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Original Article

Effectiveness of a school-based fire preparedness program on the knowledge and skills for fire response among primary school students

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ABSTRACT

Introduction: In the border region of Thailand, the absence of a standardized school preparedness program exposes schools to the risk of fires, which can result in injuries, fatalities, and property damage. This study aims to assess the effectiveness of a fire preparedness program for primary schools in Chiang Rai province's border area, serving students from various ethnic backgrounds.

Methods: A quasi-experimental research design was utilized to assess the influence of a fire preparedness program on the knowledge and skills of fire response in primary school students. The study was conducted between July and October 2022, involving a total of 420 primary school students.

Results: This program significantly increased students' knowledge of fire composition ($p<0.001$), types of fire ($p<0.001$), fire response ($p=0.049$ and <0.001), and the basic inspection of a fire extinguisher ($p<0.001$). The fire preparedness program can enhance the fire prevention knowledge scores of students across all grade levels ($p<0.001$). Furthermore, the program has enhanced students' fire response and evacuation skills, elevating their scores from 1.22±0.43 to 3.83±0.51 ($p<0.001$).

Conclusion: These findings emphasize the vital role of fire preparedness programs in enhancing fire safety knowledge and equipping students with essential fire response skills. Such programs are important in preparing students from diverse ethnic backgrounds to effectively respond to fire emergencies.

Keywords: Fire education, Fire knowledge and skills, Fire prevention, Primary school, School-based programs.

Introduction

Fires in schools can result in injuries, fatalities, and property damage.[1-4] Between 2014 and 2018, local fire departments in the United States responded to approximately 3,230 fires within educational institutions, ranging from preschools to high schools. Fires in these schools cost 37 million in direct loss of property and 39 civilian injuries annually.[5] In 2021, the U.S. Fire Administration's report disclosed that the fire death rate per million population was 5.5 for children aged 5 to 9 and 3.1 for those aged 10 to 14.[6] Several severe fire incidents in primary schools have been reported from different parts of countries in Asia. For instance, in India, there was a catastrophic school fire in Kumbakonam that started in the kitchen of the thatched-roofed primary school, resulting in the loss of 94 students.[7] Two more fire cases in Iranian primary schools resulted in 26 injuries

among children and six fatalities.[8,9] While there is no official information regarding fire incidents at schools in Thailand, the Department of Disaster Prevention and Mitigation in Thailand reported that between 2010 and 2020, approximately 4.2% (630 cases) of fire incidents occurred in schools.[10] In Chiang Rai province, a fire incident occurred in a primary school in 2016, resulting in 5 injuries and the tragic loss of 17 children's lives.[11] It's important to note that there are 139 primary schools located in the border area of Chiang Rai province that can impede and obstruct access for the fire department. Therefore, there is an urgent need for an effective fire preparedness program for these schools to prevent fire incidents. It is also in line with the Ministry of Labor's regulations on fire prevention and suppression, B.E. 2555, which was issued under the Occupational Safety, Health and Working Environment Act, B.E. 2554.

Previous studies have indicated that school fires were a concern among environmental hazards in 20 primary schools in Uganda.[3] Risk factors, such as the absence of adequate management plans or readiness, may lead to school fires.[2,12] Additionally, outdated or defective electrical systems, overloaded circuits, and poor wire installation have been identified as potential risks for electrical fires in schools. [13, 14] To build resilience in the face of emergencies and to be well-prepared to mitigate their effects, schools and students need to develop these skills. This preparedness ensures an effective response and enables prompt and efficient continuation of education.[2] Several studies have revealed effective approaches to reducing loss due to fire incidents.[15] For example, one study taught students how to evacuate during a fire using NetLogo agent-based simulations to express and evaluate student behavior to understand crowd movements during a fire disaster in a classroom with two exits. Students' awareness increased by 22.99% after seeing the NetLogo evacuation simulation, which improved evacuation time and safety.[16] Another study focused on assessing and enhancing students' awareness of fire emergencies through expert-led training programs. The findings demonstrated a significant improvement in fire awareness among the participating students, with the percentage rising from 53.5% to 87.9%.[17] Furthermore, implementing a focused fire and burn prevention curriculum in a high-risk school system significantly improved elementary students' fire safety and burn prevention knowledge.[18]

Therefore, in this work, we aimed to develop and evaluate the effectiveness of a fire preparedness program designed for primary schools in the border area of Chiang Rai province, including students from ethnic and non-ethnic groups.

Methods

This study employed a quasi-experimental research design (a one-group pretest-posttest design), aiming to investigate the impact of a school-based fire preparedness program on the knowledge and skills related to fire response among primary school students. The study was carried out between July and October 2022 at a school on the border of Chiang Rai province. Representative primary schools were chosen based on their location in the border area of Chiang Rai province through purposive sampling. Specifically, schools with limitations in implementing the fire safety program were chosen, and they also expressed willingness to participate in this study. Environmental characteristics relevant to fire prevention and response in these schools were assessed (as detailed in Supplementary Table 1). The assessment was conducted by a panel consisting of five officers from the Disaster Prevention and Mitigation Center (District 15, Chiang Rai), 15 staff members, and senior students from the Program in Occupational Health and Safety, School of Health Science at Mae Fah Luang University, as well as 20 teachers from the selected schools. Although the overall evaluation indicated a moderate level with an average score of 3.01±0.61, it's worth noting that six out of the twelve items scored at low levels, ranging from 2.52 to 2.90. None of these schools have implemented standard procedures for school-based fire preparedness programs.

The study population comprises primary school students aged 6 to 15 years old. The sample size was 420 primary school students, calculated using the formula provided by Yamane (1967:886), which accounts for a 95% confidence level and a P-value of 0.05. Primary school students were invited to participate and were informed about the study's objectives. The CONSORT flowchart in Figure 1 clarifies the study design and participants' progress throughout the study. Initially, 519 students were enrolled to participate in the program in a primary school setting. However, 99 students were excluded from the study due to incomplete questionnaires and ineligibility criteria. Ultimately, the sample size was 420 students. All participants confirmed their consent to the researcher and expressed their willingness to participate in the study. The inclusion criteria were as follows: 1) an age range of 6 to 15 years old, and 2) parental consent. Incomplete participants and/or questionnaires were considered as exclusion criteria.

The fire preparedness program utilized in this study was developed based on the guidelines of the Comprehensive School Safety Framework 2022-2033 (Specifically, Pillar Two: School Disaster Management and Pillar Three: Risk Reduction and Resilience Education),[19] as well as the School Fire Prevention Handbook from the Disaster Prevention and Mitigation Office in Bangkok.[20]

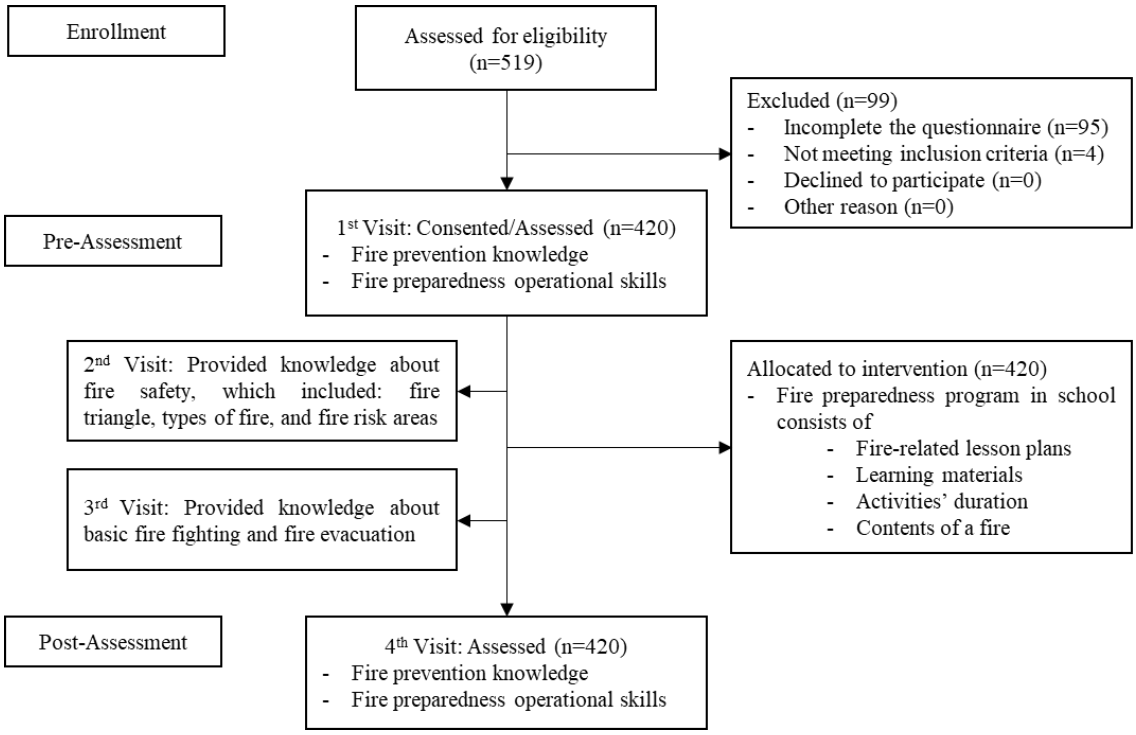

Figure 1: The CONSORT flowchart for the selection process and enrolling participants in the study

The program also incorporated the teaching model recommended by the Learn Not to Burn programs introduced by the National Fire Protection Association (NFPA).[21] The program encompassed various aspects, including learning styles, materials, and content related to fire safety (Supplementary Table 2). The program was implemented with a sample of students in grades 1-6 from primary schools located in the border area of Chiang Rai province. Additionally, students at each grade level were provided with consistent knowledge transfer information, encompassing fire prevention knowledge and fire preparedness operational skills. The lessons on fire prevention knowledge were structured as group activities, integrating visual aids such as photographs, flashcards, posters, and school equipment like fire extinguishers. The educational content encompassed concepts including the fire triangle, types of fires, inspection of fire extinguishers, fire-risk areas, and effective fire response strategies. The learning techniques for fire preparedness operational skills emphasized hands-on experiences.

The program consisted of four separate instances, each with unique features. It was implemented according to a timetable from July to October in the year 2022, as follows: The first instance involved conducting a thorough investigation into the fire environment within schools. This phase included evaluating students' comprehension and competency in fire-related knowledge and skills before participating in the program. Each student was provided with a scorebook to track their involvement in activities. Various assessment tools were employed to evaluate the fire environment inspection, fire prevention knowledge, and fire evacuation practice skills. In the second instance, students were educated about fundamental fire-related concepts through a learning arrangement divided into three distinct bases: the fire triangle base, types of fire bases, and the fire risk map base. Students in grades 1-3 and grades 4-6 were divided into separate groups. Various learning styles were employed, including group activities, Q&A sessions, flashcard matching games, and creating risk maps. During the third instance, students were taught basic firefighting knowledge, divided into the basic fire extinguishing and fire evacuation bases. This phase involved hands-on practice using fire extinguishers, understanding the procedures for extinguishing fires, and knowing how to respond upon hearing a fire alarm. The fourth instance included a fire evacuation drill and a learning summary. The teaching approach concentrated on practical fire response and evacuation skills within school premises. After participating in the program, students' fire prevention knowledge was assessed using the self-evaluation form. Their fire evacuation practice skills were evaluated by a panel of experts, which included five officers from the Disaster Prevention and Mitigation Center (District 15, Chiang Rai), along with 13 staff members and senior students from the Program in Occupational Health and Safety, School of Health Science at Mae Fah Luang University.

The fire prevention knowledge assessment form was distributed to students. Each participant was required to complete the assessment form twice: once before and once after the knowledge transfer session with the fire preparedness program. The fire prevention knowledge assessment form aimed to evaluate participants' understanding through ten questions that covered aspects such as the fire triangle, types of fires, fire risk areas/activities, fire extinguishers, and fire response. Each question included four choices (a, b, c, d) and was scored as follows: a correct response earned 1 point, an incorrect response received 0 points, and no response received 0 points. Upon completing the assessment, the results were evaluated using the following criteria: excellent (9-10 points), good (7-8 points), moderate (5-6 points), low (3-4 points), and very low (0-2 points). To assess students' fire response and evacuation skills, the fire evacuation practice skill assessment form was employed twice—once before and once after participating in the fire preparedness program. This assessment form was evaluated by a team of well-trained and competent evaluators, consisting of five officers from the Disaster Prevention and Mitigation Center (District 15, Chiang Rai), as well as 13 staff members and senior students from the Program in Occupational Health and Safety, School of Health Science, Mae Fah Luang University. The assessment form for practical skills in fire preparedness encompassed five crucial elements: communication/notification, basic firefighting, fire evacuation, counting, and first aid/rescue for the injured. The fire evacuation practice skill assessment form comprised a total of 26 items, which were categorized into five levels for scoring: excellent (five points), good (four points), moderate (three points), low (two points), and very low (one point).

A peer review was undertaken to scrutinize the questions, involving instructors in occupational health and safety, officers from the Disaster Prevention and Mitigation Center (District 15, Chiang Rai), and school directors. They were asked to assess the content validity of items using the Objective Congruence Index (IOC) to measure the alignment of the content with the research

objectives. The fire prevention knowledge form achieved a score of 0.93, and the fire evacuation practice skill assessment form received a score of 0.94, indicating strong content validity. Moreover, the instrument's reliability was evaluated through a pilot study using distinct samples from the current study. This pilot study involved 30 students from a selected primary school near the border. The questionnaire was subsequently utilized to compute Cronbach's alpha coefficient and Kuder-Richardson's coefficient for assessing the precision of question interpretation in alignment with the researcher's intentions. The test outcomes revealed a Cronbach's alpha of 0.89 for the fire evacuation practice skill assessment form, indicating high internal consistency. The fire prevention knowledge assessment form achieved a confidence score of 0.50 using Kuder-Richardson's method. Consequently, the questionnaire's reliability was confirmed. These results affirmed the questions' alignment with the research objectives. The statistical analysis comprised the following methods. Descriptive statistics were employed to present data values in percentages, frequencies, means, and standard deviations. Standard deviation was used to depict the general background characteristics of the sample, which was presented in a table along with the descriptive interpretation. The Paired Sample T-test compared fire knowledge and evacuation practice skills before and after the training. The number of students who answered fire prevention questions correctly and incorrectly before and after the program was tested using Fisher's exact test.

Results

This study aims to evaluate the skills and knowledge of students in two primary schools regarding school-based fire preparation programs. A total of 420 students consented to participate in the study and underwent assessments of their fire knowledge and skills before being assigned to the fire preparedness program. This assignment took place during the first site visit. During the second site visit, the focus was on imparting knowledge about fire safety to the students, covering essential topics such as the fire triangle, types of fires, and fire risk areas. Similarly, the third visit aimed to educate the students about basic firefighting techniques and fire evacuation procedures. Finally, the fourth visit involved assessing the students' fire knowledge and skills after they had completed the program.

The selected representative schools for this study are situated in the border areas of Chiang Rai province. As a result, there is a limitation in implementing the school fire safety program. The socio-demographic variables and the participants' knowledge of fire prevention were collected using the fire prevention knowledge assessment form. As shown in **Table 1**, the study involved 420 students from grades 1 to 6, with an average age of 10.10±2.2 years, including 207 males (49.3%) and 213 females (50.7%). Regarding nationality and race, 97.6% of the participants held Thai nationality, while the remaining 2.40% belonged to other nationalities, such as Chinese, Myanmar, and Lao. Among the participants, 56.7% identified with ethnic groups such as Akha, Tai Yai, and Tai Lue, while 43.3% were from non-ethnic groups. Moreover, the majority of participants (96.7%) reported having no underlying health conditions, while a small percentage (3.3%) indicated having underlying conditions such as anemia, dyspepsia, asthma, and attention deficit hyperactivity disorder. Two participants (0.5%) witnessed a fire at their school. Notably, over 80% of the students have not received any fire training in the past year. As there is an association between agility and BMI, the participants' average BMI was measured and found to be 18.57 ± 4.68 kg/m^2 and 17.29 ± 3.09 kg/m^2 for males. Among these participants, 82.45% were classified as having a healthy weight, while 9.04% and 8.51% were categorized as overweight and obese students, respectively.

Table 1. Demographic characteristics of primary school students in border areas Chiang Rai (n = 420)

Characteristics	Number	Mean ± SD
Gender		
Male	207 (49.3)	
Female	213 (50.7)	
Age (years)		10.10 ± 2.2
Education level		
1st grade	76 (18.1)	
2nd grade	68 (16.2)	
3rd grade	62 (14.8)	
4th grade	79 (18.8)	
5th grade	71 (16.9)	
6th grade	64 (15.2)	
Ethnic group		
Yes	238 (56.7)	
No	182 (43.3)	
Nationality and Race		
Thai	410 (97.6)	
Other	10 (2.4)	
BMI (kg/m^2)		18.57 ± 4.68 (Male) 17.29 ± 3.09 (Female)
Underlying diseases		
Yes	14 (3.3)	
No	406 (96.7)	
Have you ever witnessed a fire at your school?		
Yes	2 (0.5)	
No	418 (99.5)	
Have you received any fire training in the past year?		
Yes	78 (18.6)	
No	342 (81.4)	

To investigate whether the implementation of this school-based fire preparedness program influenced the number of students with accurate information about fire composition, types of fire, fire risk areas, fire extinguishers, and fire response, the number of students who responded correctly after attending the fire preparedness program is described in **Table 2**.

Our results revealed that the proportion of students who had correct knowledge of fire composition, fire type, and fire response increased significantly due to this program. The percentage of students who correctly answered the questions related to fire composition and types of fire increased by 12.4% (from 80.7% before attending the program to 93.1% after attending the program) and 20-29% (from 26-45% before attending the program to 55.2-79.8% after attending the program), respectively. Furthermore, in the fire response topics, around 93.3% and 60.0% of students correctly answered both questions—these questions involved the appropriate response upon discovering a fire and the correct action when a fire alarm sounds—after participating in the program. These percentages increased from 89.3% and 44.5%, respectively, with p-values of 0.049 and <0.001, respectively. After participating in the provided program, the number of students who correctly answered the question related to the basic inspection of a fire extinguisher significantly increased. However, there was no significant

improvement in the percentage of students who could distinguish the color of a dry chemical fire extinguisher. Moreover, concerning fire risk areas, the number of students with knowledge in recognizing risk areas or heat sources for fires and activities that may cause school fires did not show statistically significant increases.

Table 2. Examining the influence of fire preparedness program content on enhancing students' fire prevention knowledge (n = 420)

Questions	No. of students who correctly respond		
	Pre-test	**Post-test**	***p*-value**
1. Which of the following can cause a fire? (A = Matches, Pieces of leaves, Air; B = Matches, Noodles, Water; C = Matches, Pieces of leaves, Water; D = Matches, Water, Air)	339 (80.7%)	391 (93.1%)	<0.001
2. Which of the following is a solid fuel? (A = Paper box; B=Study table; C = Wooden branch; D=All items are correct)	189 (45.0%)	276 (65.7%)	<0.001
3. Which of the following is liquid fuel? (A = Cloth scraps; B= Wall paint; C= Dry leaves; D = Paper box)	240 (57.1%)	335 (79.8%)	<0.001
4. Dry leaves are classified as which type of fuel? (A = Gas; B = Solid; C = Liquid; D = All items are correct)	109 (26.0%)	232 (55.2%)	<0.001
5. Which of the following is a source of heat or ignition in a school? (A = Gas flame from the kitchen stove; B = Flames from candles in the shrine room; C = Fire from firecrackers; D=All items are correct)	135 (32.1%)	144 (34.3%)	0.558
6. Which of the following actions could potentially cause a fire in a school? (A = A boy is playing with matches and burning paper in the classroom; B = A girl brings a new doll to school; C = A girl is playing with toys in the classroom; D = A boy brings snacks to eat in the classroom)	400 (95.2%)	401 (95.5%)	1.000
7. What color is a dry chemical fire extinguisher? (A = Yellow; B = Green; C = Red; D = White	231 (55.0%)	219 (52.1%)	0.447
8. Which of the following is a basic inspection for a fire extinguisher? (A = The tank should not have any cracks; B = The tank should not be rusty; C = The hose should not be cracked or broken; D = All items are correct)	243 (57.9%)	312 (74.3%)	<0.001
9. What should you do when you discover a fire?	375 (89.3%)	392 (93.3%)	0.049

(A = Shout "Fire" and immediately inform the teacher to extinguish the fire; B = Stand and watch the fire from a distance without doing anything; C = Do nothing; the fire will extinguish on its own; D = Run to the scene to get a closer look at the fire)			
10. What should you do if a fire alarm sounds? (A = Evacuate the area to a designated assembly point calmly; B = Evacuate the area by walking fast, do not run or push others; C = Do not play or joke around while walking to the assembly point; D = All items are correct)	187 (44.5%)	252 (60.0%)	<0.001

*Fisher's exact test was used, and *a P-value < .05 indicates a statistically significant result*.

To investigate whether implementing this fire preparedness program can enhance the fire prevention knowledge scores of students across all grade levels in the primary school. The students' overall scores significantly improved from 5.83 ± 1.98 to 7.04 ± 1.96, changing their knowledge level from moderate to good. It's important to note that the fire preparedness program provided in this study significantly increased students' fire prevention knowledge scores across all grade levels. Notably, the knowledge levels of both 3rd grade and 5th grade students changed from moderate to good. Additionally, this program significantly positively impacted the knowledge scores of ethnic and non-ethnic groups (**Table 3**).

Table 3. The effect of fire preparedness program on fire prevention knowledge of primary school students at different levels (n=420)

Variables	**Pre-Test**		**Post-Test**		**95%CI**	**p-value**
	Mean ± SD	**Interpretation**	**Mean ± SD**	**Interpretation**	**(Lower, Upper)**	
Overall scores	5.83±1.98	Moderate	7.04±1.96	Good	-1.47, -0.96	< 0.001
- 1st grade (n=76)	5.34±2.11	Moderate	6.31±1.49	Moderate	-1.61, -0.34	0.003
- 2nd grade (n=68)	5.46±2.02	Moderate	6.62±1.84	Moderate	-1.81, -0.51	0.001
- 3rd grade (n=62)	5.31±1.60	Moderate	7.21±1.40	Good	-2.42, -1.39	<0.001
- 4th grade (n=79)	5.13±1.81	Moderate	6.53±2.31	Moderate	-2.11, -0.71	<0.001
- 5th grade (n=71)	6.41±1.81	Moderate	7.35±2.23	Good	-1.59, -0.20	0.005
- 6th grade (n=64)	7.53±1.23	Good	8.42±1.42	Good	-1.41, -0.37	0.001
- Ethnic groups (n=238)	5.79±1.96	Moderate	6.99±2.04	Moderate	-1.53, -0.86	<0.001
- Non-ethnic groups (n=182)	5.87±2.00	Moderate	7.09±1.86	Good	-1.60, -0.83	<0.001

*Paired Sample T-test used, and p-value < .05 indicates the statistically significant.

The evaluation form assessed a school-based fire preparedness program's influence on primary students' fire response and evacuation skills. A team of well-trained and competent evaluators assessed the proficiency of the program. This team included five officers from the Disaster Prevention and Mitigation Center (District 15, Chiang Rai) as well as 13 staff members and senior students from

the Program in Occupational Health and Safety, School of Health Science, Mae Fah Luang University. The evaluation encompassed skills such as communication/notification, basic firefighting, fire evacuation, counting, and first aid/rescue. These skills were evaluated through practical exercises simulating fire evacuation scenarios and assisting the injured. It's important to emphasize that the introduction of a school-based fire preparedness program has led to a noteworthy enhancement in students' fire response and evacuation skills, elevating their scores from 1.22±0.43 (indicating very low skill levels) to 3.83±0.51 (reflecting moderate skill levels) ($p<0.001$).

Additionally, the provided fire preparedness program has significantly enhanced five operational fire preparation skills among students, including communication/notification, basic firefighting, fire evacuation, counting, and first aid/rescue. The communication/notification skills, which reflect the student's ability to recognize signals/announcements and follow them and effectively communicate and report incidents, including loud and clear alarms/announcements, demonstrated improvement due to the implementation of this program. This improvement is evident as the skill level increased from low to good (2.28±0.53 *vs*. 4.04±0.42; $p<0.001$). The implementation of this program has also elevated basic firefighting, fire evacuation, and counting skills from low to moderate levels. These skills indicate the ability to use fire extinguishers correctly, evacuate buildings using designated fire escape routes to reach the assembly point, and effectively perform headcounts without facing any challenges or impediments. Despite the improvement brought about by the school-based fire preparedness program in the first aid/rescue skill for injured individuals, the scores of the students evaluated during the evacuation practice have shifted from a very low level to a low level (1.70±0.36 vs. 2.83±0.26; $p<0.001$) (**Table 4**). The study obtained ethical approval from the Human Research Ethics Committee of Mae Fah Luang University, Thailand (Reference: EC 21217-18, Date: 15.03.2022). All participants gave informed consent before taking part in the study.

Table 4. Practical skills in fire preparedness in schools before and after participating in the school-based fire preparedness program (n=18)

Parameters	Pre-Test		Post-Test		95%CI	p-value
	Mean ± SD	Interpretation	Mean ± SD	Interpretation	(Lower, Upper)	
Operational skills for fire preparedness (overall)	1.22±0.43	Very low	3.83±0.51	Moderate	-2.91, -2.31	< 0.001
- Communication/ Notification	2.28±0.53	Low	4.04±0.42	Good	-2.16, -1.36	< 0.001
- Basic Firefighting	2.33±0.71	Low	3.01±0.17	Moderate	-1.03, -0.33	0.001
- Fire Evacuation	2.33±0.47	Low	3.89±0.28	Moderate	-1.84, -1.27	< 0.001
- Counting	2.14±0.59	Low	3.44±0.39	Moderate	-1.60, -1.01	< 0.001
- First aid/Rescue for the injured	1.70±0.36	Very low	2.83±0.26	Low	-1.40, -0.86	< 0.001

*Paired Sample T-test used, and p-value < .05 indicates the statistically significant.

Discussion

This study highlights the positive impact of fire preparedness programs in schools, as both fire prevention knowledge and operational fire preparation skills showed significant improvements among primary students. For the first time, it has been reported that school fire preparedness programs enhance students' knowledge and skills in ethnic and non-ethnic groups. The findings support the importance of such programs in enhancing students' preparedness and response abilities in fire-related

situations, particularly in primary schools consisting of ethnic and non-ethnic populations.

The Thai-Myanmar border area of Chiang Rai province includes the following districts: Mae Chan, Mae Sai, Mae Fa Luang, and Chiang Saen. The province encompasses various non-ethnic and ethnic populations, accounting for 82,114 people (6.32%), according to the 2016 Ethnic Population Data by District in Chiang Rai Province, Thailand.[22] Therefore, the primary schools in this region, especially the 139 primary schools located in the border area, predominantly consist of non-ethnic and ethnic students. As expected, our study revealed that 56.7% of the students in this study are ethnic individuals, while 2.4% belong to other races (non-Thai).

The study evaluates the effectiveness of fire preparedness programs in primary schools on the fire safety knowledge of students in the border areas of Chiang Rai province, encompassing diverse ethnic and non-ethnic backgrounds. Despite this diversity, the program positively impacted students' fire prevention knowledge. These findings suggest that the program can be efficiently implemented in both typical schools and those with diverse student populations. A previous survey that assessed and compared the fire safety knowledge of foreign and local students regarding firefighting equipment revealed variations based on students' nationality. This study also emphasized the significant influence of safety education and the cultural backgrounds of students' home countries on their scores.[23] Hence, our results show that the developed fire preparedness pograms can educate primary school students without being influenced by their nationality.

Fire safety education and intervention programs are essential not only for enhancing students' knowledge of fire safety but also for instilling safety-conscious behavior from an early age and establishing safety measures as habits.[24, 25] The study provides evidence that the program can increase the number of students who give accurate answers regarding their knowledge of fire components, fire types, and fire response after participating in the program. Furthermore, the program has a positive impact on fire prevention knowledge among primary school students at various grade levels following their participation. These findings align with previous research studies, [15, 17, 26-28] which have shown an increase in fire safety knowledge among participants attending fire education training programs. This consistency strengthens the case for the effectiveness of such programs in improving knowledge among primary school students.

The study emphasizes the positive impact of the school-based fire preparedness program on students' fire response and evacuation skills, encompassing all five operational fire preparation skills, which include communication/notification, basic firefighting, fire evacuation, counting, and first aid/rescue skills for the injured.[20, 29, 30] The data obtained from this provided program aligns with previous studies that consistently provide evidence supporting the crucial role of fire prevention education and training in improving fire safety behavior. It indicates that such training leads to correct practices during workplace fire emergencies,[31] improved fire safety behavior among primary students in households,[32] and an enhanced capability to take precautions to prevent fires among individuals who have received the training.[33-35] Nevertheless, the program could benefit from additional enhancements, particularly in strengthening first aid and rescue capabilities, to align them with the improvements observed in other skills.

While our designed program enhanced the knowledge and skills of trained students in fire prevention, some limitations need to be addressed. The first limitation is that this program requires well-trained facilitators; therefore, program success cannot be achieved without these specialists. An additional program for training the teachers is also needed to ensure that this program can be conducted effectively. The third limitation is that the study included only 2 primary schools, highlighting the necessity to broaden the scope of the study area.

Conclusions

These findings underscore the importance of fire preparedness programs in enhancing fire safety knowledge and equipping students with essential basic fire response skills, thereby preparing them for fire emergencies. This suggests that students have become more aware of fire incidents and respond correctly when faced with a fire situation. Primary educational institutions should incorporate structured fire preparedness programs tailored to their students' backgrounds into their academic plans. To ensure the success of these initiatives, collaboration between schools, local fire stations, and fire safety specialists is highly recommended.

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Supplementary Table 1: School environment conditions related to fire prevention (n=40)

Topics	Mean±SD	Interpretation
1. The fire extinguishing equipment is appropriately and sufficiently Installed to prevent fires promptly.	3.50±0.93	Moderate
2. There is a warning system and communication methods in case of fire in the school.	3.05±0.99	Moderate
3. A map showing the fire escape route within each building/classroom is prepared inside the school.	2.75±0.78	Low
4. There are obvious signs indicating the location of the gathering place for fire extinguishing equipment.	2.73±0.99	Low
5. There is a clear sign showing the assembly point inside the school.	3.48±1.20	Moderate
6. The fire extinguishing equipment is regularly inspected to ensure it is in good working condition, not damaged, and the results are recorded.	3.12±0.91	Moderate
7. Students are not allowed to bring objects that can cause sparks or heat sources into the school, such as lithers, matches, etc.	3.40±0.98	Moderate
8. There is an on-duty teacher/student leader responsible for regularly inspecting equipment and activities that may cause a fire within the school, such as power lines, power outlets in the kitchen, computer laboratory, offices room, libraries, classrooms, garbage incineration, etc.	3.20±0.79	Moderate
9. Fire safety instruction is provided in the classroom.	2.85±0.86	Low
10. There are fire learning materials in the school, such as brochures, posters, photographs, video clips, etc.	2.63±1.03	Low
11. Supplementary learning activities/training on fire prevention are established in the school.	2.90±0.90	Low
12. School conducts fire evacuation drills annually. .	2.52±1.06	Low
Overall scores	3.01±0.61	Moderate

Supplementary Table 2: Teaching methods and main contents of the program

	Instruction	Objectives	Learning Styles/Materials
Lesson 1 (180 min)	Introduction to fire (fire triangle, type of fire, and fire hazard areas).	To equip students with knowledge and comprehension of fires, enabling them to recognize different fire types and potential fire hazard zones within the school.	Group activities, game activities/ Flashcards, School layout poster
Goal of lesson 1	Comprehending the components of fire and discerning various fire types as well as assessing fire-risk areas within the school.		
Lesson 2 (180 min)	Explain the various fire extinguisher types, inspection of fire-extinguisher, and outline the steps to take when a fire alarm sounds, encompassing fire-extinguisher usage for firefighting and fire-evacuation drills.	To instruct students on the proper use of a fire extinguisher and impart knowledge of fire evacuation procedures.	Display and hands-on experience Fire extinguishers
Goal of lesson 2	Properly utilizing a fire extinguisher and comprehending the fire evacuation procedure.		

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