Earthquake Emergency Education in Dushanbe, Tajikistan

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ABSTRACT

We developed a middle school earthquake science and hazards curriculum to promote earthquake awareness to students in the Central Asian country of Tajikistan. These materials include pre- and post-assessment activities, six science activities describing physical processes related to earthquakes, five activities on earthquake hazards and mitigation strategies, and a codification art/literacy project. This curriculum was implemented with 43 middle school students in Dushanbe, Tajikistan in the winter of 2008. We examine the effectiveness of each curriculum component in communicating the causes, effects, and mitigation strategies associated with earthquakes to young people, and find significant improvements in seismic and earthquake hazards literacy as a result of the program.

INTRODUCTION

The devastation the world witnessed following the 2008 Sichuan Earthquake, the 2005 Kashmir Earthquake, and the 2004 Southeast Asian Tsunami demonstrated the importance of communicating the causes, effects, and mitigation techniques for earthquakes in developing countries. In particular, systematic substandard school design and construction exacerbate risks to school-aged children (Revkin, 2008). Earthquake activity has been recognized as the most damaging hazard in Central Asia, especially in terms of casualties (Pusch, 2004; Eugster *et al*., 2004; King *et al*., 1999; Khalturin *et al*., 1997). The region is also characterized by a lack of public access to science-based earthquake hazard information (Halvorson and Hamilton, 2007). A form of what Degg and Homan (2005) refer to as "informational vulnerability" is evident throughout this region. In many areas the indigenous population is not aware of the self-protective steps it can take to mitigate hazards.

"Informational vulnerability" is ultimately rooted in and perpetuated by lack of access to information or ineffective dissemination methods and a depressed regional economy. This vulnerability is often reinforced in situations where experts are unable to share information with the general public. For example, the Central Asian country of Tajikistan has both institutes dedicated to earthquake research and public school systems, yet neither group has the economic resources to promote earthquake hazard education. Without material support, there are very few interested, qualified individuals within the country who can help ensure that people are aware of their options when facing earthquake hazards.

Study Setting - Tajikistan's capital city of Dushanbe shares boundaries with major geologic structures such as the Pamir, South Tien Shan, and Tajik Depression, all of which are seismically active (Burtman and Molnar, 1993). According to Geohazards International, there is about 40 percent probability that an earthquake will occur near one of the Central Asian republics' capitals within the next two decades, causing approximately 55,000 fatalities and 220,000 serious injuries in Dushanbe alone (Khalturin *et al*., 1997). Destruction of this magnitude in Dushanbe should not be surprising as nearly half of its residential buildings have the potential to collapse or be damaged beyond repair in the event of an earthquake. The majority of the newly constructed residential buildings in Dushanbe adhere to no seismic design standards (King *et al*., 1999), and its older Soviet-era residential buildings have been found to perform poorly in earthquakes.

Tajik schools are free of charge, and nine years of education is compulsory. At the national level, Tajikistan had human capital capabilities in the areas of health, education, and science comparable to the developed world throughout the 1970's and 1980's, but its education system suffered with the collapse of the Soviet Union (Sievers, 2003). During the civil war that followed the Soviet collapse, many qualified teachers fled abroad, mainly to Russia, as one fifth of the schools were destroyed. Presently, a shortage of resources such as qualified teachers, textbooks, sanitation services and heat during winter seasons is evident throughout the country including within the capital city. Schools, students and staff members are highly vulnerable to earthquake disasters. On July of 2006, nine schools were destroyed by two earthquakes in the southern district of Qumsangir in Tajikistan, affecting the lives of nearly 7000 students and thousands of others who were in need of shelter. A year later, another earthquake destroyed six schools in Rasht district of central Tajikistan, where 1800 students' education was hampered.

Study Population - Forty-three eighth and ninth grade students ranging in age from 14-15 years old in Dushanbe were involved in the study, with a male:female ratio of 42:58. The schools for this study were selected by the Tajik Ministry of Education and Tajik Institute of Earthquake Engineering and Seismology. The schools are located in the city center, and are typical of the public schools found in Dushanbe. The students reported never having completed any formal Earth sciences curriculum, though isolated elements of the Earth sciences had been covered in traditional geography, physics, and chemistry courses.

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All students reported having participated only once in an earthquake drill conducted by an emergency response organization in both schools about one year prior to the study. Classroom observations conducted prior to the study indicated that the students were accustomed to a teacher-directed, textbook-based learning environment, characterized by low levels of student engagement.

We have developed a set of curricular materials which can be employed by local and visiting teachers and scientists to reduce informational vulnerability and to help engender collective cultures of prevention. The curriculum was field-tested and implemented by the lead author of this paper as a visiting geoscientist and educator to Tajikistan in winter of 2008. The implementations were conducted in the native language, Tajik. The implementations took place after normal school hours. Student attendance was voluntary. The total time required was about 36 hours averaging about 3 hours per individual activity. These materials are optimized for scientific content, ease of implementation, appropriateness to the targeted grade level and cultural sensitivity. The key components of the curriculum include a pre-assessment survey interview, six science activities on physical processes describing earthquakes, five activities on earthquake hazards and mitigation strategies, a curriculum codification project, and a post-assessment focus group discussion. We demonstrate the effectiveness of the curriculum in communicating earthquake hazards to the participating students, based on a comparison of pre- and post-assessment data.

The primary objectives of this curriculum are as follows: (1) ensure that students understand and correctly employ basic Earth sciences terminology and concepts when discussing earthquakes and earthquake hazards; (2) encourage students to employ critical thinking skills when sharing and receiving earthquake-related information; (3) empower students to utilize all resources to protect themselves and their communities from earthquake hazards; and (4) encourage an innate interest in earthquake hazards so that the benefits of the earthquake hazards curriculum outlive the workshop.

CURRICULUM STRUCTURE

This curriculum takes a stepwise approach to prepare students for earthquakes, with later lessons building on topics covered in earlier lessons (Figure 1). This stepwise approach is necessitated by the content (i.e., later concepts cannot be thoroughly discussed without earlier concepts), but also fits well with the 5E theoretical framework described below. The curriculum introduces students to the fundamental scientific concepts behind earthquakes before progressing to earthquake hazards and mitigation techniques. The implemented activities have been adapted from a variety of published and unpublished materials developed by geoscientists, science teachers and aid and emergency agencies all around the world. The activities

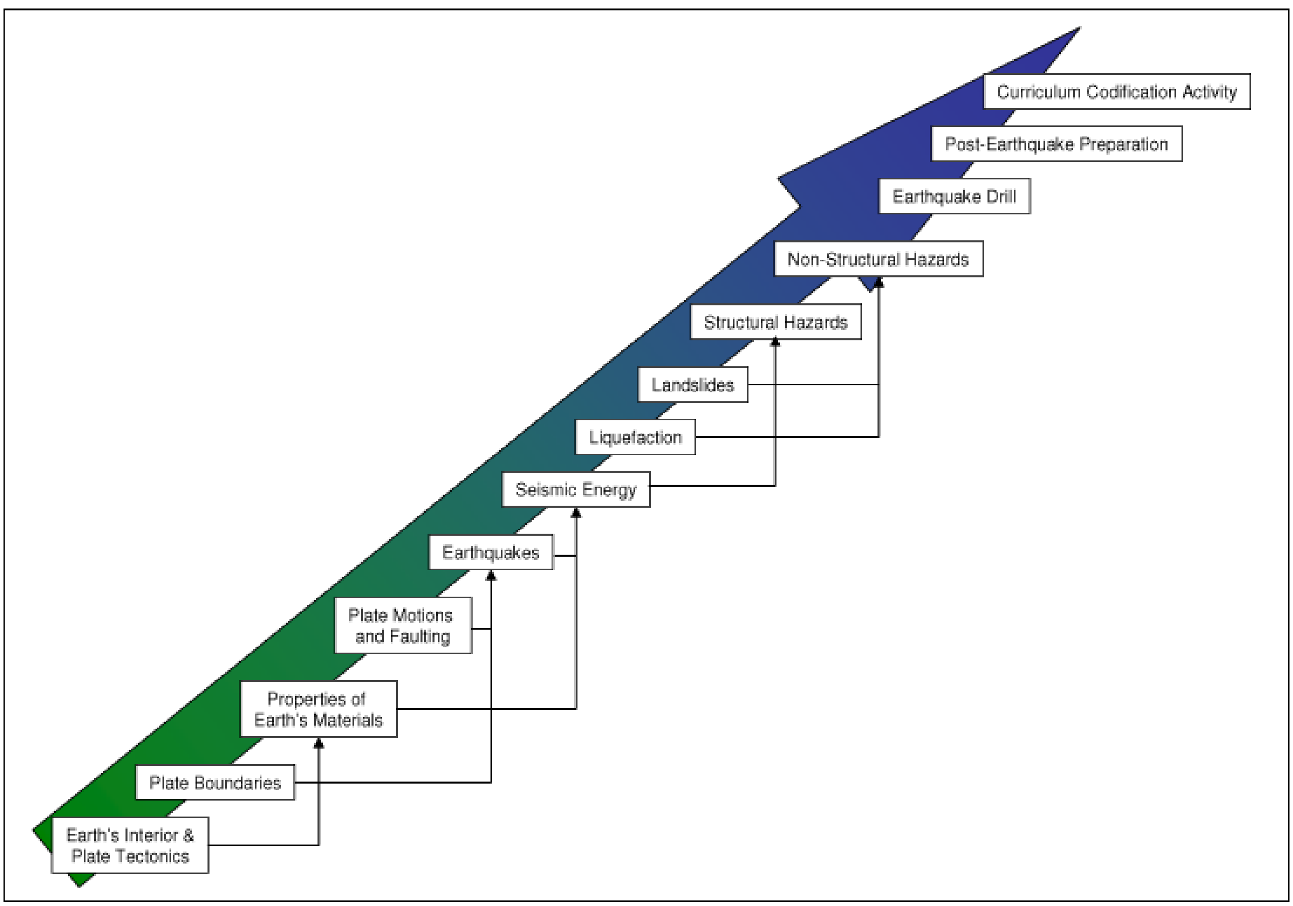

FIGURE 1. Layout of the earthquake education curriculum. The curriculum is arranged such that later lessons build upon earlier lessons, as shown.

TABLE 1. CURRICULUM COMPONENTS, LEARNING OBJECTIVES, AND RELATED ACTIVITIES

Week	Components	Objective	Activity
1	**Pre-assessment**	To assess students' preconceptions and misconceptions about earthquake hazards and Earth sciences prior to the lessons; to establish interpersonal relationships between students and the educator; and to allow for communication of curriculum's key elements.	The pre-assessment activity consists of one-on-one reciprocal interviews between the students and the educator; students are encouraged to ask and answer simple questions and to share concerns they might have prior to the lessons.
2	**Earth interior & plate tectonics**	To develop an understanding of the interior structure of the Earth, and the relationship between plate tectonics and occurrences.	Students compare the interior of a hard-boiled egg to that of the Earth, and explore limitations associated with this analogy.
	Plate boundaries	To explore what happens at plate boundaries; to learn how the scientific process works.	Students observe, describe, and classify scientific data to learn about what happens at plate boundaries.
	Properties of Earth materials	To demonstrate why and how rocks deform.	Students investigate how materials' properties can change using rubber bands, silly putty, metal wires and tootsie rolls.
	Plate motions and faulting	To learn about different kinds of faults produced by different kinds of plate motions.	Students compare Earth's crust to modeling clay and observe it when under stress. Students use strips of cardboard to construct fault models.
	Earthquake machine	To incorporate information from previous four lessons to understand mechanisms behind earthquakes.	Students build and operate a model to observe stick-slip motion along a fault, and explore the effects of several variables.
	Seismic energy	To learn how earthquake energy is released, transmitted through the Earth, and measured.	Students use Slinky toys, telephone cords and ropes to learn about different waves and their motions.
3	**Liquefaction**	To learn the effects of liquefaction and what can be done to reduce damage due to liquefaction.	Students construct a model using sand of various particle sizes to investigate the degree of liquefaction and its effects on structures.
	Landslides	To learn how and why landslides occur, and steps to take to reduce landslide hazards.	Students construct a model to simulate an earthquake-induced landslide and explore factors that affect an earthquake-induced landslide.
	Structural hazards	To understand how buildings respond to earthquake forces; why they collapse and what can be done to make structures safer.	Students construct building models and test them on a shake table; they build a wall model and reinforce it to withstand shaking.
	Non-structural hazards	To assess safety of the classroom (and homes) and to make a plan to remedy earthquake hazards.	Students identify non-structural hazards in their schools (and homes) by developing and completing a rapid visual screening (RVS) checklist.
	Earthquake emergency response plan and drill	To recognize the early signs of an earthquake; to develop an awareness of proper safety measures to follow before, during, and after an earthquake.	Students develop, test, evaluate, and improve an emergency response plan and a drill for their school. Students present their plans to appropriate school's authorities. Students develop an emergency family plan and put together a 3-day safety kit.
4	**Codification activity: bookmaking**	To help students reinforce the concepts learned from all aforementioned lessons.	Students use information from curriculum lessons to write a story about individuals or communities affected by an earthquake. Students illustrate, publish, and present their stories in their school.
5	**Post-assessment**	To measure students' performance and the effectiveness of instructional methods.	Students participate in a group discussion about the material covered in the curriculum and provide feedback to the educator.

have also been adapted to include the latest, region-specific information, and to be responsive to the needs of Tajik students in culturally appropriate ways. Curriculum materials can be accessed at www.bullsandmosquitoes.info/solmaz/website/#/lessons/ and are included in the supplementary information accompanying this article. Table 1 summarizes the learning objectives of the activities implemented in this curriculum.

Theoretical Framework - The curriculum is designed to be consistent with the Biological Sciences Curriculum Study (BSCS) 5E (Engagement, Exploration, Explanation, Elaboration, and Evaluation) Instructional Model (Bybee *et al.*, 2006). The Engagement phase consists of the pre-assessment survey interview during which students share personal earthquake stories, experiences, and opinions. The survey questions are designed to access the learners' prior scientific knowledge, perceptions, and misconceptions related to earthquake hazards. The Exploration phase aligns with the first six science activities, where students explore Earth sciences concepts and processes that may contradict the misconceptions uncovered in the Engagement phase. The Explanation and Elaboration phases are covered in the Tabletop Experiment and Tabletop Exercise sections, respectively, of the five earthquake hazards activities. Through Tabletop Experiments, students are challenged to explain how earthquake hazards arise as a consequence of the concepts covered in the six science activities. The Tabletop Exercises extend students' conceptual understanding with real world, decision-making scenarios involving the earthquake hazards. The curriculum codification project and post-assessment focus group discussions comprise the Evaluation phase. In this phase, students assess their understanding of concepts covered in all of the science and hazards activities. This also allows the curriculum implementer to assess students' learning and the effectiveness of the implementation.

Pre-assessment **-** The ultimate goals of the pre-assessment survey interviews are to establish interpersonal relationships between the students and the educator, investigate students' preconceptions and perceptions of earthquakes and earthquake hazards, and allow for clear communication of the curriculum's key elements. The pre-assessment activity consists of one-on-one reciprocal interviews between the students and the educator. This allows students to voice their opinions and thoughts in a private environment where they are not going to be judged by their peers. In so doing, the assessment provides equal opportunity to students, regardless of the amount of pre-existing earthquake knowledge or the student's gender. This latter consideration is particularly important when working with Tajik students, as we observed that female Tajik students do not tend to voice their opinions in the presence of male students. To address this issue, the educator privately encouraged the female students to participate in the activities as much as their male peers prior to the implementation. This part of the intervention was successful, as the females were at least as active as their male peers throughout the lessons and the post-assessment discussion. The pre-assessment interviews took place during school period one week prior to curriculum implementation, and lasted approximately 10 minutes per student.

To meet curriculum objectives, each interview began with personal introduction and the sharing of personal earthquake stories. Each student was then asked a series of open-ended questions about their experiences with recent earthquakes (e.g., Have you felt an earthquake before? Where were you when the ground started to shake? Were you alone? What was your immediate response? What damage did it cause? How did the shaking make you feel? Did anyone explain to you what was happening?). Students were also asked about whether they had considered making any particular immediate response to future earthquakes based on their acquired experiences or knowledge. Students' responses allowed the educator to gain insight into what gaps of knowledge most likely contribute to the students' exposure to earthquake hazards. To assess each student's level of Earth sciences knowledge, particularly their understanding of physical processes associated with earthquakes, and to make any necessary adjustments to the curriculum prior to its implementation, each student was asked about the Earth's interior structure, mountain building processes and the causes of earthquakes. During the interviews, the educator explained to students the key elements and practicality of the curriculum, and invited students to raise questions and concerns related to the curriculum.

Earthquake Science Lessons **-** To understand earthquake hazards and to mitigate their effects, students must understand earthquakes and related physical processes. This component of the curriculum is designed to introduce students to fundamental scientific concepts of seismology. The primary objective of this component is to assist students with developing a scientific explanation for earthquakes. Turcotte and Schubert (2002, p. 339) describe earthquakes as follows:

> *"When a fault sticks, elastic energy accumulates in the rocks around the fault because of displacement at a distance. When stress around the fault reaches a critical value, the fault slips and an earthquake occurs. The elastic energy stored in the adjacent rock is partially dissipated as heat by friction on the fault and is partially radiated away as seismic energy."*

For students to be able to understand and comprehend the definition of an earthquake as provided by Turcotte and Schubert, a curriculum that addresses the following fundamental questions in a logical order, and with demonstrated connections between concepts, must be employed: (1) What do we mean by plate tectonics? (2) What happens near plate boundaries? (3) What are the different kinds of plate motions, and mechanisms driving them? (4) What are faults and how are they produced? (5) How and why can rocks be deformed? (6) How does faulting cause earthquakes? (7) What is seismic energy and how does it travel through the Earth? We implemented six science activities (Table 1) with Tajik students, inviting them to explore the aforementioned questions. The lessons are ordered logically, re-introducing concepts and drawing connections between them as they proceed.

Earthquake Hazards and Mitigation Strategies **-** To prevent panic during earthquakes and to protect oneself against earthquake hazards before, during, and after an earthquake, an accurate understanding of the hazards, the physical processes producing them, and how earthquake damage can be mitigated, is critical. The primary objectives are to (1) create awareness about earthquake hazards; and (2) empower students to utilize all available resources to protect themselves and their communities from earthquake hazards.

To meet these objectives, we implemented five earthquake hazards activities with Tajik students (Table 1). These activities focus on regional hazards and the mechanisms that produce them, particularly the hazards threatening the city of Dushanbe (i.e. structural collapse, landslides, and liquefaction). Relevant information such as photographs, articles, and eye witness accounts that help to describe local and regional earthquake damage were incorporated into the activities. We also included examples of similar earthquake hazards and their effects on communities worldwide, describing earthquakes as universal phenomena that can be planned for through quantification, comprehension, and community action.

As part of the lessons, students conducted a safety assessment of their classrooms and homes. Resources to reduce or remove all earthquake hazards are limited or non-existent in Dushanbe. Therefore, emphasis was placed on risk reduction through hazards identification and community awareness activities, including communication of the identified hazards to the appropriate local authorities and families.

Curriculum Codification Project **-** Codification activities are a means of asking students to provide or invent a context that links curriculum concepts together. In the case of earthquake education, a codification project should help students reinforce the concepts that make earthquake science, hazard awareness, and hazard prevention three aspects of a unified whole: earthquake safety. The codification project adapted for this curriculum is a story writing activity originally developed at the University of Washington's Pipeline Project (www.washington.edu/uwired/pipeline/), and is similar to the scrapbook exercise developed by Burnley (2004). This project reinforces concepts learned from previous activities in a flexible and creative environment, and instills a sense of pride and accomplishment in the students as the curriculum is completed.

During this project, students used information from previous activities to write stories about individuals or communities affected by an earthquake. Students were encouraged to incorporate as much of the material covered in the curriculum as possible, but were left free to use personal experiences, cultural anecdotes, or invented characters or places to create the fundamental storyline. Students brainstormed, wrote, edited, illustrated, published and bound their stories into a single signature book, including a photograph of themselves along with a self-written 'About the Author' section in their books. Publishing a book and recognizing the students as authors are more than simple reminders that the students have successfully finished the lessons. This sense of pride was clearly evident in students' self-written author sections and in the presentation of their work to their peers and teachers at their school. To further emphasize the value of students' written words, students were invited to place their books in their school's library.

Post-assessment Focus Group Discussions - To measure students' performance, the effectiveness of the implementation, and to collect feedback for curriculum improvement, we conducted two mixed gender focus group discussion sessions. The discussion sessions also provided a means for learning how students might have discussed topics covered by the curriculum amongst themselves. A total of 31 students out of the original 43 students participated in the discussions. Each discussion lasted for about 2 hours, and took place in a classroom two weeks after curriculum completion. To draw out information from students regarding concepts learned throughout the curriculum, the educator asked students a series of questions. The discussion questions were nearly identical to the survey questions asked prior to the curriculum implementation.

OBSERVATIONS

Below, we summarize observational data collected from the pre- and post-assessment and the codification activities.

Pre-assessment Observations **-** The pre-assessment observation data are shown in three main categories: earthquake experience, response, and causes. Tables 2 and 3 summarize the data for the latter two categories.

Earthquake Experience **-** All students had experienced at least one earthquake in their lifetime, with 26 percent of them having experienced earthquakes multiple times. Fifty-two percent of students claimed they were at school when they felt an earthquake; the rest were at home. One fourth of them expressed fear and panic when describing their experiences with earthquakes. Female students were more likely to convey their fear than their male counterparts.

TABLE 2. STUDENTS' RESPONSES TO PAST AND FUTURE EARTHQUAKES REPORTED DURING THE PRE-ASSESSMENT INTERVIEWS

Response category	Immediate response to earthquakes in the past (%)	Immediate response to earthquakes in the future (%)
No action	37	25
Escape or Run away	56	50
Shelter	7	25

Earthquake Response - Overall, most students provided no coherent response describing immediate actions that would help to ensure their safety during an earthquake (Table 2), despite having previously conducted earthquake drills at their schools. Fifty-six percent of students claimed to "escape" or "run away" when describing their actions during past earthquakes. As one student explained "We ran outside and stood under a tree so nothing could happen to us." A significant portion of students (37 percent) exercised no action when experiencing an earthquake. One student explained "We stood where we were. God knows better. There's nothing we could do," but most students argued that the earthquake was too small and quick to cause them any harm. Only a small portion of students (7 percent) sought shelters inside the structures they were in. They claimed to have stood in the corners of the room where the walls converge or in door frames, or to have gone underneath a table.

When asked to list actions they think they should take during an earthquake in the future, almost 50 percent of students chose "going outside" over no action (25 percent) or taking shelter (25 percent). Overall, when describing appropriate responses to earthquakes, most students related the magnitude of an earthquake to the type of response they would take: "going outside" in case of a large earthquake and "staying outside" in the case of a small earthquake. The responses indicate that students had given some thought to how they would react differently to earthquakes in the future, based on their response to past earthquakes. Specifically, the 'no action' response to past earthquakes made some students aware of the need for response to future earthquakes (the number decreased from 37% to 25%).

The concept of pre-earthquake preparation was an unfamiliar topic to all students. When asked what they would do to prepare for an earthquake, most students provided suggestions in terms of an immediate response to an earthquake. Responses such as "I can take shelter somewhere during an earthquake until it's over," or "I'll stay at the corner of the room next to the walls or go under a desk," were most common. The question was rephrased to encourage students to think about long-term preparation. Students were asked to list the things they would do between now and next year if they are told there will be an earthquake next year. No student was able to respond to this question.

TABLE 3. STUDENTS' EXPLANATIONS OF CAUSES OF EARTHQUAKES REPORTED DURING THE PRE-ASSESSMENT INTERVIEWS.

Response Category	Total responses (%)
Scientific explanation	0
Disconnected scientific concepts or terminology:	
• extraction of natural resources	12
• volcanoes, lava, mountains	39
• avalanches, flood, waves	7
Non-scientific	
• legends	9
• religion	5
No explanation	28

Causes of Earthquakes - When asked about the causes of earthquakes, 58 percent of students used a combination of disconnected scientific and non-scientific concepts and terminology in their answers (Table 3). About 39 percent of students mentioned upward movement of lava, formation of mountains, particularly volcanoes, but also stated that "dead bodies of people and animals" constitute lava. The majority of responses were similar to this response from a student: "The people who die, after many millions of years, come out of the Earth like lava and that causes an earthquake. A mountain appears in every place the Earth shakes." A noticeable portion of students (12 percent) listed "extraction of natural resources" as a cause of an earthquake with no elaboration while a small portion (7 percent) named floods, waves and avalanches as responsible for earthquakes. One student mentioned "earthquakes in the sea" and based his observation on television, listing Sri Lanka as an example of a place where this type of earthquake occurs.

Fourteen percent of students' responses were considered completely non-scientific. These responses included stories of animals such as cows, turtles, elephants, or fish, and how their motion results in earthquakes. A negligible portion of non-scientific answers included references to God. For instance, when asked what causes an earthquake, one student answered: "I don't know. It's either in God's hands, or I don't know." However, almost all students avoided claiming non-scientific answers as their own by making clear that the given opinions were public opinions, and that they reflect nothing about their personal views. When asked about their personal views, almost all students claimed opposition to public opinions and chose to answer the question by saying "I don't know."

Post-assessment Observations - Focus group discussions revealed four main observations: (1) most students employed basic earthquake science terminology when discussing earthquakes and earthquake hazards. No student upheld any of the incorrect concepts presented during the pre-assessment interviews to explain earthquakes; (2) while most individual students lacked comprehensive understanding of scientific concepts related to earthquakes and earthquake hazards, both student groups were able to connect scientific concepts to explain the mechanisms that produce earthquakes and earthquake hazards through social interactions; (3) a number of students claimed to have shared the knowledge gained through this curriculum with others, and to have taken small actions to reduce damage associated with earthquakes in their homes and school. These actions included putting together a family emergency kit, rearranging bedrooms to make them safer, and raising concerns with appropriate authorities about their safety during an earthquake; and (4) students in both groups exhibited increased interest in learning more about the science behind earthquakes. This was demonstrated by numerous references to working as earthquake engineers, conducting a classroom Global Positioning System experiment to measure crustal motion near their school, and inquiring about plate tectonics on other planets. These observations indicate that the primary objectives of the curriculum implementation have been met.

The following sample group discussion demonstrates the first two observations mentioned above. In this discussion, students brainstormed ideas and connected scientific concepts together to generate an accurate scientific explanation for earthquakes. The concepts and terminology employed by students in this discussion are based on their observation of a fault model they built and operated in the Earthquake Machine science activity.

Educator: *Who can explain how earthquakes happen?*

Student 4 and 10: *Because of plate tectonics.*

Student 4: *Aha, elastic accumulates! Pressure accumulates and this causes earthquakes.*

Student 4 and 5: *Energy, pressure.*

Educator: *What kind of energy?*

All students*: Elastic!*

Student 14: *First very slowly, and then it becomes hard.*

Student 2 and 3: *It accumulates slowly, the energy, and then there's a big earthquake.*

Student 1: *When there are forces acting on the Earth…tectonic forces…there's friction in the Earth, elastic pressure accumulates and when it's released, it results in an earthquake.*

Student 4: *Earthquakes occur because of plate tectonics, but what causes the plate tectonics?*

Student 3 asks Student 1: *What causes an earthquake?*

Student 1: *Because of the tectonic plates, when they move, there's an earthquake.*

Student 14 asks Student1: *But what about the tectonic plates? How are they formed?*

Student 3 says to Student 1: *In Asia, there's the Indian tectonic plate and that's why there are earthquakes in this region. But what about other places with earthquakes?*

Student 4: *People ask us why earthquakes happen, and we say because of plate tectonics, then they ask us why does plate tectonics happen?*

In the discussion above, students not only answered the question raised by the educator, but also asked other fundamental scientific questions that were not discussed in the curriculum implementation (e.g., what drives plate tectonics?). This level of scientific inquiry demonstrates that students not only comprehend and correctly employed the scientific concepts discussed during the activities, but they also developed an innate interest in physical processes related to earthquakes, and could use the acquired knowledge to ask specific scientific questions. Students also demonstrate the ability to think critically when sharing and receiving earthquake information. For example, one student explained her reaction to her neighbor when the neighbor told her that "there is a cow in the Earth that causes it to shake." "I told her cows are 'on' the ground, not inside of it. Next time, I'll ask her to show me a sign that her story is true."

Discussions also revealed that students learned basic earthquake preparedness procedures during the curriculum. Most importantly, they were observed debating the usefulness and practicality of their actions. For example, a number of students raised concerns about the practicality of a 3-day safety kit at their homes when they spend half of a typical day in school: "Even if we have a 3-day kit at home, when there's no kit at school, what are we supposed to do when an earthquake hits and we are in school?" This statement demonstrates that students have identified a need for a safety kit at their schools. Other students acted to address this need by discussing the importance of having a safety kit with the school's principal.

Students also discussed the weaknesses and strengths of each type of action possible during an earthquake (i.e., shelter in place followed by evacuation, immediate evacuation, or no action). Students recognized that the most appropriate earthquake emergency response depends on the type of structure they are in as well as the proximity to an escape route.

Codification Project Observations and Assessment – Students displayed differing levels of comprehension when integrating curriculum material into their stories. Some students relied very heavily on the scientific content covered in the activities, writing stories with detailed descriptions of earthquake mechanisms, the associated damages, and character responses that indicated awareness or forethought when faced with an earthquake and its aftermath. Some students, however, demonstrated little comprehension of any connections between the concepts described in the curriculum, as indicated by simply listing disconnected scientific information and numbers out of context. This demonstrated memorization of the concepts but little or no verification of the ability to apply, further develop, or interpret these ideas under unstructured circumstances. However, as the post-assessment data reveal, it is possible that some of these students may have understood the material, but simply lacked writing skills. Most students included personal stories and cultural anecdotes in their stories.

Despite different levels of comprehension, all students described the codification activity as "the most exciting" part of the curriculum because they published a book of their own. Students' requests for making multiple books or stories during this activity indicate their active participation. While it is difficult to effectively assess students' understanding of the curriculum materials in this activity, it certainly instilled a sense of pride and accomplishment in students.

CURRICULUM EVALUATION

We assessed the effectiveness of the curriculum by comparison of pre- and post-assessment data. This comparison is possible since students answered the same questions during pre- and post-assessment activities; however, the data collection methods were different for each assessment activity, making direct data comparison difficult.

The post-assessment activity revealed students' comprehensive understanding of earthquakes and the related physical processes. In this activity, students appropriately used concepts and terminology introduced during the science activities to answer basic questions, generate discussions, and raise new fundamental inquires about Earth science processes. The high level of enthusiasm and engagement with the content during the post-assessment discussions indicated active participation of students. When discussing the causes of earthquakes, students made verbal and non-verbal gesture references to models they built and operated during the science activities. For instance, one student gestured pulling on a rubber band as another described accumulation of elastic energy in rocks. Students demonstrated mountain building, subduction, divergent and shear motions along plate boundaries using hand motions when discussing plate movements. Most students discussed the mountain building processes in a regional context, as one student explained, "because of India-Eurasia collision, Earth's crust wrinkles and mountains are formed." Students initiated a debate on the driving mechanisms of plate tectonics, and argued about the velocity of the Indian plate with respect to Eurasia. In their discussions, students mentioned earthquake legends and myths only to disprove them in a scientific context. "People ask us why earthquakes occur and we say because of plate tectonics, then they ask us why plate tectonics occurs," one student said, looking for a convincing argument to use when sharing information with others.

Students' interactions and discussions during the post assessment activity support the effectiveness of the science activities used in this curriculum. As previously discussed, no student understood or used scientific concepts and terminology when discussing the causes of earthquakes and the related physical processes in the pre-assessment interviews. The post-assessment discussions show a significant improvement in students' understanding of earthquake science.

Students' awareness of earthquake hazards is evident in post-assessment discussions during which they listed and described local hazards such as landslides, liquefaction, structural collapse, and non-structural hazards, which were all covered during earthquake hazards activities. These activities not only raised students' awareness, but provided an opportunity to introduce and discuss mitigation strategies. Unlike the pre-assessment responses, in post-assessment discussions students identified appropriate protective actions to take before, during, and after an earthquake. Students listed quick evacuation of buildings during an earthquake, but emphasized "drop, cover, and hold" procedure if quick evacuation is not possible. In post-assessment discussions, students emphasized the importance of planning ahead for earthquakes, a concept unfamiliar to all students during the pre-assessment interviews. "We need to be able to take care of ourselves before the help arrives," one student said. More specifically, students discussed the importance of finding and fixing hazards, developing a family and community emergency plan, and making a 3-day safety kit as recommended by the Federal Emergency Management Agency (FEMA). During the discussions, a number of students claimed to have already taken small actions to reduce hazards, demonstrating the effectiveness of the hazards and mitigation activities in communicating vital and relevant information to students.

The most notable remark indicative of successful implementation of the curriculum is revealed in students' interactions during post-assessment discussions where they chose to brainstorm ideas together to answer questions or to generate solutions to problems. For instance, the discussion on the usefulness of a 3-day safety kit was initiated by students during which they concluded that there is a need for a safety kit at their schools. Students then discussed sharing this information with the appropriate school authorities. This indicates that the curriculum has provided a means for effective dissemination of information, and has empowered students with knowledge necessary to generate discussion, agree upon solutions, and take actions to protect themselves.

CURRICULUM LIMITATIONS AND FUTURE WORK

One important limiting factor was the lack of time available to conduct one-on-one post-assessment interviews identical to the pre-assessment interview survey. Rigorous analysis of individual students' statements collected during the post-assessment focus group discussions was not possible. Comparison of the pre- and post-assessment data allowed only a qualitative measure of implementation success. A consistent data collection strategy must be employed for qualitative and quantitative assessment of future efforts.

The implementation revealed some limitations inherent in the curriculum stepwise approach. Most female students had recurring obligations at home that prevented consistent attendance. When the missing students attempted to pick up where they had left off, they struggled since the missed concepts were not comprehensively reviewed in later activities. The stepwise and highly integrated nature of the curriculum may present a problem in implementations where student attendance is not regular.

The general concepts are globally relevant, but curriculum implementation requires preparation and expertise on the part of the educator. The materials should be prepared, assembled, and tested in advance, increasing the investment of educator time beyond the indicated classroom time for each activity. The educator should also prepare and understand the regional, local, and school-specific earthquake hazards, and then ensure that these hazards are worked into the general curriculum framework accordingly. The activities, as currently written, may not provide all of the necessary information for some regions. For the described implementation, this problem may not have been apparent because the activities were implemented by the lead author, a trained geoscientist conducting earthquake research in Central Asia.

The sustainability of the implementation was a limiting factor. The implementation impact was limited to the participating students and their immediate contacts due to the lack of local teacher involvement. To sustain and scale future efforts, Teachers Without Borders (TWB) has incorporated the curriculum into its teacher professional development program for earthquake emergency education in Sichuan Province, China, after the 2008 earthquake. Teacher involvement is essential to creating and engendering a sustainable safety culture within an earthquake-prone community.

CONCLUDING REMARKS

There is a high probability that an earthquake will occur near the capital of a Central Asian republic within the next twenty years (Khalturin, 1997). Minimization of earthquake disaster impacts in many parts of Central Asia depends not only on the reduction of physical and social vulnerabilities, but also upon individual and community empowerment through the reduction of "informational vulnerability" (Degg and Homan, 2005). Therefore, knowledge sharing between scientists, educators, administrators and the general public is highly critical. Sharing earthquake information with young Tajiks is, therefore, not simply an exercise; it can save lives and anguish as the possibility of a large earthquake in Dushanbe looms in the near future.

Our stepwise approach to earthquake education with middle school students in Dushanbe has been demonstrated as an effective method for dissemination of science-based earthquake information to young people. Our science activities have enabled students to understand and use appropriate scientific concepts and terminology when describing earthquakes and related physical processes. The hazards activities have increased students' awareness and empowered them with knowledge and skills necessary for utilization of all resources for their protection before, during, and after an earthquake. As a result of the curriculum, some students have started to think critically when sharing and receiving earthquake information. One of the most significant and exciting outcomes is that most of the participating students developed an innate interest in Earth sciences, particularly earthquake science and hazards.

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