

博士論文（要約）

**Effects of Web GIS Technology and Curriculum Approaches  
on Education for Disaster Risk Reduction**

（Web GIS の技術とカリキュラムの編成が防災教育に与える影響）

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## **Abstract**

With the increasing national and international policy agendas for DRR (disaster risk reduction) strategies, more web hazard maps have become available for education. Some teachers and researchers have applied these materials to disaster prevention education in schools. However, few studies have compared the effectiveness of web hazard maps with that of paper hazard maps in DRR education. Not much knowledge exists about whether students can improve their understanding of DRR through Web GIS technology and which factors affect students' learning of web hazard maps.

This study has provided materials and curricula for DRR education in Chinese and Japanese senior and junior high schools. The educational materials consist of web hazard maps and conventional web pages. The web hazard maps deal with several data layers that can be optimally combined during browsing. The web pages include two sections, “principles” and “examples.” The principles section explains the concepts, causes, and characteristics of disasters in relation to widely used geography textbooks. The examples section introduces some cases of past hazards using explanation text and illustrations. The curricula provide course plans to utilize the web hazard maps and web pages in which students identify areas vulnerable to hazards. The developed educational materials and curricula were used in classes and workshops in Chinese and Japanese high schools. The early version of materials and a curriculum (Version 1) was implemented eight times from 2018 to 2019. The total number of attended students was 237, with 153 belonging to junior high schools (7th to 9th grades) and 84 to senior high schools (10th and 11th grades). In terms of gender, 139 were male, 97 were female, and one student chose not to answer. The studied cases had two types: (a) a flood disaster example was taken from an area far from each school, and (b) an example was taken from a place close to each school. For the classes, both the constructed online materials and paper hazard maps were used for comparison. Students in a classroom were divided into several groups, each having several students working together. Students in a group share a device to use the online materials. The intended length of each class was 45–60 min.

The results of the implementations indicate that most students thought that DRR learning using Web GIS technology needs to be introduced to school education. The web hazard maps are more helpful than paper hazard maps in terms of information abundance and accuracy. The web-based materials developed for this study can be used with various devices, including PCs, smartphones, and tablets, without installing additional applications. Although network speed may still affect the efficiency of online learning, the materials are relatively light and straightforward, and usable with a small number of operations. During the implementation at multiple Chinese and Japanese schools with different network conditions, technical problems related to the speed of the Internet did not occur, indicating the high usability of the materials. Many students preferred the web hazard maps, and almost all students could conduct the requested operations. Although the web maps seem to be a priority, using both web and paper hazard maps can provide the best DRR education. A somewhat unexpected result of this study is that a familiar case study area (Type B) made it harder for the students to understand the distribution of hazard risks, suggesting that more knowledge and information about a case study area made students view things from various perspectives, leading to complex thinking and difficulties with judgment. Everyone should understand the hazard risks around their place of residence. Accordingly, the education and popularization of local disasters, including historical cases, need to be advocated. Teachers and students in classrooms should work together to understand future disaster risks in local areas based on hazard maps and additional information.

To understand which factors influence students to learn web hazard maps, the second edition of the educational materials and curriculum (Version 2) was developed. More explanatory web pages with multi-media contents were added to provide a more fundamental knowledge of maps, GIS, and the natural environment. Also, hazard maps for different types of hazards were included. The Version 2 online materials utilize a local Internet server provided by the Center for Spatial Information Science at The University of Tokyo, Japan, and the domain name paid services of Alibaba Cloud, China. The Version 2 materials and curriculum were used in classes and workshops in Chinese and Japanese high schools eight times from 2020 to 2022. These classes had

three forms of implementation due to the COVID-19 pandemic: online, onsite, and online-onsite mixed. The online and onsite forms were implemented multiple times in Chinese secondary schools. In the online-onsite mixed form, students were in classrooms, but the lecturers taught online through conference software. It was implemented in four classes in a Japanese high school. The number of attended students was 526, with 226 in the online form, 238 in the onsite form, and 62 in the online-onsite mixed form. In terms of gender, 238 were male, and 288 were female. Each student used his or her device during the Version 2 implementations. The students firstly answered a pretest. Then they learned about DRR using the explanatory web pages and the web hazard maps with answering quizzes shown on the pages. After that, they answered a posttest and a questionnaire. The intended length of each class was 90-110 min. However, the onsite implementation in China took two class hours, whereas each implementation in Japan was shortened to 50 minutes due to the epidemic.

We investigate the previous DRR-related experiences of students. Among disaster types, earthquakes are often taught, and the three principal sources for students to acquire disaster knowledge are computers, smartphones, TVs, radios, and schools. This suggests that modern communication is the primary vehicle for disseminating DRR knowledge. As a supplier of fundamental and systematic knowledge, schools should combine advanced equipment and technology to achieve optimal DRR education results. In addition, many students are concerned about disaster prevention and mitigation-related content, even during ordinary times. Most students expect to introduce the digital DRR learning materials used in this study to general school curricula. Due to the network speed and the server for teaching materials, many web maps, videos, etc., were not loaded smoothly during the implementation processes, as reflected in the results of questionnaires to students. Therefore, schools should provide high-speed Internet access.

Students in Chinese high schools show significantly improved results after using the digital DRR materials. It is particularly obvious for the onsite implementations. The pretest scores for the implementations using local disaster cases are low, but the subsequent improvement is significant. Gender hardly affects the learning of students.

The ability of students to utilize electronic devices affects the learning of GIS-related content but not other aspects. Furthermore, past experience in using online hazard maps influences the understanding of DRR-related content. The frequency of daily usage of online maps and that of the daily attention to disaster prevention and mitigation affect the learning of the entire materials. Increasing the use of online maps is a key to realizing social DRR.

We also compared the learning effects between the two versions of DRR learning materials and curricula, and those between the two countries. For both versions, the understanding and satisfaction of students are high, and Version 2 shows higher performances than Version 1. This suggests that the improvement made in Version 2 is effective for DRR education. However, students' understanding of the causes of disasters for Version 2 is not as good as that of Version 1. The oral explanation was more detailed during the Version 1 implementations because the explanatory web pages were less developed, which compensated for the limited content on the web. Finally, students gave more comments on the loading speed of the online materials for Version 2 than for Version 1. This may be because several students shared one device during the Version 1 implementations, which significantly reduced the number of visits to the DRR learning materials. If the number of equipment or the network environment is limited, device sharing provides better online learning. Other than tsunamis, the percentage of disasters of concern for Chinese students is much higher than that for Japanese students, especially forest fire disasters. Tsunami disasters are more worried in Japan because it is a maritime nation. The surrounding seas provide abundant air moisture in Japan to reduce forest fire. There is no significant difference between Chinese and Japanese students in the utilization of web hazard maps to learn DRR.

In previous research on educational materials and curriculum development, educational effectiveness was usually examined in one country using a single set of materials and a curriculum, and implementations typically involved only dozens of students in one or a few schools. This study investigated the educational effectiveness of newly developed materials and curricula through the implementations to 526 students in more than ten schools in two countries, using two versions of materials and

curricula. Therefore, this study is considered more extensive in scale and more comprehensive than previous studies, and hence provided various insights into the effectiveness of DRR education on a statistical basis.

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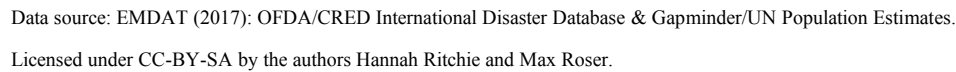
## Chapter 1 Introduction

Disaster is defined as a severe disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its resources (UNISDR 2009). Natural disasters can cause many economic losses and casualties (Abbas Khan et al. 2019; Poledna et al. 2018; Wolfson 2012). Over the past 20 years, disasters caused direct economic losses of 2.9 trillion USD worldwide (Schlein 2018). Annual disaster losses have been observed in a range of  $\sim 0.1\%$  to  $\sim 0.5\%$  of global GDP, and much larger loss potentials currently exist (Pielke 2019). Research has found that preparations for disasters can reduce injuries and prevent damage to property and infrastructure (Lori and Dennis 2006; Ronan and Johnston 2005). Disaster risk reduction (DRR) is the concept of reducing the potential impacts or losses that a population or area may face in particular hazards. It includes policies, strategies, and sound practices that could lessen the susceptibility to disaster risks of highly vulnerable communities (ASEAN Secretariat 2011). Hannah and Max (2014) visualized each disaster type data in a chart (Fig. 1.1), where the bubble size represents the death rates. It significantly reduces deaths from almost all types of disasters, except earthquakes and extreme weather. This initial success benefited through earlier prediction, more resilient infrastructure, emergency preparedness, and response systems. Disaster risk reduction education (DRRE) is also one way to reduce the negative results of disasters (La Longa et al. 2012; Mulyasari et al. 2015). Muñoz et al. (2020) indicate changes in political administration will halt, interrupt or delay progress if the authorities do not prioritize DRR in education.

Our World  
in Data

**Death rate  
per 100,000**

≤ 0.001  
50  
100  
150  
180



Children are the most vulnerable groups directly affected by disasters along with aged persons. It is predicted that children affected by disasters will increase in the coming years because both the frequency and intensity of natural hazards will rise (Webster et al. 2009). A study examining mortality during disasters in 125 countries has shown that nations with higher levels of education, especially among women and girls, experience lower levels of mortality during and following disasters (Striessnig et al. 2013). Moreover, children have the potential to be influencers spreading information about hazard preparedness to their families. Empowered by their knowledge, they can even act as leaders (Debi et al. 2008; Dunst 2002; FEMA 2013; Ronan and David Johnston 2001). The concept of disaster safety must be included in education from the childhood stage to reach the goal of sustainable disaster reduction. It is indispensable to build “a culture of DRR” in society, and schools are the building blocks that support the next generation to create this culture (Adiyoso and Kanegae 2012; ASEAN Secretariat 2011; Sinha et al. 2007). Therefore, implementing DRR knowledge in education has become essential (Nahayo et al. 2017; Ru Gwee et al. 2011). Some



policies, agencies, and schools have increasingly targeted children for DRRE (Mitchell et al. 2008; Sharpe and Kelman 2011).

In relation to this, Priority 3 of The Hyogo Framework for Action (HFA) (2005–2015) calls upon governments as well as regional and international organizations to identify the following school-related key activities (UNISDR 2005):

- Inclusion of DRR knowledge in relevant sections of school curricula at all educational levels.
- Implementation of local risk assessment and disaster preparedness programs in schools and institutions of higher education.
- Implementation of programs and activities in schools for learning how to minimize the effects of hazards.

Among these priorities, the subsequent Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 was formulated as a new initiative and guideline for DRR. They shared an essential perception with the international community: “DRR is our DNA,” which depicts the significance of DRR (Wahlstrom 2015). The meeting also pointed out that the first priority is understanding disaster risk (UNDRR 2015).

## **1.1 Review of DRRE with technology**

### **1.1.1 DRRE in formal education**

DRRE tools can be divided according to two criteria: 1) mode of education (formal and informal education) and 2) type (printed, nonprinted, etc.). Mulyasari et al. (2015) provide an overview of the various DRRE tools with particular emphasis on the users (Table 1.1). The importance of schools regarding DRRE is unquestionable. Schools can channel the knowledge, and thus awareness, of risk in different ways (Bernhardsdottir et al. 2016). Integrating formal and informal DRRE information through schools can reach every home and community and that learning is sustained for future generations (Marla 2008), of which formal education is considered the primary way for individuals

to acquire knowledge, skills, and competencies that can influence their adaptability, it offers not only the spatial thinking skill required to understand early warnings and evacuation plans but also the decision-making ability required to understand and minimize risk (Muttarak and Lutz 2014; Shiwaku and Fernandez 2011; United Nations International Strategy for Disaster Reduction (UNISDR) 2015).

Table 0.1. Overview of Disaster Risk Reduction Education Tools (Mulyasari et al. 2015).

By Categories		Tools
Learning Process	Through lectures	<ul style="list-style-type: none"> <li>• Printed materials (textbooks, comics, booklets, leaflets, handbooks, posters, working books)</li> </ul>
	Through experiences	<ul style="list-style-type: none"> <li>• Town watching</li> <li>• Interviews</li> <li>• Visit to museums</li> <li>• Disaster drills</li> </ul>
	Through experiences	<ul style="list-style-type: none"> <li>• Workshop tools (actions oriented planning)</li> </ul>
Approaches in education formats	In formal education	<ul style="list-style-type: none"> <li>• Curriculum integration</li> <li>• Extra-curricular integration</li> <li>• Curriculum infusion</li> <li>• Broad range of course</li> <li>• Stand-alone courses</li> <li>• Curriculum resource materials</li> </ul>
	In informal education	<ul style="list-style-type: none"> <li>• Dissemination of written materials</li> <li>• Cultural and performing arts</li> <li>• After-school “safety clubs,” scouting badges, and project activities</li> <li>• Projects that bring students into contact with local community, local government, and community-service-oriented clubs</li> <li>• Competitions, awards, and commendations</li> <li>• Parents and local community involvement</li> <li>• Participation of community partners</li> <li>• Disaster drills</li> </ul>

On that account, many countries have fostered DRR integration into the education curriculum. To support the cross-curricular priority of the Australian National

Curriculum, disaster education has also been part of the Australian Curriculum in Grades 6, 7, and 8 and Senior Secondary Geography (Boon and Pagliano 2015). In April 2022, Geography in Japanese senior high schools became a compulsory subject, and the guideline for the subject was provided by the Ministry of Education, Culture, Sports, Science, and Technology. The guideline indicates that the new Geography subject will refer to the following three points:

- Maps and GIS
- ESD (Education for Sustainable Development) and international understanding
- DRR and regional surveys

In some other countries, DRRE has not yet been included in formal education, but related interests have been growing. For example, after the Wenchuan earthquake in 2008, elementary and secondary schools in China paid more attention to disaster education. For developing DRRE, Zhu and Zhang (2017) conducted surveys on teachers and students in Chinese schools. The results indicate that many teachers hope schools will develop compulsory disaster-related curricula and design particular textbooks for disaster education.

### **1.1.2 Web GIS technology for DRRE**

In today's world, science and technology are the decisive forces in economic and social development. People are getting used to being supported by technologies, especially computer-related ones, in various situations and activities of the daily social routine. Digital learning is becoming not optional but a necessary method in schools as it offers new experiences and unconventional approaches to students and improves their motivation to learn (Savova 2016). In addition, students today are familiar with mobile technologies from an early age and are capable of working with tablets, computers, and smartphones. It is almost natural that up-to-date learning methods replace traditional methods.

Geographic information systems (GIS) are integrated computer systems for the input, storage, analysis, and output of spatially referenced data (Burrough 1986; Goodchild 1991). Koutsopoulos (2010) confirmed that GIS provides knowledge, understanding, and application in Geography, and they can be utilized in teaching Geography. GIS can also solve spatial problems with wise decisions (Torres 2015). Some educators consider GIS to be one of the most promising means for implementing educational reform (Kerski 2001). Some countries have introduced GIS in schools for teaching subjects such as social studies, geography, and earth sciences (Eray 2012; Johansson 2003; Kidman and Palmer 2006; Makino and Watanabe 2002; Roulston 2013). A desktop GIS allows each user to display and edit spatial data stored in computers. However, financial costs to purchase software and hardware may limit GIS applications in schools, and the installation of software and operation of various functions sometimes require professional support (Johansson 2003; Oshima 2015; Tan and Chen 2015). Table 1.2 summarizes the functions of some available GIS software packages (Oshima 2015), showing that Web GIS customized for a specific purpose can be a powerful tool. The main advantage of using web-based solutions instead of desktop software is the easier use of these services, making them better suited for classrooms (Riihelä and Mäki 2015).

Table 0.2. Functions, facilities and budgets for each GIS software (after Oshima 2015).

Software	Functions							Facilities	Budgets
	Reading GIS map			Editing GIS map				Offline use	Free
	Topographical map	Town map	Aerial photo	Editing GIS data	Editing photo	Statistic map	Elevation map		
Web GIS Customized	•	•	•	•	•	•	•		•
Google Maps/Earth		•	•	•					•
Picasa		•	•		•				•
<u>Chizutaro</u>	•	•		•	•	•	•	•	
MANDARA	•	•	•	•		•	•	•	•
Quantum GIS		•	•	•		•	•	•	•
Arc GIS		•	•	•		•	•	•	•
Green Map/Hi map mister						•		•	

Web GIS originate from a combination of web technology and GIS. They are a type of GIS that use web technologies to make geospatial data accessible to the public regardless of whether or not they have a background and knowledge about GIS. The main objective of Web GIS is to inform people through interactive maps, and the user interface is straightforward (South Atlantic Environmental Research Institute 2021). Web GIS perform basic things, but they are also capable of various data analyses like creating density clusters or determining the geographic center of a particular set of data by clicking buttons on web pages. Modern Web GIS are frequently considered the frontend of geographic information systems, where the Internet, mapping, and database servers can work in concert (Baker 2015). Some organizations developed collaborative Web GIS for education, supporting interactive websites that allowed students to collect, analyze, and map their data (Baker 2005). Web GIS has been employed in K-12 education in some countries since the mid-1990s (Baker 2005; Cirruci et al. 2012; Henry and Semple 2012; Riihelä and Mäki 2015).

Many countries have incorporated Web GIS technology into DRRE. In 2017, ESRI UK made the ArcGIS Online software available to all UK schools. The company also organized a dedicated educational team that assists teachers in getting familiar with the ArcGIS Online platform (Healy et al. 2018). They use the format of ESRI Story Map for school education (CGeog 2018), and some contents are related to natural hazards. In Indonesia, Ariyanti et al. (2018) developed a Web GIS system for schools to learn mapping and disaster mitigation. Thirteen information-system experts tested the system, and the results show that it is feasible to applicable to disaster-prone areas. Through its National Disaster Management Agency, the Indonesian government has developed and launched a mobile application called InaRisk Personal, to help citizens become more aware of disasters. Sari et al. (2020) assess whether InaRisk Personal is effective as a disaster learning tool for senior high school students, and collected 361 questionnaires from four high schools. They found that the application on mobile devices has provided higher map readability and user satisfaction compared to printed maps. However, such government-developed DRR applications tend to be elaborate in function and complicated for beginners. In Japan, the combination of Web GIS and disaster risk

reduction has also received attention in recent years. Uchida et al. (2020) established an ICT-based program and developed the Disaster Information Tweeting and Mapping System (DITS/DIMS) to raise awareness of DRR among young people. They also report the results of DRR workshops using this program at six schools in Kanagawa Prefecture, Japan. Three hundred twenty-six post-questionnaires were collected, and the results show that many participants had a positive impression on the developed education program. However, the improvement of students after implementing the DRR education was not evaluated. In China, Li et al. (2022) used the 2021 Zhengzhou torrential rain as a disaster teaching case. They discussed the educational benefits of applying Web GIS to natural disaster education for high schools. However, the study did not evaluate the feedback of students to understand learning outcomes.

### **1.1.3 Spreading DRRE experience**

Due to its geographical and climate conditions, Japan has long been exposed to disasters, including earthquakes, tsunamis, floods, volcanic eruptions, debris flows, and heavy snow. They have grown knowledge, systems, and technologies from numerous disaster experiences (Sato 2021; Wahlstrom 2015). After World War II, Japan established its DRR framework to mitigate natural disasters and played a leading role in establishing the International Decade for Natural Disaster Reduction (IDNDR) (JICA 2017). The Third UN World Conference on Disaster Risk Reduction Conference allowed Japan to share the lessons learned and technologies Japan has developed through disasters. Over the coming years, promoting the SFDRR is the responsibility of the international community and Japan as a country that has led the world in the field of DRR (Wahlstrom 2015).

Hazard maps are tools developed to reflect areas affected by or vulnerable to a particular hazard and are typically made for natural hazards such as earthquakes, flooding, landslides, and tsunami. They can save lives and economic losses by avoiding exposure to some risks while designing other development to mitigate or neutralize the

potential negative effects of these hazards (Pacific Northwest Seismic Network 2021). Such information must also be available to students, and hence hazard maps have been used as educational materials. In the aftermath of the 2011 Tōhoku earthquake and tsunami, the Japanese government guideline for the education of high school geography students emphasizes improving students' awareness of DRR through acquiring geographical skills, for example, reading hazards and thematic maps (Sakaue 2013). Students should be guided to look at paper hazard maps as early as possible, preferably in elementary schools. The introduction of maps showing local hazards can be the first step in teaching school children and their parents about specific local hazards and appropriate responses (Vitek and Berta 1982). Cross (1988) reported geography instructors at various levels who incorporated paper hazards maps into their teaching. Currently, not only paper hazard maps but also web hazard maps and digital devices are used for disaster data representation.

With the increasing national and international policy agendas for DRR strategies, more materials have become available for education (Dar et al. 2014). For example, some Japanese governmental agencies have constructed online systems for DRR using hazard maps available on the Internet, such as the websites of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT; <https://disaportal.gsi.go.jp/>), Fukuoka City (<https://webmap.city.fukuoka.lg.jp/bousai/>), and Kashiwa City ([https://www.city.kashiwa.lg.jp/staticcontents2/hazardMap/flow\\_01.html](https://www.city.kashiwa.lg.jp/staticcontents2/hazardMap/flow_01.html)).

## **1.2 Research gaps and Objectives**

Web hazard maps are still relatively new. Fewer studies have compared the effectiveness of web hazard maps with that of paper hazard maps in DRRE. Citizens may not effectively utilize hazard maps on the Internet because of the lack of cognition about the included information (MLIT 2015). Some Japanese researchers have already constructed online Web GIS-based systems for DRRE using hazard maps available on the Internet (MLIT 2017). Shirai et al. (2017) propose a new educational curriculum

for creating hazard maps with tablet-type devices for DRR and a Web GIS-based software as the educational tool. They found that electronic maps are suitable for creating hazard maps and help students comprehend maps. Recently, in response to the guideline for the new Geography subject, various teaching plans have been proposed in Japan. For example, ESRI Japan provides an ArcGIS Online service to Japanese schools for learning geography and expects teachers to use state-of-the-art technology in school classrooms (Akimoto and Suzuki 2019). However, not many orientations exist about whether students can improve their understanding of DRR through GIS technology and what factors can affect students' learning of web hazard maps.

To meet aspirational goals of changing the culture of safety and resilience, disaster education programs for children must be both effective and scalable. The international community needs to benefit from research on national curriculum integration processes to help identify replicable, large-scale models, particularly ones that facilitate children's comprehension of science, geography, and other elements (Johnson et al. 2014). Curriculum infusion is a more comprehensive approach that distributes DRR content throughout the curriculum, using lessons, readings, activities, and problems, enriching the existing curriculum rather than displacing it. The process requires six aspects of preparation (Schultz et al. 2008):

1. Elaborate the full scope and sequence of knowledge, competencies, and skills desired for disaster risk reduction.
2. Conduct a complete audit of the existing curriculum to find where the disaster risk reduction content can be integrated into lesson plans.
3. Develop and adapt educational materials and tools for curriculum infusion.
4. Train the faculty of teacher-training institutes.
5. Provide in-service training and distance learning tools for working teachers.
6. Evaluate impact and adjust and support accordingly.

Therefore, this study newly develops materials for DRRE including web hazard maps, and examines the effectiveness of the web maps by comparing the developed materials with conventional paper hazard maps. Then this study investigates the factors influencing students to learn DRR and how much the materials improve students'



understanding of electronic maps and DRR information. In addition, this study provides curriculum approaches corresponding to the constructed teaching materials for student practice that can be used in schools, and suggests optimal guidelines for future research and applications. For this purpose, pretests, posttests, and questionnaire surveys are conducted during the courses.

## **Chapter 2 Development of DRR learning materials**

The produced DRR learning materials are designated for senior and junior high school students and are available in Chinese and Japanese. These materials have two versions. Version 1 consists of a text section in a webpage for learning about flood disasters, and a section of web hazard maps. In the Version 2 materials, some functions and content of Version 1 have been improved and increased, including all kinds of natural disasters and the basic knowledge for learning web hazard maps, such as maps, GIS, and natural environment. The following explains the common elements of the two versions. Details of the two versions will be described in Chapters 4 and 5.

### **2.1 DRR learning materials technical construction**

The DRR learning materials follow the logical structure shown in Fig. 2.1. A responsive educational system was constructed using programming libraries, including HTML5 and jQuery. It looks and works similarly on any device, including mobile phones, tablets, and laptop/desktop PCs. The interface used an open-source web UI front-end framework called Layui (<https://www.layui.com/>) that applies the development models of HTML/CSS/JS and is suitable for the rapid development of a tidy web interface with relatively fewer codes. The maps and layers in the constructed system were arranged using the ESRI ArcGIS API for JavaScript, one of Web GIS tools with the functionality of GIS operations using a simple web browser. A server or portal can be constructed to include maps and tools called by the API. An ArcGIS Online subscription or an ArcGIS Server is necessary for hosting the network data with this API (Wendel 2015). This study utilized a subscription by the Center for Spatial Information Science, the University of Tokyo. The entire website is hosted on service platforms. Version 1 educational materials were published online using the GitHub website (<https://github.com/Disaster-Education>) for flexible sharing with users and external developers. Version 2 was hosted on Alibaba Cloud, the largest cloud service provider in China.

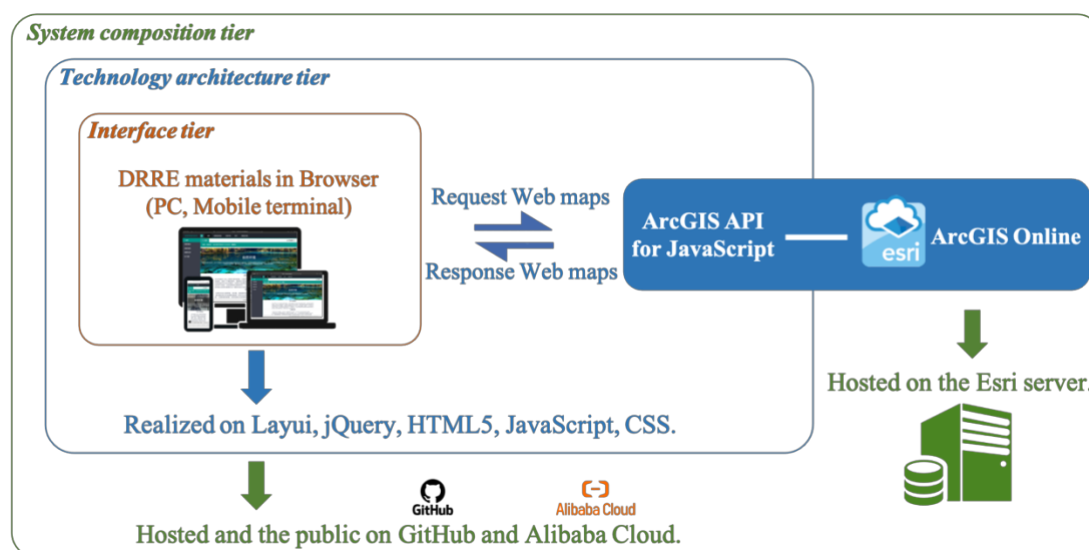


Fig. 0.1. The logical structure of the DRR learning materials.

The following briefly explains the tools and services used. Layui is a front-end UI framework written in its own module specification, and the first version was released in 2016. It follows the writing and organizational form of the native HTML/CSS/JavaScript and has abundant components. In Layui, every detail from the core code to the API has been carefully crafted, making it ideal for rapid interface development.

jQuery is a fast, small, and feature-rich JavaScript library. It has various functions such as HTML-document traversal and manipulation, event handling, animation, and Ajax. It is a relatively simple and easy-to-use API, working across many browsers, with a combination of versatility and extensibility (The jQuery Foundation 2019).

Most libraries or tools for web development are centered around HTML, CSS, and JavaScript. HTML is a markup language most widely used to construct web pages, which provide detailed instructions concerning style, type, format, and structure. CSS stands for Cascading Style Sheets and is a design language that makes the web pages look appropriate and presentable. JavaScript is a language for programming a web page and individual elements to react in a certain when an event happens (Ubah 2021).

A back-end REST API powers the ArcGIS API for JavaScript to retrieve information statuses from the server. When a user runs an application, the code runs in the browser, not on the server, enabling fast operations. The API is built on top of the Dojo JavaScript toolkit, making it independent of browser idiosyncrasies (ESRI 2015).

GitHub is a social coding site that uses Git3 as its distributed revision control and source code management system. It implements a social network where developers can broadcast their activities to interested subscribers (Thung et al. 2013). Many packages of open-source software have been constructed on GitHub (Jason et al. 2014).

Alibaba Cloud provides cloud computing services on a pay-as-you-go basis for online businesses. It has many products and services to enable fast and efficient development and intelligent analysis, such as elastic compute, data storage, relational databases, and big-data processing (Zhou 2017).

## **2.2 Content construction of DRR learning materials**

The DRR-related introductory text in the materials refers to two Chinese and one Japanese high school geography textbooks: 1) High School Geography 5 – Natural Disaster and Prevention (People’s Education Press, China), 2) High School Geography 7 – Geographic Information Technology Application (People’s Education Press, China), and High School New Geography A (Teikoku-Shoin Press, Japan).

The People’s Education Press (PEP) was founded in 1950 and is a specialized publishing house directly under the leadership of the Ministry of Education of the People’s Republic of China. It undertakes overall tasks of researching, compiling, publishing, and distributing teaching materials for elementary education, including various textbooks and educational books (Purple Culture 2019). Since 2013, more than 20 provinces, autonomous regions, and municipalities such as Beijing, Tianjin, Guangdong, and Yunnan have been using textbooks published by PEP (Liao 2018).

The Teikoku-Shoin Press, founded in 1917, has been producing textbooks and atlases for students in Japan (Teikoku-Shoin 2019). It provides the most widely used high-

school textbook of geography in Japan, with a market share in 2009 was 51.2% (Tan 2009).

## **Chapter 3 Disaster cases and data sources of DRR learning materials**

In the DRR learning materials, some specific geographical areas were selected as typical cases. Different flood cases were used in the early Version 1 implementations because the author assumed that local and non-local disaster cases might impact student learning. Based on past flood histories, data availability, and the location of schools where the constructed DRR learning materials will be tested, the watersheds of four rivers were selected: the Tedor River in Japan, the Tsurumi River in Japan, the Kinugawa River in Japan, and the Second Songhua River in China. Matsuzaka City in Japan was also selected as a case area of tsunami disasters.

### **3.1 Disaster cases**

The Tedor River is located in southern Ishikawa Prefecture in the Hokuriku region of Japan, which debouches from the top of Hakusan Mountain (Hokuriku Regional Agricultural Administration Office 1987). The alluvial fan of the Tedor River comprises one of the most important regions in Ishikawa Prefecture because the area contains major industrial and commercial facilities as well as widely developed agricultural land (Maruyama et al. 2014). This piedmont area underwent flood damage many times. Table 3.1 summarizes the historical record of natural disasters in the Tedor River Basin. The flood in 1934 was the most typical and largest in the past 100 years. Snow in the source area was abundant that year, which melted with a rapid rise in temperature and heavy rain of more than 400 mm. The floodwater transported eroded soil and debris into the downstream area and caused unprecedented damage along the river (Kanazawa Regional Office 2018).

Table 0.1. Record of natural disasters that affected the Tedorì River Basin (Kanazawa Regional Office 2018).

Time	Disaster Record
April 21, 1659	The last eruption of Hakusan
June 11 & 12, 1668	Flood of the Tedorì River 8 killed 39 houses washed away
August 9, 1671	Flood of the Tedorì River 32 killed 88 houses washed away
August 26, 1855	Overflow of the Tedorì River 18 houses washed away at Kawakita Village
Date unknown, 1858	Hietu Earthquake Landslides in the Yanagi Valley and the Jinnosuke Valley
May 5, 1877	Overflow of the Tedorì River Banks broke at Kitaichi, Kamishimizu, Yamadasenden, Yoshihara and Akai
April 29, 1881	Overflow of the Tedorì River Ricefields were damaged in 46 villages, Mitsukuchi, Iwauchi, Shimizu, etc. in Nori County.
July 2, 1881	Overflow of the Tedorì River in Ao Village 10 houses washed away 3 barns lost 1 watermill lost 180 houses inundated 100ha of rice fields damaged
October 6, 1890	Flood of the Tedorì River Overflow around Yoshida Village and Yoshii Village
October 28, 1891	Great Mino Earthquake 25 houses completely destroyed 80 houses partially destroyed
August 11, 1894	10 areas along the Tedorì River collapsed Ao Bridge collapsed
August 2, 1896 September 7, 1896	Overflow of the Tedorì River 84 killed 185 injured 320 houses completely destroyed or washed away
July 14, 1902	Overflow of the Tedorì River Ao levee destroyed, 900m long
July 11, 1934	Overflow of the Tedorì River 172 houses washed away 586 houses inundated 97 killed 35 injured 15 missing
July 26, 1958	Overflow of the Tedorì River 5 killed 12 injured 40 houses completely destroyed or washed away
September 16, 1961	The Second Muroto Typhoon
September 8~14, 1976	Overflow of the Tedorì River Hakusan Park Line was partially destroyed and became impassable.
July 11~13, 1985	Overflow of the Tedorì River The same as above.
September 15, 1999	Mud flow occurred at Betto Valley; Debris flooding occurred at Jinnosuke Valley and came close to the Tokachi Bridge and Hosodani Sabo Dam No. 10.

The Tsurumi River flows from its source in Machida City, Tokyo Metropolis, Japan, down to Tokyo Bay at the river mouth of Tsurumi Ward, Yokohama City. The Tsurumi River Basin is regarded as a representative of urbanized river basins in Japan. It has undergone rapid urbanization since the 1960s (Ogawa and Shikazono 2012). Moreover, the river flows through the central part of the Tokyo Metropolitan Area with social and economic significance (Nakao and Tanimoto 2009). When Typhoon No. 4 approached in 1966, the average two-day rainfall in the Tsurumi River area reached 307 mm. At the Sueyoshi Bridge gauging station, the water stage reached an all-time high of 3.94 m above mean sea level at Tokyo Bay. The resultant flood caused the inundation of 5,495 houses above the floor and 11,664 houses below the floor.

The Kinugawa River is located in Tochigi and Ibaragi Prefectures, Japan. From ancient times, it has been known to cause floods (Jones et al. 2001). Affected by two typhoons, heavy continuous precipitation occurred from September 7 to 11, 2015. The 700 mm of rainfall exceeded the historical record for the Kinugawa River. The widespread flooding resulted in the worst disaster-related damage in this area (Kazuaki and Yasuo 2017; Kitabatake et al. 2017; Ushiyama et al. 2017).

The Songhua River Basin is located in the northeastern region of China. The basin is one of the biggest river basins in China, which includes two major tributaries, the Nenjiang River and the Second Songhua River, along with the mainstream of the Songhua River (Fig. 3.1). The total basin area is 556,800 km<sup>2</sup> (Li et al. 2009). The basin is the major freshwater source for industries, farms, and millions of residents, and water demand there has been expanding (Ministry of Environmental Protection of China 2006; Ren et al. 2002). The Second Songhua River, with a total length of 958 km and a basin area of 73,000 km<sup>2</sup>, originates from Tianchi on Changbai Mountain. The river and the Nenjiang River converge to form the Songhua River at Sanchahe (Songliao WRC-HB 1994). Severe stormy weather affected Jilin and Heilongjiang Provinces on July 13 and 14, 2017, resulting in at least eight dead and one missing person. The 250 to 296 mm of rainfall on July 13 exceeded the historical record for this region. As of 09:00 local time on July 14, some 50,000 people were affected in the two provinces. This torrential rain triggered an extraordinary flood disaster, ruining crops on farmland, disrupting transportation, and interfering with businesses and other activities of people (Wan et al. 2019). The disaster affected about 23,000 hectares of farmland and led to the direct economic loss of more than 29 million RMB (Blašković 2017).

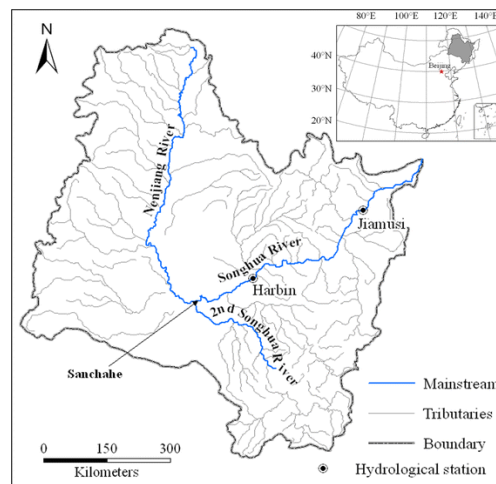


Fig. 0.1. Location of the Songhua River Basin in China (Miao et al. 2011).

The Nankai Trough coast of Japan is known as a tsunami-prone area, and has been severely damaged by the 1707 Hoei earthquake and the 1854 Ansei Tokai earthquake



(Kawasaki et al. 2012). Large tsunamis, similar to that associated with the 1707 Hōei earthquake, occurred at recurrence intervals of several hundred years (Hyodo and Hori 2013). The 14th Central Disaster Prevention Conference organized by Disaster Management, Cabinet Office, Japan in 2003 predicted the losses caused by the three linked earthquakes along the Tokai, Tonankai, and Nankai regions. The magnitude of the three linked earthquakes will be 8.7, the death toll about 24,700, and the economic loss about 81 trillion JPY. Matsusaka City in central Mie Prefecture, Japan, will be affected severely by a tsunami. The city is bordered by Ise Bay on the Pacific Ocean to the east. If the magnitude of the Nankai Trough earthquake reaches 9.0, tsunami heights in some areas around Matsusaka City will be about 10 m (Kawasaki et al. 2012). In response to such estimates, the city created tsunami hazard maps to provide citizens with disaster prediction information (Matsusaka City Website 2021).

### **3.2 Data sources**

Geospatial data represent objects, events, and phenomena on the earth's surface, using location information, attribute information, and often also temporal information (Stock and Guesgen 2016). All geospatial data utilized in the constructed DRR learning materials are freely available public data downloadable from websites. It can be divided into two types, disaster cases data and general data. As described in the previous section, disaster case data are for some specific regions. The general data are part of national or global data.

Data of disaster cases consists of hazard prediction information and related geographical information for each target area. The hazard prediction information is a polygon layer showing the predicted height of flood inundation. The related geographical information includes evacuation information and human activity information such as the shelter layer and the densely inhabited districts (DIDs) layer. The DIDs are defined by the Japanese government based on some criteria such as a population density higher than 4,000 people km<sup>-2</sup> (Statistics Bureau, Ministry of

Internal Affairs and Communications, and Government of Japan 2017). The data for China and Japan were obtained from different sources. Japanese data of disaster prediction, shelters, and the DIDs were downloaded from the website of National Land Numerical Information (<https://nlftp.mlit.go.jp/>). Table 3.2 shows the additional information of these data. The data were arranged in ArcGIS and converted into the KML format.

Table 0.2. Information on disaster-related data for Japan.





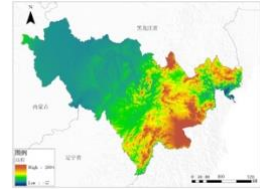
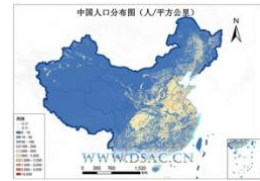
Data	Feature	Coordinate	Year	Data Preview	Format
Shelter	Point	JGD2000	2012		Shapefile
Hazard prediction information	Polygon	JGD2011	2012/2018		
DIDs			2015		

Table 3.3 shows the properties of the Chinese data. The evacuation facilities information was obtained from the web pages of local administrations (e.g., the Jilin City Seismological Bureau: [http://dzj.jlcity.gov.cn/yjjy/yjbncs/201704/t20170420\\_7397.html](http://dzj.jlcity.gov.cn/yjjy/yjbncs/201704/t20170420_7397.html)). The flood inundation areas and water depth for the Songhua River basin were estimated using the 30-m SRTM DEMs downloaded from the Geospatial Data Cloud of China (<http://www.gscloud.cn/>) and the MIKE software from DHI by adopting the methodology of Hou and Ma (2016). Population densities higher than 2,000 people km<sup>-2</sup> were identified as DIDs in China. The threshold value of 2,000 people km<sup>-2</sup> was chosen because the population density in Jilin Province is generally lower than that in Japan. The population density data were downloaded from the Geographical Information Monitoring Cloud Platform (<http://www.dsac.cn/DataProduct/Detail/201111>).

These data were processed using the ArcGIS software from ESRI, and converted into the KML format that can be invoked on the web.

Table 0.3. Information on disaster-related data for China.

Data	Feature	Coordinate	Year	Data Preview	Format
Shelter	Text	-	2017		Sheet
Hazard prediction information	Raster data	WGS_84	2013		GRID/ TIFF
DIDs	Polygon	WGS_84	2015		Shapefile

The general data include road maps, topographic maps, elevation colored maps, rectified satellite imagery, rectified old aerial photos, volcanic maps, and seismological maps. The general data for the Japanese case study areas were tile layers provided by the Geospatial Information Authority of Japan (GSI) and the ESRI. The Chinese general data were obtained from the ESRI ArcGIS Online map database. The ArcGIS Online portal is a ready-made cloud GIS application that stores and publishes spatial data, and provides maps, tools, and services (ArcGIS Online Help 2019). It supports various types of data and services such as WMS, KML, GPX, CSV, and SHP, and contains many ready-made maps published by user communities. Almost all of them are available for immediate use, such as imagery base maps, historical maps, earth observation maps, urban system maps, and transportation maps (Mariushko et al. 2018). It also exchanges data between different users. Figure 3.2 shows the search results for Chinese seismic data in the ArcGIS Online database.

Home
Gallery
Map
Scene
Groups
Content
Organization


jiali song  
songjiali

Search

Earthquake China

Relevance
Filter

Content
Groups
1 - 20 of 166




**ESS205 Individual Map - Earthquakes in China (The Wenchuan Earthquake)**

Web Map by [chenruod\\_utoronto](#)

The map lists all significant earthquakes in China with magnitudes at least 4.5. It also highlights the Sichuan Province of China. The red star represents the Wenchuan Earthquake that happened in May 2008 in Sichuan.

Created: Nov 15, 2020   Updated: Nov 15, 2020   View Count: 124



**Major Earthquakes in China from 2008 to 2018**

Web Map by [chenleta\\_utoronto](#)

This map shows the major earthquakes in China from 2008 to 2018 and the unemployment status in each province.

Created: Nov 15, 2020   Updated: Dec 1, 2020   View Count: 198

Fig. 0.2. Search results for Chinese seismic data using the ArcGIS Online database.

## Chapter 4 Construction and applications of the Version 1 materials and curriculum

### 4.1 Construction of the Version 1 materials and curriculum

As mentioned, the constructed Version 1 learning materials consist of learning and practice parts (Fig. 4.1). The learning part utilizes web pages with two sections, “principles” and “examples.” The principles section explains the concepts, causes, and characteristics of disasters through widely used geography textbooks. The examples section deals with cases of past flood hazards with explanation text and illustrations on web pages. The practice part asks students to identify areas vulnerable to predicted floods using web hazard maps with several data layers.

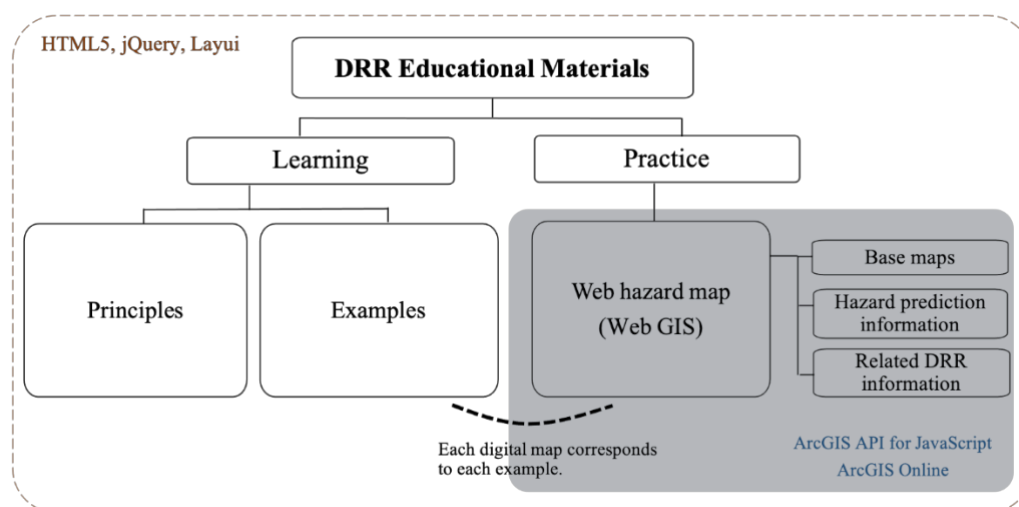


Fig. 4.1. Framework of the DRR learning materials.

Figure 4.2 shows the learning part of the material. At the top, the “principles” section introduces flood disasters, including causes such as rainfall and snowmelt, as well as consequences, based mainly on textbooks commonly used in high schools. The “examples” section in the middle demonstrates a typical flood disaster, with a link to the web hazard maps of the target area (green button).

### About Flood Disasters

When rain water falls on the land, some seeps into the ground, and some flows downhill on the surface forming streams and rivers, which erode the land and transport sediment, leading to deposition downstream. When the amount of water flowing into a river exceeds a certain amount, some water overflows the bank, resulting in flood. Plains along rivers are formed naturally by recurrent floods. Flood inundation of land and properties in built-up areas, particularly densely populated areas cause damage, which is called a flood disaster.

#### Major reasons of river flooding

- > Rainfall due to frontal activities, tropical cyclones, etc.
- > Snowmelt

### Example of Flood

#### Kinugawa

The Kinugawa River in central Japan is a tributary of the Tone River, which originates from the Kidonuma peatland. With a total length of 176.7 km, it is the longest tributary of the Tone River. When heavy rains occurred in the Kantō and Tohoku regions in 2015, the embankment of the Kinugawa River broke near the Kamimisaka district, causing large-scale inundation damage over approximately 40 km<sup>2</sup> on the flat land between the Kinugawa and Kokaigawa rivers (Ministry of Land, Infrastructure, Transport and Tourism Chubu Regional Development Bureau). Due to this flood disaster, 20 people were dead, 82 people were injured, 81 houses were completely destroyed, 7,090 houses were partially destroyed, 384 houses were partially damaged, and 1,722 non-residential houses were damaged (Fire and Disaster Management Agency).

[Open the Map](#)



State of the levee breakage of the Kinugawa River

(Source: Geospatial Information Authority of Japan GSI Maps (Digital Land Web))

Fig. 4.2. Webpage of the learning part. The original page contains text in Chinese or Japanese, translated into English in this figure.

Figure 4.3 shows an example of the web hazard maps for the Kinugawa River, Japan, which provides users with a series of information. Students operate the web hazard



maps to consider disaster risks using geospatial data and GIS functions, such as switching layers and measuring lengths. The implemented geospatial data consist of base maps, hazard prediction information, and related geographical information for each target area. The base maps include road maps, topographic maps, colored elevation maps, rectified satellite imagery, and rectified old aerial photos. A polygon layer showing the predicted height of flood inundation provides hazard prediction information. The other layers include the shelter layer and the densely inhabited district (DID) layer. Clicking on the evacuation shelter layer displays detailed information, such as shelter names, addresses, and types. The legend of the presented map is available in a floating box.

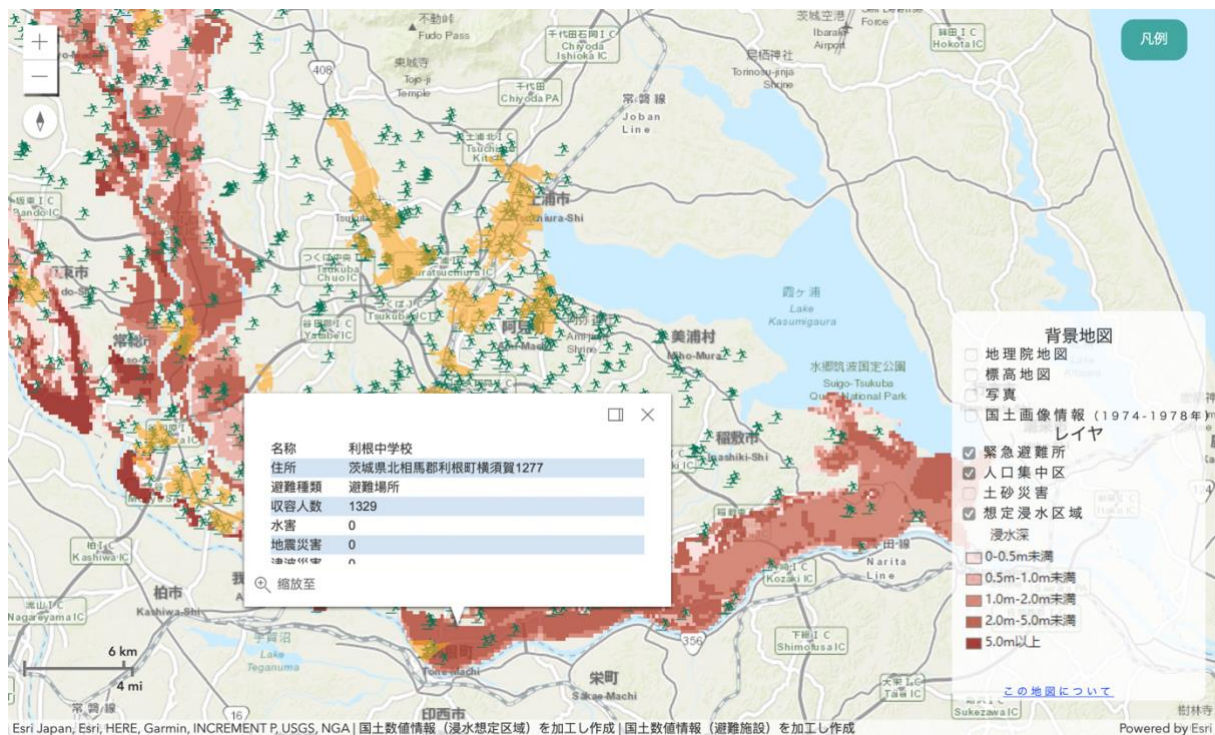


Fig. 4.3. Screenshot of the web hazard map with DRR information for the Kinugawa River, Japan.

Figure 4.4 is a screenshot of the DRR learning material showing web addresses and the organizations that host code files. Version 1 materials in three languages (Chinese, English, and Japanese) are available for the Disaster-Education Organization of GitHub.

Typical disaster case data converted to the KML format are also included in each repository, and API can call these data directly via the URL.

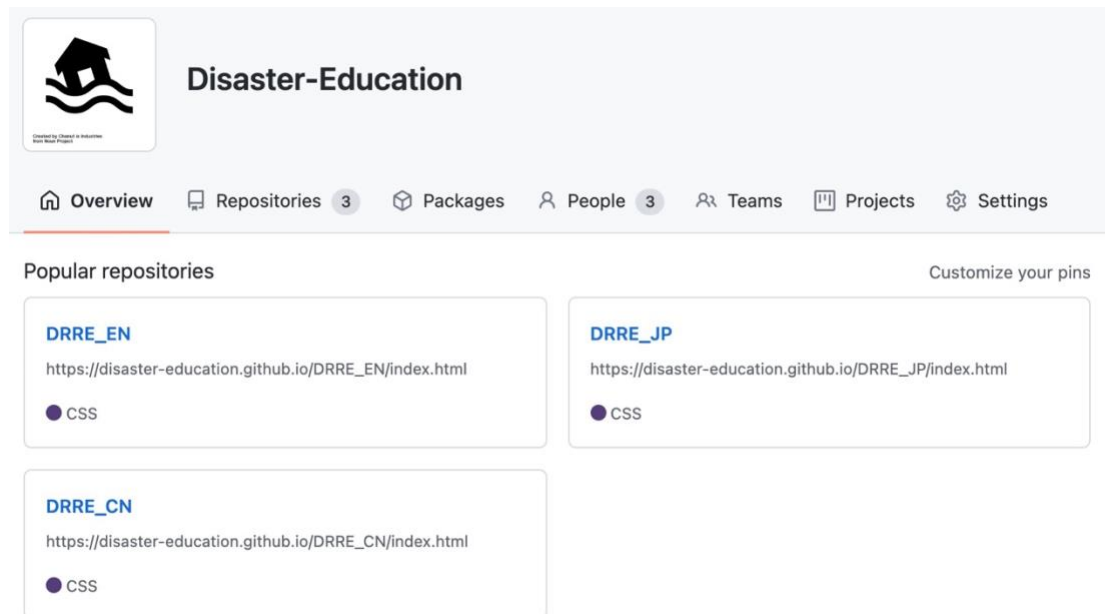


Fig. 4.4. URLs of the Version 1 DRR learning materials on GitHub.

## 4.2 Version 1 implementations

The developed learning materials were used in classes and workshops in Chinese and Japanese high schools and were implemented eight times from 2018 to 2019 (Table 4.1). To ensure consistent performance results, the instructors in all implementations are the same, mostly the author. The total number of attending students was 237, with 153 belonging to junior high schools (7th to 9th grades) and 84 to senior high schools (10th and 11th grades). In terms of gender, 139 were male, 97 were female, and one student chose not to answer. In five of the eight cases, students attending the event were from the same grade and the same school. The other three cases were workshops held at the University of Tokyo, for students from different grades and schools. The cases were grouped into two types according to the case study area (Table 4.1). For Type A, an example of a flood disaster was taken from an area far from the schools. For Type B, an example was taken from an area close to each school.



Table 4.1. Details of schools and participants.

Type	Grade	Case Number	School and Date	N of Students	Gender	
					Male	Female
A	7th to 10th	1	Multiple schools, Japan (Aug. 3rd, 2018)	10		
	7th to 11th	2	Multiple schools, Japan (Aug. 17th, 2018)	32	43	47
	11th	3	Senior high school, Jilin Province, China (Sep. 4th, 2018)	48		
B	9th	4	Junior high school, Jilin Province, China (Feb. 28th, 2019)	31		
	8th	5	Junior high school, Jilin Province, China (Mar. 3rd, 2019)	26		
	8th	6	Junior high school, Kanagawa Prefecture, Japan (May 9th, 2019)	35	96	50
	11th	7	Senior high school, Kanagawa Prefecture, Japan (May 9th, 2019)	16		
A	7th to 11th	8	Multiple schools, Japan (Aug. 17th, 2019)	39*		

Note: \* One student chose not to answer about gender.

For the implementation, course plans for learning DRR were provided using both the constructed online materials and paper hazard map to discuss the effectiveness and feasibility of Web GIS technology in DRR education compared to the traditional and elucidate differences between Chinese and Japanese students. While the plans were somewhat modified depending on the target class, grade, and country, the common aspects were as follows: students in a classroom were divided into several groups, each having several students working together; the intended length of a class was 45–60 min. The Tedoru River was used for cases 1 and 2, the Songhua River for cases 3–5, the Tsurumi River for cases 6 and 7, and the Kinugawa River for case 8. The course consisted of six steps.



Fig. 4.5. Photo of the author teaching the introduction part in China (Photo by Baoxi Song, Sep. 4th, 2018).

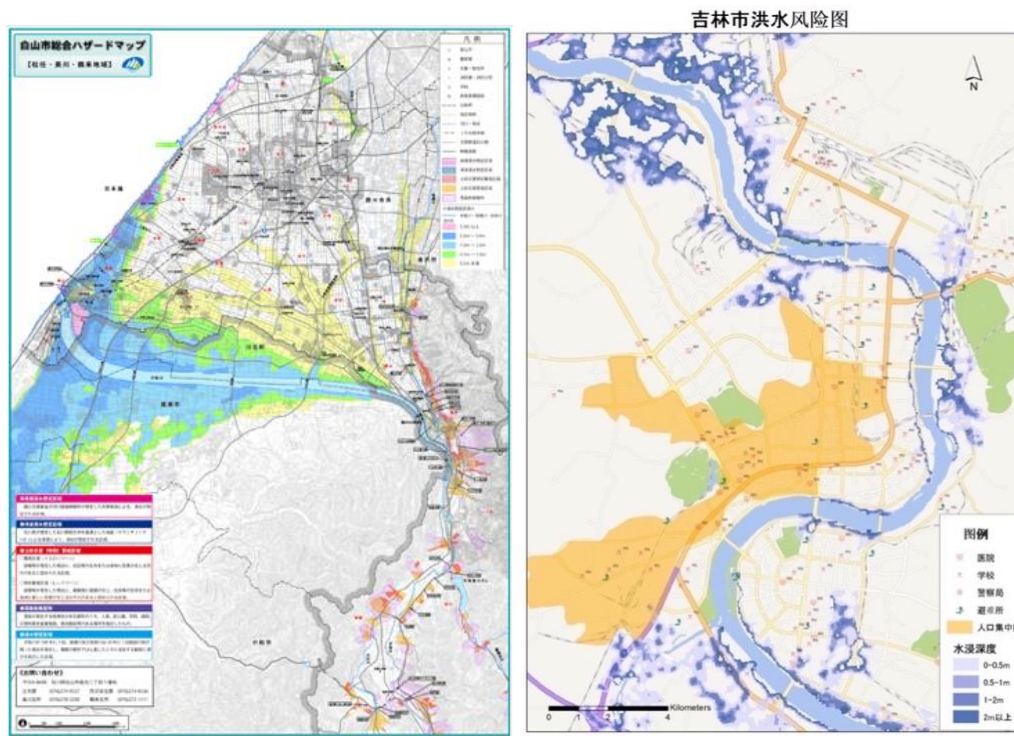
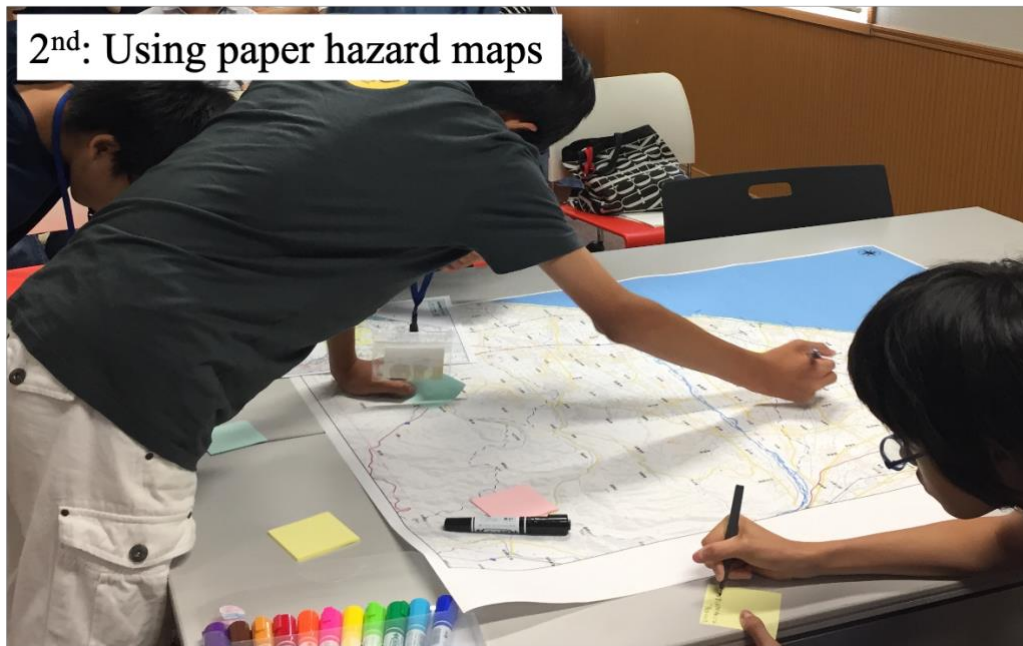


Fig. 4.6. Upper: students using paper hazard maps (Photo by the author, Aug. 3rd, 2018). Lower: Paper hazard maps used in classroom. Lower-left: Hakusan City, Japan (Hakusan City Office 2013). Lower-right: Jilin City, China (Jilin Province Seismological Bureau 2018).



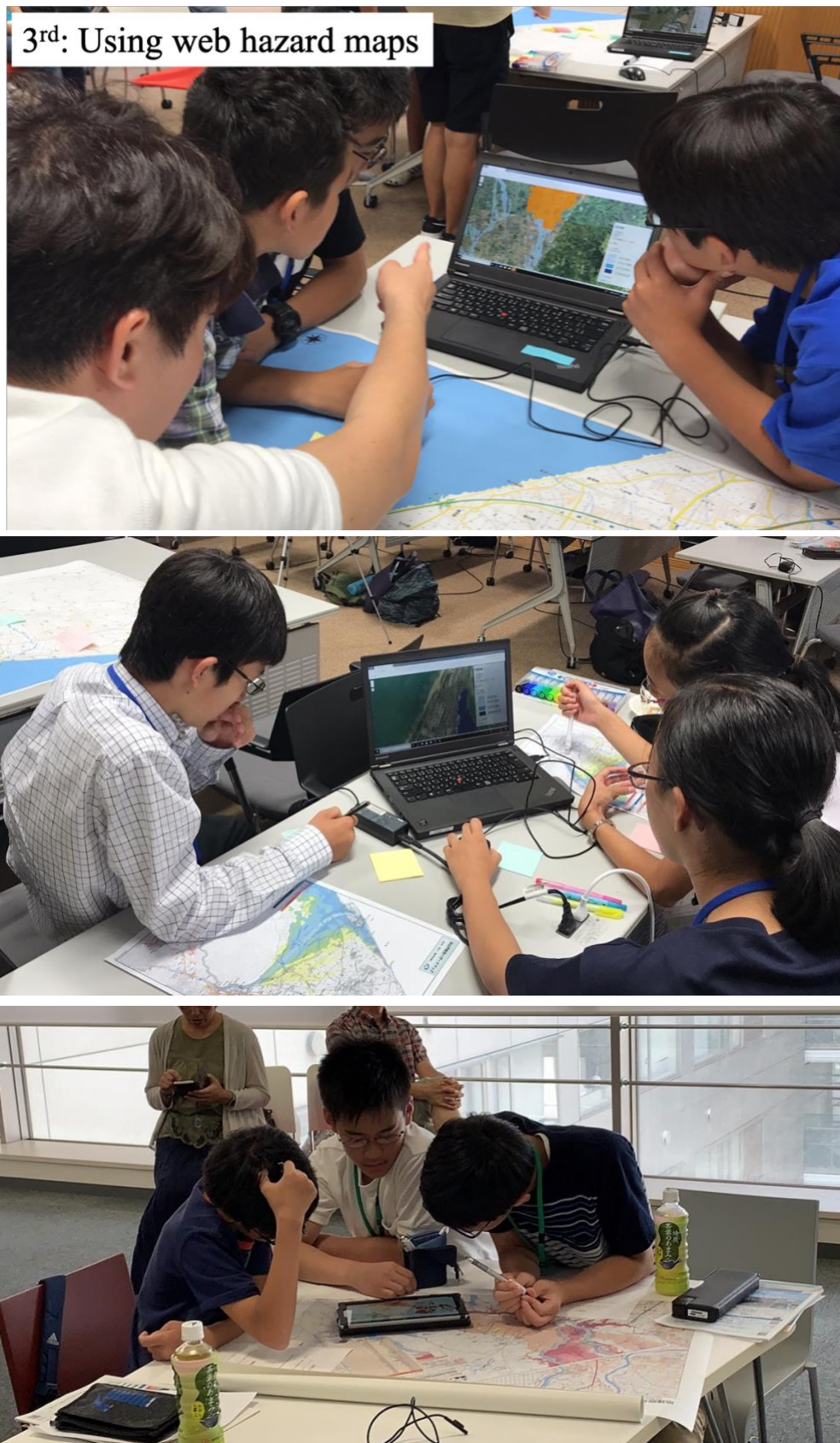


Fig. 4.7. Students using the Version 1 materials (Photos by the author: upper two, Aug. 3<sup>rd</sup>, 2018; lower one, Aug. 17<sup>th</sup>, 2019).

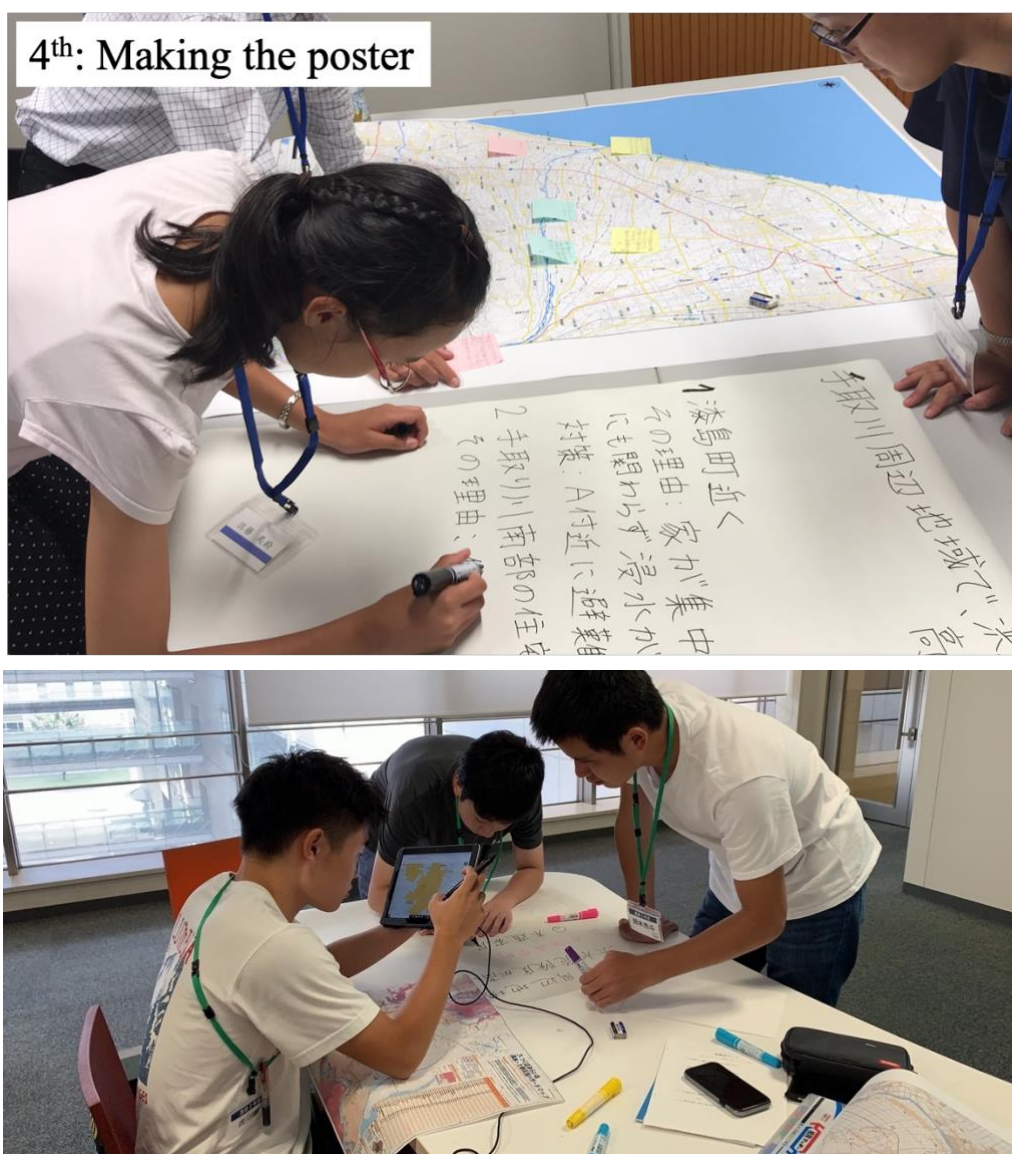


Fig. 4.8. Making a poster (Photos by the author: upper, Aug. 3rd, 2018; lower, Aug. 17th, 2019).



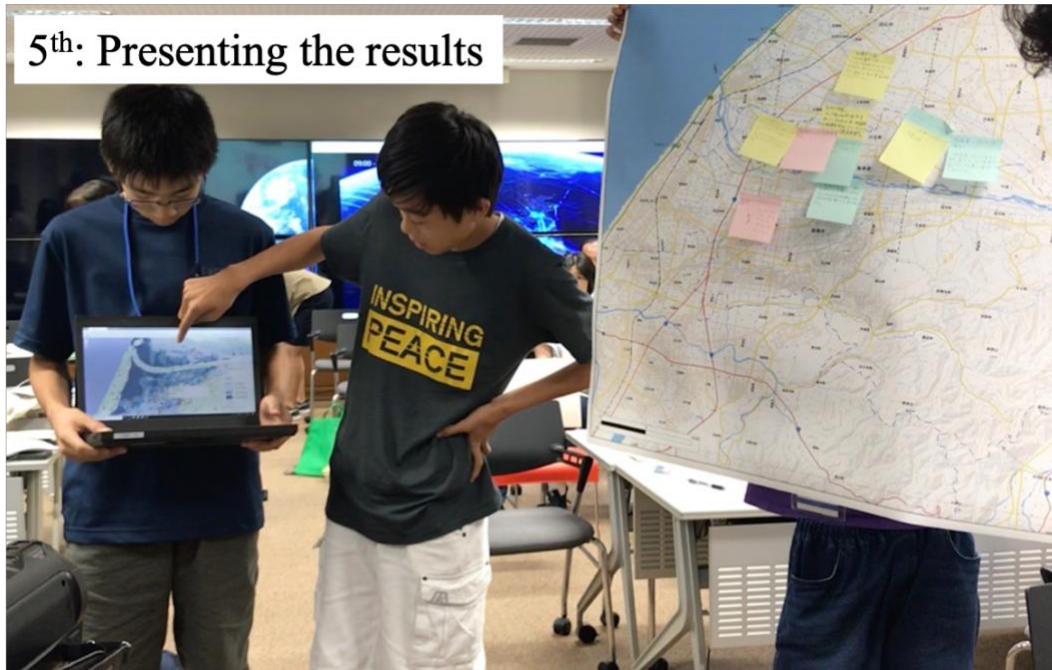


Fig. 4.9. Presenting results (Photo by Takuro Ogura, Aug. 3rd, 2018).

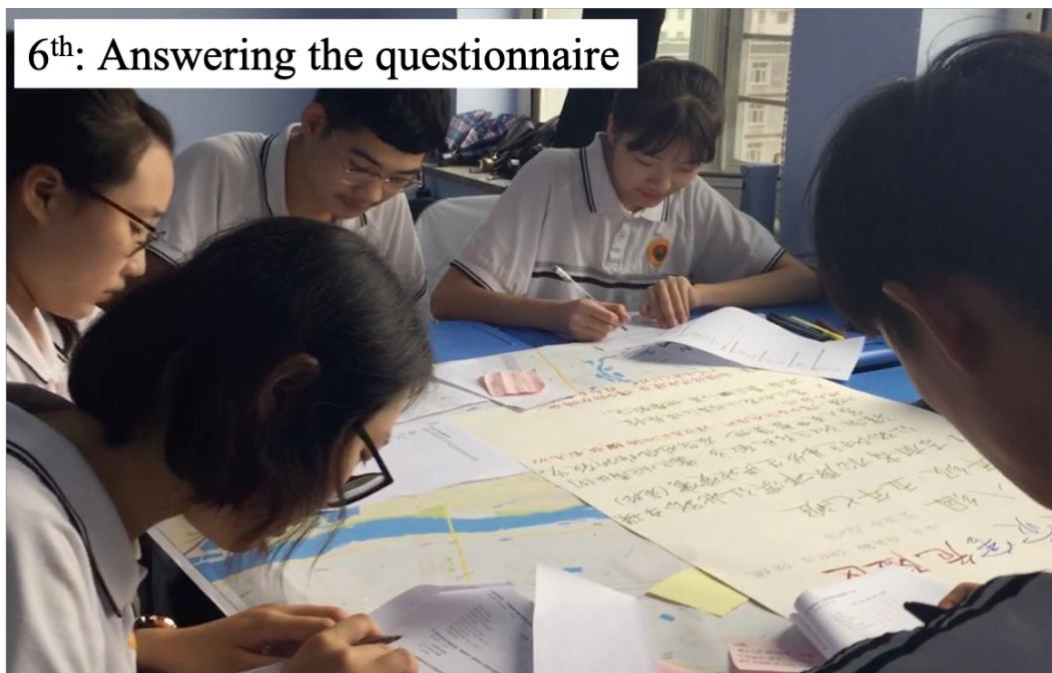


Fig. 4.10. Chinese students fill out questionnaires (Photo by the author, Sep. 4th, 2018).

In the 1st part (Fig. 4.5), the instructor used projected slides for a short lecture about the area selected for subsequent practice, such as topographic features and historical

records of flood disasters. The instructor also talked about the usefulness of hazard maps and the basic concepts of GIS including the visualization of geographical data, overlay of layers, and viewing of property information. Finally, the instructor explained how to use the educational materials we provided for the practice.

In the 2nd part (Fig. 4.6), students visually investigated the target area on a paper hazard map of size A0 and presented their opinions by putting memos on the map using sticky notes of three colors: 1) blue: areas or buildings at high risk; 2) yellow: areas requiring shelters; and 3) red: other concerns. Students gave reasons for 1) and 2) and freely commented on 3).

In the 3rd part (Fig. 4.7), students utilized the web hazard maps with the layer overlay function. They could compare layers, such as the predicted flood inundation areas and DIDs, to identify dangerous areas. Other functions, including map zoom-in and zoom-out, and the display of property boxes, were also usable.

In the 4th part (Fig. 4.8), each group made a poster summarizing the information they obtained from the paper and the web hazard maps, and their opinions about dangerous areas. In the 5th part (Fig. 4.9), a student representing each group presented the results using the poster to all participants, enabling communication among groups, broadening their considerations. In the 6th part (Fig. 4.10), a questionnaire survey was conducted to collect information about the students' understanding and feedback. The results were used to evaluate the comparative educational effectiveness of the DRR materials with the traditional paper hazard maps, and the usefulness of the course plan. The survey was divided into four sections (Table 4.2).

Table 4.2. The survey questionnaire.

Section	Questionnaire items	Answer method	Implementation case
1: General	Gender, grade	Choice	All
2: Web GIS and paper maps comparison	Which hazard map is more informative?	Five-point Likert scale	1–5
	Would you like to use similar web-based DRR educational materials in school curricula?		All
	Impressions of each type of map.	Free text	All
3: Educational effectiveness of Web GIS	Understanding and satisfaction levels of the DRR materials.	Five-point Likert scale	All
	Difficulty in determining the extent of disaster-affected areas.		
	Difficulty in using the educational materials.	Short free text	4–8
	If a river is flooded, is the local primary school safe? Please give a reason.		
4: Overall evaluation	Please evaluate the system used and the course plan, including possible improvements.	Free text	All

The 1st section collected general information about the student's gender and grade.

The 2nd section compared the informativeness of the two types of hazard maps, focusing on the students' opinions about the superiority of web hazard maps, and their willingness to use web-based materials in school curricula, answered using a five-point Likert scale (1 = very low to 5 = very high). As some students could not see the web hazard maps in cases 6 and 7 due to problems with their devices, the following question was avoided: "Which hazard map is more informative?"

The 3rd section evaluated the educational effectiveness and usability of the DRR materials, answered using a five-point Likert scale (1 = very low to 5 = very high). In cases 4 to 8, an additional question asking whether a particular school was safe when a particular river was flooded required the students to explain with reasons.

The 4th section collected students' evaluations about the system used and the course plan, including possible improvements.



## 4.3 Results of Version 1 implementations

### 4.3.1 Educational effectiveness of paper and web hazard maps

One hundred and eighty students answered the question “Which hazard map is more informative?” (Fig. 4.11); 77% thought web hazard maps were more informative. Some of them commented that such maps were helpful for obtaining more information with one click, such as the distribution of densely populated areas, zooming in and out of a layer, and overlying layers for optimal viewing. In all, 10% preferred paper hazard maps. Some of them commented that viewing the computer screen tired their eyes, personal annotations on maps using sticky notes were impossible, people with poor computer skills can understand things better with paper hazard maps, and the required network connection may be unavailable during a disaster.

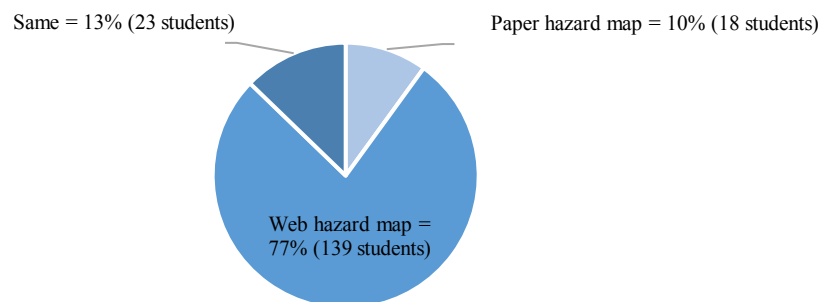


Fig. 4.11. Answers to the question “Which hazard map is more informative?” (n = 180).

A total of 101 students evaluated the DRR materials and outlined expected improvements. The comments were classified and are summarized in Table 4.3, with the number of students in brackets. Overall, the students had positive impressions of the web-based materials. However, they also expected some improvements, especially with the addition of more functions and materials.

Table 4.3. Students' evaluation of the materials and expected improvements.

Evaluation	Expected improvements
• Easy to use (not tedious) (22)	• Adding more detailed information about locations with names (7)
• Important functions are provided (11)	• Providing maps of other places (4)
• Disaster affected areas can be identified (9)	• Adding 3D terrain view (3)
• Proper evacuation can be planned (4)	• Adding more geographical layers (3)
• The importance of geographical knowledge can be understood (3)	• Modifying the system for use by the public (3)
• Wide range of map viewing (2)	• Improving map-loading speed (2)
• Can help people escape when the danger increases (2)	• Adding more relevant items, such as photographs of the surrounding landscape (2)

#### 4.3.2 Usability of the DRR learning materials

Besides most students finding the contents easy to learn, about 75% were willing to use web-based materials in school lessons (Fig. 4.12).

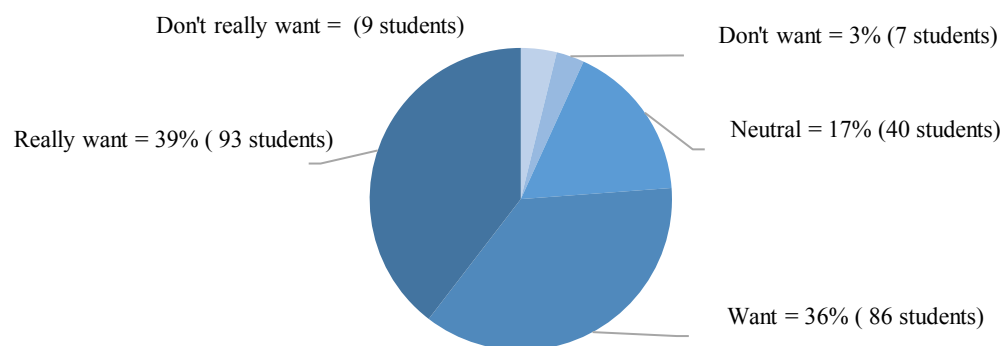


Fig. 4.12. Student views on the use of DRR learning materials in school classrooms.

Although no serious technical problems related to computers and networks occurred when students used the DRR materials, the evaluation of the materials, such as usefulness for interpreting hazard risks, was different among students. Among 235 students, 51.5% thought that the DRR materials were easy or very easy to use, 24.7% thought they were difficult or very difficult, and 23.8% found them neither easy nor difficult (Fig. 4.13).

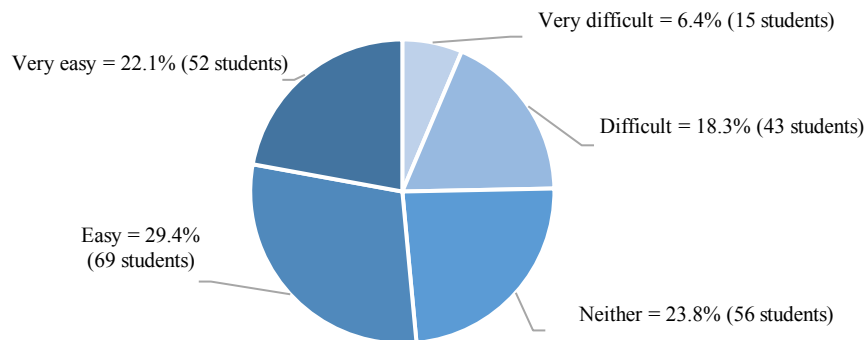


Fig. 4.13. Difficulty in using the DRR learning materials (n = 235).

An independent t-test was used to check whether the evaluations were influenced by grade and gender (Tables 4.4 and 4.5), with 153 junior high school students and 84 senior high school students, and 139 males and 97 females. Some students were removed from the analysis for not answering. The results did not show any evaluative difference between grades and genders ( $p > 0.05$ ).

Table 4.4. Differences in the evaluated usability of the DRR materials between junior and senior high school students.

School	N	Mean (SD)	t (df = 233)	p-value (two-tailed)
Junior high schools	151	3.94 (1.021)	-0.982	0.327
Senior high schools	84	3.81 (0.898)		

Table 4.5. Differences in the evaluated usability of the DRR materials between males and females.

Gender	N	Mean (SD)	t (df = 232)	p-value (two-tailed)
Male	139	3.96 (1.082)	1.321	0.188
Female	96	3.80 (0.803)		

This study also investigated whether answers to the other questions were influenced by grade. The results showed no significant differences according to grades, except for the understanding of GIS. Table 4.6 indicates that junior high school students have a

lower understanding of GIS than senior high school students, and the difference is significant ( $p < 0.05$ ).

Table 4.6. Differences in the understanding of GIS between junior and senior high school students.

School	N	Mean (SD)	t (df = 228)	p-value (two-tailed)
Junior high schools	147	3.18 (1.133)	-2.355	0.019
Senior high schools	83	3.53 (1.016)		

The location of the target areas apparently influenced the evaluation of the difficulty in understanding hazard risks. Figure 4.14 and Table 4.7 show statistically significant differences between the two types: whether the target areas are close or far from the schools ( $p < 0.05$ ). When the areas were close to the schools (Type B), the students found it more difficult to determine dangerous areas.

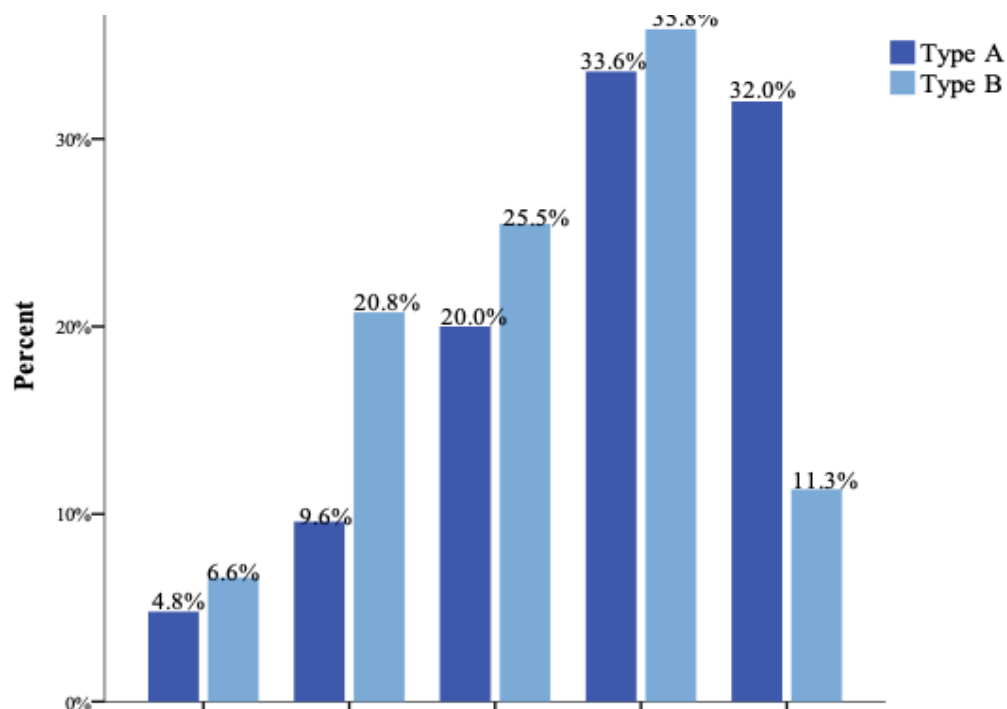


Fig. 4.14. Difficulty in determining the extent of dangerous areas using maps.

Table 4.7. Difficulty in determining the extent of dangerous areas based on their proximity to schools.

Type	N	Mean (SD)	t (df = 229)	p-value (two-tailed)
A	125	3.78 (1.140)	3.621	0.00
B	106	3.25 (1.111)		

A quiz about the safety of a school, introduced from case 4, was answered by 128 students. Figure 4.15 shows that about 84% answered correctly (the school is safe), giving reasons based on the school's location, terrain characteristics, the distance from the river, the expected depth of floodwater, and the capacity of shelters. About 16% answered incorrectly (the school is not safe) and expressed concern about the capacity of the shelters and the accuracy of flood prediction on the hazard maps.

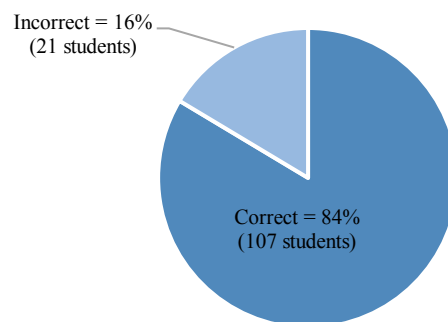


Fig. 4.15. Accuracy of answers to the quiz about the safety of a school (n = 128).

## 4.4 Discussion

School education is one of the most effective ways to make people aware of DRR at a young age (Wahyuningtyas et al. 2020). Therefore, it is important to establish effective DRR education in schools. The results indicated that most students thought that DRR learning using Web GIS technology needs to be introduced to school education and that web hazard maps are more useful than paper hazard maps in terms of information abundance and accuracy. Geospatial technologies, such as Web GIS,

promote spatial thinking skills of students and enhance content knowledge (Goldstein and Alibrandi 2013; Kulo and Bodzin 2011). Sari et al. (2020) also suggested better efficiency of web hazard maps over paper hazard maps.

Some higher education institutions around the world have created web mapping systems for students in each country (Baker 2015), such as MyFireWatch (Haimes et al. 2015), SIMBAK (Ariyanti et al. 2018), and InaRisk Personal (Sari et al. 2020). The National Disaster Management Agency of the Indonesian government developed a mobile application called InaRisk Personal to help citizens become more aware of disasters. Sari et al. (2020) assessed whether this map-based application is an effective disaster learning tool for senior high school students. The results indicated that the application can increase students' map readability and satisfaction, and they prefer using it to printed maps. However, they tend to have technical issues, such as a limited number of compatible devices. The educational materials developed for this thesis can be used with various types of devices, including PCs, smartphones, and tablets, without installing additional applications. Although network speed may still affect the efficiency of online learning, the materials are relatively simple and light, and usable with a small number of operations. During the implementation at multiple Chinese and Japanese schools with different network conditions, marked technical problems related to the speed of the Internet did not occur, indicating the high usability of the materials. It is important to overcome technical issues related to devices and networks for successful education using Web GIS.

Although Web GIS technologies facilitate education, paper maps are still widely used and held in high regard (Hagemeier-Klose and Wagner 2009; Hurst and Clough 2013). The survey also indicated that besides being challenging to some people, digital devices may be visually tiresome. Collins (2018) pointed out that both analog and digital media should be utilized to teach students different spatial thinking skills. Therefore, although web maps seem to be a priority, using them along with paper hazard maps can provide the best DRR education.

The survey showed that many students preferred web maps, and almost all students could conduct the requested operations, except that junior high school students had

more difficulties in understanding GIS than senior high school students. However, the students had different opinions about the usability of the materials. As the grades and gender of the students did not affect the difference, other aspects, such as the frequency of past usage of digital devices and the Internet, seemed to have played important roles. Students' efficient use of the web hazard maps does not confirm their high spatial thinking abilities. Indeed, some students noted the difficulty to understand the process of determination of the disaster-affected areas. Therefore, both web hazard maps and education to develop spatial thinking skills should be introduced in schools.

A somewhat unexpected result of this study showed that a familiar case study area made it harder for the students to understand the distribution of hazard risk, suggesting that more knowledge and information about a case study area made students view things from a different perspective, leading to complex thinking and difficulties with judgment. A related problem is that many students were often unaware of natural disasters devastating their regions several decades earlier (Vitek and Berta 1982). Moreover, disaster-related books for students often provide typical and easily understandable examples from a country, whereas local examples may be more complicated and disconnected (Hsu et al. 2018).

Everyone should understand the hazard risks around their place of residence. Therefore, Hermann (1996) suggested that instead of relying on examples taken from distant places, local cases should be used in the classroom to teach geography. Hagemeyer-Klose and Wagner (2009) also stated that information tools have to create emotional empathy by referring to the local situation, supporting the use of local cases in DRRE. Accordingly, the education and popularization of local disasters, including historical cases, need to be advocated, and teachers and students in classrooms should work together to understand future disaster risks in local areas based on hazard maps and additional information.

However, the most effective DRRE needs to have broad applicability, and effective evacuation is required even when someone is traveling or has just moved to a new place. Therefore, it seems better to use both local and other cases for DRRE. In the past, each

case study on DRRE using Web GIS focused on only one country. It is necessary to conduct research encompassing more than one country as our study does.

The survey also revealed that students expected the inclusion of more functions and items in the educational materials. Poplin (2015) suggested that accomplishing more tasks using web maps leads to better learning. As noted above, simple and concise educational materials also deal better with technical constraints, such as network speed. Therefore, the addition of more functions and items should be addressed without losing the advantages of light systems, and this requires updating technical knowledge frequently. For example, 3D printed models and 3D viewing based on virtual reality have become more affordable and have the potential to be utilized more in schools, including DRR education (Shaw 2020).



本博士論文中、5章と6章（pp.56-106）の部分は、International Journal of Disaster Risk Reduction に掲載等の形で刊行される予定であるため、学位授与日から3年間インターネットでの公表をすることができません。

## Chapter 7 Conclusions

This study constructed two sets of DRR learning materials using Web GIS technology, an online map server, HTML, and CSS, and implemented them in the classrooms of several high schools in China and Japan. The Version 1 implementations were intended to compare the effectiveness of web hazard maps with that of paper hazard maps in DRR education. The Version 2 implementations were optimized based on the students' suggestions, using the pretest and posttest results to analyze the factors that affect students' learning using web hazard maps.

Most of the surveyed students thought that web hazard maps could provide more abundant and accurate information, showing that DRR education using Web GIS technologies is valuable. However, while some students felt that DRR educational materials need to be introduced to school education, some others felt that electronic maps were disadvantageous. Therefore, implementation of both paper and web hazard maps is encouraged in DRR education. This study also suggested that web hazard maps for school education should have multiple easy-to-use functions. Assigning tasks to familiarize students with these functions is useful.

It was found that increasing the daily usage of web hazard maps can help students learn DRR knowledge effectively. The students experienced more difficulties in identifying dangerous areas if disaster cases deal with their residential areas and the surroundings. As using typical disaster cases from distant places has been common in education, students can employ their knowledge from textbooks and other sources more easily. More localized knowledge may let people think more complicatedly, leading to ineffective responses to future disasters. This aspect has seldom been indicated but deserves serious attention to realize effective DRR in local areas. In this sense, DRR education should combine both local and national/international cases. The observations of this study contribute to the development of DRR education not only in China and Japan but also in other countries.

This study has identified that students have uneven knowledge about various disaster types, because only some types are taught widely. However, according to this survey, the primary sources of disaster knowledge for students are computers, smartphones, televisions, radio, and schools. Modern communication tools provide a variety of DRR knowledge that cannot be fully conveyed to students during the limited school time. Therefore, DRR learning in schools should be combined with the latest technology related to media. For the successful educational application of the web hazard maps, developers should also consider network accessibility, interface simplicity, and loading speed.

One of the major findings from this work was that students' learning results improved after using the constructed DRR learning materials. This observation is common to the two versions of implementations and the two countries, suggesting the broader applicability of the constructed materials and curricula. The pretest scores indicate that the high frequency of electronic map usage in students' daily lives has short-term adverse effects on their spatial awareness. However, the frequency showed a positive correlation with the learning effects of the DRRE materials. Students' daily attention to disaster prevention and mitigation-related contents, students' ability to use electronic products, and the previous usage of web hazard maps did not affect the pretest scores. However, like above, all of them were positively correlated with the learning effects, meaning that both previous experiences and attention and the use of the DRRE materials are needed to maximize the DRR knowledge and skills of students. Among the three implementation methods, onsite implementations led to the most noticeable improvement because face-to-face interactions are effective even when online educational materials are used.

Gender hardly affects students' learning of DRR materials. Students' ability to use electronic products only affects the learning of GIS-related contents, not DRR-related knowledge. Previous usage of web hazard maps influences the understanding of DRR-related content. In addition, the frequency of using electronic maps and students' attention to disaster prevention and mitigation in daily life affect the learning of the

DRR-related contents and other relevant sections. Increasing the daily usage of digital maps, including web hazard maps help students learn various DRR knowledge.

Students' understanding and satisfaction during the two versions of implementations were high, and they were higher during the Version 2 implementations. This suggests that the improvements made for Version 2 are meaningful for DRR education. However, the oral explanation was more detailed during the Version 1 implementations because the explanatory web pages were less developed, which compensated for the limited content on the web. This confirms that even if the materials are available online, onsite explanations by a teacher help students understand essential elements. Furthermore, if several students shared one device, it significantly reduced the total number of visits to the online DRR learning materials, enabling fast browsing and handling. This aspect should be considered if the number of equipment or the network speed is limited.

In previous research on educational materials and curriculum development, educational effectiveness was usually examined in one country using a single set of materials and a curriculum, and implementations typically involved only dozens of students in one or a few schools. This study investigated the educational effectiveness of newly developed materials and curricula through the application to 526 students in more than ten schools in two countries, using two versions of materials and curricula. Therefore, this study is considered more comprehensive than previous studies and hence provided various insights into the effectiveness of DRR education on a statistical basis.

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## Appendix 1

Photos and information of students using the learning materials during the Version 1 implementations.




Photos	Information
	Photo by the author Students from multiple schools, Japan Aug. 3rd, 2018
	Photo by the author Students from multiple schools, Japan Aug. 17th, 2018
	Photo by the author Senior high school, Jilin Province, China Sep. 4th, 2018





Photo by the author  
Junior high school, Jilin Province, China  
Feb. 28th, 2019



Photo by the author  
Junior high school, Kanagawa Prefecture,  
Japan  
May 9th, 2019



Students use computers to browse the  
materials  
Photo by the author  
Senior high school, Kanagawa Prefecture,  
Japan  
May 9th, 2019



Students using smartphones to browse the materials)

Photo by the author

Senior high school, Kanagawa Prefecture,  
Japan

May 9th, 2019

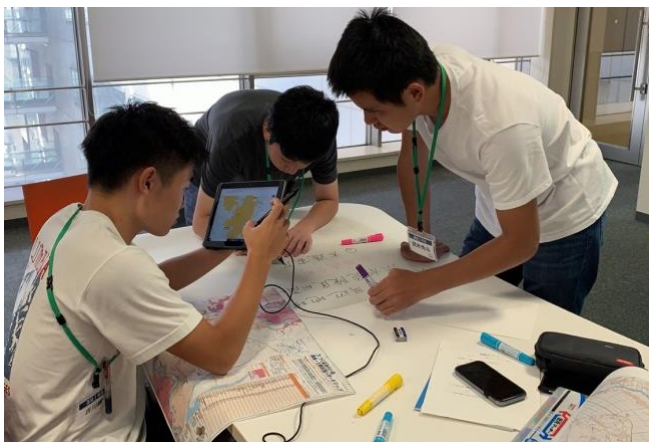


Photo by the author

Students from multiple schools, Japan

Aug. 17th, 2019

## Appendix 2

Photos and information of students using the learning materials during the Version 2 implementations.




Photo	Information
	<p>Screenshot by students Senior high school, Inner Mongolia, China Mar. 9th, 2020</p>
	<p>Photo by the author Senior high school, Liaoning Province, China Mar. 30th, 2020</p>
	<p>Scene from a video capture by Baoxi Song Senior high school, Jilin Province, China May 20th, 2021</p>





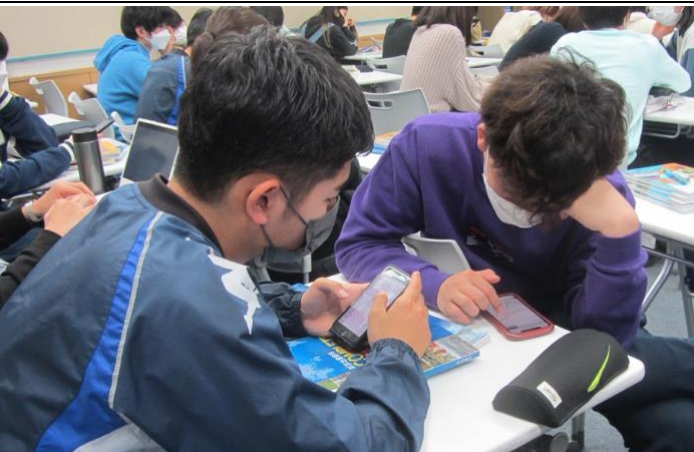
Photo by Baoxi Song  
Senior high school, Jilin Province,  
China  
May 24th, 2021



Photo by Baoxi Song  
Senior high school, Inner Mongolia,  
China  
May 27th, 2021



Students using tablet to browse the  
materials)  
Photo by Yosuke Nakamura  
Senior high school, Kanagawa  
Prefecture, Japan  
Feb. 24th, 2022



Students using smartphones to browse  
the materials)  
Photo by Yosuke Nakamura  
Senior high school, Kanagawa  
Prefecture, Japan  
Feb. 24th, 2022