Referee 1

I found it refreshing to see an evaluation of this program after it had been running for over a year. Many such programs do not publish such results and it is good to see that there is an impact on the community. I think this provides valuable insight for others that may embark on this kind of program and it certainly shows it's worth.
Thank you very much.

I think the distinction between risk and hazard could perhaps help risk perceptions. I am not sure how much help the statistical calculations are as although they are discussed in the method they are ignored after that.
Thank you for your suggestion to distinguish between hazard and risk. We will investigate whether the age of the students makes this approach suitable. A repeated survey in 1-2 years may inform us how perceptions change on the mid-term.
Regarding statistical calculations: the Discussion section and the Supplementary Table 1 shows the results. We do not discuss how much change occurred as long as they are significant.

The way in which the percentages are reported can be a little confusing for example on line 161 it says 65% of students believed they could survive in 2020 but then compares this to 57% could NOT survive in 2018. Would this not be better as 43% thought they could survive in 2018 and 65% in 2020.
Yes, it is better to write it that way and we have changed the sentence accordingly.

Despite this the results look clear to me and show that while there is more work to do in preparedness the program is definitely having an impact. It would be good to see a complete questionnaire in the supplementary materials as this could help other programs evaluate their effectiveness in the future (I can't see the question about the seismometer there)
Thank you for this suggestion. We have now inserted the complete questionnaire in the supplementary material.

Referee 2

General comments
This is a clearly written paper with well justified conclusions based on pre/post surveying of student attitudes, knowledge and behaviors related to earthquake awareness and preparedness. It is impressive to see such a significant effect on student knowledge and their sharing of that increased knowledge with the community after just 2 years. The educational program is very well designed, with a 3-pronged approach of new lessons and lectures taught by the authors, teacher professional development, and the installation of a school seismograph network, all done in collaboration with school leaders. The discussion of the difficulty of changing the perception of risk, even with the documented increase in earthquake hazard knowledge raised a number of interesting points.
Thank you very much.

Specific comments

This may be outside the scope of the paper, but I'd be interested to know whether the authors have any data, or can speculate as to the relative importance of the 3 components of the program? Particularly, is it possible to show that having a school seismograph increased student engagement beyond what would have occurred with only lessons and lectures taught by the authors and teacher professional development? If such a claim can be made, it would be helpful for the seismographs in schools' community.

Thank you so much, this is a very good idea. We agree that it would be nice to see the impact of the seismometer and special lectures independently and the result could help to develop such educational program in large scale. Unfortunately, there are no schools where a seismometer is not installed and all schools also had special lectures and therefore we do not have a control to test against. We keep this idea in the list of perspectives for the future development of the program.

Line 143: A little more information would be helpful about the question relating to students knowing when an earthquake will occur, as I didn't quite understand what was being asked. Could you include the full question in the figure 7 caption? That question doesn't seem to be in the supplement.

This was a generic question, the title and answer options for this question were as shown on Figure 7, with multiple choice answers. Also, we have now included the complete questionnaire in the supplement, the corresponding question is Q13. We also add each question number at the corresponding figure.

Figure 8: I suggest modifying the caption to more closely reflect the question, e.g. Need to avoid making phone calls after earthquake.

The figure caption was modified with the suggested text.

Technical/typographic corrections

Line 58: missing comma between awareness and preparations.

Thanks, we have inserted the comma.

Line 99: extra "the" : "and the all the"

We have removed the extra 'the' and the sentence now reads "and all the …"

Line 166: I think this should be "hit by objects, not collapse of constructions"

We kept the sentence "hit by objects, collapse of constructions" as most of casualties/injuries are by both of these reasons in developing counties like Nepal, where construction quality is not good enough to resist big earthquakes.

Line 240: I think this should be "level was increased"

We modified the beginning of the sentence and now "have" makes sense.

Line 312: I think this should be "implemented and achieved"

We have added "and" in the sentence.

Line 327: I think this should be "allowed us to invite"

We have changed the sentence accordingly.

Table 1, Q11: I think this should be “preparedness for a major”
We have changed the sentence accordingly.

Referee 3

I enjoyed reviewing it which covers the major aspects of Geoscience Communication. I found it scientifically sound and useful for the general public. This is a important work to be done in a country like Nepal which has high seismic hazard. Besides some specific, following comments I don’t have major comments for the publication.
Thank you very much.

Specific Comments
Line 54: After or before Fig. 1 mention source/reference.
We have added the reference *Dixit et al., 2013* in the sentence.

Line 54: After magnitude please mention the type of earthquake before the number.
We kept moment magnitude (Mw) in all cases and the sentence is revised.

Line 61: It is well-refereed NSET, an NGO working in Nepal however, it is worth mentioning similar activities performed by Government agencies like the National Seismological Center under the Department of Mines and Geology, National Reconstruction Authority, Department of Education, Department of Urban Development and Building Construction, etc.
The paragraph is updated with this information.

Line 125: Revise the spelling "hid".
We used hid as the past tense of hide.

Line 139: Mention the type of magnitude
In the questionnaire, we have not specified the magnitude type as this complexity is not known to students.

Line 226: It is better to replace regional and central government by the Government of Nepal only.
We have changed the sentence to “Local, Provincial and Federal Government of Nepal” as they have all have some field of possible action.

Line 226: Revise the spelling of "survey".
Sorry for typo, we have corrected it.

Line 227: Write in the correct order. (eg. Local, Provincial and Federal government)
We have changed the sentence accordingly.

Line 386: It is better to define the term Chi-square, p-value, etc. in the main text.

Both parameters are mentioned in the “Methods” section and also in the Statistic sub-section of the main text. For chi-square, we have now inserted the actual Greek symbol.

Line 388: Table. Why Q1 to Q6 are not mentioned in the same table?
Table 1 includes primarily questions related to earthquake preparedness with Yes/No answers, while questions on broader topics with more complex answers are mostly represented in Figures 5-12. In the revised version of the manuscript all questions are listed in the supplementary material.

Line 524: Fig. 1 add a table about the location of the school. eg. Lat, Lon, place name, type of school public or privet, number of students, staff, etc.
This information is already in our earlier publication (Subedi et al. 2020) to which we refer here.

Line 527: Fig. 2 where and which school is this?
This school is Shree Himalaya Secondary School in Barpak, Gorkha district and this information is written in the caption, former Lines number 344-347.

Line 553: Fig. 4 Correct Nepali word (1. Parba to Purba). In the same figure, some texts are cropped in the bottom row.
Thank you for nice catch. We have updated figure with correct word and not-cropped text.

Line 562: Fig. 5 on-wards, eg. April 2018 (318) and January 2020 (480). As discussed in the main text, the respondents are not repeated from 2018 survey to 2020 survey, it is worth to compare and discuss the variation among the repeated ones.
Undoubtedly, it is good to have repeated survey before and after the initiation of the program. As we surveyed high school pupils including grade 10 students, it was almost impossible to repeat the survey with the same persons as grade 10 students normally change school for higher education. For this reason, we can only note that 70 % of schools are the same in both surveys. In addition, we did not ask to fill personal information during the surveys so that students feel more comfortable.

Impact of an educational program on earthquake awareness and preparedness in Nepal

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Keywords: School education, Hazard, Attitudes, Nepal, Science and education

ABSTRACT

Scientific education of local communities is key to help reduce the risk associated with natural disasters, such as earthquakes. Western Nepal has a history of major seismic events and is highly prone to further earthquakes; however, the majority of the population is not aware about or prepared for them. To increase earthquake awareness and improve preparedness, a seismology education program was established at 22 schools in Nepal. In each school, educational activities were performed by teaching earthquake related topics in classrooms, offering training to teachers and through installing a low-cost seismometer network which supported both teaching and awareness objectives. To test the effects of this program we conducted two surveys with school children, one before and one after the initiation of the program, with several hundred participants in each. The survey findings highlighted that educational activities implemented at schools are effective in raising awareness levels of children, promoting broader social learning in the community thus improving the adaptive capacities and preparedness for future earthquakes. However, perceptions of risk did not change so much. The high and positive impact of program on the students and the community is encouraging to continue and expand the program.

INTRODUCTION

It is becoming increasingly important to educate people in the era of global change about environmental hazards to ensure they are well prepared to face the rising number of challenges. Education may play a central role for the risk management of natural hazards and help to reduce vulnerability and improve adaptability though allowing people to anticipate and prepare for hazards (Godschalk, 2003; IRGC, 2005).

Exact earthquake prediction is currently not possible, but responses to such events can be prepared for in advance to mitigate the effects they can have on society and human well-being (Turner, 1976). The impacts of earthquake disasters can be minimized by learning what to do before, during and after earthquakes, and by taking a variety of personal safety measures (Lehman & Taylor, 1987). Whether people prepare for future earthquakes or not can be significantly influenced by their education and their engagement on the topic (Tanaka, 2005). All-inclusive public awareness and education is fundamental to reducing causalities, personal injuries, and property damage from natural disasters (NRC, 1991; Torani et al., 2019). Researchers can contribute and play a key role in the education of society; not just to engage more people in research, but also to provide scientific explanations for natural hazards and related consequences to local communities and help to develop polices for mitigation of effects.

Earthquakes are the most common and deadliest natural hazard in Nepal with a long history of impacts in the country (Bollinger et al., 2016). Historical records indicate that many houses and temples in Nepal collapsed during the 1255 earthquake, and one third of the population including the King, Abhaya Malla, was killed. There are also records of an earthquake with a moment magnitude > 8 in 1505 (Ambraseys and Jackson, 2003) and indications that even larger earthquakes are plausible in the Himalayas (Stevens and Avouac, 2016). In 1934, during an earthquake (Fig. 1) with a moment magnitude (Mw) of 8.2 over 8'500 people lost their lives, 200'000 houses were severely damaged and more than 80'000 buildings completely collapsed (Dixit et al., 2013). The most recent major earthquake (Mw 7.8), in 2015, hit central Nepal resulting in about 9'000 causalities, and nearly 800'000 buildings were damaged or destroyed, leaving millions of people homeless. The resulting losses were equivalent to 50 % of total national GDP (Chaulagain et al., 2018). In addition, 19'000 classrooms were destroyed and 11'000 damaged (NPC, 2015b). It is suggested that if people had better awareness, preparations could have been more adequate and the negative impacts might have been lower (Hall & Theriot, 2016).

In Nepal, the National Seismological Center under the Department of Mines and Geology has been conducting seismic monitoring since 1978. The Dept. of Education is responsible to develop different educational activities across the nation, and the Dept. of Urban Development and Building Construction has been working for building codes design and implementation. After the 2015 earthquake, the National Reconstruction Authority has been established and works for reconstruction of buildings damaged during the Gorkha earthquake. Despite these efforts, the topic of earthquakes is not included at any level of the official school curriculum in the Nepali education system. However, recently the National Society for Earthquake and Technology (NSET) initiated the Public-School Earthquake Safety Program in Nepal, but only in a few districts of the country (Dixit et al., 2014). This program focuses mainly on the retrofitting of school buildings to restore and minimize future damage following the 2015 earthquake; however, educational efforts are still very limited.

Following the devastating 2015 Gorkha event, and considering the history of major earthquakes and the likelihood of many more as well as poor educational effort on the topic, we initiated and implemented a seismology education program in schools in Western Nepal (Fig. 1; Subedi et al., 2020) including the area affected by the 2015 earthquake and expanding towards the West (Fig. 2). The aim of the program is to increase the earthquake awareness levels in Nepal, starting from the schools, with the hope that this knowledge will be spread into the community through social learning, and partly through the establishment of a low-cost seismic network (Figs. 1, 3). In this study, the effects of the education program for earthquake awareness and preparedness are evaluated. The evaluation was performed by collecting data from students through two surveys, one before and one after the initiation of the education program.

METHODS

The data for this study were collected using two questionnaire surveys on paper, conducted in Nepali language: in 2018, before the initiation of the education program, and in 2020, nearly a year after the full implementation of the program.

Before the initiation of the education program, we undertook fieldwork to help inform our strategy and the educational materials, and to ensure the education program was well adapted to the Nepali

education system. In 2018, during the first visit, we talked with the school leaders about the program and its benefits, and gave sample lectures (ca. 1-2 hours including questions) to students between the ages of 14-16, providing key information on earthquakes. Before the sample lecture and in each school, students were requested to fill in a paper questionnaire survey on earthquake related questions. In special lectures we also taught students how to prepare before an earthquake, how to save lives during an earthquake. We also provided a flyer containing detailed information and pictures (Fig. 4), of which we distributed 500 copies. Similarly, we designed a sticker to remind people about earthquake hazards (Fig. 3), and distributed this to students and teachers (3'000 so far).

In April-May 2019, during the second visit, the program was fully implemented with the installation of an educational, low-cost seismometer in every school. The seismometer's record is displayed on a computer, which is easily accessible to students in their physics class, or through an online application. During the visit, we also identified the open place near the school where students should meet in case of earthquake and installed an Emergency Meeting Point sign in Nepali. To increase the efficiency of the learning and to ensure long-term uptake, we organized a 2-day workshop for nearly 100 school teachers, which was very well received. The full details of the program are documented in an earlier paper (Subedi et al., 2020) and all the material is accessible on the program website (www.seismoschoolnp.org).

In this article, we focus on evaluating the efficiency of our program in terms of knowledge and behavior change of students related to earthquakes. Out of 22 schools participating in the program, 15 schools were chosen for the survey, covering a range of socio-economical contexts. Students for the surveys were selected randomly from grades 9 and 10, representing the 14-16-year-old age group. The total number of responses collected was 318 in 2018 and 480 in 2020, respectively. For logistical reasons, some responses in the pre- and post-survey (27 %) came from different schools, but this is not expected to affect the results as they were independent samples. While the first set of students surveyed had no earthquake education whatsoever, those who filled out the second survey were exposed to information and lectures frequently about earthquakes from the teachers who were trained in our program.

When the exact same question was asked before and after our program's implementation, we quantify the change using χ^2 test analysis. In doing so, our null hypothesis (H_0) is that our program

had no effect on the students. If this null hypothesis is unconfirmed (i.e., the χ^2 value is above the threshold for the corresponding number of possible answers, and the respective p-value is below 5%), then we interpret that the program had an effect on the students as their answers show a clear, statistically significant change. The complete set of questionnaires are available in the Supplementary materials file.

RESULTS

The first measurement of this study, performed in the 2018 survey, was about the experience of the 2015 Gorkha earthquake. The majority of respondents, 94 %, felt the shaking. As the earthquake was on Saturday, schools were closed and students were at home; 71 % of students answered that they ran out of a building, and only 15 % hid under a table, 8 % did not know what to do, 3% stood next to the wall or the doorframe, 3% had other reaction.

Knowledge about the causes and possibility of earthquakes in Nepal

Before the implementation of the program, 7 % students believed that earthquakes were caused by a moving fish carrying the Earth (a Hindu belief and myth). However, 64 % still chose the correct scientific answer: plate tectonics. The majority of students, 84 %, chose the "plate tectonics" answer in 2020, and the percentage of responses relating to the cultural/religious reasons dropped to 2 % (Fig. 5).

Regarding the probability of a future earthquake greater than in 2015, more students knew that such an earthquake in their region was quite likely after the education program (Fig. 6a). At the same time, there was a clear drop in the number of responses for very unlikely (17 % in 2018 to 5 % in 2020) and a slight drop in the percentage answering that a future great earthquake is impossible.

Relating to the effects of a $M_w > 8$ earthquake, after the program, the answer *I could die* has increased by a factor of 1.8, and all other answers (*I could be buried alive*, *I could get hurt*, *I could lose friend* and *My home could collapse*) are increased by a factor of at least 1.3 compared to 2018 (Fig. 6b; multiple answers were possible).

In 2018, 31 % students answered they know when an earthquake will occur, which is reduced to 11 % in 2020. The answer itself is not true, and this mis-information could drive people to incorrectly prepare for or act during an earthquake. While our efforts clearly decreased this mis-conception among the students, we could not yet reach each and every student to teach them about the unpredictability of earthquakes. The students answer agreeing on the impossibility of preventing an earthquake was 86 % in 2020, showing an absolute increase of 18 % from 2018. This question also shows that by 2020, more than double of the respondents have participated in disaster risk education training compared to 2018 (Fig. 7).

Knowledge and perceptions about how to behave during and after an earthquake

Three quarters (75 %) of students in 2020 responded that their family knows what to do and where to go during an earthquake, an increase of 55 % from 2018. Only 37 % of students in 2020 believed that their home could resist a large earthquake. For comparison, 65 % students were scared and 22 % panicked during the Gorkha earthquake in 2015 (10 % had calm reactions, 3 % did not care) according to answers in 2018.

In 2018, 62 % respondents didn't know that they should not call others after an earthquake to leave the phone lines available for rescue operation, but in 2020 nearly 80 % students knew this useful practical point (Fig. 8).

After the implementation of our program, 65 % of the students believed that they can survive if a large earthquake occurred at night, whereas 43 % felt they could survive in 2018. This information reflects more confidence of students as they become familiar with earthquake topics and heard more information about them.

In 2020, 93 % of children knew that during an earthquake, the majority of injuries and deaths are caused by people being hit by objects, through the collapse of constructions; the proportion of people not knowing this dropped by 2/3 after the educational program was implemented. More than 2/3 of the students in 2020 were aware about the additional hazards, such as fires, landslides and floods that can be triggered by an earthquake. There is a 7% decrease for this answer since the 2018 survey, but as students who claimed partial knowledge increased by 7 % as well, a net change in knowledge is not really perceptible on this point.

The proportion of students who regularly discuss earthquake related topics within their families has increased by 18 % (absolute increase; see Table 1). This shows that the education program at

schools has led to widespread social learning within communities. This is reinforced by the finding that nearly all students (98 %) are interested to learn more about earthquakes in detail, which will aid communities towards better earthquake preparedness in the long run.

Earthquake preparedness and adaptation

In 2018, 36 % of students perceived that to remain alive during an earthquake depends on luck, while this number has decreased by a relative 60 % after our program started and is a concern for only 21 % of students (Fig. 9). All possible answers regarding adaptation options to earthquakes record an increase from 2018 to 2020 (Fig. 11). The majority (72 %) of respondents answered that they are aware of the shelter areas and open spaces where they can go in case of an earthquake. The same proportion of people are aware of evacuation areas in 2020, but the increase here is much more important (from 38 to 69 %), potentially thanks to the Nepali Emergency Meeting Point signs we installed in schools. The information about which governmental authority to contact after an earthquake is relatively low, but has increased by 10 % (absolute). Information about earthquake prone areas and the reception of knowledge on earthquake disaster adaptation have increased by the factor of 2.5, from 12 % in 2018 to 31 % in 2020 after the education program.

The relatively small number of respondents who claimed that the government will provide help after an earthquake increased by a factor of almost 3: from 8 % in 2018 to 23 % in 2020. This percentage is not yet sufficient in general, but the improvement following our program's implementation is noteworthy. Moreover, the level of confidence in the government's reconstruction activities has also grown, from 13 to 30 %, which is a good sign and shows increasing level of trust. In 2020, 68 % of the respondents knew about the importance of talking about earthquakes with neighbours, friends and colleagues, a nearly two-fold increase in two years. Furthermore, we found that all students discussed their new knowledge and learning about earthquakes with the people around them in the community. Ninety-one percent of the students talk at least with some people in the community, only 9 % discuss this with their parents only, and there is no student who had not had a discussion in her/his surrounding (Fig. 10).

Perception of risk

More than 60 % of the answers showed that students considered the level of seismic risk in their city as medium, which means their risk perception is underestimated with respect to the actual

seismic risk level in the region (Stevens et al., 2018). Only every 6th person claims to perceive high risk, which is clearly less frequent than people declaring low risk. As opposed to our expectation, there is very little change in the level of risk perception in the group of students from 2018 to 2020: the medium risk level group is the same, and there is minor change in low and high-risk level groups (Fig. 12). This result is a surprise, especially when compared to the 72 % of responses in 2020 who believe that there is more than 70 % chance of experiencing an earthquake larger than the 2015 Gorkha earthquake in their life (Fig. 6a).

Project acceptance and future education

To measure the program's acceptance level, some questions regarding the program itself were also included in the 2020 questionnaire. It is found that 91 % of the students know that a seismometer is installed in their school for earthquake education purposes. A total of 61 % of the students have observed waveforms recorded by the seismometer, either at the school computer (39 %), on the teacher's mobile phone (18 %) or/and on their parents' or own mobile phone (8-8 %). Furthermore, 85 % of the students answered that teachers teach about earthquakes in the classroom regularly (weekly, monthly, on demand, and/or following an earthquake). In 2020, 99 % of the students expressed that they like the earthquake information we have provided them. Regarding future plans, almost all students are very much (69 %) or simply (29 %) interested to learn about earthquakes by inserting the theme in the official curriculum, which can be instituted by the Local, Provincial and Federal Government of Nepal as they have all have some field of possible action. Hence, our program and the methods we use for teaching about earthquakes are well accepted.

Statistics

All questions except the last (Question 12 in Table 1, level of interest to learn is 98% in both surveys) record a clear change in the pattern of answers given following our program's implementation (see Supplementary Table 1). The biggest statistical change was seen for Question 6 (avoid post-earthquake use of mobile communications) suggesting a big increase in knowledge and a very new information. Each question (excluding those with multiple choice answers) and their corresponding χ^2 and p-values are reported in the Supplementary Table 1.

DISCUSSION

Have earthquake awareness levels increased?

As a result of the novel school-based education program, themes related to earthquakes are more familiar to the students now than in the past, and their awareness level have increased since the program was initiated. Students know more about the earthquake phenomena and have changed their behavior to better prepare and adapt to forthcoming earthquakes. Earthquake related knowledge learnt by students at schools has also reached across the broader community, though social learning processes (Reed et al. 2009).

Why have the awareness levels increased?

Beyond the prescribed school education, our program has provided an opportunity for informal and free-choice education forms, in which people can learn about topics outside of formal educational settings, which has been well supported by enthusiastic teachers (Falk & Dierking, 2002). This form of social learning enables an increase in knowledge, and through further communication with others, it spreads knowledge in communities, which may lead to changes in attitudes, behavior, and building of trust in society (Reed et al., 2010). This method is widely applied for the study of natural hazards and its management (e.g., Brody, 2003; O'Keefe et al., 2010). During our program's implementation, despite being in contact only with the school children, the knowledge has spread much more widely in local communities through social learning, thus reaching and impacting the original and intended target group.

People's behavior can also be developed through education. The idea is that if people are made knowledgeable of earthquakes, they are more likely to adopt and perform behaviors that will increase their earthquake awareness and preparedness (Hungerford and Volk, 1990). This has similarly been shown for other environmental issues like invasive species, where campaigns building knowledge and awareness changed behaviors therefore minimizing risk (e.g. Cole et al. 2019).

As a result of our educational program, earthquake related knowledge has increased and the behavior to cope with earthquakes has also changed. Despite this, the earthquake risk perception of students has not fully changed yet. Our results show that a realistic and appropriate distribution of earthquake related knowledge and increased awareness level are not (or not yet) sufficient to influence the perception of risk. Perceptions are a complex phenomenon and can take a long time

to change (De Dominicis et al., 2015; Estévez et al., 2015; Cole et al., 2019; Shackleton et al., 2019). Education and awareness raising is the key factor for changing long-term risk perceptions – although programs need to be well tailored to appropriate audiences (Lee et al., 2015). Although, some studies discuss that increased knowledge does not always relate to increased risk perceptions, and increasing perceived risk does not necessarily result in the reduction of risk behavior (e.g. Noroozinejad, 2013; Petros, 2014). In addition, knowing more of a given topic makes people more certain, self-confident, which may lead to underestimate the related risk (e.g. Stringer, 2004). Moreover, increased knowledge and behavior to adapt and feel more secure during an earthquake should reduce the fear of associated risk and therefore reduce the risk perception. The limited change in risk perception in this study may be due to better knowledge of the hazard and how to mitigate it (Ndugwa Kabwama and Berg-Beckhoff, 2015).

Hence, how people perceive risk is not necessarily related to the actual risk. We cannot draw a definitive conclusion as the related knowledge can contribute to the amplification or the attenuation of the related risk; as such, it could be one of the potential reasons for the low risk perception of people having more knowledge (Reintjes, 2016). Risk perception is thus important for preventative actions, but risk perceptions are often biased (Weinstein, 1988). It could be that more time is needed to change students' risk perceptions, and it is also likely that there are other factors such as economic status, gender, age group, location of home in city, etc. that may influence the level of risk perception of people. A repeated survey in the same age category in a few years' time may give an answer to this question. We suggest that further monitoring and adaptation of the education system might be needed to better link awareness raising, behavior change and risk perception change.

Further action needed

Since other sources of information, such as newspapers and television, are not easily available to people in the Nepali countryside, we believe that the school is the best platform to transfer knowledge to the community. The proper education at school reaches deep across the families and into the community, and the discussions in those circles are essential to prepare the whole society for future earthquakes. The proportion of students who regularly discuss earthquake related topics within their families has increased by 18 % (absolute increase; see Table 1). This shows that the

education program at schools has led to widespread social learning within communities, and possibly beyond our program's current area. We therefore, advocate for a continuity of this program and to get education about environmental hazards more deeply embedded in the Nepali education system.

Although this program has increased the earthquake awareness level among students and the broader community in the program area, it is alone not sufficient for seismic risk reduction. Further monitoring and adaptation of the program to promote changes in risk perception and improved learning is advised. Education will help communities to prepare for future earthquakes, but the local, national and regional governments are responsible for the rescue, support and reconstruction operations in the case of a severe earthquake and well as developing and implanting policy to mitigate against threats. People's situation after an earthquake depends on how well they are prepared for the event, so developing policy, for example, on construction quality depending on expected shaking intensities is advised. Since the shaking level of an earthquake cannot be controlled, the impact of an earthquake on the community is strongly dependent on the actions taken by the government for its preparedness, such as education (so far our program's effort) as well as, for example, a suitable, locally calibrated and enforced building code. For both aspects, the provincial governments could overtake some of the efforts drawing on our bottom-up approach, and adapt them to continue earthquake education in schools, which is an efficient way to make earthquake safer communities. In parallel, local initiatives are encouraged to strengthen these efforts.

CONCLUSIONS

The Seismology at School in Nepal program has been successfully implemented and achieved the aim of raising earthquake awareness and preparedness by educating students in their schools. The program itself and the methods we used for teaching about earthquakes and demonstrating with low-cost seismometers are well accepted by students and teachers. The new knowledge learned by the students at school reaches their parents and is transferred into the local community. The results we observed through two surveys, before and after initiation of the education program, are measurable, statistically significant and with positive changes for earthquake related knowledge and preparedness level, but not (yet) for the perception of the related risk. A high and positive

impact of the program on the students and their communities is encouraging for the continuation and expansion of the program in the region. Governmental institutions are encouraged to build on this experience as well as develop further policy to mitigate the risk of future earthquakes in Nepal.

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Figure 1: Map of Nepal, with the locations of schools participating in the Seismology at School in Nepal program. Background represents population density data (CIESIN and CIAT, 2005). The Main Frontal Thrust (MFT), the surface trace of the fault underlying most of Nepal and hosting all great earthquakes in the region, is indicated in red solid line. Three colored segments represent the rupture extent of the corresponding major and great earthquakes with moment magnitude (Mw) as indicated (after Bollinger et al., 2016). For the 2015 Gorkha earthquake the rupture area is also plotted (blue contour). Letters P and K refer to cities Pokhara and Kathmandu, respectively, marked with black circles.

Figure 2: Students gathered at the morning assembly in the *Shree Himalaya Secondary School, Barpak, Gorkha* district. The school building was damaged during the 2015 earthquake and students were in temporary shelters. The construction of the new building is visible at the top of the picture. (Photo: S. Subedi, in May 2018, with permission of the school).

Figure 3: Left: The Raspberry Shake 1D low-cost seismometer, installed in 22 schools across Central Nepal (Fig. 1). Right: Earthquake awareness sticker, as a reminder, in English and Nepali language (artwork of M. Dessimoz). The sticker image is available for download from our program's webpage: www.seismoschoolnp.org.

Figure 4: Educational flyer in Nepali language on what to do before, during and after an earthquake. The flyer has been translated and adapted from an English version, compiled by and available from the CPPS earthquake education centre in Sion, Switzerland (www.cpps-vs.ch). The Nepali flyer is available for download from our program's webpage: www.seismoschoolnp.org.

Figure 5: Student opinions on what causes earthquakes (Q1), before and after the initiation of our education program. ($\chi 2 = 78.15$, p-value = < .00001, the change is significant).

Figure 6: *(a)* Student views on how likely the occurrence of a next earthquake bigger than the 2015 Gorkha earthquake is (Q3), before and after the initiation of our education program. ($\chi 2 = 43.59$, p-value = < .00001, the change is significant). *(b)* Student answer on the outcome of a potential Mw>8 earthquake in Nepal (Q2), before and after the initiation of our education program. *Multiple answers were possible.

Figure 7: Students' personal knowledge about earthquakes (Q13), before and after the initiation of our education program. *Multiple answers were possible.

Figure 8: Student's knowledge on the recommendation to avoid making phone calls after an earthquake to leave lines available for rescue operations (Q6), before and after the initiation of our education program. ($\chi 2 = 138.72$, p-value = < .00001, the change is significant).

Figure 9: Student's own opinion on earthquake preparedness (Q14), before and after the initiation of our education program. *Multiple answers were possible.

Figure 10: Student activities to transfer the knowledge to the community (question e), after initiation of our education program.

Figure 11: Student ideas about earthquake adaptation (Q15), before and after the initiation of our education program. *Multiple answers were possible.

Figure 12: Students' perception of the level of seismic risk in their respective location (Q10), before and after the initiation of our education program. ($\chi 2 = 6.33$, p-value = 0.042, the change is slightly above significant level).

No	Question	Answer in 2020 survey			Answer in 2018 survey		
		Yes	Partially	No	Yes	Partially	No
Q7	If a large earthquake occurred at night, could you save yourself?	65%	-	35%	43%	-	57%
Q8	Do you know that the majority of injuries that occur in earthquakes are caused by people being hit by or stumbling over fallen objects?	93%	-	7%	76%	-	24%
Q9	Do you know that earthquakes can make additional damage such as fire, landslides and floods?	68%	21%	11%	75%	14%	11%
Q11	The preparedness for a major earthquake is the most important thing. Are you	71%	-	29%	53%	-	47%

	regularly discussing this topic with your family?						
Q12	Are you interested to know more about earthquakes and its preparedness in details?	98%	-	2%	98%	-	2%

Table 1: Questions and respective answers about earthquake preparedness among students who participated in the surveys, before and after our education program was initiated in Central Nepal. Respective statistical indicators are reported in Supplementary Table 1.

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CONFLICT OF INTEREST AND ETHICS

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors declare that an ethical approval was not required as per local legislation. The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

The project concept and implementation details were developed by S.S. and G.H. Most of the fieldwork was carried out by S.S. with some help by G.H. The preparation of the manuscript, figures, tables and the calculations were done by S.S. and guided and verified by G.H and R.S. All authors discussed the results, and contributed to the final manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found in supplementary material file.

DATA AVAILABILITY STATEMENT

The datasets used for this study can be available on request to corresponding author.

Figure 1

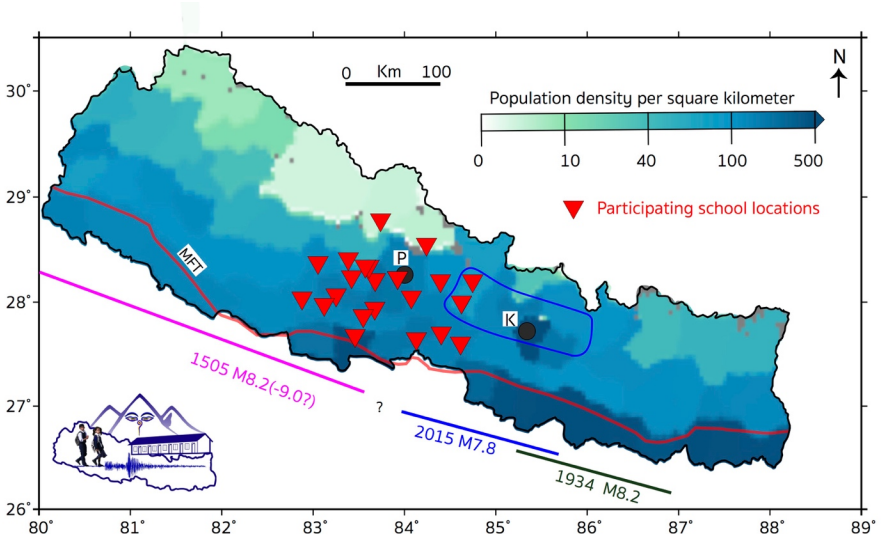

Figure 2

Figure 3

589 Figure 4

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Figure 5

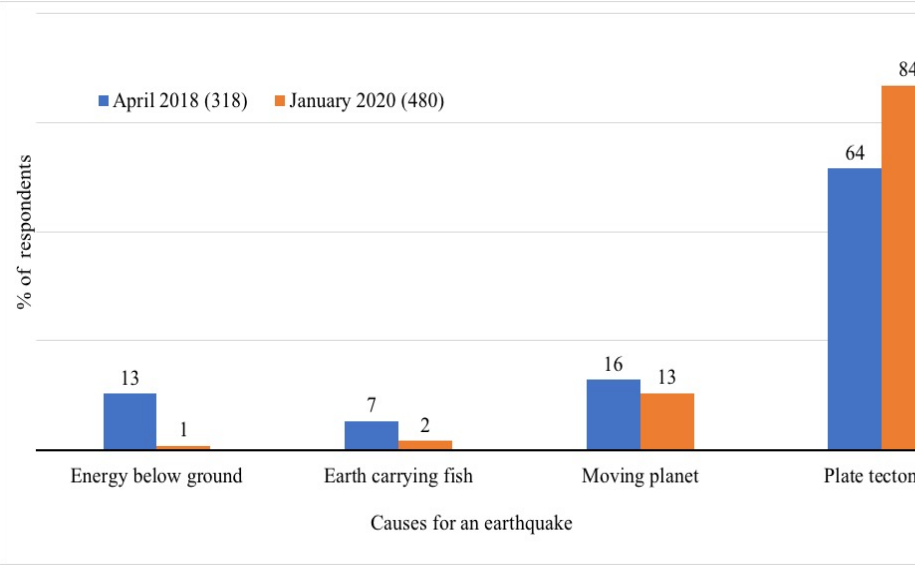

April 2018 (318)
January 2020 (480)
% of respondents
13
1
7
2
16
13
64
84
Energy below ground
Earth carrying fish
Moving planet
Plate tecton
Causes for an earthquake

Figure 6

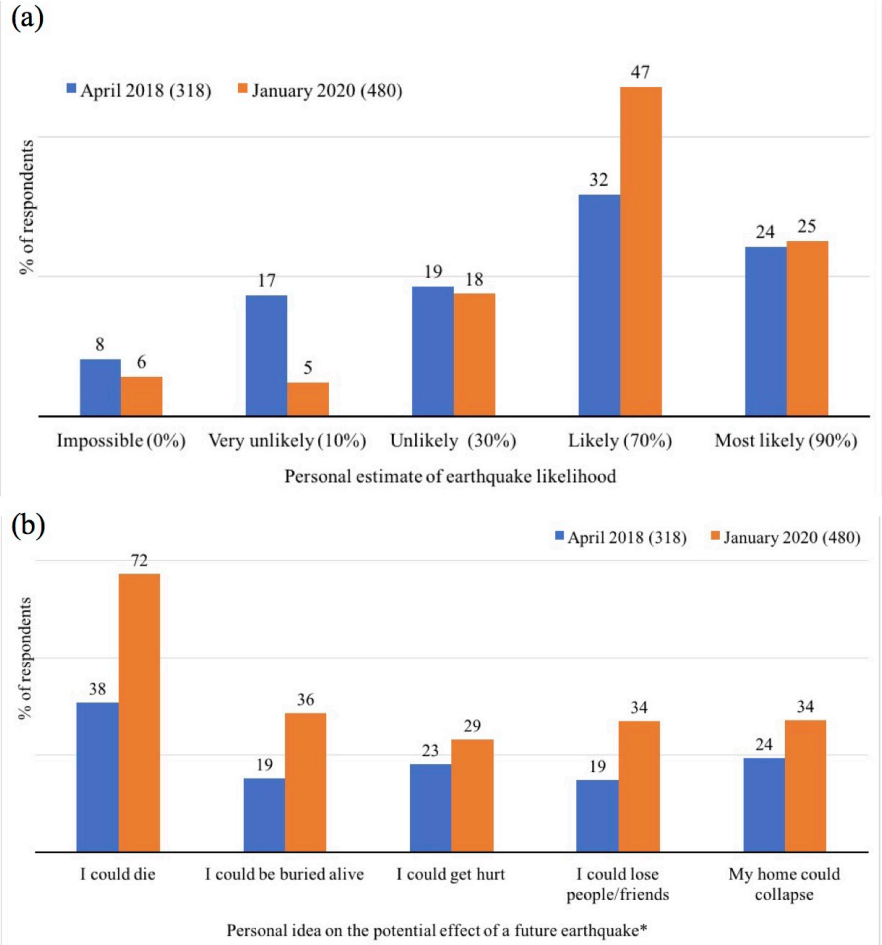

(a)
April 2018 (318)
January 2020 (480)
% of respondents
8
6
17
5
19
18
32
47
24
25
Impossible (0%)
Very unlikely (10%)
Unlikely (30%)
Likely (70%)
Most likely (90%)
Personal estimate of earthquake likelihood
(b)
April 2018 (318)
January 2020 (480)
% of respondents
38
72
19
36
23
29
19
34
24
34
I could die
I could be buried alive
I could get hurt
I could lose people/friends
My home could collapse
Personal idea on the potential effect of a future earthquake*

Figure 7

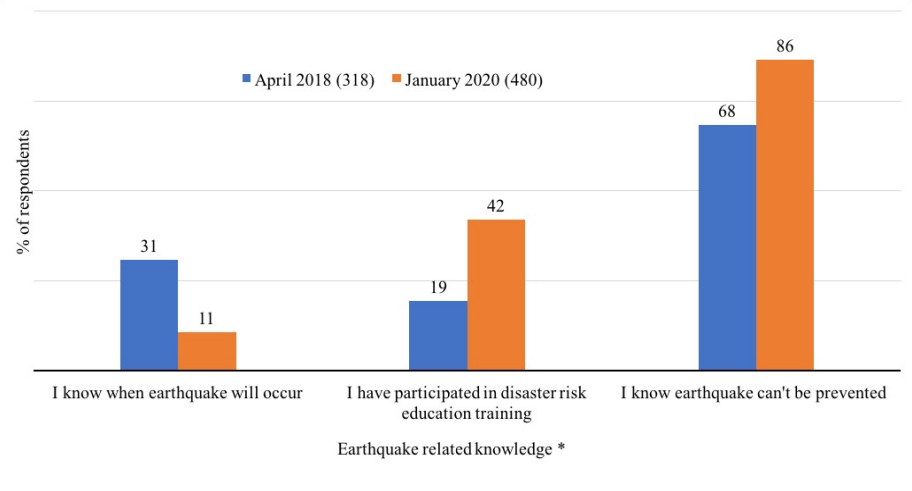


Figure 8

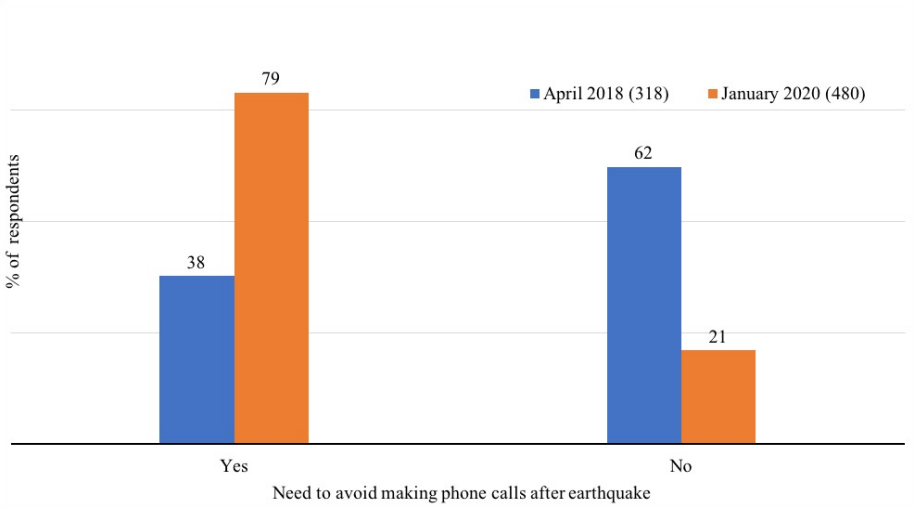
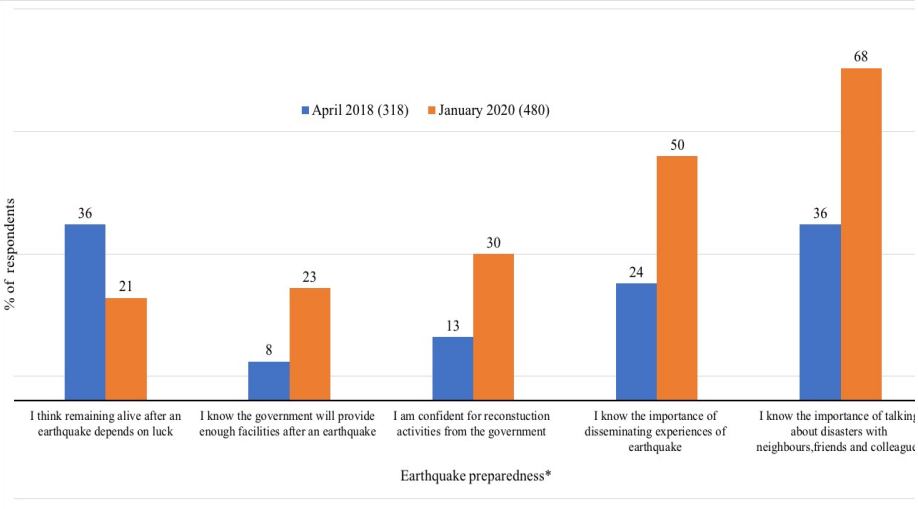
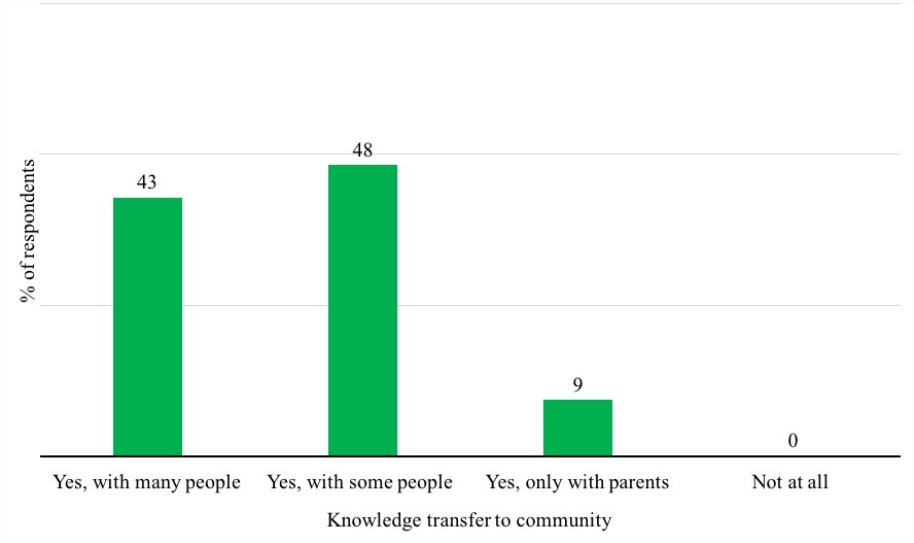


Figure 9


April 2018 (318)
January 2020 (480)
% of respondents
36
21
8
23
13
30
24
50
36
68
I think remaining alive after an earthquake depends on luck
I know the government will provide enough facilities after an earthquake
I am confident for reconstuction activities from the government
I know the importance of disseminating experiences of earthquake
I know the importance of talkin about disasters with neighbours,friends and colleagu
Earthquake preparedness*

637 Figure10



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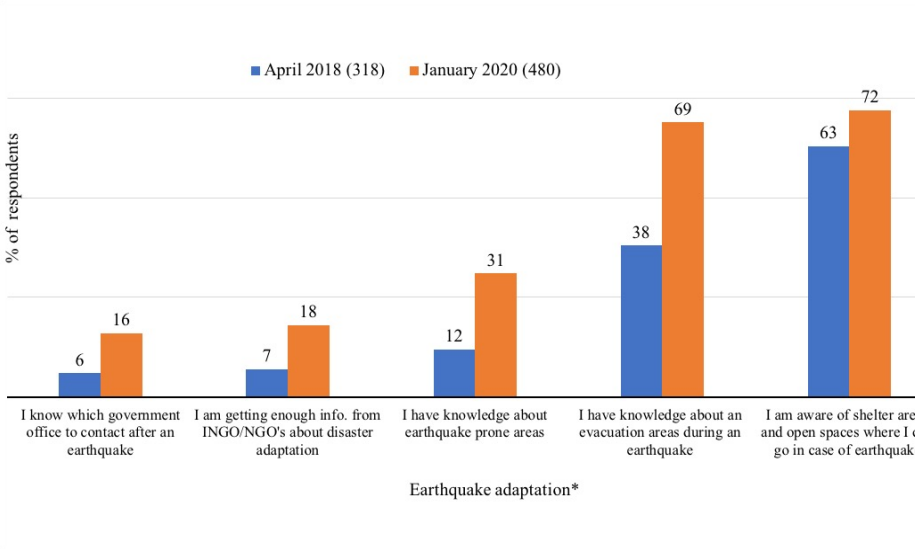
640 Figure 11



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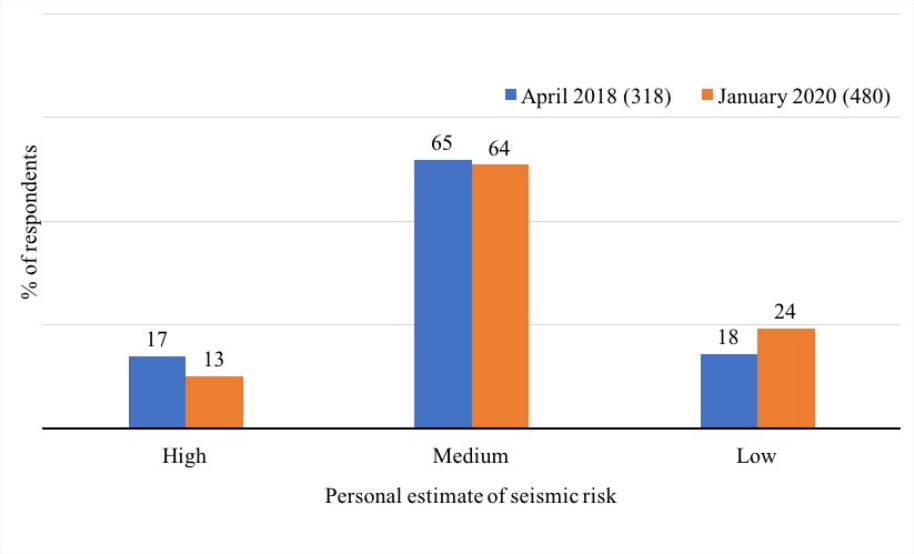
644 Figure 12



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