https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

Seismic risk assessment of schools in Nepal for effective disaster risk reduction practices

Shiba Subedi[1], György Hetényi[2], Sarah Houghton[3], Priyanka Dhami[4], Aastha Poudel[5], Shreedhar Dhakal[6], and Kushal Pokhrel[7]

[1]Nepal Academy of Science and Technology, Lalitpur, Nepal
[2]Institute of Earth Sciences, University of Lausanne, Lausanne, Switzerland
[3]St Michael Steiner School, London, United Kingdom
[4]Department of Earth, Environmental, and Resource Sciences, The University of Texas at El Paso, Texas, United States
[5]Central Department of Geology, Tribhuvan University, Kathmandu, Nepal
[6]Shiva Model Secondary School, Kawasoti, Nepal
[7]Central Department of Physics, Tribhuvan University, Kathmandu, Nepal

Correspondence to: Shiba Subedi (shibashibani@gmail.com)

Abstract

The 2015 Mw 7.9 Gorkha earthquake severely affected 40% of Nepal's districts, damaging ~7,200 school buildings and ~30,000 classrooms. As Nepal remains highly susceptible to large earthquakes, improving earthquake awareness and preparedness among students and teachers is essential. Since 2018, the Seismology at School in Nepal (SASIN) program has promoted earthquake education through school-based outreach activities. This study presents the first comprehensive school-based seismic risk assessment in Nepal, evaluating 24 schools in western Nepal to (1) assess the seismic risk of school buildings and classrooms, (2) identify structural and non-structural vulnerabilities, and (3) propose practical, low-cost measures for earthquake risk reduction. The assessment integrates information from school authorities, qualitative assessments, systematic visual inspections, and a newly developed Earthquake Evacuation Drill Guide tailored to local contexts. A total of 730 classrooms were classified into four seismic risk categories: low (35%), medium (35%), high (17%), and very high (13%). Buildings constructed after the 2015 Gorkha earthquake generally showed lower vulnerability, whereas older buildings or those not complying with the National Building Code accounted for most medium, high, and very-high risk categories. The proposed framework supports priority setting, low-cost risk reduction strategies, and safer, more resilient school environments throughout Nepal. These kinds of classroom earthquake risk assessments are highly recommended in all schools in Nepal and across the Himalayan region.

1 Introduction

Nepal is located at the convergent boundary between the Indian and Eurasian plates, where ongoing plate collision and crustal shortening generate frequent tectonic earthquakes all along the Himalayan region (e.g., Molnar and Tapponnier, 1975). The present-day convergence rate between these two plates is approximately 4 cm/year, with about half of this

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

accommodated along the Main Himalayan Thrust (MHT) beneath and at the front of the Himalayan orogen (e.g., Bilham et al., 1997; Lavé and Avouac, 2001; Zheng et al., 2017). Due to this active tectonic setting, Nepal has experienced several damaging historical earthquakes, including events in 1255, 1810, 1866, 1934, 1980, 1988, and 2015, as documented by previous studies (e.g., Bilham, 2019; Dal Zilio et. al., 2021). These earthquakes had a widespread impact on human life, physical infrastructure, and landscape. for example: the most recent large earthquake, the 2015 Mw7.9 Gorkha earthquake, killed ~9,000 people, ~600,000 houses were destroyed, and ~9,000 school buildings and ~35,000 classrooms across 31 districts of Nepal were affected. The total estimated damage cost wa ~50% of the national GDP (NPC, 2015), and in the education sector, the damage was 205 million USD (NPC, 2015). The most affected 14 districts suffered a heavy loss of more than 80% of the total school buildings, which were destroyed during the earthquake due to insufficient construction quality, resulting in damage to educational infrastructure and destruction of tangible property (Paudyal et al., 2020). Despite the occurrence of the 2015 Gorkha earthquake, Nepal remains susceptible to future large and great earthquakes. Western Nepal, where no great earthquake has been documented since 1505, represents a prominent seismic gap and is widely recognized as a potential source of a future great earthquake (e.g., Bilham, 2019; Ghazoui et al., 2019).

According to the National Population and Housing Census 2021 (NPHC, 2021), Nepal's building stock comprises more than 6.6 million households with diverse foundation types. Mud-bonded brick/stone foundations account for 33% of the housing stock, followed by cement-bonded brick/stone (30%), reinforced cement concrete (RCC) pillar foundations (22%), and wooden/bamboo pillar foundations (14%). These data indicate that a large proportion of Nepal's buildings are traditional masonry structures, many of which are generally more vulnerable to strong ground shaking than well-engineered RCC buildings. Of course, there is increasing use of RCC construction in recent years; nevertheless, seismic vulnerability remains a major concern because many buildings are non-engineered or do not fully comply with seismic design provisions. Sharma and Mashal (2023) reported that only ~one-fifth of Nepal's building stock complies with earthquake-resistant construction regulations, highlighting the country's continued exposure to future large earthquakes. Previous risk assessments indicate that an Mw 8.0 earthquake occurring near the Kathmandu Valley could damage nearly 50% of buildings and result in fatalities equivalent to about 1.3% of the population (Dixit et al., 2000; JICA, 2002). Similarly, for western Nepal, an Mw 8.1 earthquake is estimated to cause between 15,000 deaths in less densely populated areas and up to 150,000 deaths in heavily populated regions, with the number of injuries ranging from approximately 40,000 to 250,000 (Wyss, 2005). According to the seismic risk assessment conducted during 2015–2018, a major earthquake occurring in central Nepal could severely impact the Kathmandu Valley, potentially damaging more than 270,000 buildings (approximately 62%) and requiring the evacuation of over 1.2 million people (around 42% of the valley's population) (JICA, 2018). Given the time elapsed since these numbers have been published, the population of Nepal and especially urban areas has increased, while there is no convincingly recognizable sign of improved preparedness or building quality.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

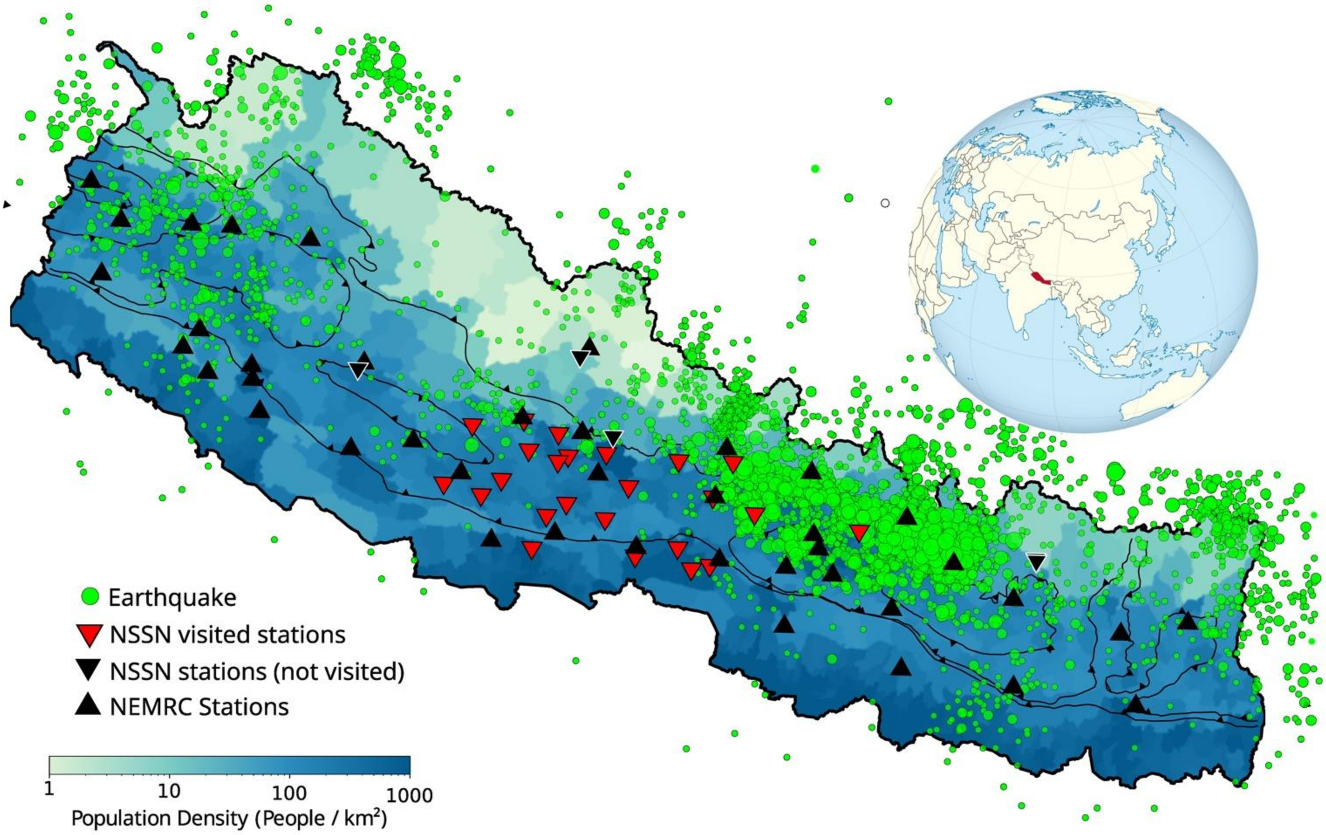

Figure 1: Study area map showing population density (NPHC, 2021), school locations, and seismic stations. Red inverted triangles indicate schools included in this study, black inverted triangles represent schools hosting seismometers but not included in this study, and black triangles denote National Earthquake Monitoring and Research Centre (NEMRC) stations. Seismicity (2015–2020) is shown by green circles with circle sizes proportional to the earthquake magnitude (Adhikari et al., 2023). Black lines represent the main faults. NSSN refers to the Nepal School Seismological Network.

The main reasons behind extensive damage to school buildings due to earthquakes are the unique geographical region, traditional and non-engineering construction and structural practices, and lack of compliance with building code. School buildings in mountainous regions are mostly built utilising locally available resources such as rounded stones, mud, and raw timber, and locally available, partially trained masons, mainly due to accessibility. In lowlying hills and plain regions, the construction practice mostly uses reinforced concrete and cemented-mortared brick masonry walls, primarily due to a lack of budget and available means (e.g., Paudyal and Bhandary, 2024). Poor construction practices and lack of awareness have led to the loss of thousands of innocent lives in the past years. Besides, the construction quality, lack of awareness regarding earthquake preparation, and approaches to be taken before, during, and after an earthquake are also subjects of concern. Open spaces in the school premises, safe (or simply: any) emergency evacuation route practices, and regular earthquake evacuation drills like "Drop, Cover, and Hold on!" are essential safety practices to be taken to minimize the risk of earthquakes in a school environment.

Earthquakes do not kill as many people as the collapse of poor infrastructure does. Depending on the structural typology of a school building, earthquake safety practices differ in Nepal. For example, a school building that is not reinforced concrete cement (hereafter, RCC) and is built using raw materials such as mud, wood, sand, and brick is not considered safe to practice "Drop, Cover, and Hold on!" In Western countries, strict building codes and technologies are followed at a much higher level to greatly reduce the potential of structural collapse. In such countries, "Drop, Cover, and Hold on!" is a primary survival action taught to the public. Earlier studies show that such activities prevent injuries by making oneself a smaller target and protecting oneself from falling debris landing on one's head (e.g., deGroot et. al., 2025). Several international search-and-rescue teams, emergency managers, and researchers recommend "Drop, Cover, and Hold on!" as the appropriate action to mitigate injuries during an earthquake (e.g., Alpar, 2025). The only exception to this action is if the building construction is unengineered and is not earthquake-resistant. In countries like Nepal, "Drop, Cover, and Hold on!" cannot be fully implemented because the majority of buildings are not properly engineered, and there is irregular compliance with the national building code (Marshall & Agarwal, 2025). So, for such cases, one should try to evacuate from the building towards the nearest open space or emergency meeting point as soon as possible.

Based on eyewitness reports after the 2015 Gorkha earthquake, it was found that some children and adults ran into an unsafe stone building to Drop, Cover, and Hold on, and were then killed seconds later (Paci-Green et al., 2015). Additionally, in the schools with load-bearing stone walls, neither evacuation during an earthquake nor the "Drop, Cover, and Hold on!" would have safeguarded students. As a result, staff have lost faith in the "Drop, Cover, and Hold on!" practice (Paci-Green et al., 2015). Specifically, an unfortunate incident that occurred in Nepal in 2015, the Gorkha Earthquake in Indreshwori Secondary School, Melamchi, a student lost her life as she had learnt the concept of hiding under the table during an earthquake would save life while she was playing in the playground (Hetényi & Subedi, 2023).

Several studies have investigated the seismic vulnerability and safety performance of school buildings in Nepal. Cross et al. (2020) evaluated the seismic safety of typical two-storey RCC template school buildings, highlighting the potential structural vulnerabilities of commonly adopted school designs. Earlier, Kandel et al. (2004) assessed the seismic vulnerability of public school buildings throughout Nepal and emphasized the need for systematic evaluation and strengthening measures. Beyond individual research studies, institutional initiatives have also played an important role in improving school earthquake resilience. Collaborative efforts by the National Society for Earthquake Technology–Nepal (NSET), the Department of Education, Government of Nepal, and the Global Facility for Disaster Reduction and Recovery (GFDRR) contributed to the development of seismic assessment frameworks, retrofitting approaches, and school safety programs aimed at reducing

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

earthquake risks in educational facilities (NSET et al., 2011). These studies and initiatives provide an important foundation for understanding the seismic performance of Nepalese school infrastructure and guiding future risk reduction strategies.

To promote seismology education in schools and enhance earthquake awareness among teachers and students in Nepal, the Seismology at School in Nepal (SASIN) program was established in 2018. As part of this initiative, 33 selected schools were equipped with seismometers to record seismic activity and support hands-on, inquiry-based learning in classrooms (Subedi et al., 2020a, 2020b). In addition, the program provides regular teacher training, educational resources, and outreach activities to strengthen earthquake education within classrooms and beyond schools (Subedi et al., 2021; 2026). These efforts have been well received by participating schools and local communities, contributing to increased public awareness of earthquake hazards and improved preparedness.

This study identifies simple, practical measures that can be implemented with minimal effort to reduce earthquake risk in schools. We present a comprehensive seismic risk assessment of 730 classrooms in schools across Central Nepal, representing diverse construction types, geographic settings, and resource conditions. The assessment includes inspections of classrooms, laboratories, administrative buildings, open spaces, and evacuation routes to identify structural and non-structural vulnerabilities. The findings demonstrate that low-cost mitigation measures can substantially reduce the potential for casualties and damage during future earthquakes. In addition, we compare the seismic resilience of school buildings constructed before and after the 2015 Gorkha earthquake to evaluate the influence of updated building practices. Moreover, earthquake evacuation drills conducted in selected schools further reveal significant improvements in students' response following drill exercises. Overall, this study provides practical evidence to support safer school environments, strengthen earthquake preparedness, and inform policies and strategies for building more earthquake resilient communities.

1.1 Motivation for earthquake evacuation drills

Earthquake preparedness and awareness play a crucial role in reducing disaster risk and minimizing casualties. In Nepal, public understanding of appropriate actions before, during, and after an earthquake remains limited, which further increases vulnerability to seismic hazards. Therefore, there is a critical need to promote and practice Earthquake Evacuation Drills (EEDs). An Earthquake Evacuation Drill is a structured practice exercise designed to train individuals to respond safely during and immediately after an earthquake. Despite its importance, the concept of EEDs in Nepal remains relatively underdeveloped and has received limited attention. Current earthquake preparedness practices are often restricted to simple “Drop, Cover, and Hold On!” measures, such as taking shelter under a desk or bed, without adequate guidance on when, where, and how evacuation should/could be conducted under different circumstances. To address this gap, a proposed guideline for conducting Earthquake Evacuation Drills has been developed and is provided as supplementary material (Supplementary file: EED). Although the guideline has not yet been published in a peer-reviewed article, it serves as a practical framework for improving earthquake preparedness and evacuation planning in dozens of schools in Nepal.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

2 Data and Methods

Out of 33 schools participating in the SASIN program, seismic risk assessments were carried out in 24 schools based on their accessibility (Fig. 1). During our visits, we conducted a visual inspection of every classroom, the surrounding school environment, and the overall building configuration. A standardized school earthquake risk assessment form (Fig. 2) was used to systematically identify and document potential earthquake hazards in each classroom and surrounding areas. The form included the following sections: (1) hazard identification (e.g., unsecured furniture, blocked exits, falling ceiling materials, unsafe building); (2) persons at risk and potential consequences (e.g., students, teachers, or visitors and the type of injury or harm that could occur); (3) risk severity (low, medium, or high); (4) likelihood of occurrence (unlikely, likely, or very likely); (5) existing control or mitigation measures already in place; (6) additional actions required to reduce the identified risk; (7) person responsible for implementing the recommended actions; (8) target completion date; and (9) completion status. The assessment form was completed on-site during the inspection of each classroom, and written justifications were provided for each identified risk together with recommended mitigation measures. We did not differentiate the schools' locations in terms of seismic hazard, given that the level is high to very high everywhere, and cannot be changed by better preparedness.

2.1 Risk assessment

The earthquake risk assessment was carried out using visual inspections of school buildings and classrooms, information provided by school officials, and qualitative analysis. The assessments were conducted by the same team throughout the study to ensure consistency in the evaluation. The assessment team consisted of 5 members with backgrounds in seismology, earthquake engineering, and geology. Before the field surveys, all team members received training on the use of the standardized earthquake risk assessment form, hazard identification, risk classification, and assessment procedures to ensure a consistent interpretation of the evaluation criteria across all schools. During each school visit, team members worked together to inspect the school premises, discuss observed hazards, and reach a consensus on the assigned risk levels. This approach minimized observer bias and ensured that the same assessment criteria were applied across all participating schools. While visiting the schools, the following tasks were conducted:

- The school administration, teachers, and staff were consulted regarding the history of the school building and other necessary technical information.
- The number of teachers, staff, and students was noted, and the number of students studying in each classroom was ascertained.
- Classrooms, administrative rooms, laboratories, corridors, balconies, halls, open spaces, were inspected and assessed for potential risk factors.
- Forms were completed along with a rough sketch of rooms, and additional photograph evidence.
- Significant findings and unexpected hazards were listed.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

- Suggested evacuation & preparedness recommendations based on the floor, type of building, access to open space, and evacuation routes.

Earthquake Risk Assessment for _____________________ school / site

Date: _________________
Place/Room: _________________

Risks are assessed according to a) how serious they would be if they happened and, b) how likely they are to happen. Then a written description is given of the circumstances and reason for each risk and what precautions (if any) have been taken to bring it to an acceptable level. The risk levels given are with all reasonable precautions in place.

A risk would be unacceptable if the risk was considered high after all reasonable precautions were in place. Use Figure 7 on the previous page to assess your risk:

What are the hazards?	Who might be harmed and how?	Severity (High, medium, low)	Possibility (Very Likely, Likely, Unlikely)	What is already being done?	What further action is necessary?	Action by whom ?	Action by when ?	Done

Should the plan go ahead?

Review after evacuation trial (Was the assessment appropriate? Were there any unexpected hazards? Significant findings during assessment):

-
-
-

Risk assessment completed by:

Figure 2: Example of an earthquake risk assessment form used to identify, evaluate, and mitigate earthquake-related hazards in schools. The form records potential hazards, associated risks, existing control measures, recommended mitigation actions, responsible personnel, and implementation timelines.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

2.1.1 Criteria of classification

All school buildings and classrooms were classified into one of four earthquake risk categories: low, medium, high, or very high, using the standardized earthquake risk assessment form (Fig. 2). Classification was based on multiple criteria, including (i) structural characteristics (e.g., RCC or non-engineered masonry construction, building age, and number of stories), (ii) classroom location within the building (ground floor or upper floors), (iii) evacuation route characteristics (distance, width, obstructions, and accessibility), (iv) occupancy (number of students and teachers), and (v) accessibility to a safe open space. Buildings constructed after the 2015 Gorkha earthquake were also considered because many were designed according to improved seismic design provisions.

Classrooms were assigned to the low-risk category if they were located in earthquake-resistant or well-engineered RCC buildings, typically on the ground floor, with short and unobstructed evacuation routes, low occupancy, and direct access to a safe open space that could be reached within approximately 10–15 seconds without exposure to falling hazards.

The medium-risk category included classrooms located in buildings with generally adequate structural performance but with one or more limitations, such as upper-floor locations requiring longer evacuation times, moderate occupancy, partially obstructed evacuation routes, or open spaces that were accessible but not immediately adjacent to the building.

The high-risk category included classrooms in non-engineered masonry or older buildings, buildings with visible structural deficiencies, narrow or obstructed evacuation routes, high occupancy, limited access to safe assembly areas, or combinations of these factors that would significantly increase evacuation difficulty and the likelihood of injury during strong ground shaking.

The very high-risk category was assigned to classrooms with multiple critical deficiencies, including structurally vulnerable buildings, heavily congested classrooms, upper-floor locations without adequate evacuation routes, lack of accessible open space, or the presence of significant falling hazards both inside and outside the classroom. These conditions were considered to pose the greatest risk to occupants during a strong earthquake.

2.2 Earthquake evacuation drill (EED)

Earthquake evacuation drill practices were conducted in a total of 7 schools, where 507 students aged 12 - 16 participated. The approach for the evacuation drill for students was divided into the following steps:

First step: Students without prior instruction responded to an imaginary earthquake, instructed with the help of a blow whistle. Reactions from the students in the classroom were carefully observed and recorded.

The earthquake evacuation drill form (Fig. 3) was completed recording: the behaviour of participating students, the number of students, and teachers.

In the second step, after observing the students' response to a hypothetical earthquake, three major approaches based on location were suggested, i.e., 1) outside in the open space; 2) on the ground floor; and 3) the second or top floor.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

Students were also trained on the structure-specific precautions to take, depending on the orientation of the building they are in; for example, what should be done when they are in an earthquake-resistant building, RCC, or a brick building.

After a detailed session on EED, the scenario of an earthquake was recreated using the whistle and the students' reaction was observed after EED sessions and behaviour noted in the EED Form.

The duration of an assessment in a given school was typically 3-5 hours. Only the school administration/principals/teachers have been informed in advance of this activity; the students had no prior information.

Earthquake evacuation procedure report

Name of the School:
Tel No: Email:
Address: Contact Person:

Number of students who participated:
Number of teachers:
Any physically impaired students?

When was evacuation procedure conducted?
How long did evacuation take?
Was the register taken after evacuation to safe zone? (y/n):
What any other activities were carried out during the procedure? (Search & Rescue, First Aid etc):

During debriefing what improvements were noted?

Any other remarks

Reporting Instructions

- Email a copy of report to your school director and to Seismology at School in Nepal
- For any questions contact the local government officer and Seismology at School in Nepal program
- Send additional evidence, e.g., photographs with report

Figure 3: Earthquake evacuation procedure report form used to document school evacuation drills, including participation, evacuation time, drill activities, observations, and recommendations for improving future earthquake preparedness.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

3. Results and discussion

A total of 730 rooms were assessed across the visited schools. Among the assessed rooms, 591 were classrooms, accounting for 81% of all evaluated rooms. The risk distribution for classrooms showed that 35% were classified as low risk, 35% as medium risk, 17% as high risk, and 13% as very high risk. These findings indicate that a substantial proportion of classrooms fall within the medium- to very-high-risk categories, highlighting the need for focused interventions to reduce seismic vulnerability (Fig. 4). Administrative rooms and laboratories constituted smaller proportions of the assessed spaces but exhibited comparable risk patterns. Of the 60 administrative rooms evaluated (8% of the total rooms), 38% were categorized as low risk, 28% as medium risk, 15% as high risk, and 18% as very high risk. Similarly, 79 laboratories from 24 schools, representing 11% of the total assessed rooms, were evaluated. Among these, 16% were classified as low risk, 46% as medium risk, 22% as high risk, and 16% as very high risk. The relatively high proportion of laboratories in the medium-to very-high-risk categories suggests an increased potential for earthquake-related damage and disruption in these specialised learning spaces.

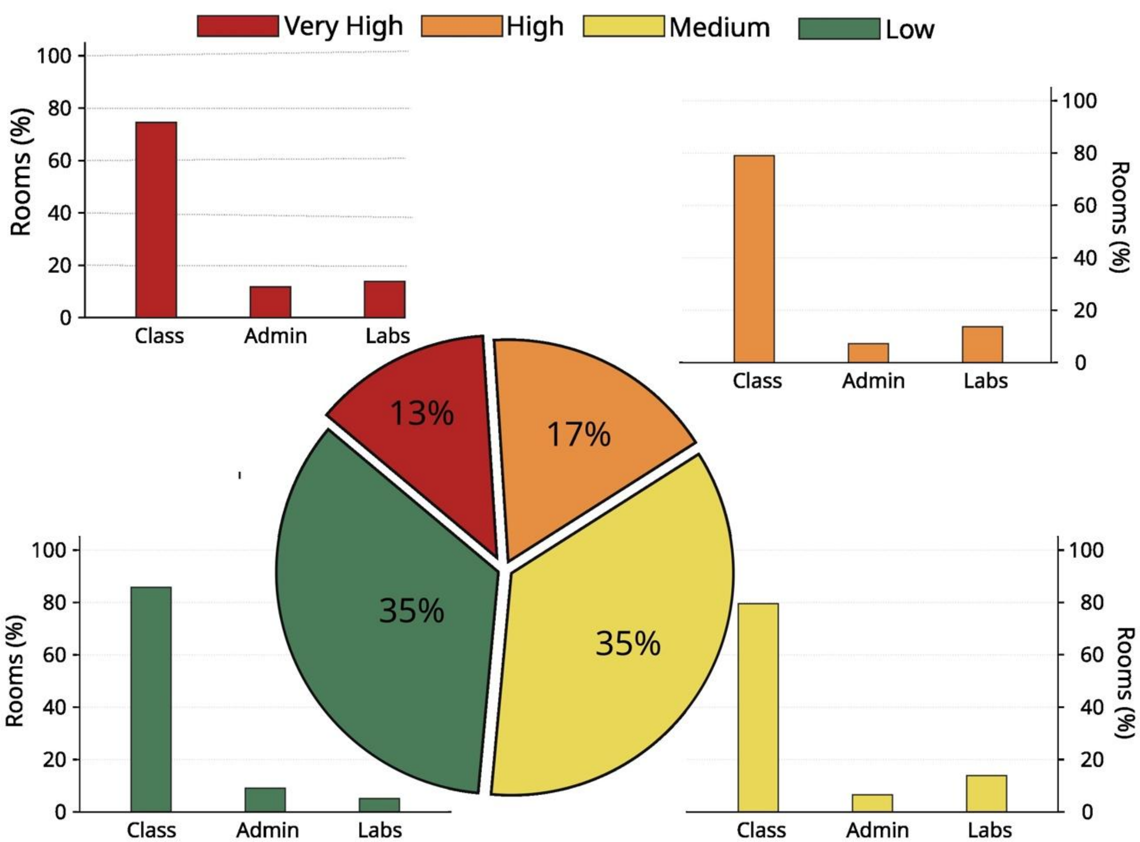

Figure 4: Distribution of types of school rooms by risk levels. Class refers to classrooms, Admin refers to administrative rooms, and Labs refers to laboratory rooms.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

During our earthquake risk assessment in the schools, we observed different trends, some of which demonstrated a need for immediate changes, and some showed good examples of practice. For example: the placement of kindergarten and play group classes on the ground floor of the school buildings, wide corridors offering enough room for movement, railings attached to pillars, well-anchored laboratory equipment and hanging objects, and the presence of more than one door for exit showed good practice (Fig. 5). Meanwhile, we observed several practices in the schools that demanded immediate change: furniture placed haphazardly on the exit routes, laboratories placed on the top floor of the school buildings, use of marble tiles in the evacuation route making the path slippery, use of big barrier blocks for gardening in front of classrooms, unanchored flower vases on top floors, undefined evacuation routes, and lack of emergency meeting points in open spaces. Some examples of good and bad practices are shown in Figure 5.

Figure 5: Examples of good and bad practices observed during the risk assessments. (a): A smart classroom demonstrating good practice of space management and furniture quality. (b): Pillars provide additional support to the railing, representing a positive safety measure. (c): Unanchored flower vases placed on each floor, illustrating a non-structural hazard. (d): A narrow corridor constructed using mud, stone, and wood may impede safe evacuation. (e): A traditional classroom building illustrating a vulnerable construction type.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

In most of the schools, the absence of clearly marked evacuation routes were observed and a lack of designated open spaces for emergency assembly. Several evacuation paths were obstructed by various items, and in some cases, the routes themselves posed safety risks. Inside classrooms, unsecured furniture and objects increased the potential for injuries during shaking, and in principals' offices, unanchored items such as medals and display materials were found to be potential falling hazards. For each room assessed, practical and achievable measures were proposed to help mitigate these risks.

3.1 Building type and risk levels

RCC buildings constitute the largest share of the assessed school rooms, accounting for ~47% (342 rooms) of the total inventory (Fig. 6a). In terms of seismic risk, approximately 32% of RCC rooms were classified as low risk, 42% as medium risk, and 26% as high risk (Fig. 6b). This shows that all RCC buildings are not safe from earthquakes. Low-risk classrooms were generally located in earthquake-resistant buildings with short, unobstructed evacuation routes and direct access to safe open spaces. Medium-risk classrooms had moderate evacuation constraints, while high-risk classrooms were associated with non-engineered buildings and longer or obstructed evacuation routes, upper-floor locations, higher occupancy, and limited access to safe open spaces. Earthquake-resistant buildings comprise ~40% (294 rooms) of the total assessed rooms shown in Figure 6a. These buildings exhibit comparatively lower seismic risk levels, with ~49% categorized as low risk, ~39% as medium risk, and only ~12% as high risk. Nevertheless, the presence of high-risk rooms within earthquake-resistant structures indicates that non-structural vulnerabilities and maintenance issues may still pose significant safety concerns. Brick masonry buildings account for ~13% (94 rooms) of the total assessed rooms. Notably, all assessed brick masonry rooms (100%) fall within the high-risk category, highlighting their substantial vulnerability to earthquake hazards.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

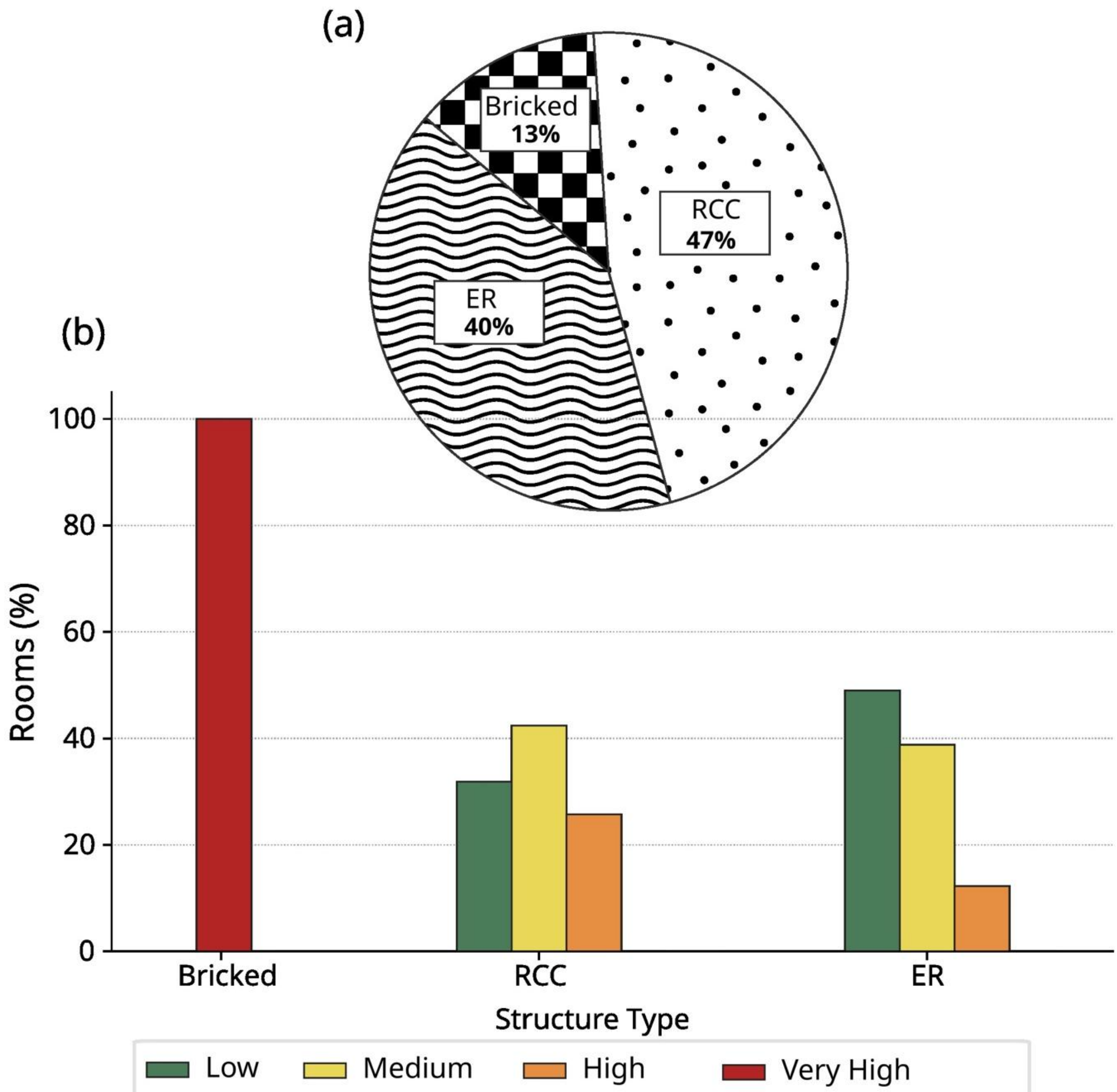

Figure 6: Statistics of school buildings. (a): The pie chart is plotted for the total no of school buildings. (b): The bar graph shows the risk level of buildings with respect to the building structure type. Bricked means stone, mud, and brick-made buildings; RCC is a reinforced concrete building, and ER is an earthquake-resistant building.

Overall, earthquake-resistant buildings demonstrate the lowest proportion of high-risk rooms (~12%) and the highest proportion of low-risk rooms (~49%), indicating better preparedness against seismic hazards. In contrast, RCC buildings exhibit a considerable proportion of medium- and high-risk rooms (~68% combined), while brick masonry buildings are the most vulnerable, with all assessed rooms classified as high risk. Some images depicting the different structural types and risk levels among all the visited schools and their representative classrooms are shown in Figure 7.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

285 **Figure 7: Example of school buildings and classrooms associated with different risk levels. (a): low risk levels with earthquake-resistant buildings. (b): medium risk level with the RCC building, (c): high risk levels with the RCC building, (d): very highrisk levels with the traditional stone and mud building. The black-contoured red circle represents the location of the inset classroom images for each school building.**

3.2 Comparison of risk levels of the classrooms built before and after the 2015 Gorkha earthquake

Among the 730 classrooms evaluated for the seismic risk assessments, we found that ~54% of the classrooms were built
290 before the devastating 2015 Gorkha earthquake, whereas ~46% of the classrooms were constructed after. Further comparison revealed that within the post-earthquake cohort, ~58% of the rooms are classified under the low risk level, ~37% fall into the medium risk tier, and a nominal ~5% are categorized as high risk, with no rooms reaching the very highrisk threshold.

295

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

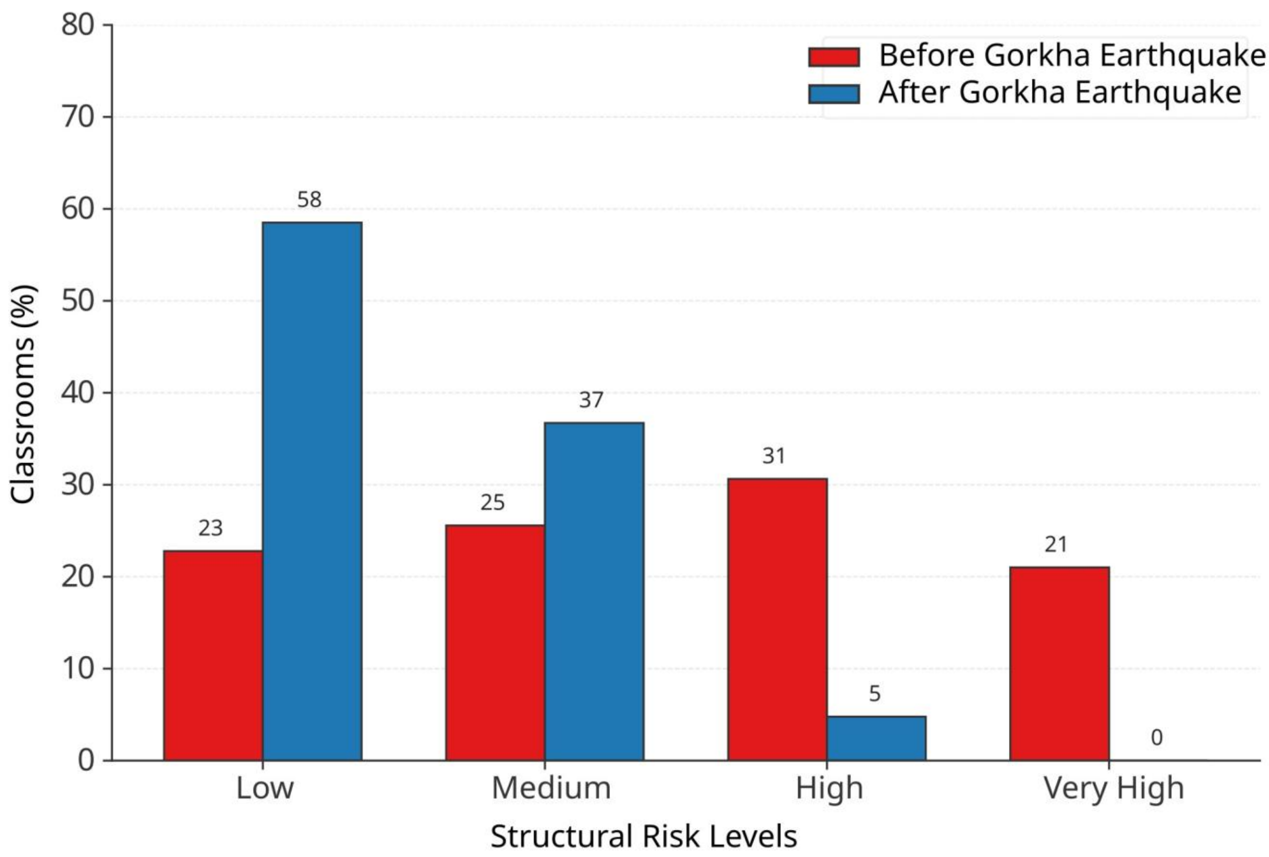

Figure 8: Comparison of the risk levels of the classrooms that were built before and after the 2015 Gorkha earthquake.

Conversely, among the classrooms built before the 2015 earthquake, only ~23% are categorized as low risk. The remaining structures are distributed across higher vulnerability tiers, with ~25% classified as medium risk, ~31% as high risk, and ~ 21% designated at the very high-risk level (Fig. 8).

3.3 Earthquake evacuation drill practices (EEDs)

Earthquake evacuation drills (EEDs) were conducted in seven schools involving a total of 507 students from lower secondary and secondary levels. The objective of these drills was to assess students' initial responses during a simulated earthquake scenario and evaluate the effectiveness of hands-on preparedness training. Effective implementation of EEDs requires consideration of several key factors, including evacuation routes, accessibility to open spaces, evacuation time, and building characteristics.

Before the EED practice, students exhibited a wide range of responses, including unsafe evacuation behaviors, hesitation, and lack of knowledge of appropriate earthquake safety procedures. Common inappropriate actions included running

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

immediately from classrooms, rushing toward open areas without protection, jumping from desks or benches, climbing through windows, and remaining unaware of the required response actions. These observations indicate limited prior exposure to earthquake preparedness practices among many students.

After the EED training, a significant improvement in students' evacuation behavior was observed across all participating schools. In several schools, students demonstrated proper earthquake response and evacuation procedures both before and after the drill, maintaining a 100% success rate. In other schools, substantial improvements were recorded following the training. For example, in one school, the proportion of students correctly performing the recommended earthquake response and evacuation procedures increased from 81% before the drill to 100% after the training, with all 54 participants successfully following the recommended evacuation protocol.

A notable improvement was also observed at Padma Public Secondary School, Palpa, where most students initially lacked awareness of proper evacuation procedures. Among 29 participants, 26 students were unable to identify appropriate actions before the drill and remained inside the building while performing drop, cover, and hold procedures. Following the EED practice, all students successfully evacuated the classroom and assembled safely in the designated open area.

At a school close to the epicenter of the 2015 Gorkha earthquake, lower secondary students showed considerable improvement after the drill. Before the EED practice, 20% of students adopted unsafe behaviors such as running and rushing toward open spaces, 55% were unable to respond appropriately, and only 24% followed safe evacuation practices. After the training, students demonstrated improved awareness, with 33% performing well and 16% showing moderate improvement. In a second EED session conducted among higher secondary students, all 21 participants initially lacked appropriate evacuation knowledge; however, after training, 52% demonstrated moderate performance, and 43% followed appropriate evacuation procedures.

Similarly, a school in Tanahun district showed substantial improvement after the intervention. Before the drill, more than 90% of students demonstrated inappropriate evacuation behavior, while only 6% safely evacuated to the open area. After the EED practice, all students successfully followed the evacuation procedure and reached the designated safe area. In Mahindra Secondary School, among 100 students, 4% attempted unsafe actions such as climbing windows, 25% showed no appropriate response, and 71% evacuated correctly before the drill. Following the EED practice, 100% of students completed the evacuation process.

Overall, the results demonstrate that practical earthquake evacuation drills significantly improve students' awareness, decision-making, and evacuation behavior. The observed transition from confusion and unsafe responses to organized evacuation highlights the importance of regular school-based earthquake evacuation drills, particularly in earthquake-prone regions such as Nepal. Although this study evaluated the immediate effects of the drills, maintaining these improvements over the medium and long term requires periodic reinforcement. We recommend that schools conduct earthquake evacuation drills at least twice each academic year, accompanied by refresher training for teachers, to reinforce appropriate protective actions and sustain preparedness over time. Two appropriate occasions would be the National Earthquake Safety Day (2nd Jan) and the Gorkha Earthquake Memorial Day (25th April) of each year.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

4. Recommendations

Among the schools assessed for earthquake risk assessment, we found that different construction materials were used while building them, depending on the geographical region they were located in. Construction practices such as traditional methods and modern methods of construction vary in the materials used, building speed, and sustainability. We observed school buildings made up of mudstone and timber, which belong among the traditional types, and concrete, cement brick, and steel types belonging to RCC. We also observed that most schools that were built after the 2015 Gorkha Earthquake were earthquake-resistant and/or had a stronger foundation in comparison to others.

What is the safest action during an earthquake in a school? The answer depends on several factors: Is the building earthquake-resistant, RCC, or brick masonry? Which floor is the classroom on? How close is the nearest evacuation exit or safe open space? Can the open space be reached quickly and safely, or is it safer to remain inside and do "Drop, Cover, and Hold on!? These questions are critical for minimizing earthquake risk. In Nepal, inadequate preparedness and inappropriate response practices have resulted in the loss of many lives, including those of pupils, highlighting the need to strengthen school earthquake preparedness. Schools can improve safety by establishing designated open spaces and emergency assembly points, maintaining clear and unobstructed evacuation routes with adequately wide corridors, and conducting regular earthquake evacuation drills involving both students and teachers. In addition, providing training on appropriate approaches before, during, and after an earthquake can significantly improve the ability of school communities to respond effectively. Simple measures such as keeping all available exit doors unlocked and accessible, securing flower pots and other decorative items, and anchoring hanging objects can further reduce earthquake-related hazards and create a safer school environment.

5. Conclusions

This study presents a comprehensive earthquake risk assessment of 730 classrooms in central Nepal, a region exposed to high seismic hazard and the potential for future large earthquakes. Based on structural characteristics, classroom configuration, evacuation routes, and the availability and accessibility of safe open spaces, classrooms are classified into four seismic risk categories: low, medium, high, and very high. Of the assessed classrooms, 47% are located in RCC buildings, 40% in earthquake-resistant buildings, and approximately 13% in unreinforced brick masonry buildings. Among the RCC classrooms, 32% are classified as low risk, 42% as medium risk, and 26% as high risk. These findings demonstrate that the presence of an earthquake-resistant building alone does not necessarily ensure a low-risk classroom. Instead, classroom layout, evacuation route conditions, and access to safe open spaces are equally important factors in determining the overall level of seismic risk.

The study further demonstrates that practical earthquake evacuation drills significantly improve students' earthquake response and evacuation behavior, emphasizing the importance of integrating regular drills into routine school activities. In addition, school buildings constructed after the 2015 Gorkha earthquake generally exhibit better seismic performance than

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

older buildings, reflecting improvements in earthquake-resistant design and construction following the implementation of revised building codes.

Importantly, the assessment indicates that a substantial proportion of classroom vulnerabilities can be reduced through simple and nominal efforts at the school level, including securing non-structural components, improving evacuation routes, and ensuring safe and unobstructed access to assembly areas. These measures have the potential to reduce seismic risk in approximately 38% of the assessed classrooms, thereby enhancing the safety of approximately 7,800 students. These kinds of classroom earthquake risk assessments are highly recommended in all schools in Nepal and in the Himalayan region; eventually becoming part of the policy to regularly carry out drilling exercises.

Data availability

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

Supplement link

The link to the supplement will be included by Copernicus, if applicable.

Author contributions

SS, GH, and SH conceptualized the study. SS and SH developed the methodology and performed validation. GH and SS provided resources and managed the project administration. SS, PD, AP, and SD conducted the investigation and performed data curation. SS, PD, and AP prepared the original draft. AP and SS contributed to software and visualization. PD, AP, KP, and SD carried out the formal analysis. All authors contributed to reviewing and editing the manuscript.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

We would like to express our sincere gratitude to the school administrators, teachers, staff, and students for their cooperation throughout the study and for providing valuable information on the school background and other essential data. We also acknowledge the Nepal Academy of Science and Technology (NAST) for hosting Priyanka Dhami (PD), Aastha Poudel (AP), and Kushal Pokhrel (KP) as intern and Master's thesis students, and for providing them with working space to contribute to this manuscript.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

Financial support

This work received no specific funding.

References

Adhikari, L. B., Laporte, M., Bollinger, L., Vergne, J., Lambotte, S., Koirala, B. P., Bhattarai, M., Timsina, C., Gupta, R. M., Wendling-Vazquez, N., Batteux, D., Lyon-Caen, H., Gaudemer, Y., Bernard, P., and Perrier, F.: Seismically active structures of the Main Himalayan Thrust revealed before, during and after the 2015 Mw 7.9 Gorkha earthquake in Nepal, Geophys. J. Int., 232, 451–471, https://doi.org/10.1093/gji/ggac281, 2023

Alpar, S.: Earthquake Survival Strategies: Potential Advantages of the Fetal Position in the Triangle of Life to Survive Over the "Drop, Cover, and Hold On", Disast. Med. Pub. Health Prep., 19, e181, 1–2, https://doi.org/10.1017/dmp.2025.10116 , 2025.

Bilham, R.: Himalayan earthquakes: a review of historical seismicity and early 21st century slip potential, Geol. Soc. Lond. Spec. Publ., 483, 423–482, **https://doi.org/10.1144/sp483.16**, 2019.

Cross, T., De Luca, F., De Risi, R., Ranamager, T. R., Mitchell, T., and Sweetman, A.: Mapping the seismic safety of RC "template schools" in Nepal, Int. J. Disast. Risk Reduct., 51, 101844, https://doi.org/10.1016/j.ijdrr.2020.101844, 2020.

Dal Zilio, L., Hetényi, G., Hubbard, J., and Bollinger, L.: Building the Himalaya from tectonic to earthquake scales, Nat. Rev. Earth Environ., 2, 251–268, https://doi.org/10.1038/s43017-021-00143-1, 2021.

deGroot, R. M., McBride, S. K., Vinci, M. J., Lotto, G. C., Anderson, M. L., Sumy, D. F., and Terbush, B.: ShakeAlert®—Communication, education, outreach and technical engagement strategic vision, Open-File Rep. 1561, US Geological Survey, 2025.

Dixit, A., Dwelley-Samant, L., Nakarmi, M., Pradhanang, S. B., and Tucker, B.: The Kathmandu Valley earthquake risk management project: an evaluation, Regional Report, Asian Disaster Preparedness Center, 2000.

Ghazoui, Z., Bertrand, S., Vanneste, K., van der Beek, P., Yokoyama, Y., and Sigdel, A.: Potentially large post-1505 AD earthquakes in western Nepal revealed by a lake sediment record, Nat. Commun., 10, 2258, https://doi.org/10.1038/s41467-019-10093-4, 2019.

Hetényi, G. and Subedi, S.: A call to action for a comprehensive earthquake education policy in Nepal, Seismica, 2, 242, https://doi.org/10.26443/seismica.v2i2.242, video file available at: https://www.youtube.com/watch?v=wLfKpA7Lug0, 2023.

Japan International Cooperation Agency: The project for assessament of earthquake disaster risk for the Kathmandu Valley in Nepal: Final report (Vol. 1), JICA Report, https://openjicareport.jica.go.jp/pdf/1000039154_01.pdf, 2018.

Japan International Cooperation Agency and National Planning Commission: The study on earthquake disaster mitigation in the Kathmandu Valley in the Kingdom of Nepal, Technical Report, Nippon Koei Co., Ltd. and OYO Corporation, 2002.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

Kandel, R. C., Pandey, B. H., and Dixit, A. M.: Investing in Future Generation: The School Earthquake Safety Program of Nepal, 13th World Conference on Earthquake Engineering (WCEE), Vancouver, Paper No. 1730, https://www.iitk.ac.in/nicee/wcee/article/13_1730.pdf, 2004.

Lavé, J. and Avouac, J. P.: Fluvial incision and tectonic uplift across the Himalayas of central Nepal, J. Geophys. Res. Solid Earth, 106, 26561–26591, https://doi.org/10.1029/2001JB000359, 2001.

Marshall, E. and Agarwal, J.: Building code implementation and compliance in Nepal, 18th World Conference on Earthquake Engineering (18WCEE), Earthquake Engineering International Association, Lisbon, Portugal, Paper No. 23270, https://proceedings-wcee.org/view.html?id=23270&conference=18WCEE, 2025.

Molnar, P. and Tapponnier, P.: Cenozoic tectonics of Asia: effects of a continental collision: features of recent continental tectonics in Asia can be interpreted as results of the India-Eurasia collision, Science, 189, 419–426, 1975.

National Planning Commission: Nepal earthquake 2015: Post-disaster needs assessment, Vol. A: Key Findings, Government of Nepal, Kathmandu, Nepal, Report, https://www.worldbank.org/content/dam/Worldbank/document/SAR/nepal/PDNA%20Volume%20A%20Final.pdf, 2015.

National Population and Housing Census (NPHC): National Population and Housing Census 2021: National Report, National Statistics Office, Government of Nepal, Report, https://censusresults.nsonepal.gov.np, 2021.

National Society for Earthquake Technology–Nepal (NSET), Department of Education, Government of Nepal, and Global Facility for Disaster Reduction and Recovery: Developing a strategy for improving seismic safety of schools in Nepal, GFDRR, World Bank, Report, https://www.eeri.org/images/sesi/GFDRR_Seismic_Safety_of_Schools_Nepal.pdf, 2011.

National Statistics Office: National Population and Housing Census 2021 (National Report), Kathmandu, Nepal, Report, https://data.nsonepal.gov.np/ca/dataset/population-census-2021/resource/e113b03f-ea64-488b-9f37-00e8ebe537fc, 2023.

Paudyal, Y. R., Bhandary, N. P., and Yatabe, R.: Preliminary damage survey of school buildings and proposed plan for reconstruction of school buildings after the 2015 Gorkha earthquake in Nepal, Preprint, 2020

Paudyal, Y. R. and Bhandary, N. P.: An analytical study on the damage to school buildings by the 2015 Nepal earthquake and damage level-based reconstruction experience, Buildings, 14, 451, https://doi.org/10.3390/buildings14020451, 2024.

Paci-Green, R., Pandey, B., and Friedman, R.: Safer schools, resilient communities: A comparative assessment of school safety after the 2015 Nepal (Gorkha) earthquakes, Risk RED, Report, https://doi.org/10.13140/RG.2.1.3370.3128, 2015.

Shrestha, A.: On shaky ground, Nepali Times, Issue 76, https://nepalitimes.com/on-shaky-ground-1, 2001.

Sharma, B. and Mashal, M.: Deadly quake in Nepal renews fears of an even deadlier one, The New York Times, https://str.sg/iNcB, 2023.

Subedi, S., Hetényi, G., Denton, P., and Sauron, A.: Seismology at School in Nepal: A Program for Educational and Citizen Seismology Through a Low-Cost Seismic Network, Front. Earth Sci., 8, 73, https://doi.org/10.3389/feart.2020.00073, 2020a.

Subedi, S., Hetényi, G., and Shackleton, R.: Impact of an educational program on earthquake awareness and preparedness in Nepal, Geosci. Commun., 3, 279–290, https://doi.org/10.5194/gc-3-279-2020, 2020b.

https://doi.org/10.5194/egusphere-2026-4706
Preprint. Discussion started: 17 August 2026

Subedi, S., Denton, P., Michailos, K., and Hetényi, G.: Making seismology accessible to the public in Nepal: an earthquake location tutorial for education purposes, J. Nepal Geol. Soc., 63, 105–115, 2021.

Subedi, S., Valenzuela, N., Dhami, P., Böse, M., Hetényi, G., Chardot, L., and Upreti, B. N.: Organizing an Earthquake Learning Exhibition for transferring geoscience knowledge to the public: the example from Nepal, Geosci. Commun., 9, 101–114, https://doi.org/10.5194/gc-9-101-2026, 2026.

Wyss, M.: Human losses expected in Himalayan earthquakes, Nat. Hazards, 34, 305–314, 2005.

Zheng, G., Wang, H., Wright, T. J., Lou, Y., Zhang, R., Zhang, W., Shi, C., Huang, J., and Wei, N.: Crustal deformation in the India-Eurasia collision zone from 25 years of GPS measurements, J. Geophys. Res. Solid Earth, 122, 9290–9312, https://doi.org/10.1002/2017JB014465, 2017.