japan Earthquake, the giant tsunami generated by the earthquake inundated 36.4% of the town area, leaving 111 people dead or missing and destroying 674 houses (**Fig. 2**).

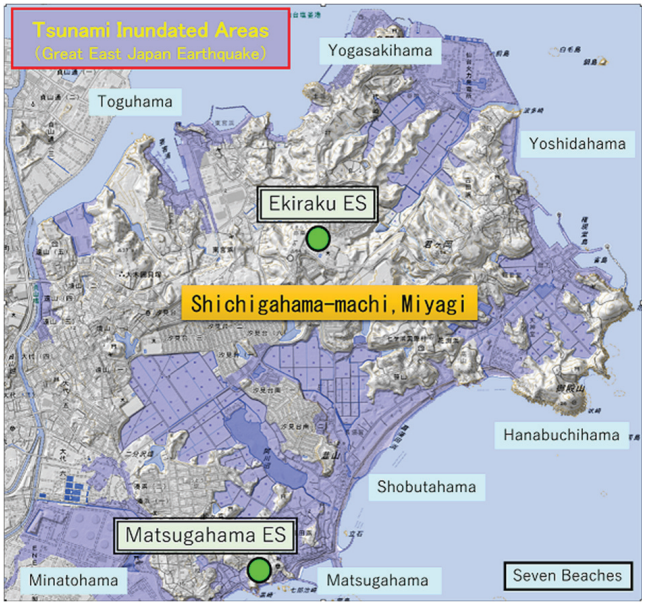


Fig. 3. Shichigahama Town, Miyagi Prefecture.

The NIED has been supporting tsunami preparedness education for elementary schools in response to a request from Shichigahama after the Great East Japan Earthquake. In this study, Eiraku Elementary School (fifth-grade students) and Matsugahama Elementary School (fourth-grade students) in the Shichigahama area were selected as the subject schools (subject students) for the study (**Fig. 3**). They were selected due to their continued DRR education centered on community walking and disaster map-making in cooperation with elementary schools and residents of the area.

3. Development of Tsunami DRR Education Program

3.1. Program Outline

Eleven years have passed since the earthquake disaster. However, the current generation of children living in disaster-affected areas did not directly experience the tsunami damage. Shichigahama Town is no exception where the local teachers felt the need to reexamine DRR education for children without experience of the disaster.

In the past, DRR education had been practiced in Shichigahama by using the DRR education supplementary reading material, "Link to the Future," produced by Miyagi Prefecture. In addition, residents and schools jointly conducted experiential learning activities using the "Study Guide for DRR Map Making" produced by the town government based on the experience of tsunami damages. However, interviews with school personnel revealed that preparatory learning programs, whereby students can acquire the basic knowledge of earthquakes and tsunamis, learn about the area's tsunami risks, and acquire the skills to visualize a tsunami and evacuate, were lacking. Although the teachers used the DRR educational supplementary reading material to conduct classes, they had to develop and teach the course content based on their experience and knowledge since the study objectives were not clearly defined and a standard teachers' guide was unavailable. Moreover, the teachers had been unable to begin teaching the courses using the tablets distributed under the GIGA School Concept.

Therefore, we consulted with the teachers to develop a program configured to obtain the study objectives of learning the basic information on earthquakes and tsunamis and acquiring the skills necessary to protect oneself. Furthermore, we introduced ICT education and experiential learning, which link geographical learning with DRR education and encourage the students to employ tablets. To achieve the specific learning objectives, we developed a teacher's guide, worksheets, and slides for classroom use based on course units. Through this program, children with little memory/experience of the disaster will understand the tsunami damage that occurred in their community and its vulnerability. In addition, the program will improve their thinking ability to protect themselves during a tsunami.

3.2. Program Composition

The tsunami DRR education program developed in this study consists of four units (1–4), which can be broken down into six study periods, each with an independent study objective (**Table 1**).

3.2.1. Outline of Unit 1 – "Preparatory Learning"

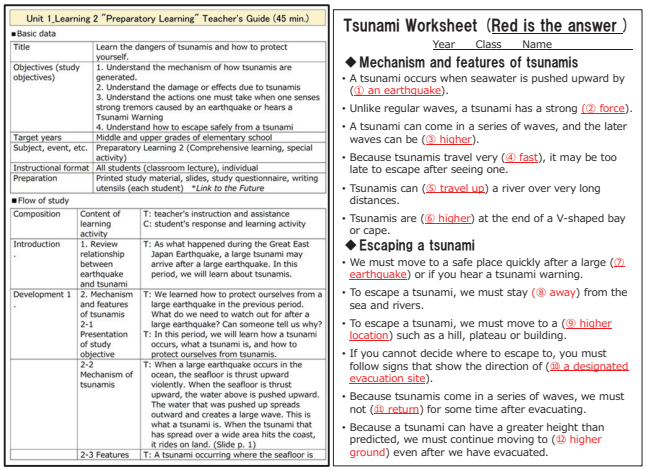
Unit 1 consists of preparatory learning (classroom instruction) where students acquire the basic knowledge about earthquakes and tsunamis, learn how to act to protect themselves, acquire DRR information knowledge necessary to make decisions, and develop an awareness to protect one's life from earthquake and tsunami disasters. It consists of two learning sessions.

In learning session 1 – "Learn the dangers of earthquakes and how to protect yourself" – the study objectives are to (1) understand the mechanism of earthquakes and Earthquake Early Warning (EEW), (2) understand the damage due to and the effects of earthquakes, (3) understand the actions to be taken when one senses strong tremors caused by an earthquake or hears an EEW, and (4) use one's judgment to avoid earthquake danger. The teaching materials are adapted from certain study guides and worksheets of the earthquake preparedness education program developed by the author in previous studies [34, 35]. Improvements to the program include the addition of the importance of associating the strong shaking of an earthquake with the subsequent occurrence of a tsunami to the study guide. The study time is one period of 45 minutes.

In learning session 2 – "Learn the dangers of tsunamis and how to protect yourself" – the study objectives are to (5) understand the mechanism of tsunami generation, (6) understand the damage due to and the effects of

Table 1. Unit composition.

Unit	Learning	No. of period(s)	Study objective
Unit 1	Learning 1 Learn the dangers of earthquakes and how to protect yourself	1	(1) Understand the mechanism of earthquakes and Earthquake Early Warning (2) Understand the damage or effects due to earthquakes (3) Understand the actions one must take when one senses strong tremors caused by an earthquake or hears an Earthquake Early Warning (4) Able to use your own judgment to avoid danger due to earthquakes
	Learning 2 Learn the dangers of tsunamis and how to protect yourself	1	(5) Understand the mechanism of how tsunamis are generated (6) Understand the damage or effects due to tsunamis (7) Understand the actions one must take when one senses strong tremors caused by an earthquake or hears a Tsunami Warning (8) Understand how to escape safely from a tsunami
Unit 2	Learning 3 Examine the tsunami risks of the local area using YOU@RISK	2	(9) Able to confirm estimated tsunami inundation levels using YOU@RISK (10) Able to confirm the position or elevation of evacuation site using YOU@RISK (11) Able to confirm the route to the evacuation site using YOU@RISK
	Learning 4 Discuss evacuation to avoid tsunamis	2	(12) Able to confirm estimated tsunami inundation levels of home or road used for commuting to school using YOU@RISK (13) Able to confirm evacuation site near home or road used for commuting to school or its elevation using YOU@RISK (14) Able to engage in a group discussion about the places to evacuate or dangerous places when a tsunami may arrive
Unit 3	Learning 5 Check one's own area by taking a disaster-mitigation town walk	3	(15) Know the safe places and the dangerous places in my town when a tsunami may arrive (16) Able to listen to adults in the area and ask them about the risks of earthquakes and tsunamis
Unit 4	Learning 6 Summarize what you have found to make a DRR map	2	(17) Able to summarize items that one has found about tsunamis into a map and make a presentation (18) Able to make decisions and act to protect oneself when a tsunami may be arriving
	Learning 7 Presenting the DRR map	1	


Unit 1 Learning 2 "Preparatory Learning" Teacher's Guide (45 min.)

■Basic data

Title	Learn the dangers of tsunamis and how to protect yourself.
Objectives (study objectives)	1. Understand the mechanism of how tsunamis are generated. 2. Understand the damage or effects due to tsunamis 3. Understand the actions one must take when one senses strong tremors caused by an earthquake or hears a Tsunami Warning 4. Understand how to escape safely from a tsunami
Target years	Middle and upper grades of elementary school
Subject, event, etc.	Preparatory Learning 2 (Comprehensive learning, special activity)
Instructional format	All students (classroom lecture), individual
Preparation	Printed study material, slides, study questionnaire, writing utensils (each student) *Link to the Future*

■Flow of study

Composition	Content of learning activity	T: teacher's instruction and assistance C: student's response and learning activity
Introduction	1. Review relationship between earthquake and tsunami	T: As what happened during the Great East Japan Earthquake, a large tsunami may arrive after a large earthquake. In this period, we will learn about tsunamis.
Development 1	2. Mechanism and features of tsunamis 2-1 Presentation of study objective	T: We learned how to protect ourselves from a large earthquake in the previous period. What do we need to watch out for after a large earthquake? Can someone tell us why? T: In this period, we will learn how a tsunami occurs, what a tsunami is, and how to protect ourselves from tsunamis.
	2-2 Mechanism of tsunamis	T: When a large earthquake occurs in the ocean, the seafloor is thrust upward violently. When the seafloor is thrust upward, the water above is pushed upward. The water that was pushed up spreads outward and creates a large wave. This is what a tsunami is. When the tsunami that has spread over a wide area hits the coast, it rides on land. (Slide p. 1)
	2-3 Features	T: A tsunami occurring where the seafloor is

Tsunami Worksheet (Red is the answer)

Year Class Name

◆Mechanism and features of tsunamis

- A tsunami occurs when seawater is pushed upward by (① an earthquake).
- Unlike regular waves, a tsunami has a strong (② force).
- A tsunami can come in a series of waves, and the later waves can be (③ higher).
- Because tsunamis travel very (④ fast), it may be too late to escape after seeing one.
- Tsunamis can (⑤ travel up) a river over very long distances.
- Tsunamis are (⑥ higher) at the end of a V-shaped bay or cape.

◆Escaping a tsunami

- We must move to a safe place quickly after a large (⑦ earthquake) or if you hear a tsunami warning.
- To escape a tsunami, we must stay (⑧ away) from the sea and rivers.
- To escape a tsunami, we must move to a (⑨ higher location) such as a hill, plateau or building.
- If you cannot decide where to escape to, you must follow signs that show the direction of (⑩ a designated evacuation site).
- Because tsunamis come in a series of waves, we must not (⑪ return) for some time after evacuating.
- Because a tsunami can have a greater height than predicted, we must continue moving to (⑫ higher ground) even after we have evacuated.

Fig. 4. Teacher's guide and worksheet for Unit 1, Learning 2 (examples).

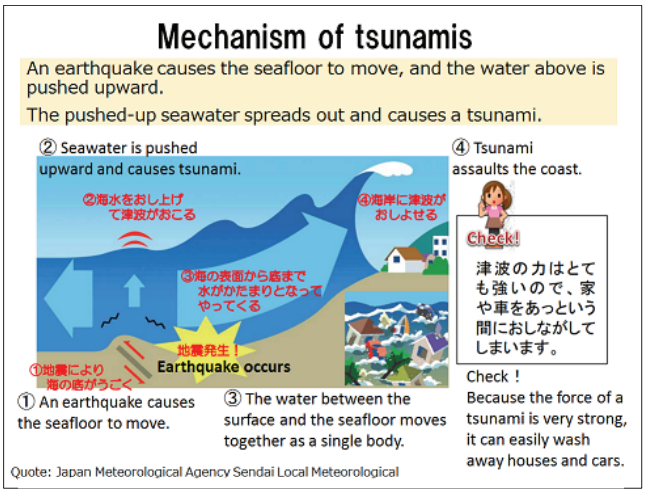


Fig. 5. Study slide for Unit 1, Learning 2 (example).

tsunamis, (7) understand the actions to be taken when one senses strong tremors caused by an earthquake or hears a Tsunami Warning, and (8) understand how to escape safely from a tsunami. The student is expected to understand the basics of tsunamis and learn the appropriate behavior to protect oneself upon hearing a Tsunami Warning or during the disaster. For the teaching material, the DRR education supplementary reading material produced by Miyagi Prefecture [10] and materials produced by Japan Meteorological Agency [36, 37] are used. A teacher's guide, worksheets, and slides for classroom instruction are developed in line with learning session 1. The study time consists of one period of 45 minutes (**Figs. 4** and **5**).

3.2.2. Outline of Unit 2 – "ICT Learning"

Unit 2 is for active learning, where the knowledge and skills acquired in Unit 1 are used to understand the local area's tsunami risks and natural environment and acquire the skills to decide on proper evacuation sites or evacuation routes to protect oneself. It consists of two learning sessions. In these sessions, the students use tablets, provided to each student under the GIGA School Concept, to engage in ICT learning using the map learning site, "YOU@RISK-Tsunami Disaster Version," developed by the NIED. YOU@RISK-Tsunami Disaster Version is an ICT learning material that employs digital map information, which presents the tsunami disaster that occurred

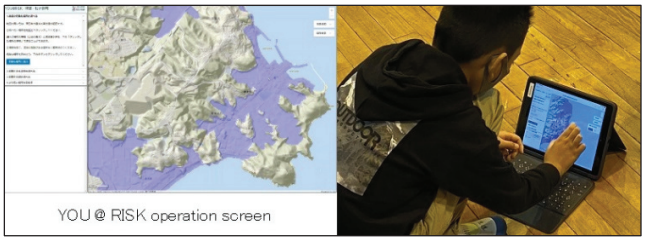


Fig. 6. Screen display and operation of "YOU@RISK-Tsunami Disaster Version."

during the Great East Japan Earthquake in a visual format and allows the students to learn by linking the natural environment with the disasters. There is also a heavy rain disaster version of YOU@RISK, the learning effect of which has been verified by Ikeda et al. [30].

In learning session 3 – "Examine the tsunami risks of the local area using YOU@RISK" – the study objectives are to be (9) able to confirm estimated tsunami inundation levels using YOU@RISK, (10) able to confirm the position or elevation of evacuation site using YOU@RISK, and (11) able to confirm the route to the evacuation site using YOU@RISK. Each student takes part in the ICT learning by using their tablet to operate the YOU@RISK-Tsunami Disaster Version and acquires the skills to find out the tsunami inundation levels of specific locations and the evacuation site and route. The basic operations of the tablet and YOU@RISK-Tsunami Disaster Version are learned individually (**Fig. 6**). We produced a teacher's guide to assist in providing learning instructions. The study time consists of two periods of 45 minutes each.

In learning session 4 – "Discuss evacuation to avoid tsunamis" – the study objectives are to be (12) able to confirm estimated tsunami inundation levels of homes or roads used for commuting to school using YOU@RISK, (13) able to confirm evacuation site near home or road used for commuting to school or its elevation using YOU@RISK, and (14) able to engage in a group discussion about the places to evacuate or places at risk when a tsunami may arrive. The students are expected to use the skills acquired in learning session 3 to operate the YOU@RISK-Tsunami Disaster Version and find out the tsunami risks for their homes and the route they use to commute to school. Following this, the geographical area subjected to search is extended, and the students form groups to find out and discuss local landmarks and places with high tsunami risks and, thus, engage in group learning to understand the area's vulnerability to earthquake disasters. Furthermore, in groups, they will discuss courses for the "town walk" in which the students will take a walk in the local area to check for tsunami risks, which is carried out in the "experiential learning" of Unit 3, and draw up a "Town Walk Plan (Mission Card)" (**Fig. 7**). The students are expected to improve their cognitive and judgmental capabilities by listening to others in the group learning process. In this section, the groups were formed by students living in the same areas. The study time consists of two periods of 45 minutes each.

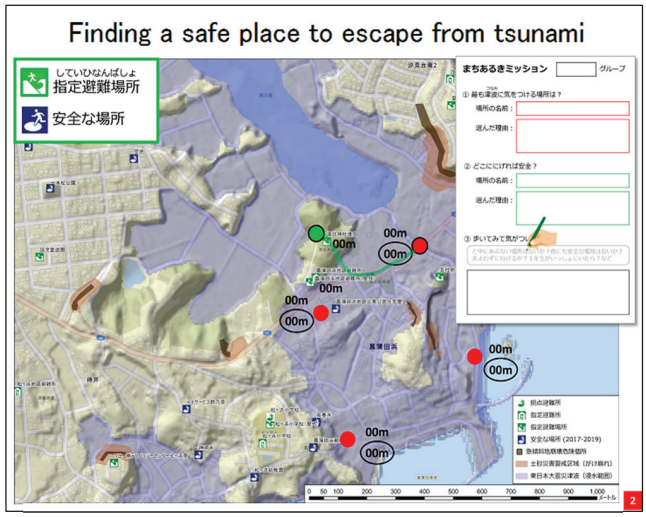


Fig. 7. Unit 2, Learning 4, "Town Walk Plan."

3.2.3. Outline of Unit 3 – "Experiential Learning"

The learnings that take place in Units 3 and 4 are experiential-based and are planned and implemented as per the "DRR education supplemental reading material" [10], published by the Miyagi Board of Education, and the "Study Guide for DRR Map Making."

In Unit 3, the students will engage in exploratory learning in which the residents, "actors" in the transmission of the area's disaster experiences, will serve as guides by using the Town Walk Plan, which was drawn in Unit 2 to identify the local places with high tsunami risks, the evacuation sites, and the evacuation routes from high-risk areas. Through fieldwork conducted with the residents, the students are expected to learn about the tsunami disaster in the local area that was caused by the earthquake.

In learning session 5 – "Check one's area by taking a disaster-mitigation town walk" – the study objectives are to (15) know the safe and the dangerous places in the town when a tsunami may arrive and be (16) able to listen to adults in the area and ask them about the risks of earthquakes and tsunamis. Here, the students engage in self-initiated learning. Based on the Town Walk Plan, the students are expected to personally confirm the tsunami risks in the local area, which were found by operating YOU@RISK-Tsunami Disaster Version. Since the residents participate in the town walk with the students, this session provides an opportunity to orally transmit disaster experiences. In addition, geographical learning takes place when the students are provided with the chance to see and confirm the local topography, which they had checked on the tablet. The study time consists of three periods of 45 minutes each.

3.2.4. Outline of Unit 4 – "Summary"

The learning that takes place in Unit 4 entails the summation of the Unit 3 fieldwork. It consists of two learning sessions. The learning objectives are to be (17) able to summarize and present the research about tsunamis on a

map and (18) able to make decisions and take actions to protect oneself when a tsunami is likely to reach the area.

In learning session 6 – "Summarize what you have found to make a DRR map" – the students are expected to bring together the information obtained through the Unit 3 fieldwork in the form of a DRR map, understand the tsunami risks by gaining a bird's-eye view of the area's disaster features and vulnerability, and understand the earthquake disaster lessons. The study time consists of one period of 45 minutes.

In learning session 7 – "Presenting the DRR map" – the students are expected to make a presentation of their learnings to the residents by using the DRR map produced in learning session 6. Through this learning process, the students and participating residents can obtain a greater awareness of disaster mitigation. The study time consists of three periods of 45 minutes each.

3.2.5. Outline of the Study Questionnaire

A "learning questionnaire" is created for the students to self-evaluate the achievement of learning objectives set in Units 1–4 of the teaching material. The questionnaire consists of 18 questions corresponding to the 18 learning objectives, and the respondents are instructed to evaluate themselves quantitatively on a four-point Likert scale. The respondents' averages in each unit were used for the program's assessment. The questionnaire items on the worksheet are written using only the *kanji* learned in the respondent's grade; the other items are written in *hiragana*, a syllabic alphabet unique to Japan. The questionnaire items for each unit are as follows.

The questions for Unit 1 were "(1) I know what may happen when an EEW is issued," "(2) I know what kind of damage can be caused by an earthquake," "(3) I know how to act when I feel large tremors caused by an earthquake or hear an EEW," "(4) I can protect myself if I feel large tremors caused by an earthquake or hear an EEW," "(5) I know how a tsunami occurs," "(6) I know the kind of damage a tsunami can cause," "(7) I know how to act when I feel a strong earthquake near the sea or hear a Tsunami Warning," and "(8) I know a safe place to escape from a tsunami." The answers are mapped on a four-point Likert scale with 4: I know very well, 3: I know a little, 2: I don't know so well, and 1: I don't know.

The questions for Unit 2 were "(9) Using a map, I can find places that have a high risk of tsunami," "(10) Using a map, I can find evacuation sites and the elevation of land," "(11) Using a map, I can find the road to get to the evacuation site," "(12) Using a map, I can find places close to the school or home where a tsunami may arrive," "(13) Using a map, I can find places close to the school or home where I can escape from a tsunami," and "(14) I can discuss with another person the places or roads close to the school or home to escape to when a tsunami may be coming." The four-point Likert scale was used with 4: I can very well, 3: I can a little, 2: I can't so well, and 1: I can't.

The questions for Unit 3 were "(15) I know the dangerous places close to the school or home when a tsunami may arrive and the safe places where I can escape to," with the possible answers on the Likert scale ranging from 4: I know very well, 3: I know a little, 2: I don't know so well, and 1: I don't know and "(16) I can listen to the stories of adults about the time when an earthquake or tsunami occurred near the school or home," with the answers of 4: I can very well, 3: I can a little, 2: I can't so well, and 1: I can't.

The questions for Unit 4 were (17) I can summarize the facts I have learned about what to do if a tsunami arrives in my local town in the form of a map and make a presentation, and (18) I can protect myself if a tsunami comes to my town for which the answers on the Likert scale ranged from 4: I can very well, 3: I can a little, 2: I can't so well, and 1: I can't.

To evaluate whether children with limited memories and experiences of the disaster gained the ability to understand the tsunami damage and vulnerability that occurred in their community and to think about actions to protect their lives from a tsunami, we used the results of the analysis of items (15) and (18) from the questions in Units 1–4.

Table 2. Timeline of program implementation and measurement of its effectiveness.

Category	Content	Date of implementation
Measurement of effectiveness	1st study questionnaire	Oct. 25, 2021
Learning	Unit 1, Learning 1 and 2 (45 min × 2)	Oct. 26, 2021
Measurement of effectiveness	2nd study questionnaire	Oct. 26, 2021
Learning	Unit 2, Learning 3 (45 min × 2)	Oct. 26, 2021
Learning	Unit 2, Learning 4 (45 min × 2)	Nov. 1, 2021
Measurement of effectiveness	3rd study questionnaire	Nov. 1, 2021
Learning	Unit 3, Learning 5 (45 min × 3)	Nov. 4, 2021
Measurement of effectiveness	4th study questionnaire	Nov. 5, 2021
Learning	Unit 4, Learning 6 (45 min × 2)	Nov. 8, 2021
Learning	Unit 4, Learning 7 (45 min × 1)	Nov. 12, 2021
Measurement of effectiveness	5th study questionnaire	Nov. 12, 2021

4. Practice and Evaluation of Tsunami DRR Educational Program

4.1. Implementation of Program

We implemented the tsunami DRR educational program at the Ekiraku Elementary School in Shichigahama Town and measured its effectiveness (**Table 2**). The 43 subjects comprised fifth-grade students from two classes. The program was carried out jointly by the teachers and the authors (**Figs. 8–14**). To measure the effectiveness, we employed the paired t-test, which is used for statistical analysis.

Fig. 8. Unit 1, Learning 1, "Learning about earthquakes."

Fig. 9. Unit 1, Learning 2, "Learning about tsunamis."

Fig. 10. Unit 2, Learning 1, "Basic operations of YOU@RISK."

Fig. 11. Unit 2, Learning 2, "Group learning using YOU@RISK."

Fig. 12. Unit 3, Learning 5, "Town walk."

Fig. 13. Unit 4, Learning 6, "Map making."

Fig. 14. Unit 4, Learning 7, "Group presentations."

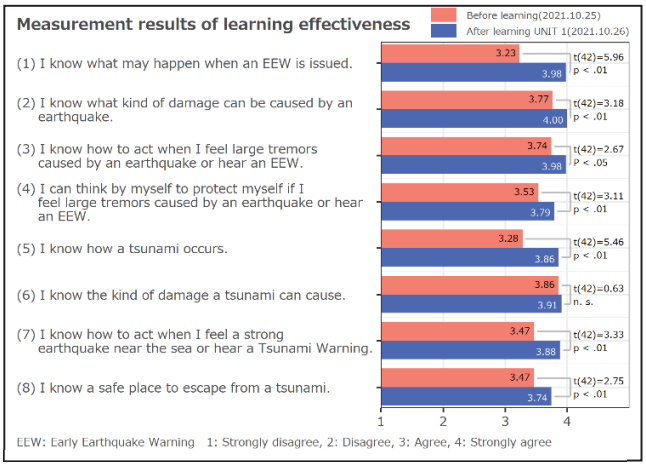


Fig. 15. Measurement of effectiveness of Unit 1.

4.2. Program Evaluation

4.2.1. Analysis Results for Unit 1

The analysis results of questions (1)–(8) for Unit 1 are presented in **Fig. 15**. The scores of the questions corresponding to the study objectives changed from 3.23 before the program to 3.98 after the program for "(1) I know what may happen when an EEW is issued," from 3.77 to 4.00 for "(2) I know what kind of damage can be caused by an earthquake," from 3.74 to 3.98 for "(3) I know how to act when I feel large tremors caused by an earthquake or hear an EEW," from 3.53 to 3.79 for "(4) I can protect myself if I feel large tremors caused by an earthquake or hear an EEW," from 3.28 to 3.86 for "(5) I know how a tsunami occurs," from 3.86 to 3.91 for "(6) I know the kind of damage a tsunami can cause," from 3.47 to 3.88 for "(7) I know how to act when I feel a strong earthquake near the sea or hear a Tsunami Warning," and from 3.47 to 3.74 for "(8) I know a safe place to escape from a tsunami." When analyzed using the paired t-test, questions (1), (2), (4), (5), (7), and (8) displayed differences with a 1% significance level, while question (3) displayed a difference with a 5% significance level. Question (6) did not display a statistically significant difference where the difference between the before and after scores is small because the before-learning score was high; therefore, the after-learning score had a small margin for increase. Scores increased for all eight items after the program application as did the percentage of respondents who answered that they knew the items. These results confirmed the learning effect of acquiring knowledge about earthquakes

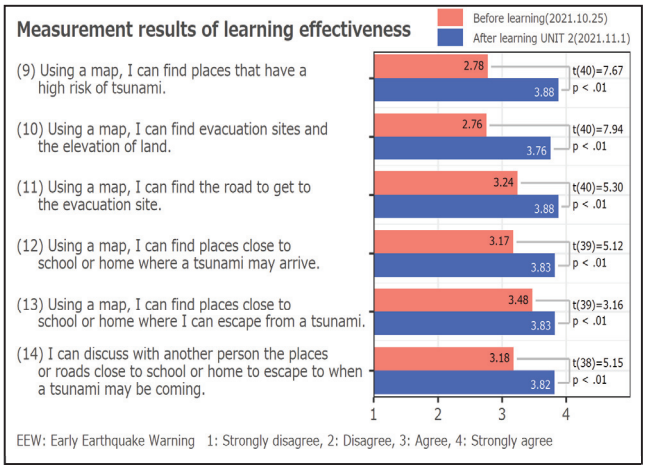


Fig. 16. Measurement of effectiveness of Unit 2.

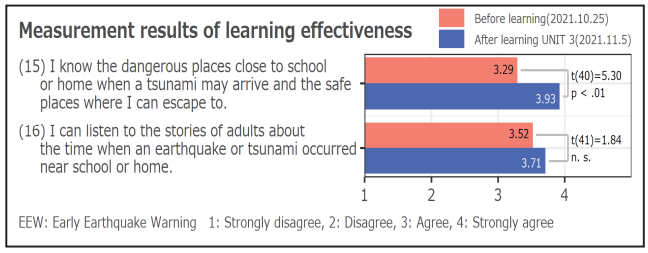


Fig. 17. Measurement of effectiveness of Unit 3.

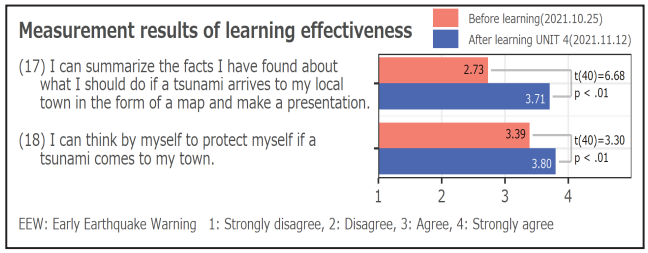


Fig. 18. Measurement of effectiveness of Unit 4.

and tsunamis, protecting oneself, and disaster preparedness necessary for making decisions during disasters.

4.2.2. Analysis Results for Unit 2

The analysis results of questions (9)–(14) for Unit 2 are presented in **Fig. 16**. The scores of the questions corresponding to the study objectives changed from 2.78 before the program to 3.88 after the program for "(9) Using a map, I can find places that have a high risk of tsunami," from 2.76 to 3.76 for "(10) Using a map, I can find evacuation sites and the elevation of land," from 3.24 to 3.88 for "(11) Using a map, I can find the road to get to the evacuation site," from 3.17 to 3.83 for "(12) Using a map, I can find places close to the school or home where a tsunami may arrive," from 3.48 to 3.83 for "(13) Using a map, I can find places close to the school or home where I can escape from a tsunami," and from 3.18 to 3.82 for "(14) I can discuss with another person the places or roads close to the school or home to escape to when a tsunami may be coming." When analyzed using the paired t-test, all questions displayed differences with a 1% significance level. The scores increased for all six items after program application, as did the percentage of respondents who answered that they knew the information delivered by the program. These results confirmed the learning effect of acquiring the skills to understand tsunami risk in the area and determine evacuation routes using YOU@RISK: Tsunami Disaster Version.

4.2.3. Analysis Results for Unit 3

The analysis results of questions (15) and (16) for Unit 3 are presented in **Fig. 17**. The scores of the questions corresponding to the study objectives changed from 3.29 before the program to 3.93 after the program for "(15) I know the dangerous places close to the school or home when a tsunami may arrive and the safe places where I can escape to" and from 3.52 to 3.71 for "(16) I can listen to the stories of adults about the time when an earthquake or tsunami occurred near the school or home." When analyzed using the paired t-test, question (15) displayed a difference with a 1% significance level, while no significant difference was found for question (16) because the difference between the before and after scores was small. Scores increased for both the items after program application, as did the percentage of respondents who answered that they knew the information. These results confirmed the learning effect of walking around the community with the residents to understand the local tsunami-related traditions and tsunami risk in the region concerning geographical and spatial dimensions.

4.2.4. Analysis Results for Unit 4

The analysis results of questions (17) and (18) for Unit 4 are presented in **Fig. 18**. The scores of the questions corresponding to the study objectives changed from 2.73 before the program to 3.71 after the program for "(17) I can summarize the facts I have found about what I should do if a tsunami arrives to my local town in the form of a map and make a presentation" and from 3.39 to 3.80 for "(18) I can protect myself if a tsunami comes to my town." When analyzed using the paired t-test, both questions displayed a difference with a 1% significance level. The after-learning scores are high for both the questions, indicating that the majority of students knew the information, thus, confirming the effectiveness of the learning process.

Through the study of Units 1–4, we examined the understanding level of tsunami disaster among children with limited memory/experience of the disaster. The analysis used questions (15) and (18), whereby the scores increased for both the items after the study, and statistically significant differences were observed at the 1% level. These results confirmed the learning effects of being able to present a summary of the learnings of Units 1–3 and

Table 3. Timeline of program implementation and measurement of its effectiveness.

Category	Content	Date of implementation
Measurement of effectiveness	1st study questionnaire	Oct. 21, 2021
Learning	Unit 1, Learning 1 and 2 (45 min × 2)	Oct. 21, 2021
Measurement of effectiveness	2nd study questionnaire	Oct. 22, 2021
Learning	Unit 2, Learning 3 (45 min × 2)	Oct. 25, 2021
Learning	Unit 2, Learning 4 (45 min × 2)	Oct. 25, 2021
Measurement of effectiveness	3rd study questionnaire	Oct. 25, 2021
Learning	Unit 3, Learning 5 (45 min × 3)	Oct. 28, 2021
Measurement of effectiveness	4th study questionnaire	Oct. 28, 2021
Learning	Unit 4, Learning 6 (45 min × 2)	Nov. 2, 2021
Learning	Unit 4, Learning 7 (45 min × 1)	Nov. 5, 2021
Measurement of effectiveness	5th study questionnaire	Nov. 12, 2021

of fostering an awareness of disaster preparedness to protect oneself during a tsunami, despite never having experienced one before.

The results of the above analysis confirmed the program's effectiveness for acquiring disaster response skills by learning about earthquake-induced tsunami risks in the region and considering decisions and evacuation actions to protect one's life.

4.3. Program Applicability and Improvement

4.3.1. Practice and Verification at Matsugahama Elementary School

In this study, to examine the scope of application of the ICT teaching material, YOU@RISK: Tsunami Disaster Version, on elementary school students, we implemented and measured the effectiveness of the program with children in different grades. Matsugahama Elementary School in the Shichigahama Town was selected as a subject school. A total of 33 students from fourth grade participated in the program. The teachers and the authors collaborated according to the program application at Eiraku Elementary School. The effectiveness of the program was measured using the paired t-test as a statistical analysis method (**Table 3**).

4.3.2. Analysis Results for Units 1–4

The analysis results of questions (1)–(8) for Unit 1 are presented in **Fig. 19**. The scores of the questions corresponding to the study objectives changed from 2.94 before the program to 3.85 after for "(1) I know what may happen when an EEW is issued," from 3.73 to 3.85 for "(2) I know what kind of damage can be caused by an earthquake," from 3.55 to 3.82 for "(3) I know how to act when I feel large tremors caused by an earthquake or hear an EEW," from 3.52 to 3.76 for "(4) I can protect myself if I feel large tremors caused by an earthquake or

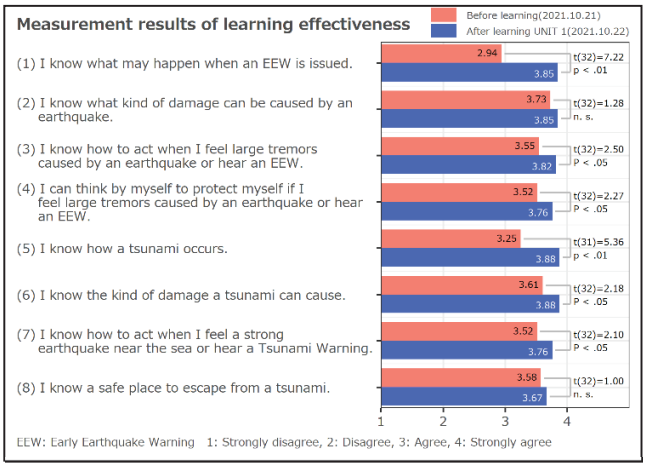


Fig. 19. Measurement of effectiveness of Unit 1.

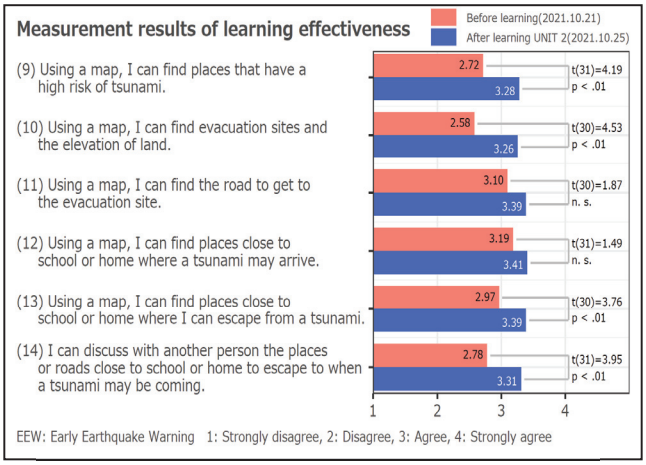


Fig. 20. Measurement of effectiveness of Unit 2.

hear an EEW," from 3.25 to 3.88 for "(5) I know how a tsunami occurs," from 3.61 to 3.88 for "(6) I know the kind of damage a tsunami can cause," from 3.52 to 3.76 for "(7) I know how to act when I feel a strong earthquake near the sea or hear a Tsunami Warning," and from 3.58 to 3.67 for "(8) I know a safe place to escape from a tsunami." When analyzed using the paired t-test, questions (1) and (5) displayed differences with a 1% significance level, while questions (3), (4), (6), and (7) displayed a difference with a 5% significance level. Questions (2) and (8) did not display statistically significant differences since the difference between the before and after scores were small. The after-learning scores were high across all eight questions, indicating that the majority of students answered that they knew the information, thus, confirming the effectiveness of the learning process.

The analysis results of questions (9)–(14) for Unit 2 are presented in **Fig. 20**. The scores of the questions corresponding to the study objectives from 2.72 before the program to 3.28 after the program for "(9) Using a map, I can find places that have a high risk of tsunami," from 2.58 to 3.26 for "(10) Using a map, I can find evacuation sites and the elevation of land," from 3.10 to 3.39 for

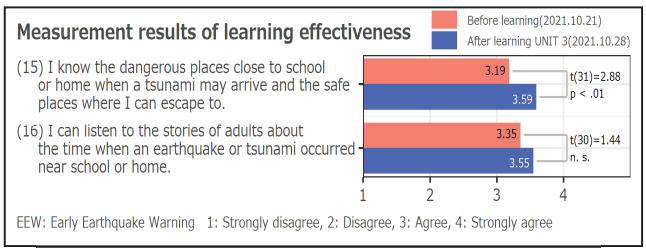


Fig. 21. Measurement of effectiveness of Unit 3.

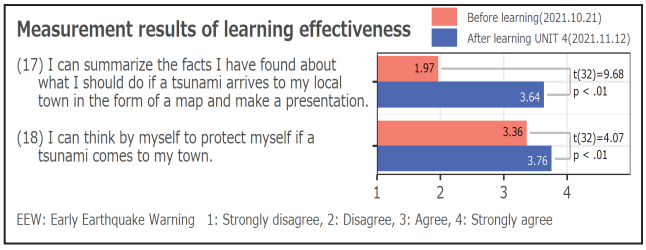


Fig. 22. Measurement of effectiveness of Unit 4.

"(11) Using a map, I can find the road to get to the evacuation site," from 3.19 to 3.41 for "(12) Using a map, I can find places close to the school or home where a tsunami may arrive," from 2.97 to 3.39 for "(13) Using a map, I can find places close to the school or home where I can escape from a tsunami," and from 2.78 to 3.31 for "(14) I can discuss with another person the places or roads close to the school or home to escape to when a tsunami may be coming." When analyzed using the paired t-test, questions (9), (10), (13), and (14) displayed differences with a 1% significance level. Questions (11) and (12) did not display statistically significant differences. Although the increase in the scores indicates that the achievement levels of the study objectives were low as compared to the other units since many students were unfamiliar with tablet operation, the results show that the learning process was effective to a certain degree.

The analysis results of questions (15) and (16) for Unit 3 are presented in **Fig. 21**. The scores of the questions corresponding to the study objectives changed from 3.19 before the program to 3.59 after the program for "(15) I know the dangerous places close to the school or home when a tsunami may arrive and the safe places where I can escape to" and from 3.35 to 3.55 for "(16) I can listen to the stories of adults about the time when an earthquake or tsunami occurred near the school or home." When analyzed using the paired t-test, question (15) displayed a difference with a 1% significance level, while no significant difference was found for question (16). Although the increase in the scores indicates that the achievement levels of the study objectives were low compared with the other units, the results show that the learning process was effective to a certain degree.

The analysis results of questions (17) and (18) for Unit 4 are presented in **Fig. 22**. The scores of the questions corresponding to the study objectives changed from 1.97 before the program to 3.64 after the program for "(17) I can summarize the facts I have found about what I should do if a tsunami arrives to my local town in the form of a map and make a presentation" and from 3.36 to 3.76 for "(18) I can protect myself if a tsunami comes to my town." When analyzed using the paired t-test, both the questions displayed a difference with a 1% significance level. The after-learning scores were high for both the questions, indicating that the majority of students answered that they knew the information, thus, confirming the effectiveness of the learning process.

The understanding of the tsunami disaster among children with limited memories/experiences of the disaster was tested with questions (15) and (18), and the scores for both the items were higher after learning with statistically meaningful differences at a 1% significance level, thus, confirming the learning effect.

The above analysis indicates that the implementation of the developed program resulted in achieving the study objectives, thus, confirming its validity.

4.3.3. Program Applicability and Improvement

Based on the results of the measured effectiveness of the program at Ekiraku and Matsugahama Elementary Schools, we examined the applicability of the developed program for different school years.

In Unit 1 for Matsugahama Elementary School, the scores indicated a high achievement level of the study objectives before the program. This is perhaps because the school had a tsunami educational program due to its proximity to areas that were inundated by the tsunami during the earthquake disaster and some of its students use roads in those areas to commute to school.

In Unit 2, for which the students used tablets, the scores of Matsugahama Elementary School were low for all the questions. This was because some of the students used tablets in their daily lives while others had no experience with tablets, and this difference was reflected in the scores. During program implementation, many students were assisted by the teacher or the authors in learning the tablet's operation. This indicated that YOU@RISK needs to be made more user-friendly to facilitate learning for fourth graders through tablets.

In Units 3 and 4, the scores indicated an increased achievement level of the study objectives after the program, thus, confirming the program's effectiveness as a general learning method.

From the above practices and verification results, it was found that, while the developed program yielded results in the learning of the basic knowledge about earthquakes and tsunamis and the response actions, the method to learn the operation of YOU@RISK-Tsunami Disaster Version, using a tablet, must be improved when the program is used for fourth-grade students.

5. Conclusions and Future Deployment

In Japan, the learning environment is evolving, and each elementary-school student has access to an information terminal under the MEXT GIGA School Concept.

In this study, we developed a tsunami DRR educational program targeting children with little or no memory/experience of the Great East Japan Earthquake. We implemented the program in the township of Shichigahama, Miyagi Prefecture, which faced extensive tsunami damage during the earthquake. The program was developed by using the ADDIE model used in ID theory, a learning theory. It was implemented for elementary school students, and its validity was confirmed. The program incorporated the YOU@RISK-Tsunami Disaster Version, which is a map learning site developed by the NIED to realize a learning method that merges ICT and DRR education from a geographical standpoint. YOU@RISK-Tsunami Disaster Version was developed as an ICT teaching material where a digital map visually displays the tsunami disaster that took place during the earthquake and allows the users to learn by linking the natural environment with the disasters.

The program was implemented at Ekiraku and Matsugahama Elementary Schools in Shichigahama Town, Miyagi Prefecture, under the collaboration of local teachers and the authors, and the learning effect was verified using the measured effectiveness it had on the students. Through this program, we confirmed the learning effectiveness of children with limited memories/experiences of the disaster to understand the tsunami damage and community vulnerability and acquire the ability to think about actions to protect their lives.

The analysis results indicated that the implementation of the developed program improved the learning effect, thus, verifying the program's validity when it was used for the fifth-grade students of Ekiraku Elementary School. However, when implemented for the fourth-grade students at Matsugahama Elementary School, we found that several students were unable to operate the tablet during the learning sessions using the YOU@RISK-Tsunami Disaster Version, which resulted in a low achievement level of the study objectives. This pointed out the need to improve the usability of the YOU@RISK-Tsunami Disaster Version.

To follow up on this study, we intend to implement and verify the program in areas that were affected by other tsunamis and areas that are expected to be subjected to tsunamis in the event of the Nankai Trough Earthquake. This would help improve its accuracy and develop a program with a high degree of perfection, necessary for social implementation. Since the use of YOU@RISK proved to be effective in ICT education, we plan to develop and apply versions of YOU@RISK that target sediment disasters, volcanic eruptions, and other natural disasters.

Acknowledgments

In conducting this study, we received the cooperation of Ekiraku and Matsugahama Elementary Schools in Shichigahama Town, Miyagi Prefecture, which carried out the DRR educational program, the Shichigahama Board of Education, and members of the residents' associations of the school districts. We wish to express our deep gratitude to these parties. The Shichigahama Social Welfare Council extended to us their unstinting cooperation in the necessary logistical adjustments and preparations for study implementation. We express our gratitude to the personnel involved. This research is based on a funded research project, "Establishment of a Disaster Prevention and Management Educational Hub for Improving Disaster Prevention Literacy among a Wide-Ranging Stakeholders" (Representative: Reo Kimura, University of Hyogo), which is supported by the SECOM Foundation for Promotion of Science.

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