Damages to school infrastructure and development to disaster prevention education strategy after Typhoon Morakot in Taiwan

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Abstract

Purpose – As a result of awareness of the increasing school accidents in recent years and severe damage to school infrastructure by Typhoon Morakot, this paper seeks to discuss the current natural disaster prevention education strategy in Taiwan and investigates the seriously damaged schools from Typhoon Morakot.
Design/methodology/approach – Methods of analysis used in this paper include aerial photo interpretation of landslides and debris flows with the aid of field investigation and spatial rainfall distribution by GIS analysis. Additionally, the reasons attributed to the schools’ damages and disaster prevention education strategies in schools after Morakot are discussed.
Findings – After an overall review of the current disaster prevention education programs, the following items are to be stressed in disaster prevention education as a result of studying the effects of Typhoon Morakot: integration of disaster prevention education into formal school curricula; teacher training for campus disaster prevention education; development of a coalition of campus and community-based disaster management; and study of the impact of climate change and school vulnerability. School infrastructure safety evaluation and risk assessment, education materials and design activities for psychological recovery after disasters, and the connection of school safety management and community-based disaster prevention are deemed urgent after Typhoon Morakot in Taiwan.
Originality/value – The current achievements of disaster prevention education in Taiwan include the development of operation and support mechanisms, curricula development and experimental schools selection, development of teacher training program, the popularization of disaster prevention education, the development and use of learning materials, and the determination of an effective assessment mechanism. It is expected that disaster prevention education will become part of the formal school curricula. School safety and vulnerability assessments as a result of climate change and student psychological recovery following disasters are urgent lessons to be implemented after learning from the results of Typhoon Morakot in Taiwan.
Keywords Natural disasters, Disaster prevention education, Education and school safety, Risk identification and assessment, Risk management, Education, Schools, Taiwan

Introduction

Natural hazards including storms, earthquakes, drought, volcanic eruption, and tsunamis total approximately 400 times a year, with an average of 74,000 deaths and more than 230 million people that are affected (Centre for Research on the Epidemiology of Disasters (CRED), 2008). Each time a disaster occurs, masses of
children are excluded from school, many never to return. Disaster risk reduction
begins at school (UN/ISDR, 2006). Disaster prevention education is of great urgency in
developing countries (e.g. An, 2006; Takeuchi and Shaw, 2011; Gwee et al., 2011). There
are 2,654 schools including 1,275 elementary schools, 740 junior high schools,
477 senior high school, and 162 colleges and universities as recorded by the Ministry
of Education in Taiwan in 2009. The number of reported injury by natural hazards
increased from 2003 to 2009 in Taiwan (Table I). The average yearly number of
accidents in schools from 2003 to 2008 was 16,059, and in 2009 the injury by natural
hazards suddenly increased to 138,170 as a result of Typhoon Morakot (Campus
Security Report Center, 2010). There are 958 student deaths on average per year, and
the number has been reduced yearly as a result of the efficiency of disaster prevention
education in school. The statistics show that the highest numbers of natural hazards
occurred in elementary schools mostly located in mountainous area.

Student accidents in Taiwan by natural hazards have mainly been caused by
eartquakes, the severe winds from typhoons, floods, landslides, and debris flows. The
percentage of natural hazards is only 0.38–3.87 per cent of the total accidents in
school (Table I). During the Chi-Chi earthquake in Taiwan on 21 September 1999,
51 schools collapsed and 786 were damaged, there were 329 student deaths and
288 injuries (Campus Security Report Center, 2010). As a result, the 21 September
has since been designated as School Safety Day. Many disaster prevention education
activities and drills are conducted on this day in remembrance of that major national
disaster.

Natural hazard-induced accidents increased in 2005 as a result of the sequenced
intense typhoons Haitang (July), Matsa (August), and Longwang (September) hitting
Taiwan. Additionally, typhoons brought severe wind, floods, landslides, and debris
flows from Kalmaegi (July 2007), Sinlaku (September 2007), and Jangmi (September
2008). Typhoon Morakot, which hit land on 8 August 2009, caused the second highest
school facility damages in history of Taiwan.

As a result of awareness of the increasing school accidents in recent years and
severe damages to school infrastructure by Typhoon Morakot, this paper discusses
the current natural hazard prevention education strategy in Taiwan and investigates
the seriously damaged schools from Typhoon Morakot. Methods of analysis include
aerial photo interpretation of landslides and debris flows with the aid of field
investigation and spatial rainfall distribution by GIS analysis. Additionally, the
reasons attributed to the schools’ damages and disaster prevention education
strategies in schools after Morakot are discussed.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
<th>% of natural disasters</th>
<th>Death</th>
<th>Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>10,206</td>
<td>0.58</td>
<td>1,234</td>
<td>10,947</td>
</tr>
<tr>
<td>2004</td>
<td>14,934</td>
<td>0.5</td>
<td>902</td>
<td>9,386</td>
</tr>
<tr>
<td>2005</td>
<td>15,828</td>
<td>3.87</td>
<td>1,107</td>
<td>15,108</td>
</tr>
<tr>
<td>2006</td>
<td>14,814</td>
<td>1.86</td>
<td>1,044</td>
<td>12,437</td>
</tr>
<tr>
<td>2007</td>
<td>17,786</td>
<td>3.39</td>
<td>802</td>
<td>16,094</td>
</tr>
<tr>
<td>2008</td>
<td>22,787</td>
<td>1.35</td>
<td>731</td>
<td>20,490</td>
</tr>
<tr>
<td>2009</td>
<td>138,170</td>
<td>0.38</td>
<td>885</td>
<td>210,005</td>
</tr>
</tbody>
</table>

Table I.
Number of student deaths
and reported injury by
natural hazards from 2003
to 2009 in Taiwan

Source: Campus Security Report Center (2010)
School damages as a result of Typhoon Morakot

Typhoon Morakot hit land on 8 August 2009, and brought a south-west current, which caused torrential rains in southern Taiwan. Rainfall was concentrated in the mountainous areas of Chiayi, Tainan, Kaoshu, and Pintung counties (Figure 1). The highest rainfall was recorded at Mountain Ali in Chiayi County and was over 2,700 mm from 5 to 10 August. The rains were greater than the annual average rainfall of 2,493 mm (as recorded from 1949-2007, Water Resources Agency, 2008). There were 19 schools located in the region that recorded a cumulative rainfall of over 2,000 mm, and 54 in the area that received 1,500 mm. The torrential rains caused flash flooding that inundated 213 schools and initiated numerous landslide and debris flow disasters in schools.

Typhoon Morakot brought a south-west current and torrential rainfall caused serious school flooding disasters in southern and eastern Taiwan. The disaster caused 678 deaths and 75 missing persons (Central Emergency Operation Center (CEOC), 2009). Schools in Tainan had the most serious economic losses, followed by Kaoshiung and Pingtung counties. The total school facility economic losses were up to NT$2.9 billion, and 1,328 schools were damaged (Table II), including 13 schools that needed to be relocated. The disaster caused nine student deaths, 76 missing persons, and one serious injury.

There were four schools destroyed by flash flood-induced flowing debris Longhua Elementary School in Nantou County (Plate 1), Xiaolin Elementary School (Plate 2), Minquan Elementary School, and Minzu Elementary School in Kaoshiung County

![Diagram showing the spatial distribution of Typhoon Morakot's accumulated rainfall](Central Weather Bureau, www.cwb.gov.tw) and location of all the schools

**Figure 1.** Spatial distribution of Typhoon Morakot's accumulated rainfall (Central Weather Bureau, www.cwb.gov.tw) and location of all the schools
during Typhoon Morakot. The destroyed Longhua Elementary School was scoured by the migration of a stream flow of branch debris and torrential rainfall (1,845 mm), which induced the rise of flash floods. This was the third time the campus was destroyed since the Chi-Chi earthquake in 1999 and Typhoon Xangsane in 2000. School is a public place and is commonly choose as a shelter for disaster prevention in mountainous areas in Taiwan. School damage affects students’ learning and could be

<table>
<thead>
<tr>
<th>School</th>
<th>Flood in playground</th>
<th>Pounding in classroom</th>
<th>Death</th>
<th>Losses (NT$ in million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>College and university</td>
<td>57</td>
<td>13</td>
<td>16</td>
<td>1,171</td>
</tr>
<tr>
<td>Senior high school</td>
<td>126</td>
<td>28</td>
<td>25</td>
<td>214</td>
</tr>
<tr>
<td>Grades 1-9</td>
<td>1,145</td>
<td>38</td>
<td>51</td>
<td>1,474</td>
</tr>
<tr>
<td>Total</td>
<td>1,328</td>
<td>79</td>
<td>92</td>
<td>2,860</td>
</tr>
</tbody>
</table>

Source: Campus Security Report Center (2010)

Plate 1.
Debris flow blockages resulting in a stream that scoured the lower terrace of Longhua Elementary School in Nantou County (29 August 2009)
harmful to refugees. The most serious disaster happened in the shelter Xiaolin Elementary School in Kaoshiung County, where nine students died and 49 were missing. It was buried by the deep landslide measuring a depth of approximately five floors. The landslide slope height was 1,000 m, the area was 3.5 km², and the runoff distance was 3.2 km. The torrential rainfall (1,825 mm) initiated the back slope landslide that blocked the stream flow then caused another flash flood that breached the dam, causing flowing debris that overwhelmed the entire school and village.

Field investigation and GIS spatial analysis showed that the reasons attributed to school damages included torrential rains that induced a flash flood, schools located on the lower stream terrace that experienced debris flowing downstream to the affected area, landslides, and a breached landslide dam (Table III).

**Disaster prevention education in Taiwan**

In recent years, Taiwan’s governmental units at all levels have become more and more aware of the importance of disaster reduction education, and therefore have increased investment in related activities. However, some problems still remain to be solved. For example, only about 2 per cent of colleges in Taiwan offer common education in the disaster-related fields, and most courses only introduce one single type of disaster, rarely mentioning different types (Yen *et al.*, 2006). Early efforts in disaster education focused on worldwide hazards not introduction with the local hazards (Lidstone, 1999). Disaster reduction education particularly stresses pre-disaster preparedness and emergency response during disasters. Little is mentioned about mitigation and recovery. In the meantime, although governmental units have some education resources, they are independent and there is little collaboration.

As a result of awareness of the increasing catastrophic disasters, the Ministry of Education (referred to as MOE) in Taiwan started planning disaster prevention education schools in 2001. In 2003, the MOE Advisory Office and academic institute
planned “Pilot Programs to Promote Technological Disaster Prevention Education” in 2003 through 2007 for Grades 1-12, college students, and society in general. The e-learning educational resources included natural hazards (typhoon, flood, debris flow, landslide, and earthquake) and technological disasters (chemistry, fire, and explosive) (available at http://disaster.edu.tw/). The project was for natural and technological disaster reduction by integrating educational resources to build a culture of safety and strengthen society resilience to disasters. The project “Technological Disaster Prevention Education and Cultivation Experiment Research and Development Programs” was planned for 2007-2011 for all level students. A historical timeline of disaster prevention education planning in Taiwan is shown in Figure 2.

Scientific and technological literacy for disaster prevention education is important in order to recognize problems, to consider how to solve them, and to make decisions (Gregario, 2010). The disaster prevention literacy is defined as one’s personal knowledge, attitude, and skills towards disaster prevention. It includes three main categories: disaster prevention knowledge, disaster prevention attitude, and disaster prevention skills (Yeh, 2007). The disaster prevention knowledge contains three indexes including disaster recognition, prevention knowledge, and response knowledge (Figure 3). Disaster prevention attitude is evaluated by items of sensitivity of disaster prevention, disaster prevention-related value, and responsibility to disaster prevention. Disaster prevention skills are a combination of

<table>
<thead>
<tr>
<th>Elementary school</th>
<th>Maximum rainfall (mm/hr)</th>
<th>Location</th>
<th>Reasons attributed to disaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xiaolin in Kaoshiung County</td>
<td>1,825/104</td>
<td>Lower stream terrace, potential debris flow affected area</td>
<td>Landslide formed dam breach-induced flash flood and debris flows</td>
</tr>
<tr>
<td>Longhua in Nantou County</td>
<td>1,845/102</td>
<td>Lower stream terrace</td>
<td>Flash flood scoured/debris flow</td>
</tr>
<tr>
<td>Minquan in Kaoshiung County</td>
<td>1,591/108</td>
<td>Lower stream terrace</td>
<td>Debris flow downstream affected area</td>
</tr>
<tr>
<td>Minzu in Kaoshiung County</td>
<td>1,591/108</td>
<td>Stream meander</td>
<td>Debris flow movement path</td>
</tr>
</tbody>
</table>

Note: "Measured from nearest rain gauge station"
preparedness activities and response activities. The eight indexes of disaster prevention literacy were used for the effectiveness assessment of disaster prevention education (Yeh, 2007). It is found that the students in experimental schools have better performances in literacy of disaster prevention attitude and skills. The same results are found during the earthquake in Christchurch, New Zealand (Finnis et al., 2004) and in Taiwan (Yeh, 2007).

Campus disaster prevention and rescue plans were asked for from all of the experimental schools. The plans were based on the management of disaster reduction, preparedness, response, and recovery cycles. Details of each plan and working items are listed in Figure 4. MOE has encouraged nationwide primary and senior high schools to participate in “Technological Disaster Prevention Education and Subsoil Experiment Research and Development Programs”. According to different local character to devise plans, the promotion content has five sub-areas in 2010, such as localization of disaster prevention education modules, campus disaster prevention and rescues plans, teacher training programme mechanisms for disaster prevention education buildup, e-learning disaster prevention education materials, and other activities to enhance disaster prevention education (Lee et al., 2011).

The MOE began the study project based on the mechanism from the Service Corps for Disaster Prevention Education (SCDPE). The mission of SCDPE is to provide consultations for the experimental schools through telephone, e-mail, site instruction, and public awareness meetings. Additionally, the SCDPE assists the experimental schools in problem solving, which includes five issues:

1. materials for disaster prevention education;
2. set up campus disaster prevention and rescue plan;
strengthen the local teaching resources for disaster prevention education;
(4) e-learning technology; and
(5) others (Wen et al., 2007).

The programme is aimed at transferring the achievements of the departments of the MOE in 2010 into continuous, fully integrated normal responses. It is focusing on the, “operation and support mechanism”, “curricula development and experimental schools selection”, “teacher training programme”, “disaster prevention education popularization”, “learning materials popularization”, and “effectiveness assessment mechanism” (Figure 5). Also, a continuous yearly revision mechanism is operating.

The disaster prevention educational achievements over the past years are shown in Figure 5. The educational resources for all levels of learning are shown in Figure 6. The developed teaching materials included 16 books on disaster prevention educational materials for all learning levels, 13 revised editions and lesson plans, one volume of a general course for college and six for professional courses, and a long distance learning course. The disasters include natural hazards such as earthquakes, hydrometeorological events, and landslides along with technological and other disasters. The preschool disaster prevention education consists of four disasters (earthquake, fire, flood, and severe wind) and five injuries (hand-foot-mouth disease, violent accidents, car accidents, falls, and scalding).

Lessons in disaster prevention education following Typhoon Morakot
In reviewing the current state of school disaster prevention education in Taiwan, the following findings have been provided (Hsu, 2007; Chen and Lee, 2009):

(1) Disaster prevention education is not included in the formal curricula:
There are seven formal learning areas in Grades 1-9, they are: language arts, physical, mathematics, society, nature and technology, art and humanity (including music, vision, and platform arts), and integrative activities. The seven learning areas force integration into the core curricula through
Disaster prevention education

Figure 5. Achievements in disaster prevention education in Taiwan from 2003-2010

Figure 6. List of disaster prevention educational resources
information and computer education, environmental education, gender equity education, human rights education, career development education, home economics education, and marine education. Education in disaster risk reduction, formal integrated into curricula, as well as informal education introduced through co-curricular and extra-curricular activities is power in disaster risk reduction (Petal and Izadkhah, 2008). The disaster prevention education is neither the formal courses nor across learning areas. The current stage of education is emphasized upon entering a school and examination content is less concerned with disaster prevention. It is difficult to ask a teacher to integrate disaster prevention education into formal core courses and non-formal activities.

(2) Lack of professional disaster prevention education teachers:
There are few teachers in Grades 1-9 with the disaster prevention-related background, and no full-time administrators in Grades 1-12 to take over campus disaster prevention affairs. Hardly any disaster prevention education is integrated in formal courses and non-formal activities.

(3) No unified administrators or managers for disaster prevention education:
The target of disaster prevention education includes elementary schools, high schools, colleges, and society in general; those managers are different in the departments of MOE. There is a lack of unified managers to supervise and assess the efficiency of disaster prevention education.

As a result of the mentioned findings of the disaster prevention education strategy in Taiwan, the following lessons may mitigate the impacts or need solve issues by the MOE executing results (Lee et al., 2011) and the school hazards investigation after Typhoon Morakot:

(1) Integration of formal and non-formal localization disaster prevention education into school curricula:
There are no formal disaster prevention-related courses for Grades 1-9 and high school students. Only parts of the disaster prevention knowledge are mentioned in nature and social science courses in Grades 1-9 and for high school students. The knowledge is limited in the field of causes and impacts to society. School education can provide useful information for disaster risk reduction and the best way for it is to include the disaster management education in the school curriculum (Bonifacio et al., 2010). The combination of various types of education (formal, non-formal, and informal education) is an essential part of learning (Hofstein and Rosenfeld, 1996; Lidstone and Nielsen, 1999; Eshach, 2007; Shaw et al., 2011). It is suggested that Taiwan integrate localization disaster prevention education into formal curricula and non-formal activities.

(2) Teacher training programmes for campus disaster prevention education:
A proper teachers’ training is an essential component in school disaster education (Bonifacio et al., 2010). Short of the professional disaster prevention educated teachers, a stand-alone certified three levels of teaching training programmes for school, county, and central levels for disaster prevention education are planned (Chen, 2012). The goal of the “Campus Level” is to strengthen the knowledge of disaster prevention and promote disaster
awareness for school-based disaster reduction. The goal of this level is to educate more teachers in awareness of the importance of campus disaster prevention education. Disaster prevention teachers at the “County Level” are educated to cover school-based to community-based disaster prevention education. Disaster prevention teachers at the “Central Level” are selected from professional engineers and university professors to train the schools and county level teachers. This level provides assistance in school recovery planning after disasters. There were 1,064 teachers (740 from elementary schools) that finished the school level training courses (in-service training) in August 2010 after Typhoon Morakot (Chen, 2012). An online self-learning programme and after course test are also available (http://disaster.edu.tw/teacher_education/). The institutionalizing teacher’s training in pre-service and regular monitoring still need efforts.

(3) Coalition for campus and community-based disaster management:
It is necessary to link school and community education (Shaw et al., 2011). Most of the schools have had campus emergency evacuation drills for earthquakes, but there has been little concern to practice for floods or debris flows out of campus. In the meantime, schools were closed and most of the young men work in urban areas, leaving the elders and children in the mountainous areas when the typhoons made landfall on Taiwan. An integrated community-based disaster management program was launched in 2001 to strengthen community resistance in Taiwan (Chen et al., 2006). The process has been applied to more than 100 communities in Taiwan. The community-based debris flow evacuation, that included the two major components of emergency adjustment and long-term adaptive capacity, saved 1,046 people in the 2009 Typhoon Morakot (Chen and Wang, 2010). The collaborations between governmental agencies and other non-governmental organizations, schools, local communities and volunteers collaboration is critical to the successful operation for disaster risk reduction (Zhang et al., 2011). The effects of education can be transferred to parents and community (Shiwaku, 2009; UN/ISDR, 2006). Meanwhile, the community plays an essential role in promoting students’ actual actions for disaster risk reduction (Shiwaku et al., 2007). The formal and non-formal education through schools, with linkages to community-based risk-reduction promises the development of a “culture of safety” (Petal and Izadkhah, 2008). The integration of various types of disaster prevention education through school is one way of ensuring that these messages reach every family and community (Petal and Izadkhah, 2008). However, few students had ever attended the community-based emergency evacuation drills for floods and debris flows. It was found that many students lost their lives out of school because of landslides and debris flows during Typhoon Morakot (e.g. Xiaolin Elementary School, Tsou et al., 2011). Considering the lack of availability of local first responders and extensive response times for assistance, the coalition of campus safety and community-based disaster prevention training is urgently needed in the mountainous areas of Taiwan.

(4) Impacts of climate change and vulnerability assessment:
School is a place to develop a talent and provide public shelter for disaster prevention. School safety has become an important issue since 1999 following
the Chi-Chi earthquake. The National Center for Research on Earthquake Engineering (NCREE) (2010) developed a school buildings database in July 2004, it reports that there were 11,724 school buildings evaluated for safety and suggestions made since that time. However, there were still many schools destroyed and damaged during Typhoon Morakot. The inclusion of climate change and indigenous local knowledge in formal disaster prevention education was highlighted in Bangladesh (Islam et al., 2010). Typhoon Morakot brought torrential rains exceeding over 200 years of records in southern Taiwan (Chu et al., 2011), therefore the vulnerability and impact assessment for adaptation to climate change is also urgent for school safety. Analysis of school risk vulnerabilities is a team effort that needs research to identify a school’s risk, a selection of disaster assessment tool, determination of risk priorities, and revisions and reassessments.

There are 1,237 schools located in the slope area, among which 37 schools are in the affected area of 1,552 potential debris flows. Those schools in the mountainous areas are exposed to possible landslides and debris flows when experiencing torrential rainfall. The 137 school locations within the 100 m buffer of active faults have higher vulnerabilities to seismic damages. Schools under potential inundated areas are exposed to possible floods.

The MOE started to setup a school geo-information management system to analyse further school vulnerability in 2005, and a three-year project (2009-2012) is being conducted to determine school risk vulnerability. Schools in potential rainfall inundated areas, and in slope areas that may be affected by debris flows or landslides, are also likely to be impacted by climate change. This is another result of Typhoon Morakot found in the case of Xiaolin Elementary School where 58 students died (including missing). The surviving students experienced shock that is having a great psychological impact. The psychology recovery activity design after catastrophic disaster is one lesson that would be of great benefit in situations similar to this.

Conclusions

Typhoon Morakot caused 1,328 schools to be damaged and 13 schools needing to be relocated. The disaster was responsible for nine student deaths, 49 missing students, and one serious injury. Field investigation and GIS spatial analysis show that most of the school infrastructures were damaged by multi types of disasters that include landslides, debris flows, floods, and breached dams. Reasons attributed to the school damages were schools located on the lower stream terrace that was in the path of flowing debris, and landslides occurred. Climate change and school vulnerability analysis, emergency response of teachers, and after school disaster prevention education are urgent in Taiwan.

The aim of disaster prevention education is to promote teacher and student knowledge in disaster prevention. After an overall review of the current disaster prevention education programmes, the following items are to be stressed in disaster prevention education as a result of studying the effects of Typhoon Morakot:

(1) integration of formal and non-formal disaster prevention education into school curricula;

(2) teacher training for campus disaster prevention education (emergency evacuation drills, disaster prevention map, and strengthen of emergency response);
(3) development of a coalition of campus and community-based disaster management; and
(4) study of the impact of climate change and school vulnerability.

School infrastructure safety evaluation and risk assessment, education materials and design activities for psychological recovery after disasters, and the connection of school safety management and community-based disaster prevention are deemed urgent after Typhoon Morakot in Taiwan. It is expected that disaster prevention education will become part of the formal or non-formal school curricula. School safety and vulnerability assessments as a result of climate change and student psychological recovery following disasters are urgent lessons to be implemented after learning from the results of Typhoon Morakot in Taiwan.

References


Further reading

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