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Ex-post evaluation of preparedness education in disaster prevention, mitigation and response

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ABSTRACT

As global climate change exacerbates the potential damage of natural disasters, the need for sustained investment in comprehensive disaster prevention training increases. Taiwan is an island located in a seismically-active area and is regularly subject to natural disasters such as floods, landslides, and earthquakes. Therefore, disaster prevention education must be expanded. This study investigates current practices and suggests future disaster prevention training directions in Taipei, first by conducting a review of practical implementation experience and the literature on learning theory. A questionnaire survey was performed to solicit input from community leaders who had completed the training program. Structural equation modeling is used to determine the learning satisfaction index and the impact of construct interaction on learning outcomes. Finally, a two-dimensional pattern is developed as an important performance evaluation indicator, which can then be fed-back into the long-term disaster prevention strategy formulation process to ensure that the improvements in learning effectiveness are sustainable.

1. Introduction

The location of Taiwan in a seismically-active area of the Pacific Rim makes it vulnerable to natural disasters such as typhoons, earthquakes and flooding [1]. Taipei City is the political and commercial heart of Taiwan and is the city with the highest population density. The government is tasked with providing effective disaster prevention and loss-prevention measures with limited resources [2].

In particular, Taiwan Ministry of the Interior (MOI) policy is to prevent or reduce the damage caused by natural disasters, promote disaster prevention planning, analyze threats and preparedness on a regional basis, strengthen the prevention awareness and capacity of all agencies, improve disaster response, readjust the allocation of prevention resources, and accelerate post-disaster recovery [3–5].

During 2000, the "Disaster Protection and Response Act" has been enacted due to a series of long-term research and development programs for disaster reduction and response that have been promoted since the year of 1982. After several severe domestic natural disasters occurred in Taiwan, the government units at the central, county (city) and township (town, district) levels began taking action directed by the MOI so that, when another disaster strikes, a rapid and precise response will enable timely rescue and relief work that reduces the social impact of disasters and prevents further damage.

The studied disaster prevention training programs were implemented in Taipei. Each training program focused on different disaster prevention and rescue tasks to suit the requirements at various levels (Fig. 1). Improved basic disaster prevention and response knowledge required local governments to assess and analyze potential disaster risk with a focus on contingency planning in disaster-prone areas. Disaster management personnel in each district were required to improve disaster prevention and response notification procedures and to enhance the operations and warning efficiency of regional response centers.

Additionally, opinion leaders and officers at each level were required to perform drills repeatedly to increase the effectiveness of their disaster response and to use resources effectively in order to minimize casualties and losses. This system provides disaster prevention and response personnel at different levels with an overall understanding disaster prevention concepts and techniques, thus ensuring the overall robustness of the system and mechanisms.

Domestic disaster relief programs are currently delivered in two stages: a planning stage and an execution stage. The planning stage emphasizes observation and process documentation, testing, and efficiency evaluation [6]. However, once implemented, the effectiveness of these programs must be evaluated to determine

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Global climate change and disaster potential

Basic disaster prevention knowledge

Regional review of major disasters

Theme-based instruction

Disaster prevention and response operations

Response center operations and community-based disaster prevention concepts

Fig. 1. Disaster prevention training and practice.

whether the project has achieved the desired goals. A mechanism is also needed for using impact factors as feedback in the training strategy formulation process.

The objective of this study is to review domestic medium and long-term preparedness education for disasters and evaluate government performance so as to possibly improve future implementation efficiency. Based on the correlations identified between implementation items, policy reforms and improvements are recommended. The study highlights the importance of using performance evaluation benchmarks to integrate feedback into the incremental improvement of disaster prevention education policy.

Moreover, this study aims to explore the impacts of various factors on post-event learning outcomes, to suggest improvements, and to establish a feedback loop for disaster prevention training. The first step is to create a model that reflects the current state of disaster prevention training planning and implementation processes in Taipei City. Evaluation indicators and construct modeling assumptions from the literature on learning theory are then linked to the training practice.

After performing a questionnaire survey for data collection, structural equation modeling (SEM) is used to validate the data analysis and to explore implicit correlations of mediation and moderation effects on learning outcomes. Finally, benchmarking concepts are used to create a learning satisfaction index for further use in baseline analysis. The index measures the assessment indicators. By facilitating recommendations for improving ex-post performance effectiveness, this study contributes to facilitate future government initiatives to improve disaster prevention-related training.

2. Literature review

2.1. Disaster prevention planning in Taipei

In 1994, the Executive Yuan established the “Disaster

Prevention and Response Program", a "Basic Disaster Prevention Plan", a "Disaster Prevention Operations Plan" and a "Regional Disaster Prevention Plan", to improve disaster and accident prevention in Taiwan by developing disaster prevention mechanisms at all central and local government agencies. The overall disaster prevention system and emergency response capacity of Taiwan was sorely tested by an earthquake on September 21, 1999 that left 2,415 people dead, 29 missing and over 11,000 injured.

Facing the large-scale, high intensity, and continuously occurring disasters, the concept of community resilience in disaster management has gradually developed and drawn significant attention. The following year, the government passed the "Disaster Prevention Act" to consolidate and rationalize responsibility for disaster prevention and preparedness among various agencies and to clarify their management and operations responsibilities. In addition, Taiwanese central government has designed a community-based process for disaster adaption based on the Hyogo Framework for Action 2005–2015. Since 2004, the process has been applied to more than one hundred communities in Taiwan, not only by our research team but also by the Taiwanese government [7].

Hyogo Framework for Action (HFA) identifies several specific priorities for action, containing improving risk information and early warning, building a culture of safety and resilience, reducing the risks in key sectors, and strengthen disaster preparedness for effective response [8]. Therefore, in 2006, the "Regional Disaster Prevention and Rescue Three-Year Plan" included in the National Disaster Prevention and Rescue Report proposed measures and strategies for strengthening disaster preparedness and mitigation, improving emergency response, and accelerating disaster recovery. The proposed measures included vertically integrating central, county and municipal government disaster prevention plans and resources, and establishing strong links to rural areas to ensure a comprehensive disaster prevention capacity.

However, given the expanding impact and scale of natural disasters, further efforts are needed to improve grassroots disaster prevention and response. Thus, the Executive Yuan implemented Phase 1 of the Disaster Prevention and Response Plan in 2010–2012 and implemented Phase 2 in 2014–2017. This plan expands disaster prevention expertise and capacity at the township level, upgrades relevant work goals and processes at the local level, and cultivates basic disaster prevention capacity [3–5].

Notably, the aim of the Disaster Prevention and Response Plan is to resolve dilemmas and issues that limit the effectiveness of frontline disaster prevention and response, to guide the direction and formulation of strategic goals for national disaster prevention and response, and to develop an outline for program content, thus improving the overall effectiveness of national disaster prevention and response work.

2.2. Importance of training for disaster prevention and response work

The purpose of natural disaster risk management is to minimize the impact of natural disasters by continuously monitoring potential threats and by implementing dynamic processes such as disaster planning, project implementation, and emergency rescue and response. Regular and rigorous disaster prevention training, preparedness work and the integration of rescue resources can effectively enhance disaster response capabilities [9–12].

Since the Taiwanese central government has designed a community-based process for disaster adaption, disaster management plans should now focus on the grassroots level. That is, national preparedness and resiliency should be enhanced by improving local disaster prevention capacity [13,14]. Local governments and NGOs (non-governmental organizations) should organize seminars to provide local residents with basic knowledge and skills in disaster prevention and response [15]. Raising public awareness of the importance of disaster prevention can minimize local environmental risks.

The Taipei City disaster prevention and response plan currently focuses on averting or minimizing disaster risk, reducing disaster loss, and promoting awareness. The plan calls for systematically implementing appropriate measures to raise awareness of the basic principles of disaster prevention and associated techniques needed for effective disaster prevention.

2.3. Assessing the effectiveness of disaster prevention training

Training evaluation models developed so far assess the implementation effectiveness of domestic plans, with an emphasis on process documentation, behavior modification, and implementation efficiency [12,16]. Determining the implied value and long-term benefits of such plans requires a comprehensive analysis of longitudinal data to support recommendations for improvement.

From the current disaster management perspective, efforts to improve the efficiency of disaster prevention strategies should first re-examine the theoretical foundations of such strategies and review relevant data to facilitate the interpretation and application of theoretical concepts. Therefore, after reviewing the relevant literature and case studies, this study performed semi-structured interviews to obtain feedback and opinions from residents who had experienced natural disasters and from personnel who had gone through disaster prevention training. The resulting data were then used to improve current measures and to develop additional measures [17].

From a cost efficiency perspective, however, the cost/benefit of training must be considered to maximize the impact of future investment. Thus, evaluating training effectiveness not only provides insight into actual training outcomes, but also provides a reference for the continuous improvement and updating of training content [18].

The Taipei City disaster prevention and response plans, which are currently in the second phase, focus on allocating resources efficiently and on planning for future implementation of disaster prevention and response training. This study presents the results of a continuous integrated post-event assessment process to investigate factors that affect learning outcomes and to explore ways to make further improvements in training unit performance.

2.4. Learning through benchmarking

Promotion of organizational learning and reflection requires comparative baselines established by a continuous investigation of industry dynamics to identify optimal performance goals for the continuous improvement of learning outcomes. This approach not only helps develop cultural or organizational learning, but also facilitates organizational reform and innovation [19].

Before benchmarking is performed, the researcher must first re-examine the internal structures, service modalities and operations flows of the organization to establish key performance indicators and to identify areas for improvement [20]. For example, to improve the international competitiveness of domestic firms, Anderson and Fornell were commissioned by the US government to develop a customer satisfaction index and service quality benchmarks in the expectation that these tools would facilitate domestic economic analysis and help improve the effectiveness of economic policy [21].

This study first analyzed the operations of the Phase 1 Disaster Prevention and Response Five-Year Plan implemented by the National Fire Agency, MOI in order to assess the impact of potential

Table 1
Constructs and measurement items.

Research construct	Construct measurement variable		References
Disaster prevention literacy (DPL)	Familiarity with disaster prevention equipment	DPL_1	[22,23,24,59,60]
	Access to disaster-prevention related information	DPL_2	
	Ability to act autonomously to prevent or reduce disaster damage	DPL_3	
	Understanding of appropriate responses to different disaster types	DPL_4	
	Familiarity with disaster contingency measures	DPL_5	
Disaster prevention attitude (DPA)	Awareness of impact of disaster prevention on personal health and property	DPA_1	[22,23,24,61]
	Recognition of the importance and value of disaster prevention	DPA_2	
	Recognition of the importance of disaster prevention work	DPA_3	
	Personal initiative to determine security status of personal living environment	DPA_4	
	Advocacy for disaster prevention programs	DPA_5	
Instructor performance and course design (IP&CD)	Instructor attitude	IP&CD_1	[25,26,27,62,63,64]
	Instructional methods	IP&CD_2	
	Instructor expertise	IP&CD_3	
	Background and experience	IP&CD_4	
	Instructional environment	IP&CD_5	
	Number of class sessions	IP&CD_6	
Learning satisfaction (LS)	Satisfaction derived from learning about disaster prevention	LS_1	[28,29,30,31,53,65]
	Satisfaction with instructor	LS_2	
	Satisfaction with instructional venue arrangements	LS_3	
	Satisfaction with enrollment procedure	LS_4	
	Overall satisfaction with the training course	LS_5	
Learning effectiveness (LE)	Enhanced disaster prevention knowledge	LE_1	[10,12,32,33,53,66,67]
	Achievement of learning goals	LE_2	
	Effectiveness of training	LE_3	
	Increase in confidence to respond to disasters	LE_4	
	Improvement in awareness of evacuation practices	LE_5	
	Improvement in safety of self, family and property	LE_6	

natural hazards on the requirements for disaster prevention training, build a learning satisfaction index, establish benchmarks, assess trends in the satisfaction with training, and assess overall project performance. After Phase 1 is completed, improvements in integration, supervision and implementation will be proposed in Phase 2 (2014–2017). Based on the Phase 2 results, the government can assess investment priorities and use of funds to achieve further improvements in learning outcomes.

2.5. Causal assumptions and evaluation indicators

After a review of the relevant literature, a questionnaire was developed for data collection. The research study was to use structural equation modeling (SEM) to validate the applicability of theoretical constructs and to evaluate the adequacy of the model for describing the characteristics of the data. The questionnaire integrated indicators suggested by the literature and was tested and revised before formal implementation. Table 1 reviews and summarizes the causal assumption paths for items in each construct in the analysis of changes achieved by training. Brief discussion is provided as follows.

2.5.1. Disaster prevention literacy and attitudes towards disaster prevention

Motivation is essential for good learning outcomes, and learners who develop intrinsic motivations are able to form extrinsic organizational patterns of behavior [22,23]. Disaster prevention training is intended to cultivate the skills and awareness needed to react positively and actively to a disaster. Therefore, “attitudes toward disaster prevention” include concern about disaster prevention, the ability to recognize situational severity, relevant beliefs and values, and a sense of responsibility for preventing disasters.

The theory of reasoned action suggests the existence of relationships among personal intention, attitude and behavior. Of these, attitude has the greatest impact on learning behavior, and such attitudes are impacted by subjective norms (e.g., social customs, the opinions of peers, etc.) to form the individual's subject literacy, and finally inform the individual's extrinsic learning behavior [24]. Thus, the following hypothesis is assumed.

H1: Disaster prevention literacy positively affects attitudes about disaster prevention

2.5.2. Instructor performance and course design

Since most participants in this round of training were middle-aged or older, this study was performed from an adult learning perspective and focused on solving current practical problems [25,26]. Therefore, the benefits of participating and training must be clearly communicated to students in order to stimulate their awareness and positive attitudes toward disaster prevention. A qualified instructor and quality materials are needed not only to improve learning outcomes, but also to ensure that the course satisfies the learning goals and the student expectations [26,27]. The following hypotheses regarding the impact of instructor performance and course design (IP&CD) are proposed accordingly:

H2: A positive attitude toward disaster prevention positively affects IP&CD.
H3: Disaster prevention literacy positively affects the course design.
H7: IP&CD positively affect learning outcomes.

2.5.3. Learning satisfaction

Various theories of learning satisfaction have been proposed in the literature. Some studies indicate that learning satisfaction depends not only on successful completion of the learning process, but also on the removal of obstacles to learning and whether

learners have an improved understanding of their learning achievement level [28–30]. Therefore, we propose the following hypotheses:

H8: Attitude toward disaster prevention is positively associated with learning satisfaction.
H9: Disaster prevention literacy is positively associated with learning satisfaction.

Additionally, different instructors apply different curriculum design strategies, which indirectly affect the overall learning process, learning satisfaction, and outcomes. Jung et al. experimentally confirmed that learning satisfaction affects learning outcomes [31]. In Lim et al., comparisons of pre-test and post-test performance indicated that increased learning satisfaction correlates with improved learning outcomes [29]. Therefore, this study proposes the following hypotheses:

H4: IP&CD have positive effect on learning satisfaction.
H10: Learning satisfaction has a positive and significant positive effect on learning outcomes.

2.5.4. Learning effectiveness

By improving disaster prevention knowledge, skills, attitudes and behaviors and by applying such knowledge to everyday life through self-study, values and learning expectations can raise or lower learning transfer outcomes [10,12,32]. The training instructor must have a deep understanding of the nature and characteristics of the learners in order to make appropriate adjustments to the curriculum content, to improve learner behavior, and to improve learning outcomes [33]. Therefore, increased disaster prevention literacy and attitudes result in increased learning effectiveness and good learning outcomes. Based on the above, the following hypotheses are proposed:

H5: Individual disaster prevention literacy has a significant positive effect on learning outcomes.
H6: Individual attitudes toward disaster prevention have significant positive effects on learning outcomes.

Fig. 2 is a diagram of the structural paths of these hypotheses. In further empirical analyses, the model is used to quantify the impacts of constructs on learning outcomes and associated performance indicators.

3. Research methodology

3.1. Qualitative approach

Three qualitative approaches employed in this study are case study, participant observation, and action research. The case study is intended to provide a true understanding of spatially- and temporally-limited social phenomena and to provide complete information, including context, causal relationships and hidden factors deeply rooted in particular cultural values [34–36]. In the case study reported here, field observations of management planning and execution processes for data compilation and analysis were analyzed and supplemented with evidence from the literature and data experts as the basis for constructing an overall theory of disaster prevention and response training.

Participant observation in the field gives researchers insight into the historical background of a phenomenon, its activity relationships, its social context and causality, and the actual requirements and challenges of each unit level [33]. This study applied participant observation methods to courses in disaster prevention and response. The data were expected to be useful for

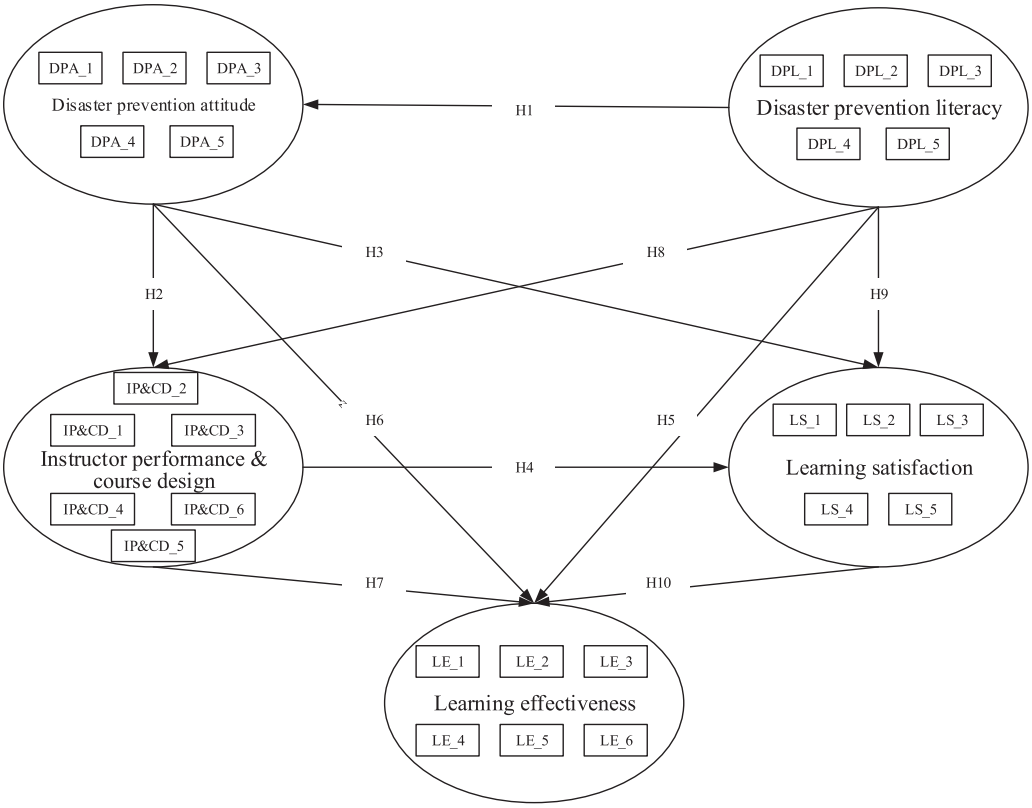

Fig. 2. Research model.

improving future training programs by identifying and assessing the impact of constructs and indicators on learning outcomes and training effectiveness.

In action research, social experiments are performed to explore the causes of social problems by first focusing resources on priority areas [37]. The findings are then used as the basis for practical solutions. This study selects seven administrative districts in Taipei City (Xinyi, Songshan, Neihu, Nangang, Wanhua, Peitou, and Chungshan) for comparison of their planning for disaster prevention training courses, curriculum design and arrangements, learning materials and training effectiveness, historical disaster record, disaster potential, risk factors and local environment for each district. The findings are then integrated with quantitative results to identify valuable coping strategies, knowledge and experience for future disaster prevention training.

3.2. Quantitative approach

3.2.1. Structural equation modeling

Structural equation modeling (SEM) was originally developed by Jöreskog (1973) for factor analysis in psychology and for path analysis in biology. The SEM is now widely used in psychology [38], social science [39], health sciences [40] and management [41–45], which indicates its importance in academic research.

An SEM comprises a measurement model and a structural model [46]. The measurement model shows linear relationships between indicator variables and constructs and whether or not the indicators explain the constructs. The structural model establishes a linear regression relationship between the established constructs and simultaneously evaluates the causal relationships between measurement problems in the system to provide better handling of measurement errors.

The measurement model is calculated as follows:

$$X = \Lambda_{\boldsymbol{x}}\xi + \delta \tag{1}$$

$$Y = \Lambda_{\boldsymbol{y}}\eta + \varepsilon \tag{2}$$

where X is the exogenous observed variable, Y is the endogenous observed variable, ξ is the endogenous latent variable, Λ is the regression coefficient matrix of the observed variable and the latent variable, and δ, ε are the measurement errors.

The structural model matrix equation is

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3}$$

where η is the endogenous latent variable, B is the regression coefficient matrix between the endogenous latent variables, Γ is the regression coefficient matrix between the exogenous and endogenous latent variables, ξ is the exogenous latent variable, and ζ is the potential error.

The SEM uses statistical analysis of covariance (ANCOVA) methods to estimate the difference between the test covariance matrix and the sample covariance and to derive specific parameters for evaluation and analysis [38]. The basic assumption of the ANCOVA method is that the covariance matrix of the measured variables is used to set the parameters using the following equation:

$$\sum = \sum(\theta) \tag{4}$$

where Σ is the covariance matrix of the observed variables, θ is the model parameter estimated vector, and $\Sigma(\theta)$ is the covariance matrix of θ.

In SEM analysis, the model parameter θ proceeds with estimation mainly using the sample covariance matrix and model covariance matrix with the smallest difference. Estimation is usually performed by maximum likelihood estimation (MLE) method, in which a normal sample distribution is used to reproduce the $\Sigma(\theta)$ matrix. This iterative process obtains the smallest difference between the sample covariance matrix and the model covariance matrix. The MLE function is as follows:

$$F_{ML=}\log\left|\sum(\theta)\right| - \log|S| + tr\left(S\sum(\theta)^{-1}\right) - (m+n) \tag{5}$$

where $\Sigma(\theta)$ is the covariance matrix of the estimation model and S is the sample covariance matrix. When the estimation model matrix and the sample matrix correspond completely, subtracting the S matrix from the $\Sigma(\theta)$ matrix equals 0 while $tr\left(S\boldsymbol{\Sigma}(\theta)^{-1}\right)$ is equal to $(m+n)$. Therefore, F_{ML} is 0 theoretically. Thus, the similarity between the sample covariance matrix and the model covariance matrix indicates compliance with the model assumptions.

3.2.2. Learning satisfaction index

According to learning theory, learning satisfaction, i.e., the feeling of satisfaction once training is completed, contributes to good learning outcomes. Therefore, for a clear understanding of the learning satisfaction trends in students during the 3-year training period, this study used American Customer Satisfaction Index (ACSI) [47] as a theoretical basis for establishing a Learning Satisfaction Index (LSI). Confirmed indicators within the learning satisfaction construct were used for performance evaluations according to the LSI which is calculated as follows:

$$\mathrm{LSI} = \frac{\sum_{i=1}^{n} w_i\overline{y_i} - \sum_{i=1}^{n} w_i}{(r-1)\sum_{i=1}^{n} w_i} \times 100 \tag{6}$$

where $\overline{y_i}$ is the average score of the learning satisfaction indicators i, W_i is the indicator weight (standardized factor loading derived from SEM), r is the number of Likert scale items (this study uses a five-level Likert scale), and n is the number of indicators measured.

3.2.3. Importance–performance analysis

Importance–performance analysis (IPA) is a simple and effective method used by decision makers to rank the relevant attributes of particular services or products and appraise performance [48]. By succinctly presenting the pros and cons of a product or service, IPA helps managers understand customer expectations and levels of performance. Thus, the public service sector uses IPA extensively for product strategy and service management [49–51].

From a market demand perspective of educational training, recent studies of educational operations indicate the need to satisfy student learning needs and the need to improve attendance and willingness to learn [52].

To enable re-examination of training course performance and evaluation of the analysis results, the horizontal axis in IPA is defined as the learner perception of learning outcomes (taken from questionnaire results) while the vertical axis is defined as the indicator impact on learning outcome (taken from SEM analysis results). Thus, the relative positions in the matrix can then be grouped as shown in Fig. 3.

Quadrant I shows indicators that have a high impact on learner perceptions of learning outcomes. Current resources and inputs should be maintained to ensure continued high performance levels. Quadrant II shows students who recognize the importance of the indictors but are unsatisfied with their learning experience. Thus, the content of the assessment indicators in this quadrant should be considered first and appropriately adjusted according to the reaction of the trainees. Quadrant III indicates areas requiring review and improvement. The indicators in this quadrant not only have a low impact on trainee learning outcomes, but are also associated with poor self-perceived learning outcomes.

Quadrant IV indicates a trainee perception of a good learning

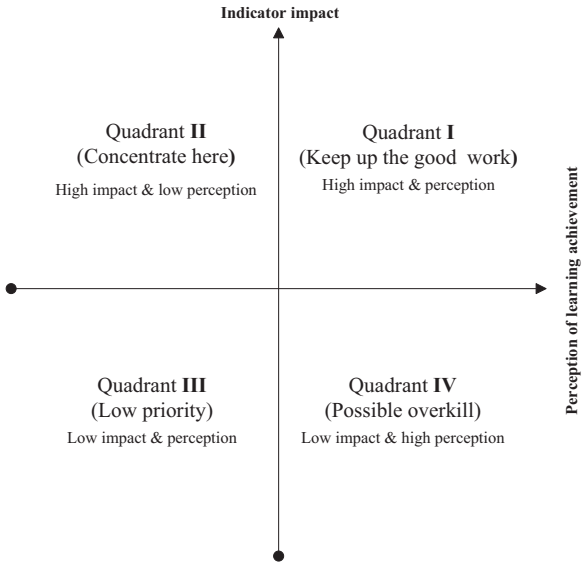

Fig. 3. Importance–performance analysis.

outcome, even if the considered indictor did not significantly affect the learning outcome. Given limited disaster prevention resources, the priority of indicators in this quadrant can be considered low.

4. Disaster preparedness education and knowledge sharing

After reviewing disaster prevention planning policy and models in the literature, this study investigated disaster prevention training programs in order to identify key content areas for disaster prevention training, along with core values and strategic applications for economic development. One year after the program was completed, the above measurement indicators were used to design a questionnaire while the described methodologies were employed to assess the learning outcomes of trainees.

4.1. Education performance assessment mechanisms

The efforts of Taipei city to promote disaster prevention and response training include plans to enhance policy and system regulations, and the formation of public disaster guidance. With the assistance of the public sector, the program is designed to integrate diverse resources and expertise to meet the needs of different research focuses and development trends.

Specifically, the training curriculum integrates accumulated experience and knowledge to achieve course objectives and program goals. This training is designed to facilitate the transfer of knowledge, expertise and skills that communities need to identify and address potential environmental disaster threats and to reduce the social, economic, and environmental impacts of disasters in Taiwan.

The training goals were established by the Taipei city government while the planning and implementation of the training courses (Fig. 4) were organized by a team of instructors from the National Taiwan University of Science and Technology. Experts and scholars were periodically invited to share their experience with the trainees. The disaster prevention training was performed at the Emergency Operations Center of Taipei, not only to provide easy access to instructional media and appropriate materials for the training curriculum, but also to provide concise explanations and a presence to increase trainees' learning performance.

By demonstrating the effectiveness of student learning along with instructional resource inputs, the theoretical investigation and practical action was clarified, and a mechanism was established for assessing learning outcomes for basic literacy and core competencies. A review of the performance assessment literature found that the results of performance evaluation mechanisms (e.g., Kirkpatrick learning and behavioral levels [53], CIPP process evaluation [54], IPO process and output stages [55]) should be provided to the training unit for continuous review and improvement of curriculum planning for both instructors and students. This procedure ensures the effectiveness of future curriculum changes to meet changing socioeconomic needs.

Therefore, to develop effective disaster prevention training, this study performed a questionnaire survey with the assistance of government agencies to collect data prior to and post-training to gain insight into trainee knowledge and attitudes prior to the onset of training and to assess knowledge acquired during the training. Suggestions were solicited from various sources by dynamically adjusting the course content and instructors to create an integrated and complete disaster prevention training for use at all levels. Analysis results are discussed to track post-training performance and to solicit feedback needed to improve the quality and effectiveness of future regular trainings to promote and improve disaster prevention knowledge, skills and attitudes.

4.2. Integrating disaster prevention efforts and knowledge of technological developments

Recent trends in global urbanization and climate change have focused attention on the difficulty of forecasting and controlling

Fig. 4. Disaster prevention training materials.

Fig. 5. Symposium implementation process.

the impact of disasters in urban areas. Integrating urban disaster prevention and response efforts at all levels, including government, business, civil society, social organizations and the general public, improves public and social autonomy in disaster prevention and response. Improved disaster prevention effectiveness resulting from these integrated efforts is an emerging trend in disaster prevention in economically advanced countries.

Therefore, workshops were performed concurrently with the training to demonstrate the overall implementation progress and effectiveness of the program (Fig. 5). Experts in the field of disaster prevention were invited to present lectures which provide a broader viewpoint and specific knowledge to drive subsequent small group discussions about individual training requirements. Finally, trainees shared their disaster prevention experience and exchanged knowledge. This helped to ensure that the disaster prevention work was consistent with current trends and that the implementation of disaster prevention planning included new disaster prevention techniques. These steps were intended to minimize the damage and casualties caused by potential disasters and to accelerate the recovering process.

5. Data collection and post-training evaluation of learning outcomes

5.1. Descriptive statistics

Ex-post training questionnaire was developed to assess learning outcomes from disaster-preparedness training over a 3-year period. Out of 480 questionnaires distributed to borough presidents and officials in Taipei, 178 valid responses were collected, which was a valid response rate of 37.08%. The questionnaire design was based on indicators taken from the relevant literature. The questionnaire was tested and modified prior to implementation with the sample group.

Table 2 summarizes the socioeconomic characteristics of the surveyed community leaders: 49.4% were borough presidents, and the remaining 50.6% were lower level borough officials. Borough officials represent the borough president and are assigned to perform regular disaster prevention tasks. When a severe disaster occurs, these officials are responsible for managing, guiding, and delegating tasks to ensure an effective disaster response immediately after the disaster.

Over half of the respondents had at least 5 years of experience in their posts, and the largest group (35.4%) were aged 46–55 years. The respondents were highly familiar with their local environmental conditions and had rich experience in disaster prevention work, including an in-depth understanding of local needs. Almost two-thirds (64.6%) of the respondents were university graduates, indicating that community leaders are generally highly educated and thus have no major impediment to learning disaster prevention related knowledge. Most (52.8%) respondents had previously participated in at least four training programs related to disaster prevention. Interviews with the respondents found that each borough president and official had a high willingness to participate in training related to disaster prevention.

Table 2
Socioeconomic characteristics of community leaders.

Item	Description	Frequency	Percentage (%)
Position	Borough president	88	49.4
	Borough official	90	50.6
Age	18–25 years	2	1.1
	26–35 years	26	14.6
	36–45 years	30	16.9
	46–55 years	63	35.4
	56–65 years	42	23.6
	66 years and older	15	8.4
Education level	Elementary school and below	3	1.7
	Junior high school	8	4.5
	Senior high school or vocational school	52	29.2
	University and college	108	60.7
	Graduate institute and postgraduate	7	3.9
Years in service	4 years or less	48	27.0
	5–8 years	47	26.4
	9–13 years	43	24.2
	14–18 years	14	7.9
	18 years or more	26	14.6
Previous training	1	22	12.4
	2	35	19.7
	3	27	15.2
	4 or more	94	52.8

Table 3
Confirmatory factor analysis results.

Latent construct	Measurement variable	λ	AVE	CR	α
Disaster prevention literacy	DPL_1	0.886	0.848	0.965	0.965
	DPL_2	0.904			
	DPL_3	0.912			
	DPL_4	0.941			
	DPL_5	0.961			
Disaster prevention attitude	DPA_1	0.797	0.710	0.924	0.924
	DPA_2	0.923			
	DPA_3	0.911			
	DPA_4	0.811			
	DPA_5	0.758			
Instructor performance and course design	IP&CD_1	0.928	0.777	0.954	0.942
	IP&CD_2	0.942			
	IP&CD_3	0.912			
	IP&CD_4	0.871			
	IP&CD_5	0.904			
	IP&CD_6	0.712			
Learning satisfaction	LS_1	0.822	0.775	0.945	0.946
	LS_2	0.906			
	LS_3	0.927			
	LS_4	0.842			
	LS_5	0.901			
Learning effectiveness	LE_1	0.856	0.817	0.964	0.966
	LE_2	0.927			
	LE_3	0.941			
	LE_4	0.916			
	LE_5	0.925			
	LE_6	0.887			

5.2. Confirmatory factor analysis

The purpose of confirmatory factor analysis (CFA) is to confirm the reliability and validity of the relationship between latent constructs and measurement variables. Construct reliability is normally tested using Cronbach Alpha (α) [38] while construct validity is tested using factor loading, average variance extracted (AVE) and composite reliability (CR) [38,56].

Generally, a Chronbach Alpha value larger than 0.7 indicates a high reliability between the observed indicators and constructs. Table 3 shows that all measured constructs had Chronbach Alpha values well above 0.7, indicating high reliability. In terms of validity, factor analysis of the factor loadings is used to measure the consistency of tested indicators and constructs. A high factor loading suggests that an indicator adequately explains the variance in the tested construct. Hair et al. (2010) recommended that factor loadings should exceed 0.5 or, ideally, 0.7 [38]. The factor loadings for latent variables in this study ranged from 0.712 to 0.961 (Table 3), which indicated high validity.

Extracted variance is the estimated explanatory power of the variance in each latent construct. Thus, it indicates their convergence [38]. Fornell and Larcker recommended that the standard AVE value should be greater than 0.5 [56]. The CR value of latent constructs indicates the internal consistency of construct indicators. Hair et al. recommended that standard CR values should exceed 0.6.

Generally, if the correlation coefficient between two constructs is less than 0.7, the constructs have discriminant validity [57]. However, when using AVE as an indicator of validity, Hair et al. recommended that the test for discriminant validity should be whether the square root of the AVE of the construct is greater than the correlation coefficient between the constructs. The analysis results presented in Table 4 show that the square roots of the AVEs

Table 4
Correlation and discriminant validity.

Construct	DPL	DPA	IP&CD	LS	LE
DPL	**0.921**				
DPA	0.324	**0.843**			
IP&CD	0.444	0.433	**0.881**		
LS	0.386	0.215	0.420	**0.880**	
LE	0.363	0.229	0.470	0.837	**0.904**

Table 5
GFI criteria and output values.

Fit indices	Suggested requirement standard	Result
χ^2/df	< 3	1.667
GFI	> 0.8	0.847
CFI	> 0.9	0.967
IFI	> 0.9	0.968
RMSEA	< 0.1	0.062

for all constructs (i.e., the coefficients on the diagonal) exceed the correlation coefficients of the corresponding constructs. Thus, the constructs are mutually distinct.

5.3. Path analysis

The objective of this analysis was to determine the level of relationships between constructs and to explore their subsequent mutual mediating or moderating effects. When estimating model parameters, if the theoretical assumptions have a poor fit to the observed data, the researcher usually improves the fit by increasing or deleting the path between the model constructs or the construct indicators. Possible causes of the poor fit must be considered when correcting or rebuilding the model so that it not only matches the theoretical justification, but also has sufficient reliability and validity.

Fig. 6 shows the final path model at 5% significance level, in which the reliability and validity for each indicator and construct complied with the recommended standards. Table 5 further shows the goodness of fit output values for the modified model. Again, χ^2/df、GFI, CFI, IFI and RMSEA all complied with the values recommended in the literature [38,57,58]. Since the proposed model satisfies the goodness-of-fit test, it can be used to explain the positive impact of attitudes towards disaster prevention awareness, instructors, curriculum design and learning satisfaction. The model can also be used to explain the positive impact of attitudes towards disaster prevention awareness, instructors, curriculum design and learning satisfaction; it can also explain the positive impact of instructors, curriculum design and learning satisfaction on learning outcomes.

5.4. Benchmarking the learning satisfaction index

Based on the results of structural equation analysis and the literature on educational learning theory, this study empirically identified the level of satisfaction derived from participating in the learning process. Moreover, this study found that satisfaction with the learning process is significantly associated with learning effectiveness.

Standardized assessment indicators were constructed to develop a learning satisfaction index, which is applied to results from the disaster prevention training to provide a performance benchmark. According to the annual post-training survey results, learning satisfaction was 74.8→74.1→73.3 in the scale of 100 during 2010-2012. Thus, the level of learning satisfaction can be used as a baseline for future performance comparison. By evaluating the index periodically, the stakeholders can examine their status. However, this process requires considerable management

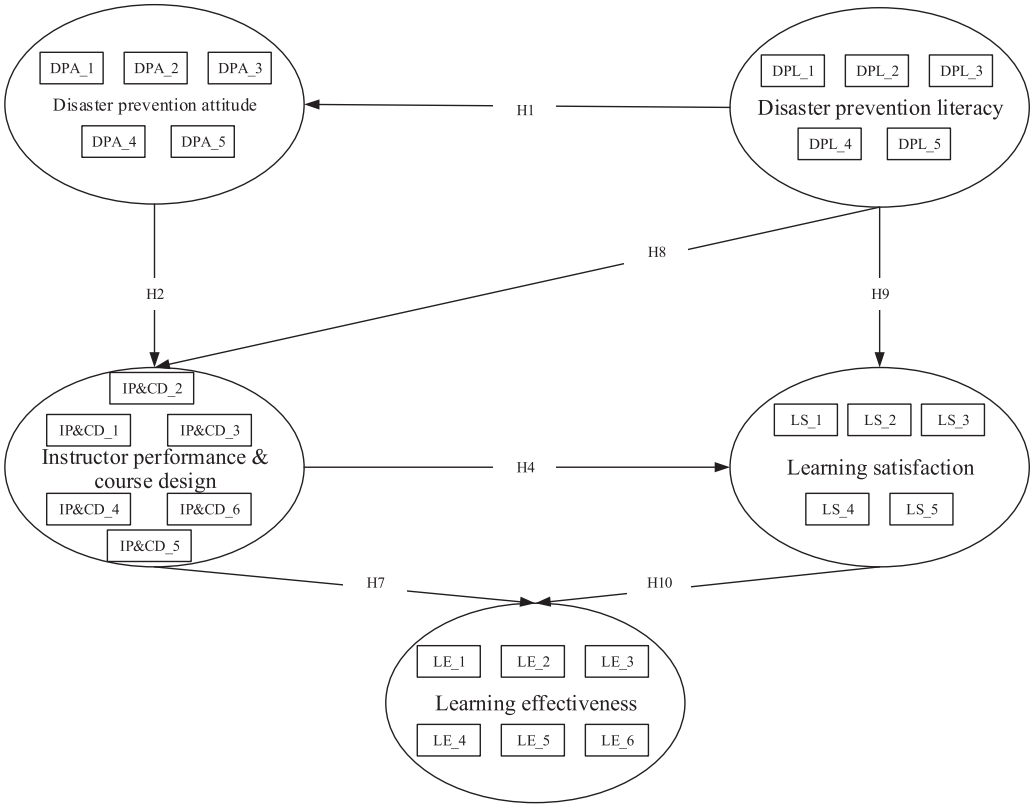

Fig. 6. Significant path model.

Table 6
Overall impact of each construct on learning effectiveness.

Construct	Effect	Learning satisfaction	Learning effectiveness
DPL	Direct effects	0.241	0.000
	Indirect effects	0.135	0.355
	Total effects	0.376	0.355
DPA	Direct effects	0.000	0.000
	Indirect effects	0.099	0.124
	Total effects	0.099	0.124
IP&CD	Direct effects	0.315	0.148
	Indirect effects	0.000	0.245
	Total effects	0.315	0.393
LS	Direct effects	–	0.776
	Indirect effects	–	0.000
	Total effects	–	0.776

effort. After implementing the program, learning satisfaction indicators should be compared in training programs annually to establish benchmarks.

5.5. Analysis of factors impacting post-training effectiveness

To achieve real benefits from independent benchmarking and for further compilation of the above statistical results, Importance–Performance Analysis (IPA) is used to present the overall impact of the indictors for each construct on learning effectiveness. This study used the average response for these indicators as the basis for ranking key impact factors and as a basis for evaluation.

Table 6 shows the direct and indirect effects of each construct on learning effectiveness. The factor loading paths for indicators of each construct were then converted into the overall impact on learning effectiveness. The vertical axis represents the impact of the indicator, and the horizontal axis indicates the average score (perception) for each indicator. The average for each axis is set as the center coordinate of the matrix, which is divided into four quadrants to enable review of proposed improvements in future implementations of disaster prevention training in Taipei.

5.5.1. Quality of learning effectiveness

The analytical results show that the learning effectiveness indicators are the most effective and most direct means of improvement. Fig. 7 shows that, after they completed disaster prevention training, students not only were better prepared for evacuation (LE_5), but also recognized the importance of disaster prevention measures. The main concerns of the students were whether the program could help them face disaster situations with increased confidence (LE_2), whether the training met their personal learning goals (LE_3), and whether the training resulting in effective learning (LE_4).

Notably, poor perceptions of learning value could be remedied by adding disaster simulations or interactive role play activities to give trainees a more authentic and applicable learning experience. Such activities would also improve the disaster prevention literacy (LE_1) of the participants and help them to recognize the importance of protecting personal property and safety (LE_6).

5.5.2. Core strategy for disaster prevention instruction performance and course design

Fig. 8 plots the impact of instructor performance and course design indicators on learning effectiveness. All training was delivered by instructors selected from the Disaster Prevention and Training Institute. At this institute, learning effectiveness is promoted by instructional method (IP&CD_1), positive teaching attitude (IP&CD_2), deep expertise (IP&CD_3) and number of hours of instruction (IP&CD_5). The impact of the disaster prevention experience of the instructor (IP&CD_4) was below average. Therefore, in the future training programs the selection of instructors should be based not only on disaster prevention expertise, but also on practical experience in local disaster prevention. Additionally, the analysis results indicate a need for improving the accessibility of training location (IP&CD_6).

The interview results revealed that, for some participants, the selected training site (the Taipei City Emergency Operations Center) caused difficulty managing administrative affairs in their boroughs and prevented them from responding to urgent events quickly. Therefore, future training courses should be staged in local community centers, which would increase participation rates and overall satisfaction.

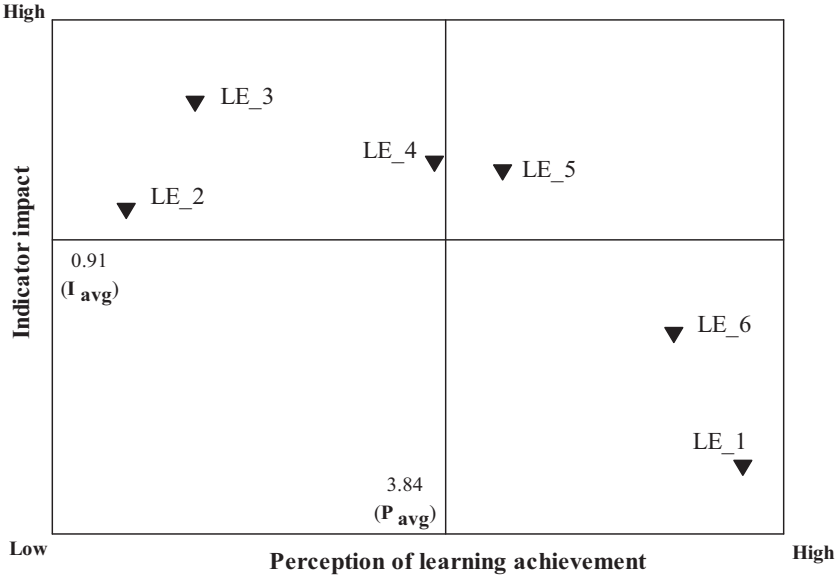

Fig. 7. Evaluation of learning effectiveness indicators.

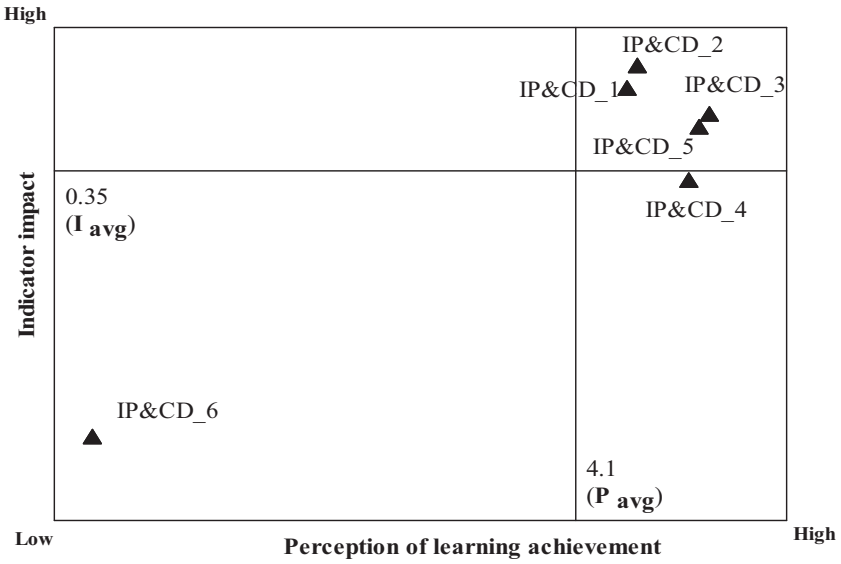

Fig. 8. Impact of instructor performance and course design on learning effectiveness.

5.5.3. Cultivating social awareness of disaster prevention measures。

As Fig. 9 shows, indicators for the transmission of disaster prevention literacy show that, after training, learners can take the initiative to promote disaster prevention work and thus mitigate potential damage and loss (DPL_5), and are able to deeply understand the importance of the program for instilling a broad disaster prevention literacy in the community. Thus, they supported continuation of the program.

After the training, regular disaster prevention drills and response simulations also gave students an improved understanding of how to obtain crucial information related to different disaster situations (DPL_4), in addition to everyday disaster response equipment (DPL_1). When disaster strikes, using these resources reduces the direct impact of the disaster by helping to protect personal safety and property.

Finally, based on the indictors for taking the initiative to obtain information related to disaster prevention for local areas (DPL_3) and for preventing or reducing the likelihood of disaster damage (DPL_2), we infer that, through regular training during the 3-year program, trainees learned to obtain relevant expertise and information autonomously. These skills can then be integrated with disaster prevention awareness at the local level to improve the effectiveness of community-based disaster prevention.

6. Conclusions and recommendations

6.1. Conclusions

Through observation, questionnaires and interviews, this study empirically assessed the impacts of various factors on learning effectiveness for disaster prevention and response training performed in Taipei. The objective was to provide training administrators and instructors with a reference for improving the allocation of training resources. A learning satisfaction index was developed for use as a performance benchmark during continuous monitoring of learning effectiveness and for further analysis of the impact of various indicators on the perception of learning

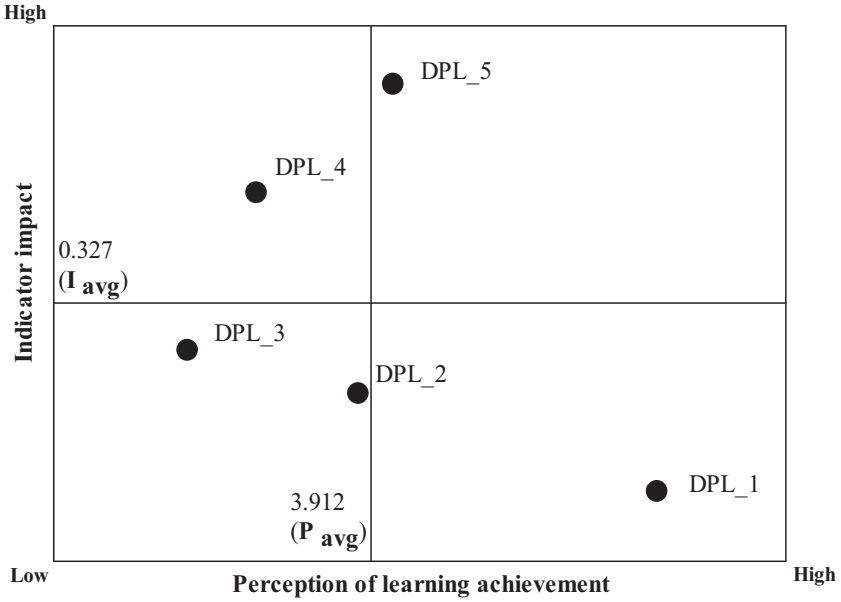

Fig. 9. Overall impact of disaster prevention literacy on learning effectiveness.

effectiveness. The index provided useful feedback for the long-term adjustment of disaster prevention education policy.

Analysis results indicate that learning effectiveness has strong or moderate correlations with learning satisfaction (0.837), instructor performance and course design (0.470), disaster prevention literacy (0.363), and disaster prevention attitude (0.229). Analysis of mediating and moderating effects revealed that good instructor performance and course design combined with high learning satisfaction has a significant positive effect on learning effectiveness. In terms of direct/indirect impact on learning effectiveness, disaster prevention literacy, instructor performance and course design and learning satisfaction have correlations of 0/0.355, 0.148/0.245 and 0.776/0, respectively.

Notably, analysis results for each of the various constructs verify that the Taipei disaster readiness program successfully achieved its education goals and that it had substantial positive impacts on outcomes at each training unit and on broader awareness of the importance of disaster prevention training. This research proposes that borough-level disaster prevention training should not only meet the training needs of learners and have a current and updated content, it also revealed that training should be integrated with broader public participation in the organized cultivation of disaster prevention literacy needed to establish a broad base of disaster prevention knowledge through drills built around local conditions. Such a program should drive public awareness of the importance of disaster prevention and should help residents to execute community-based disaster prevention measures autonomously. Thus, the program promotes a sustainable environment for disaster prevention education.

Additionally, use of LSI developed in this case study analysis for comparison of different hypothetical models over consecutive years revealed that, although learning satisfaction decreased slightly over time ($74.8 \rightarrow 74.1 \rightarrow 73.3$), trainees were largely satisfied with instructor performance and course design. Therefore, the results calculated at the closeout of the Phase 1 disaster prevention training can be used as a benchmark for performance self-evaluation while the results for the Phase 2 training not only provided feedback on the training management process, but also reinforced the continuity of assessment results.

Depending on the available funding, time and resources, indictors that significantly affect learning outcomes should be optimized to improve the allocation of scarce resources. The findings of this study should first be used to cultivate domestic disaster prevention literacy by improving the mass accessibility of disaster prevention and response information, resources and equipment, to prevent or minimize damage from different types of disasters. Participation in disaster prevention training courses along with regular disaster prevention drills increases the capability of communities to cope with disasters and unexpected situations, which reduces social and economic losses and accelerates disaster recovery.

6.2. Future research directions

6.2.1. Collection of long-term data

Given the long-term duration of the disaster prevention training program, a short-term study is inadequate for determining whether the program has achieved its intended results. Objectively evaluating the effectiveness of the program and evaluating feedback content to aid decision-making requires a study over a longer period. That is, data should be continuously collected over a long-term period, and the same metrics should be compared to provide a credible basis for evaluating program outcomes.

6.2.2. Multiple evaluation orientations

Program success is judged on the basis of overall learning effectiveness. However, the actual value of the program in terms of its direct effectiveness is difficult to determine. Therefore, future studies should investigate the experience of other countries in terms of goals, costs, economic benefits, social impact, and environmental influence.

6.2.3. Socioeconomic added value

As climate changes increase and disaster prevention techniques improve, the goals of disaster prevention training program should be able to improve disaster response behavior and to strengthen the local community response capacity, which would increase the value of the program for government, business and society at large. Therefore, future studies should focus on measuring the value of the program in terms of resource inputs and costs set against potential harm reduction in order to establish a rationale for long-term continuation of the program.

6.2.4. Establish data sharing through a disaster prevention and response performance evaluation system

Poor management of domestic disaster prevention and response systems results in the loss of valuable experience. Post-training survey results should be used to assess the training content at each level, and future studies should identify effective evaluation mechanisms, including both domestic and international evaluation mechanisms, and should propose relevant regulations and support measures. This information can be integrated into a set of systematic indicators, frameworks and processes to allow for the future improvement of disaster prevention strategies and the appropriate allocation of disaster prevention education resources.

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