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

Jiali Song [a, c], Hiroyuki Yamauchi [b], Takashi Oguchi [c], Takuro Ogura [d], Yosuke Nakamura [e], Jipeng Wang [a, *]

[a] *School of Civil Engineering, Shandong University, 17922 Jingshi Road, Jinan 250061, China*

[b] *Graduate School of Frontier Sciences, The University of Tokyo, Kashiwanoha 5-1-5, Kashiwa, 277-0882, Japan*

[c] *Center for Spatial Information Science, The University of Tokyo, Kashiwanoha 5-1-5, Kashiwa, 277-0882, Japan*

[d] *Faculty of Life and Environmental Sciences, University of Tsukuba, Tennodai 1-1-1, Tsukuba, 305-8577, Japan*

[e] *Kumon Kokusai Gakuen Junior Senior High School, 777 Kosuzumecho, Yokohama, Kanagawa, 244-0004, Japan*

All correspondence should be addressed to:

J. Wang, School of Civil Engineering, Shandong University, 17922 Jingshi Road, Jinan 250061, China.

E-mail: ji-peng.wang@sdu.edu.cn

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Abstract

Disaster risk reduction education (DRRE) is a strategy to mitigate the harmful effects of disasters. The implementation of DRRE in schools is on the rise, and Web GIS technology in DRRE is becoming increasingly prevalent. However, little knowledge exists about whether students can improve their understanding of disaster risk reduction (DRR) through Web GIS technology and which factors affect their learning of web hazard maps. This study has provided materials and curricula for DRR education in Chinese and Japanese high schools, and utilized them eight times in the classroom between 2020 and 2022. These classes had three forms of implementation due to the COVID-19 pandemic: online, onsite, and online-onsite mixed. The students first 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. Most students show improved results after using the digital DRR materials. It is pronounced for the onsite implementations, whereas the online-onsite mixed implementation was less effective. The pretest scores for the implementations using local disaster cases are low, but the subsequent improvement is significant. The ability of students to utilize electronic devices affects the learning of GIS-related content rather than other aspects. The frequency of daily usage of online maps and daily attention to disaster prevention and mitigation affect learning the entire materials. Increasing the use of online hazard maps is a key to realizing social DRR.

*Keywords:* Disaster risk reduction education, Web GIS, High school education, Electronic learning, Digital materials

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## 1. Introduction

Annual disaster losses have been observed between ~0.1% and ~0.5% of global GDP, and much larger loss potentials currently exist (Pielke 2019). 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). Disaster risk reduction education (DRRE) is also a way to reduce the negative results of disasters (La Longa et al. 2012; Mulyasari et al. 2015). Muñoz et al. (2020) indicate that changes in political administration will halt, interrupt or delay progress if the authorities do not prioritize DRR in education.

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).

Digital learning has evolved from a supplementary teaching aid to an essential component of contemporary pedagogy in the current educational landscape. It provides students with alternative learning pathways, and increased learning motivation (Segrave and Holt 2003; Soroka 2020; Mishra et al. 2020). In addition, students today are familiar with mobile technologies from an early age and can work with tablets, computers, and smartphones. 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.

Many countries have incorporated Web GIS technology into DRRE. 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 apply 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) assessed 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

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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 of the developed education program. However, the improvement of students after implementing DRR education still needs to be evaluated. Li et al. (2022) used the 2021 Zhengzhou torrential rain as a disaster teaching case in China. 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.

Shirai et al. (2017) found that electronic maps are suitable for creating hazard maps and help students comprehend hazards. Paper maps have been the essential medium for depicting and understanding geographic information for centuries. Although numerous studies in recent years have demonstrated the benefits of digital maps in DRR education, few have compared the efficacy of web-based maps and paper maps in disaster mitigation education. Song et al. (2022) created online DRR educational materials for Japanese and Chinese high school students using Web GIS and geospatial data and compared them with paper hazard maps. According to the surveys, students think that web maps can provide plentiful and accurate information that needs to be included in DRR education. However, some students noted the difficulty in understanding the process of determination of the disaster-affected areas. During the investigation, it was found that the frequency of past use of digital devices and the Internet appeared to play a significant influence in learning DRR knowledge using web hazard maps. Only a few 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.

Therefore, this study improved the DRRE materials based on the previous research by Song et al. (2022) and investigates the factors influencing students' use of electronic maps to learn DRR knowledge and how much the materials improve students` understanding of electronic maps and DRR information. The research findings of Song et al. (2022) laid the groundwork for the research in this area. The improvement and in-depth examination in this study is of great importance for increasing educators' and policymakers' awareness and confidence in the use of electronic maps in DRR education. They can better understand the benefits and limitations of electronic maps in DRR education and take the necessary steps to strengthen and promote their application in the classroom. In addition, this study also improves 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.

## 2. DRR learning materials and curriculum

The constructed DRRE materials follow the logical structure shown in Fig. 1. A responsive educational system was built 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 the Web GIS tools with the functionality of GIS operations using a simple web browser. The entire website was hosted on Alibaba Cloud, China's largest cloud service provider.

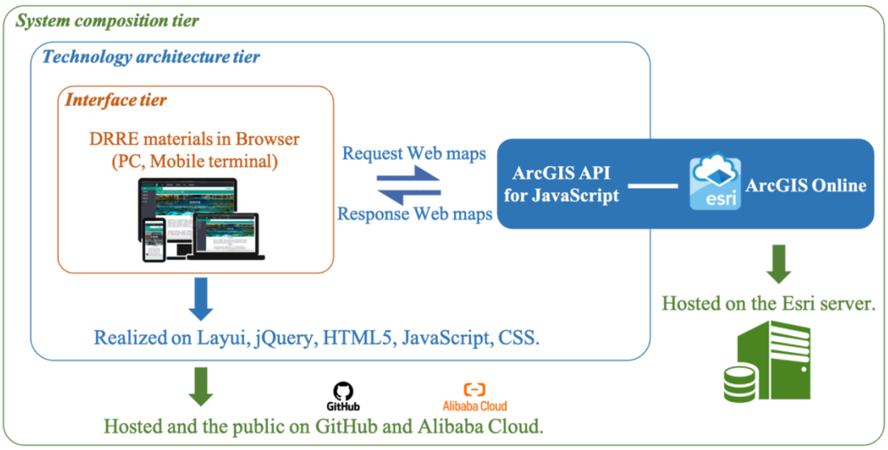


Fig. 1. Logical structure of the DRRE materials.

DRR can be systematically infused in to education by elaborating its full scope and sequence (Petal 2008), and general environmental education should be incorporated into disaster education (Tanaka 2005). Therefore, students need to learn the basics of maps, GIS, and the natural environment before learning DRR using hazard maps. The map section mainly introduces some basic knowledge of maps including their concept, regulation, classification, and form (digital and analog). The section about GIS introduces some fundamental knowledge, technology, and utilization including map creation. The natural environment section covers topography, climate, rivers, land use, and natural disasters. The DRR section explains the use of web hazard maps to learn various types of DRR. It includes the concept of hazard maps and DRR in relation to earthquakes, tsunamis, sediment disasters, volcanic disasters, wind and snow disasters, and floods.

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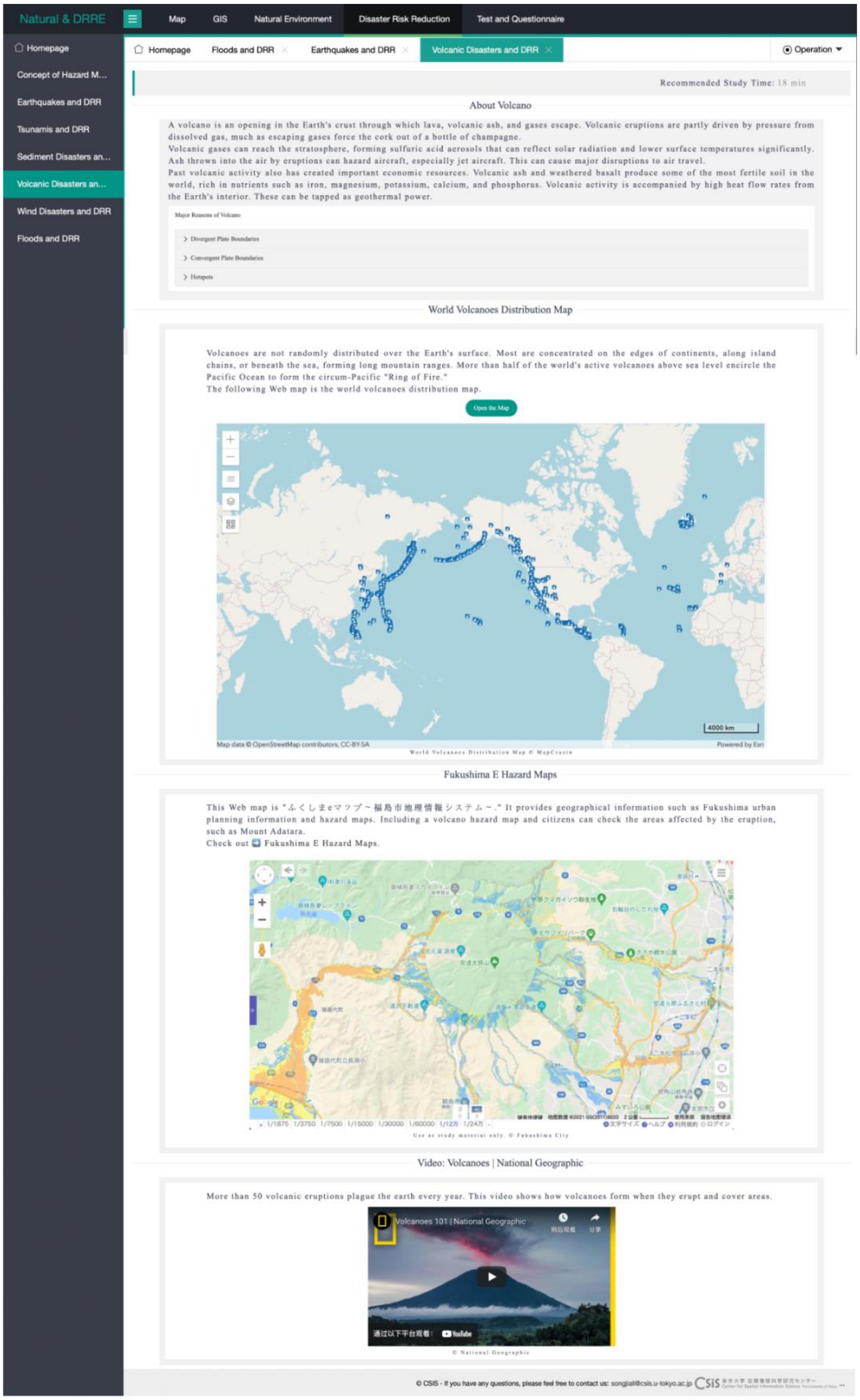


Fig. 2. Interface of the DRRE materials. This figure translates Chinese or Japanese text to English from the original page. (The material URLs are http://srdm.net.cn/, developed by the first author.)

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Figure 2 shows the interface of the DRRE materials with the main menu bar at the top of the page. The bar includes the titles of the four sections, i.e., Maps, GIS, Natural environment, and DRR, with another item entitled "Tests and questionnaires". A user first selects one of these items. A deputy menu bar on the left side of the page displays the sub-menus corresponding to the contents of the selected element. Users can click on the items in the deputy menu bar to open the corresponding sub-page, which is displayed in the middle part of the materials. The tab bar below the main menu bar shows different sub-pages. If the user clicks on another item in the deputy menu bar, a new sub-page with a tab bar will appear while the previous sub-page is retained behind. A quiz related to the contents of each sub-page is shown at the bottom of the sub-page.

The materials utilize a local server provided by the Center for Spatial Information Science at the University of Tokyo, due to the increased number of access devices during implementations. Users access this server through the domain name in Alibaba Cloud. The number of possible HTTP (s) connections is 240/min, and that of TCP connections is 30.

## 3. Implementations

The materials and curriculum were used eight times in Chinese and Japanese high school classes from 2020 to 2022 (Table 1). They leverage three forms of implementation during the COVID-19 pandemic: online, onsite, and online-onsite mixed. The online and onsite forms were implemented multiple times for students in Chinese secondary schools. The online-onsite mixed form, in which students are in classrooms but the implementers teach through conference software, has been implemented in four classes in Japanese high schools. The number of attended students was 526, with 226 online, 238 onsite, and 62 online-onsite mixed. In terms of gender, 238 were male, and 288 were female.

DingTalk was used during the implementations in China. It is a communication and collaboration platform developed by Alibaba Group. After coronavirus cases surged in China, DingTalk's new features for schools include live-streamed classes for up to 300 students and online testing and grading features (Li 2020). Most schools in China have been using it for online education. Zoom, another video conferencing tool, was used for the implementation in Japan. Many government agencies, schools, and non-profit organizations have chosen it for online lectures, meetings, webinars, etc. (Serhan 2020). It has been widespread in Japan since the beginning of the pandemic.

Table 1. Schools and participants of the implementations.

| Type | Grade | School and Date | N of Students | Gender | |
|---|---|---|---|---|---|
| | | | | Male | Female |
| Online | 10th | Senior high school, Inner Mongolia, China (Mar. 9th, 2020) | 52[a] | 238 | 288 |
| | 11th | Senior high school, Inner Mongolia, China (Mar. 13rd, 2020) | 31 | | |
| | 10th | Senior high school, Liaoning Province, China (Mar. 20th, 2020) | 64[a] | | |
| | 10th | Senior high school, Liaoning Province, China (Mar. 30th, 2020) | 79[a] | | |

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| | | | |
|---|---|---|---|
| Onsite | 11th | Senior high school, Jilin Province, China (May 20th, 2021) | 99[a] |
| | 10th | Senior high school, Jilin Province, China (May 24th, 2021) | 42 |
| | 11th | Senior high school, Inner Mongolia, China (May 27th, 2021) | 97[a] |
| Online-onsite mixed | 11th | Senior high school, Kanagawa Prefecture, Japan (Feb. 24th, 2022) | 62[b] |

Note: [a] Implemented in two classes.
[b] Implemented in four classes.

Although curriculum details were modified depending on the target class and country, the common aspects were as follows. Each student has one electronic device to use the learning materials. At the beginning of the class, students took a pretest. Then they studied the material and answered quizzes on each tab page. At the end of the class, students answered a posttest and a questionnaire. The intended length of a single class was 90-110 min. However, the onsite implementation in China took two class hours, whereas implementations in Japan were shortened to 50 minutes due to the epidemic. The curriculum consisted of three procedures:

The first procedure: A pretest is conducted to evaluate the students' knowledge. Then 30 minutes are spent to explain the contents displayed through the main and deputy menu bars of the DRRE materials, and how to use the web hazard maps on each sub-page. The instructors share the screen to demonstrate the use of learning materials during the online implementation. The onsite implementation uses a projected screen to introduce the usage of the materials.

The second procedure: Students freely use the DRRE materials, during which the school teacher and the author help students solve some problems and answer questions. Most students use mobile phones to participate in the online implementation. Fig. 3 (a) shows screen captures sent from Chinese students while they were learning how to operate the materials. Fig. 3 (b) shows two photos of the onsite implementations. Students utilized equipment in a computer room, available in most high schools in China. In China, the use of smartphones in schools is usually not allowed, so unlike online implementations, smartphones were seldom used during onsite implementations. Fig. 3 (c) shows photos of the online-onsite mixed implementation in Japan. The author taught online, and the school teacher assisted onsite. Many students used smartphones, which was allowed in the Japanese high school. Some students who did not have smartphones used tablets provided by the school.

The third procedure: Students answered a posttest, and the results were compared to those of the pretest. Finally, students were asked to fill out a questionnaire concerning their perceptions of the materials and the curriculum and other information about students.

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Fig. 3. Screen captures and photos of three implementation forms in China and Japan. (Photos taken by authors; the material URLs used in the Figure 3a are http://srdm.net.cn/, developed by the first author.)

Among the possible experimental research designs (Fraenkel et al. 1993; QuestionPro 2022), the pretest-posttest design is prevalent in educational and social science research (Kim and Willson 2010). This method can validate the experiment in the preliminary research phase and tell the researchers how their intervention will affect the study (VOXCO 2022). Therefore, a pretest and a posttest evaluate the learning outcomes of students. The questions in these tests were produced based on questions asked in Chinese high school geography textbooks. Some high school geography teachers who examined the test questions said they taught some of the contents but not all.

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Pretest questions consist of five parts. The first part is the description of the name and gender. The second part gives two basic questions about maps. The third part asks about GIS and related technologies. The fourth part asks questions about the natural environment, such as topography and rivers in China. The fifth part gives questions about the usage of web hazard maps and disaster-related questions. The contents of the posttest are similar to those of the pretest, but somewhat different in most cases, and most questions in the posttest are a bit more difficult than those in the pretest. Due to the time constraint of the implementation in Japan with a shorter class hour, it was necessary to shorten the time for both the pretest and posttest. Therefore, the tests in Japan only consist of the first and fifth parts.

## 4. Results

The implementations collected 526 valid test results and questionnaires. A preliminary analysis of the obtained data indicated that none of the data are normally distributed. Therefore, the non-parametric tests were used in the analysis because of suitability for data with a non-normal distribution (Pappas and Depuy 2004).

### *4.1 General information about DRR learning*

Figure 4 shows the frequency of computer and smartphone usage by the students. The frequency of computer usage is low; only 14.8% use computers almost every day, and 25.9% about 1-3 times a week. However, 75.1% use smartphones almost dayly, and 1-3 times a week also account for 14.1%.

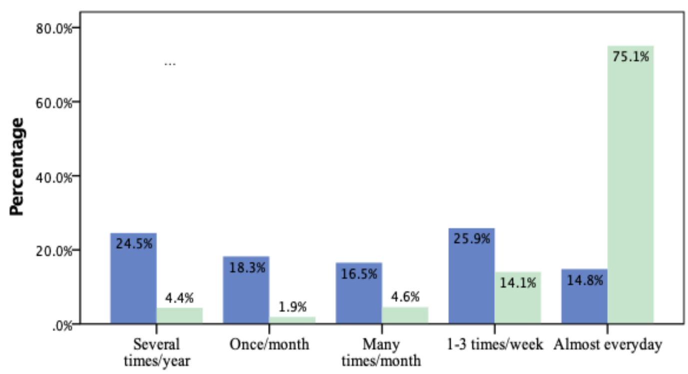


Fig. 4. Frequency of computer and smartphone usage of students.

Previous surveys indicated that students obtain disaster knowledge from different sources, including various types of school education, extracurricular reading of magazines, television or radio programs, computers, and smartphones (Zhu and Zhang 2017). Therefore, such items were included in a question

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for students to choose as sources of their disaster knowledge. School education includes five choices: in total and four specific items. The results in Fig. 5 show that 86.9% of the surveyed students acquired DRR knowledge through computers or smartphones. The next primary source of DRR knowledge is TV or radio (72.1%), followed by schools (66.7%). About half of the students get information from families and friends (47.7%). Fewer students learn about DRR through extracurricular academic reading, magazines, museums, and communities (8.6% to 28.1%). In summary, major media (Internet, TV, and radio) and school activities are the primary sources for students to acquire DRR knowledge.

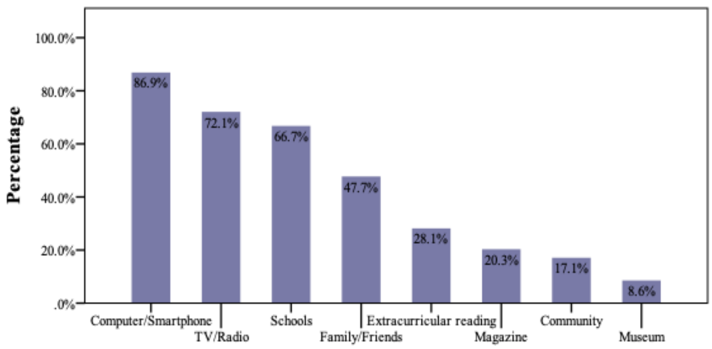


Fig. 5. Percentage of sources of DRR knowledge.

Figure 6 shows the students' responses to the two questions, revealing that 41.6% (High + Very high) pay great attention to DRR-related information in their daily lives, and 73.2% (High + Very high) wish to include electronic DRRE materials in the school curriculum. Table 2 shows the correlation between answers to the two questions. The Spearman's correlation coefficient, *rs* = 0.256, is statistically significant ($p < 0.05$), indicating that students who pay daily attention to DRR tend to be more positive about using electronic DRRE materials in schools.

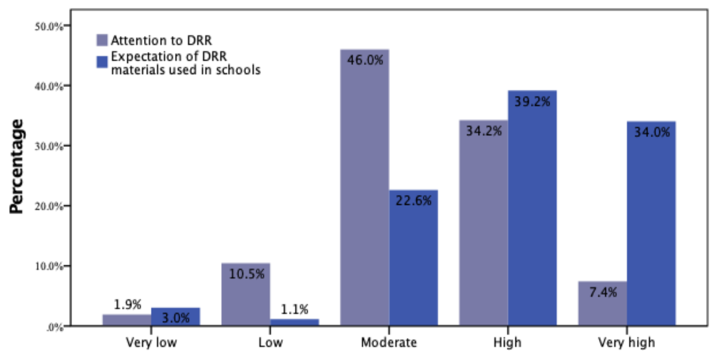


Fig. 6. Answers about the daily attention to DRR and the expectation of using digital DRRE materials in schools.

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Table 2. Correlation between the answers to the two questions about daily attention to DRR and the use of digital DRRE materials in schools.

| | | | Expectation of DRRE materials used in schools |
|---|---|---|---|
| Spearman's rho | Attention to DRR | Correlation Coefficient | .256** |
| | | Sig. (2-tailed) | 0.000 |
| | | N | 526 |

**. Correlation is significant at the 0.01 level (2-tailed).

Figures 7 and 8 summarize the answers to the questions "Ability to use electronic products" and "Frequency of usage of digital maps". Nearly all students (93.4%) considered having average or higher abilities to use electronic products, and about 30% use digital maps frequently (High + Very high).

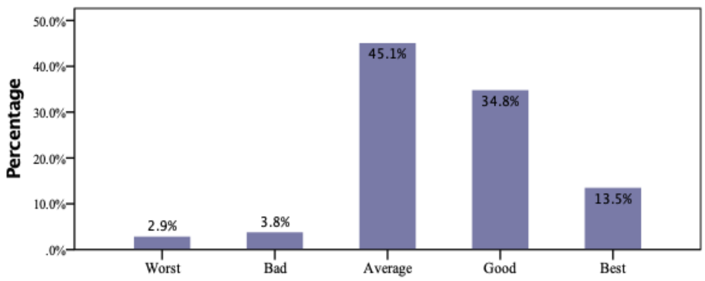


Fig. 7. Answers to the question “Ability to use electronic products”.

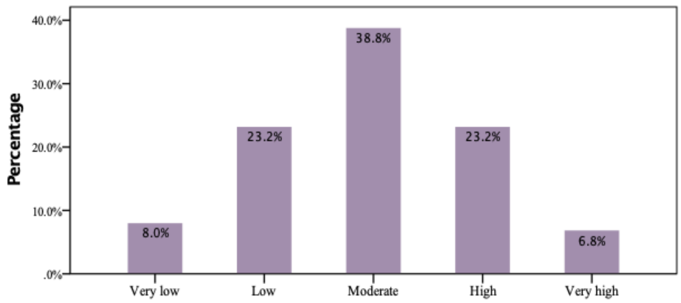


Fig. 8. Answers to the question “Frequency of usage of digital maps”.

*4.2 Pretest and posttest results*

Figure 9 shows the pretest and posttest scores of all 526 students using a boxplot, and Table 3 provides the result of the nonparametric Wilcoxon signed-rank test for comparing the pretest and posttest scores. The mean score of the pretest was 3.97, and that of the posttest was 5.74. The test shows that they are

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different with statistical significance (Asymp. Sig, i.e., asymptotic significance is lower than 0.05), although tall boxplots in Fig. 9 depict large variations. The Ranks section in the table shows that 332 students had higher posttest scores, 98 had higher posttest scores, and 96 had very similar scores.

Table 3. Comparison of pretest and posttest scores through the Wilcoxon signed ranks test.

| Test | Mean (SD) | N | Asymp. Sig. (2-tailed) | Ranks | | |
|---|---|---|---|---|---|---|
| | | | | Negative Ranks | Positive Ranks | Ties |
| Pretest scores | 3.97 (1.951) | 526 | 0.000 | 98[a] | 332[b] | 96[c] |
| Posttest scores | 5.74 (2.386) | | | | | |

a. Posttest scores < pretest scores
b. Posttest scores > pretest scores
c. Posttest scores = pretest scores

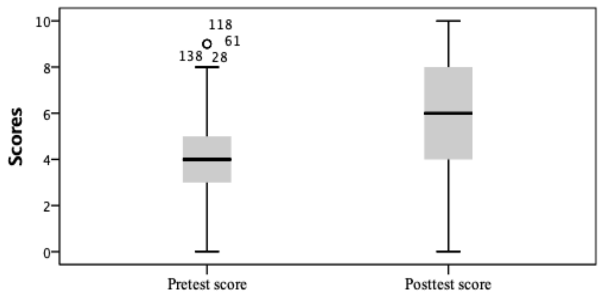


Fig. 9. Boxplot of pretest and posttest.

Table 4 shows the results of the rank-based nonparametric Kruskal Wallis test, indicating a statistically significant difference in the pretest-posttest score improvement according to the three implementation methods (Asymp. Sig. < 0.05). Figure 10 is the box plot of the pretest and posttest accuracy rates for the three different implementation methods. The accuracy rates (0 to 1) were used to include data not only for China but also for Japan, where the number of questions was smaller. The onsite implementation had the most significant improvement, while the online-onsite mixed implementation had no notable changes. The mixed implementation, conducted in a Japanese high school, had a course length of 50 min, less than half that of the implementations of the other two methods.

Table 4. Kruskal Wallis test results for the difference between pretest and posttest scores according to implementation methods.

| Method | Mean Rank | N | Asymp. Sig. |
|---|---|---|---|
| Online | 201.10 | 226 | |
| Onsite | 344.40 | 238 | 0.000 |
| Online-onsite mixed | 180.41 | 62 | |

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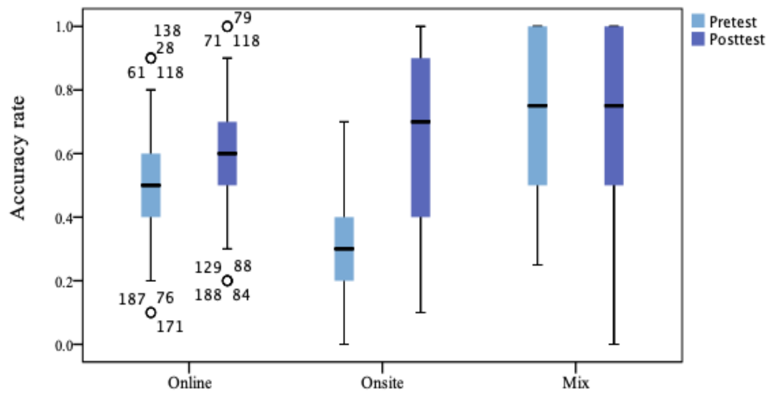


Fig. 10. Boxplot of pretest and posttest accuracy rates according to three implementation methods.

Table 5 presents the result of the Kruskal Wallis text concerning the differences between pretest and posttest scores in the four regions. The regional disparity is statistically significant (Asymp. Sig. < 0.05), with Jilin Province having the highest mean rank value and Japan having the lowest. Figure 11 is the boxplot of the pretest and posttest scores for the four regions, confirming the most significant improvement in Jilin Province. All participants in Jilin took onsite implementations, and questions about DRR in the tests were local cases in the same province. The students in Inner Mongolia also showed markedly improved pretest scores. In contrast, the improvement was limited in Liaoning Province and Japan, and their pretest scores were higher than those in the other two regions. All students in Liaoning Province took online implementations, while all students in Japan took online-onsite mixed implementations.

Table 5. Kruskal Wallis test result on the difference in pretest and posttest scores among the four regions.

| Regions | Mean Rank | N | Asymp. Sig. |
|---|---|---|---|
| Inner Mongolia, China | 245.89 | 180 | 0.000 |
| Liao Ning Province, China | 207.10 | 143 | |
| Jilin Province, China | 379.71 | 141 | |
| Japan | 180.41 | 62 | |

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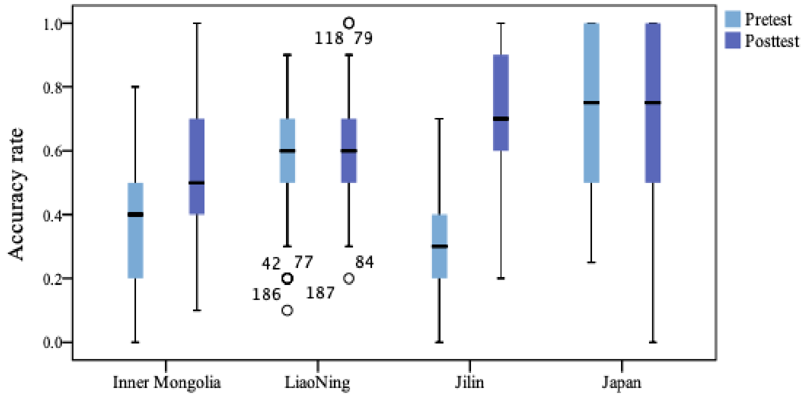


Fig. 11. Boxplot of pretest and posttest scores for the four regions.

*4.3 Factors influencing students' DRR learning*

The influence of students' attention to disaster prevention on the pretest results and the score improvement was investigated. For the pretest results, there was no linear correlation (Table 6). However, as shown in Table 7, the influence is significant not only on DRR-related questions but also on all questions (Asymp. Sig. < 0.05). More daily attention to disaster prevention led to more substantial increases in test scores.

Table 6. Correlation between the students' daily attention to disaster prevention and mitigation-related contents and the pretest scores.

| | | Pretest | |
|---|---|---|---|
| | | All questions | DRR-related questions |
| Spearman's rho | Correlation Coefficient | 0.019 | 0.058 |
| | Sig. (2-tailed) | 0.661 | 0.183 |
| | N | 526 | 526 |

Table 7. Effects of students' daily attention to disaster prevention on learning.

| Degree of concern | N | All questions | | DRR-related questions | |
|---|---|---|---|---|---|
| | | Mean Rank | Asymp. Sig. | Mean Rank | Asymp. Sig. |
| Very low | 10 | 204.00 | | 209.45 | |
| Low | 55 | 210.67 | | 226.37 | |
| Moderate | 242 | 261.60 | 0.005 | 267.36 | 0.044 |
| High | 180 | 272.92 | | 261.33 | |
| Very high | 39 | 321.58 | | 315.77 | |

Table 8 shows the lack of correlation between the ability to use electronic products and pretest scores.

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Table 9 shows the result of a similar evaluation regarding the effect of the ability to use electronic products on score improvement for the DRR-related questions. The impact is not statistically significant (Asymp. Sig. > 0.05), although the mean rank values indicate that higher ability usually led to higher score improvement. Table 10 evaluates the impact of the ability to use electronic products on score improvement for the map-related questions and the GIS-related questions. These questions were not conducted in Japan due to the limited implementation time. Therefore, Table 10 shows the results of 464 students in China. The ability to use electronic products does not significantly affect map-related learning (Asymp. Sig. > 0.05), which is consistent with the overall result. However, it significantly affects GIS-related learning (Asymp. Sig. < 0.05) with a positive correlation. A similar analysis was also conducted on the frequency of computer or smartphone usage and score improvement in each section, but no significant correlation was found.

Table 8. Correlations between students' ability to use electronic products and pretest scores.

| | | Pretest | | |
|---|---|---|---|---|
| | | All questions | Map-related questions | GIS-related questions |
| Spearman's rho | Correlation Coefficient | 0.025 | 0.047 | 0.013 |
| | Sig. (2-tailed) | 0.560 | 0.310 | 0.787 |
| | N | 526 | 464 | 464 |

Table 9. Effects of students' ability to use electronic products on DRR learning.

| Ability to use | Mean Rank | N | Asymp. Sig. |
|---|---|---|---|
| Worst | 232.83 | 15 | |
| Bad | 188.90 | 20 | |
| Average | 256.74 | 237 | 0.084 |
| Good | 278.86 | 183 | |
| Best | 273.98 | 71 | |

Table 10. Effects of the student's ability to use electronic products on learning maps and GIS.

| Ability to use | N | Map-related questions | | GIS-related questions | |
|---|---|---|---|---|---|
| | | Mean Rank | Asymp. Sig. | Mean Rank | Asymp. Sig. |
| Worst | 11 | 242.68 | | 158.05 | |
| Bad | 13 | 246.38 | | 162.81 | |
| Average | 215 | 233.34 | 0.979 | 229.27 | 0.018 |
| Good | 163 | 232.44 | | 236.83 | |
| Best | 62 | 225.02 | | 260.15 | |

Some of the test questions require the use of web maps to reply. There was no linear correlation between the questions answered without using web maps and the pretest scores. Table 11 evaluates the impact of the pretest and posttest results of questions using web maps for different electronic map usage frequencies. The impact is statistically significant (Asymp. Sig. < 0.05), and the posttest score improvement tends to increase with the increased frequency of electronic map usage.

Table 11. Pretest and posttest results for different electronic map usage frequencies.

| Frequency of use | Questions using web maps | | |
|---|---|---|---|
| | Asymp. Sig. | Pretest accuracy | Posttest accuracy |
| Very low | | 46.23% | 45.44% |
| Low | | 33.74% | 54.71% |
| Moderate | 0.030 | 30.43% | 59.84% |
| High | | 28.07% | 58.95% |
| Very high | | 38.19% | 56.48% |
| Mean | | 32.45% | 57.07% |

## 5. Discussion

This study examines the differences between 526 students in China and Japan before and after using DRR learning materials and the factors influencing the effects of learning, including the previous DRR-related experiences of students. According to this survey, the principal sources for students to acquire disaster knowledge are computers or smartphones, TV or radio, and schools. Zhu and Zhang (2017) surveyed 758 students, and the results also show that the primary three sources of disaster knowledge for students were schools, computers or mobile phones, and TV or radio. This suggests that modern communication ways contribute to the widespread dissemination of DRR knowledge, especially for young students, although school education still plays a certain role. This situation helps provide a variety of DRR knowledge to students even if school time for DRR education is limited. As noted by (Talero 2004), with proper conduct, media can offer good communication tools that can be used as educational aids to reduce the gap between scientific knowledge and awareness. This study also indicates that many students consider disaster prevention and mitigation in ordinary times, suggesting the importance of off-school learning opportunities. Meanwhile, as a supplier of fundamental and systematic knowledge, schools should combine advanced equipment and technology to achieve optimal DRR education.

The students in the Chinese high schools show significantly improved results after using the DRRE materials with digital hazard maps. This is consistent with Akimoto and Suzuki (2019) in that hazard maps can be DRR educational materials for students. The improvement is undeniable for the onsite implementations. In online education, students only communicate with their classmates digitally; thus, the real-time sharing of ideas, knowledge, and information still needs to be completed (Britt 2006). Adnan (2020) also indicates that traditional classroom learning is more effective than online learning or distance education. The online-onsite mixed implementation conducted in Japan resulted in no significant improvement of test scores. Several reasons can be considered for this exceptional case: 1) students already had high scores at the pretest stage, limiting the further increase in scores; 2) the mixture

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of online and onsite methods was unusual for students and caused some confusion; and 3) the class hour was only 50 min, which is half of the other implementations.

Gender hardly affects the learning of students. Previous research also indicated that educational curricula utilizing Web GIS could promote geospatial thinking skills regardless of gender (Bednarz and Lee 2011; Bodzin 2015; Collins 2018). The levels of previous experiences and attention of students related to electronic maps, electronic products, and hazards did not affect the pretest scores in most cases. The student's ability to use electronic products only affects the learning of GIS-related content, suggesting that the effective operation of GIS needs a skill specific to electronics, but it is technical and irrelevant to the acquisition of DRR-related knowledge. In contrast, previous experience with web hazard maps significantly influences the learning of DRR-related contents, and the frequency of electronic maps usage and attention to disaster prevention in daily life also affect the utilization of the DRRE materials. These observations suggest that the questions in the tests were relatively high level for the students, so systematic learning using the provided materials was needed to have better scores. At the same time, their previous experiences and attention surely affected the effects of learning. Therefore, both opportunities for the systematic learning and daily experiences and attention are needed to maximize the understanding of students about DRR and related issues.

Song et al. (2022) found that students experienced more difficulties recognizing risk regions when the disaster featured their dwelling and the surrounding environment. This study expands on this result with a comprehensive investigation that the pretest scores for the implementations using local disaster cases are low, but the subsequent improvement is significant. Although local examples may be more complicated and disconnected for local students (Hsu et al. 2018), the improvement after learning DRRE materials using local cases was more significant than that using non-local examples, indicating the necessity of local-level DRRE. Sutanta et al. (2014) suggested that DRR activities should be conducted at the level of local government because it is the authority of local spatial planning. However, local governments may consider DRR from different perspectives, and their activities are only sometimes effective. Therefore, some researchers recommend that municipalities and citizens collaborate to build a culture of DRR in communities (Lin and Chang 2020; Tuladhar et al. 2014). Introducing web hazard maps into such collaborative work is a key to realizing effective social DRR.

Although (Song et al. 2022) shared the DRRE materials among several students as a single web page, the materials used in this study contain multimedia contents and are designed for individual use on a single device. To make it accessible to more users, the DRRE materials were mounted on a server. Nevertheless, there are occasionally delays or lags when many devices tried to access the materials simultaneously. Some students may not have a stable internet connection throughout the implementation process, especially in online implementation. This can impact the ability of students to access the material and may also be a significant factor in delays or other problems. The internet issue is crucial to students' online learning experiences (Agung et al. 2020). Educational authorities and organizations that provide online education may mistakenly believe that most students have a reliable internet connection at home

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in the era of 4G and 5G networks (Yan et al. 2021). Students with lower-quality internet connections experience difficulties such as sluggish or dropped connections, especially for streaming multimedia contents. This can be frustrating and impact their ability to learn effectively. The development may need to implement measures to improve the size and format of multimedia files, use a content delivery network (CDN) to distribute material more effectively, or implement caching to reduce the amount of data that needs to be transmitted. In general, it is critical to be aware of the potential challenges students may face when accessing online materials and to take steps to minimize any barriers to learning that may arise.

## 6. Conclusion

This study uses the pretest and posttest results to analyze the factors affecting students' learning using web hazard maps. According to this survey, students' primary sources of disaster knowledge are computers, smartphones, televisions, radio, and schools. Students believe that online hazard maps can supply more accurate data, and modern communication tools provide a variety of DRR knowledge that cannot be fully conveyed to students during the limited school time. Therefore, DRRE in schools should be combined with the latest technology related to media, and take action to overcome potential obstacles that students may encounter when accessing online learning materials.

Students' learning results improved after using the constructed DRRE materials. This observation is common to the two countries, suggesting the broader applicability of the constructed materials and curricula. Students' daily attention to disaster prevention and mitigation-related contents, 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 DRRE materials. Students' ability to use electronic products only affects the learning of GIS-related contents, not DRR-related knowledge. 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, helps students learn various DRR knowledge. Using local examples in DRRE can help students better understand their communities' specific risks and vulnerabilities. Local governments should pay attention to this approach and consider incorporating it into their DRRE efforts.

Previous research has provided the theoretical and empirical basis for using electronic maps to promote DRR education and the foundation for this study. The improvement and deepening of this study propose more systematic and practical methods for DRR education based on the original research. These methods can not only help students better understand and apply electronic maps, but also have positive effects in

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improving students' DRR knowledge and disaster response-ability. GIS technology has become an essential tool in DRR research and application, while how to apply it effectively in education is still a problem to be solved. This study provides practice and reference for the subsequent DRR education methods based on GIS technology through the improvement of electronic maps and the design of educational methods. Finally, the results of this study provide new ideas and directions for future research and application in DRR education filed. This will help promote the sustainable development of society and build a safer and more reliable social environment.

**Data availability**

All raw data can be provided by the corresponding authors upon request.

**Author contributions**

SJ developed the online disaster risk reduction materials, conducted the analysis, and produced the manuscript draft; SJ, YH, TO, and NY implemented the materials and curriculum at schools; and TO and JW reviewed and edited the manuscript.

**Competing interests**

The authors declare that they have no conflict of interest.

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