Lesson 10: Non-structural Hazards

Many non-structural components in buildings such as furnishing and equipment, electrical and mechanical fixtures, architectural features (such as suspended ceilings), storage cabinets, shelves and glass may pose hazards when they slide, tip over, fall or collapse during an earthquake. The movement and collapse of these components may cause human injuries, fatalities, property damage, or even structural building failure in some cases. Therefore, it is extremely critical to identify and eliminate non-structural hazards. In this lesson, students learn to identify potential earthquake hazards associated with non-structural components of their school and residential buildings, and to provide recommendations for mitigating them.

The tabletop experiment is adapted from materials produced by the American Geophysical Union and supported by the Federal Emergency Management Agency (1995). The pictures used for tabletop exercise are taken from the document "Case Studies of Seismic Non-structural Retrofitting in School Facilities", December 2005; Report compiled by the Educational Facilities Research Center, National Institute for Educational Policy Research, Japan.

This lesson is designed for one 1-hour class period.

Introduction

1. Ask students to distinguish between structural and non-structural components of a building. Structural components of a building are non-decorative parts of a building that contribute to structural strength of the building whereas non-structural components of a building are not essential to structural design and do not contribute to structural strength. Ask students to name some structural and non-structural features. Alternatively, write down a mixed list of both features on the board and ask students to name which ones are structural or non-structural. Your list may include the following features: parapets, walls, vertical column supports, windows, foundations, floors, cornices, decorative overhangs, hanging light fixtures, appliances such as refrigerators or stoves, bookshelves, etc.

2. Ask students to imagine what their classroom would look like during an earthquake. Place several books on a desk, and ask a student to shake the desk. Ask students to describe what they observed. Explain to students that the books may slide and fall off the table during an earthquake, causing direct injuries and/or obstructing their way to the exit door.

3. Tell students that in this lesson they are going to identify non-structural features in their classroom that could pose hazards during an earthquake.

Tabletop Exercise: School Emergency!

Note! This Tabletop Exercise was developed to help explain non-structural hazards associated with earthquakes. Non-structural hazards vary from region to region and building to building, mostly depending on how the building is used, decorated, furnished, arranged, and maintained. This exercise will explore some of the basic lessons that can be learned by observing actual non-structural hazards documented within schools in Japan. In these areas, earthquakes are frequent and severe enough to warrant retrofitting of even seemingly benign and stable objects such as pianos and refrigerators.

Read the following scenario, stopping to ask questions and discuss the material with your students at the indicated points, or when students ask questions that are relevant to the discussion of earthquake hazards:

Three friends are joking with each other before they begin school for the day. They have been attending the same school for the last 3 years and know the building very well. They are each going to different classrooms for school activities this morning: Reza is going to the gymnasium for physical education, Farbod is going to the library to gather information for a science report, and Amin is going to chemistry class.

After class has been going for about 20 minutes, a rumbling noise can be heard. Reza doesn't even notice that the ground is shaking at first because he is having fun playing soccer. That's when he notices that people around him are confused and have stopped running. He feels the ground shake but it is not shaking very hard. Even the supervising teacher does not take any immediate actions. Aside from the slight shaking of the ground, there are only two notable indications that anything is happening at all: the lights in the gymnasium are swinging wildly, and you can see the tall trees just outside the gymnasium through the big windows shaking back and forth.

You, as a friend in Reza's gym class, go up to him and ask him what you think you two should do. Reza seems a little nervous but he tells you that since the ground is not shaking very hard, you two do not need to do anything since you are in no danger. He says the exit doors are located only 30 meters away if things get really bad. Reza takes the ball and scores a goal while everyone remains still during the earthquake.

Question 1: What are some of the early indications that an earthquake is occurring? What do you think about Reza's reaction in this situation? What are some possible reasons why Reza is telling himself that his reaction is the best? Would you follow Reza's advice or make your own decision? Why or why not? Are there any hazards present inside or outside the gymnasium?

Note! This question is intended to promote critical thinking about the situation itself (being in a gymnasium or other large room during an earthquake) and also to draw attention to the nature and limitations of decision-making processes that often occur between young friends in emergency situations. The overall goal is to empower each student to independently evaluate the situation, choose a course of action, and to make

the best possible decisions that ensure their survival. This includes situations where students are given poor advice from friends or adults. The scenario has a variety of important details that can be discussed. Below is only a summary of some of the main points regarding earthquakes and non-structural hazards. Students are likely to point out a number of things about this situation that may not be covered below. Please discuss all comments that the students suggest, emphasizing the importance of maintaining situational awareness and critical thinking throughout the earthquake emergency.

Potential answers: *People are sometimes able to hear earthquakes when earthquake waves travel through the ground. P-waves are sound waves and while their tones are generally too low to be heard by humans, earthquakes can sometimes generate sound waves in the audible frequency range before any noticeable physical movement is noticed. Other indications include the shaking overhead lights and the shaking trees outside. Hanging or tall objects can be sensitive to small movements of the ground.*

Reza does not seem too concerned about the earthquake. While panic is not the best reaction, and it is generally said that it is a good thing to remain calm during a potentially dangerous situation, Reza seems a little too calm for this situation. One can be in a state of readiness and alertness about the situation without being panicked.

Reza might be saying these things because he was taught to think this way by someone, or because it seems reasonable to him based on his previous experiences with earthquakes that haven't been particularly destructive. Alternatively, Reza might be saying this because he doesn't want to seem like a coward, or to cover up for the fact that he is nervous and doesn't really know what to do.

Regardless of his motivations for behaving this way, and regardless of the actions (or inactions) of the teacher, Reza's suggested course of action is not advisable. No two earthquakes are ever the same, and just because other earthquakes in the area may have seemed similar to this one, and may not have caused much destruction, this earthquake could easily unfold into a larger earthquake with no warning. There is no way to tell whether this earthquake will be destructive before or during its occurrence.

There are many structural and non-structural hazards in this situation. While the earthquake does not seem powerful enough to destroy the gymnasium, there is no way to know this for sure. A small construction defect, or a resonance of the gymnasium structure, may induce large movements of the building or other fixtures within the room if the earthquake is producing waves near the natural frequencies of objects in the room (recall Lesson 9: Structural Hazards, for definitions of natural frequency and resonance). The lights swinging back and forth are a perfect example. If the lights become detached, they could easily fall, or the glass in the lights can break and fall down on students.

The trees shaking outside are also a potential hazard. They can produce falling branches, or the trees can swing over and hit the windows if they are close enough to them, causing the windows to break and shower glass inside and outside the gymnasium. Most glass windows are very brittle (recall Lesson 3: Properties of Earth Materials, for a definition

of brittle) and will break free of their supports with only slight disturbances given their fragility. Glass windows can also break if the building itself begins to shift a small amount during an earthquake.

Because of these risks, in general it is best that the students leave the gymnasium as quickly as possible, taking care to avoid the large glass windows and trees outside if possible. Better to be safe, even if the earthquake is small, than to wait and see if a large earthquake is going to put the students in danger before they can react. Remind the students that during very strong earthquakes it is difficult or impossible to remain standing, let alone walk or run to safety. Even a short distance such as 30 meters to an exit or entrance may be a false comfort if the earthquake does become very strong.

Although these objects were not mentioned as part of the scenario description, there are other common objects found in a gymnasium that may cause a hazard. These may include suspended fixtures such as basketball hoops or volleyball net polls, or electrical fixtures such as large lights or loudspeakers.

Please reference Picture Group 1 to study actual scenes of damage within gymnasiums and other community areas in schools in Japan.

Farbod was in the library on the second floor of the school, studying for his science report. He liked being in the library during the summer because it is the only room in the school with a large air conditioner mounted in the window (the air conditioner helps protect the books during the hot summers from damage due to humidity and temperature changes that can affect the paper in the books). There was also a large TV on a rolling cart in the library near the door, which the librarian sometimes let Farbod use to watch interesting science videos that the library kept in the back room.

When the ground started shaking, Farbod didn't know for sure what was going on right away. He was in the reference section of the library, looking through the encyclopedias and map books. The first thing he noticed was that it felt like a big truck was going by outside, so he didn't give it much thought. Then he heard strange creaking noises from among the tall wooden bookshelves, as though somebody was standing on top of the bookshelf in front of him and trying to move it back and forth.

Farbod went to the end of the bookshelf toward the central part of the library, to see what everyone else was doing and to find out what was happening. He saw the librarian and other students looking out the window, trying to see if a big truck or airplane was causing the strange noises. They saw the trees shaking in front of the gymnasium and somebody yelled, 'It's an earthquake! The ground is shaking!'

Question 2: Is Farbod exposed to any hazards in the library? If so, what are some of those hazards? Is there anything Farbod should do in this situation?

Possible answers: Yes, Farbod is exposed to hazards in the library. He is exposed to the non-structural hazards in the library and any that might exist along the escape route

through the school to get to a safe location. Farbod is on the second story of the school, which means he is also exposed to the structural hazards of being within a multistory building.

There are windows which can easily shatter during an earthquake, so the teacher and the children looking out the window are also exposed to hazards. In libraries, oftentimes the bookshelves are completely filled up with books, so that any slight movement of the bookshelves tend to cause books to fall off the shelves, or to cause the bookshelves to fall over. This may have been what caused Farbod to hear the creaking sounds among the bookshelves. Students should keep in mind that if just one bookshelf falls onto another bookshelf, this may cause all of the bookshelves to fall, one after the other.

There are also other hazards in the room, such as the large television on the rolling cart. The television is probably not secured very well to the cart, and the cart can easily move or fall over since it is not bolted to the ground. It is mentioned that the cart is near the door, which means that students can be harmed if the cart begins to fall over as they are leaving the room, or that the fallen television may get in the way of students trying to leave if it topples onto the floor before the students are able to leave the room.

Another hazard that exists for students outside of the building is the air conditioner that is mounted in the window. Often, these units are not well-secured to the building or the window frame. They are often balanced or perched in the window frame with little or no structural support. Air conditioners like this often fall out of windows onto the building or sidewalk below during an earthquake.

Farbod should be very vocal about the hazards that he sees for the teacher and students around him. In any earthquake, the best idea is to get into a safe location as soon as possible, regardless of the perceived strength of the earthquake. A slight shaking at first can very easily turn into a very powerful earthquake with little or no notice.

Please reference Picture Group 2 to study actual scenes of damage within libraries in schools in Japan.

After leaving his friends at the school entrance, Amin went to chemistry class. That day, they were studying a chemical reaction that involved heating of the reactants. Heating the reactants was always his favorite part of chemistry experiments. He also enjoyed delicately handling the reactants that could easily burn his skin if he were not careful. He was wearing eye protection goggles and a lab jacket to protect his clothes from the chemicals they were using in the class. Each group of students in the class had small flame stands (a Bunsen burner) at their table that hooked up to a gas tank in the back of the room through a series of tubes and valves, which could be seen running along the pipes and electrical wiring mounted near the ceiling in the classroom.

Amin was at the back of the room, washing the glassware that he was using to do the experiment, when he heard a noise that sounded like a truck going by. He also heard the tinkling sounds of the chemistry glassware in the cabinets around him. He kept washing

his glassware but the sounds did not go away. His chemistry teacher then yelled, 'Earthquake! Students exit the school immediately. Assemble at the street corner in front of the school.' The teacher continued giving instructions as the students left: 'Move quickly but remain calm, do not take anything with you from the class and do not stop elsewhere in the school on the way out.'

Question 3: What are some of the hazards that the chemistry teacher must be aware of when conducting chemistry lessons in a high earthquake risk area? Why would the teacher tell the students not to take anything with them from the classroom? Compare and contrast the reaction of this teacher with the reactions of the previous teachers to the earthquake.

Possible Answers: The chemistry teacher needs to be aware of the numerous special hazards that are present in the classroom. If the chemistry glassware can easily fall out of the cabinets, then even a small earthquake would cause the glass to fall and break on the floor, which could slow or prevent some students from leaving the room (depending on the footwear that the students are wearing). If something falls on the gas tubes going from the gas tank to the flame stands throughout the room, then a leak could release gas into the classroom. This could cause a fire hazard, or could possibly cause illness or loss of consciousness of any trapped students if they are forced to breathe this gas. The teacher should have a fast means of shutting off the gas and securing the gas tank in an emergency, and the students should be educated in the location and use of these devices in case the teacher is not present or somehow unable to secure the room during an emergency. Any damage to the electrical wiring or pipes that are mounted near the ceiling could expose students to high voltage, or hot, cold, or waste water from broken or leaking pipes.

The chemistry teacher seems to have been prepared to respond to an emergency situation much better than the teachers that Farbod and Reza were with. The messages that the chemistry teacher yelled were clear, concise, and in descending order of importance: the problem was identified, followed by a simple command to move to a safe destination, and finally commands to make sure that the students did not stop until they reached the safe destination for any reason such as gathering personal belongings. While there may be some places in the school where the safest option is to shelter-in-place, a room with gas lines, pipes, electrical wiring, and glassware is not likely to be one of those places. The important point to note is that the teacher was prepared to recognize and act in a dangerous situation with clear instructions for the students. Students and teachers should be prepared to make the safest decision, in any part of the building, depending on the circumstances and layout of the school.

Please reference Picture Group 3 to study actual scenes of damage within special facilities of classrooms in schools in Japan.

Tabletop Experiment: Rapid Visual Screening (RVS)

In the Tabletop Exercise, students learned that it is important to independently assess the hazards of many locations within the school. They also learned that the safest option may be different for each location, depending on the structural and non-structural hazards present.

For this Tabletop Experiment, students will assess the hazards present in their classroom and at their home using the Rapid Visual Screening (RVS) technique. This technique is intended to be the first tool that enables a student to prepare for earthquakes by evaluating their environment for factors that contribute to earthquake hazards. Students will be encouraged to share the results of these assessments with teachers, parents, and other adults in their community to raise awareness of earthquake hazards exposure.

Materials

Paper and pencils
Chalk for the chalkboard or markers for the whiteboard
Copies of Handout No. 10a (earthquake non-structural hazards checklist)
Copies of Handout No. 10b (bedroom safety activity)

Procedures

1. Ask students to write down the name of one non-structural feature or an object in their classroom that could pose a hazard during an earthquake. On the chalkboard (or whiteboard) compile a list of hazards students noted. Ask students to explain why they considered them to be hazardous.

2. Divide students into small groups. Hand each group a copy of Handout No. 10a (earthquake non-structural hazards checklist) Explain to them that they have 15 minutes to work as a group to complete the checklist. Students should check yes or no for each of the items in the list, and skip any items that are not applicable to their classroom. Students in each group should then discuss the item that they have marked as hazardous and recommend a solution for reducing or removing the danger. If time allows, students should also discuss why their group has marked some features to be earthquake resistant. Allow students to add new items to the list when appropriate. Each group should select a spokesperson to summarize their observations and suggestions in a short classroom presentation. The presentation should not take more than 5 minutes per group.

3. Explain to students that they just conducted a rapid visual screening of potential hazards in their classroom, a common tool many experts use to assess the safety of structures and to develop plans to retrofit those structures for earthquake safety. Encourage your students to present their observations and suggestions for classroom safety improvement to their school's principle, and suggest that they volunteer to do all or some of the work. Explain to students that although identifying hazards and providing suggestions for mitigating them are critical steps towards their safety, students must

ensure that their concerns are heard by the right people and that their words have been taken into appropriate consideration.

4. Ask students to return to their groups. This time hand each group a copy of Handout No. 10b (bedroom safety activity). Ask students to compare and contrast the two rooms on the handout, and decide which room is safer during an earthquake and why. Build a classroom discussion around students' observations. Now encourage your students to develop a rapid visual screening checklist for their homes based on their screening of the classroom and the bedroom safety activity. Encourage students to this in cooperation with their family members, and prepare a report of their findings and of their suggestions for mitigating damage during an earthquake.

Useful Internet Resources & References

Guide and Checklist for Nonstructural Earthquake Hazards in California Schools (2003): http://www.documents.dgs.ca.gov/dsa/pubs/SB1122.pdf

"Case studies of Seismic Nonstructural Retrofitting in School Facilities" by Educational Facilities Research Center and National Institute for Educational Policy Research (2005) http://www.nier.go.jp/shisetsu/pdf/e-jirei.pdf

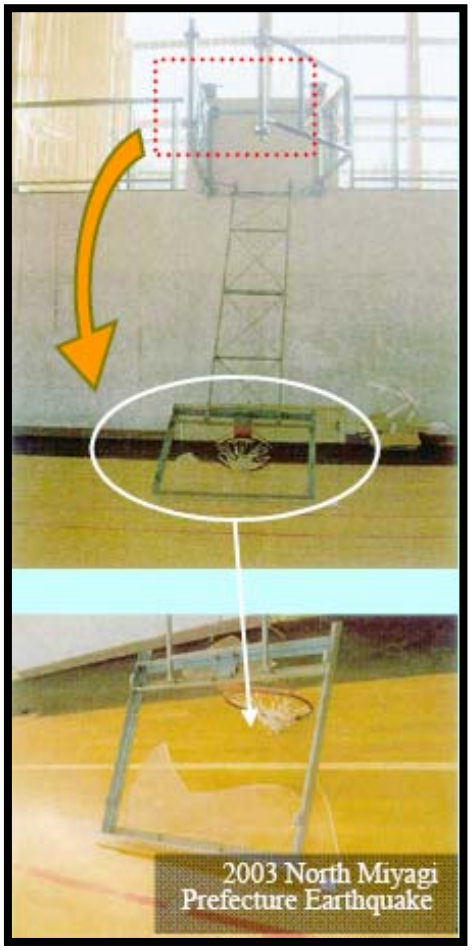
Seismic Sleuths: A teacher's package on earthquakes, produced by the American Geophysical Union with support from the Federal Emergency Management Agency, 1994:http://eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/15/c5/13.pdf

Picture Group 1:
Gymnasium and Community Area Damages

Top, left: Large, non-reinforced glass can easily shattered if mounted too rigidly to the building structure.

Bottom, left: Lighting and ceiling fixtures often shake loose during earthquakes, raining down on the floor areas below.

Right: Special items specific to sporting and community areas, such as sports equipment, loudspeakers, and signs can fall onto the floor areas below.



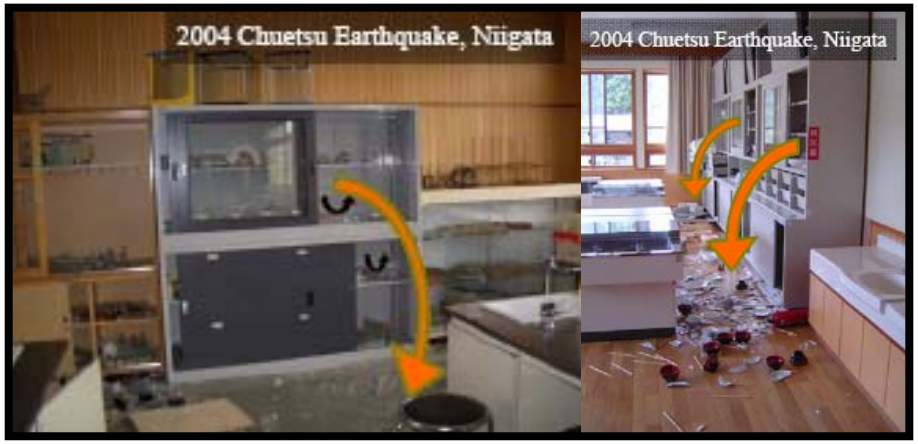
Picture Group 2:
Library and Shelving Damages

Top, left: Unsecured bookshelves are dangerous, and the fall of one can cause the fall of adjacent shelves in domino fashion.

Top, right: An unsecured television on a top-heavy cart or shelf can fall over and slide across the floor.

Bottom, right: Window-mounted air conditioners are hazards for people on the street below.

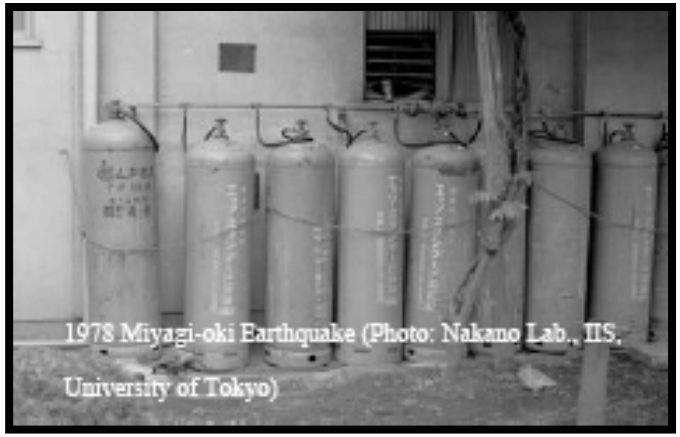
Picture Group 3:
Classroom and Special Resource Damages



Top, left: Track lighting can become loose if the mounts are not secured.

Top, right: Two instances of unsecured glassware shaking loose from shelving.

Bottom, right: Any material falling on unsecured or unprotected gas tanks or associated plumbing is a significant fire and explosion hazard.



Handout No. 10a: Rapid Visual Screening for the classroom

Group No. _____ Date: _____

Note! This screening survey may not be comprehensive for all classroom resources, layouts, and facilities. This screening survey contains reference to common hazards that are present in most classrooms, but may not reference or mention all the hazards that are present in your classroom. For completeness, this survey should be conducted in collaboration with an experienced engineer knowledgeable of earthquake hazards. For the hazards covered below, it is advised that specific comments be recorded adjacent to the checkbox to describe any peculiarities of the classroom that make the decision unclear.

This handout is adapted from materials from Seismic Sleuths (*FEMA/AGU*, 1994).

1. Are cabinets, bookshelves, and closets securely attached to the walls to prevent overturning?

☐Yes ☐ No

2. Are heavy items stored on the bottom shelves?

☐Yes ☐ No

3. Are books or materials stored on shelves have adequate restrains to keep them from flying off the shelves?

☐Yes ☐ No

4. Do cabinet doors have latches?

☐Yes ☐ No

5. Are television sets and computers securely fastened to work spaces?

☐Yes ☐ No

6. Are desks and chairs located where they cannot slide and block exits?

☐Yes ☐ No

7. Are all heavy and sharp objects/wall decorations/ hanging displays are securely mounted?

☐Yes ☐ No

8. Are laboratory chemicals or cleaning supplies secured so that they won't fall and spill?

☐Yes ☐ No

9. Are heavy furnishing or equipment on wheels protected against rolling?

☐Yes ☐ No

10. Are fire extinguishers securely mounted?

☐Yes ☐ No

11. Are the blackboards/whiteboards securely fastened?

☐Yes ☐ No

12. If there are potted plants or other heavy objects on cabinet tops, are they restrained?

☐Yes ☐ No

13. Are decorative ceiling panels or latticework securely attached?

☐Yes ☐ No

14. Are all the light fixtures secured?

☐Yes ☐ No

15. Are the fluorescent light fixtures resting on the hung ceiling grid or do they have other supports?

☐Yes ☐ No

16. Will hanging light fixtures swing freely without hitting each other if allowed to swing a minimum of 45 degrees?

☐Yes ☐ No

17. If there are suspended or decorative ceilings in the classroom, are they secured?

☐Yes ☐ No

18. If there are exposed pipes (water, gas, etc), are they secured?

☐Yes ☐ No

19. Do you see other hazards not included on this list? Specify.

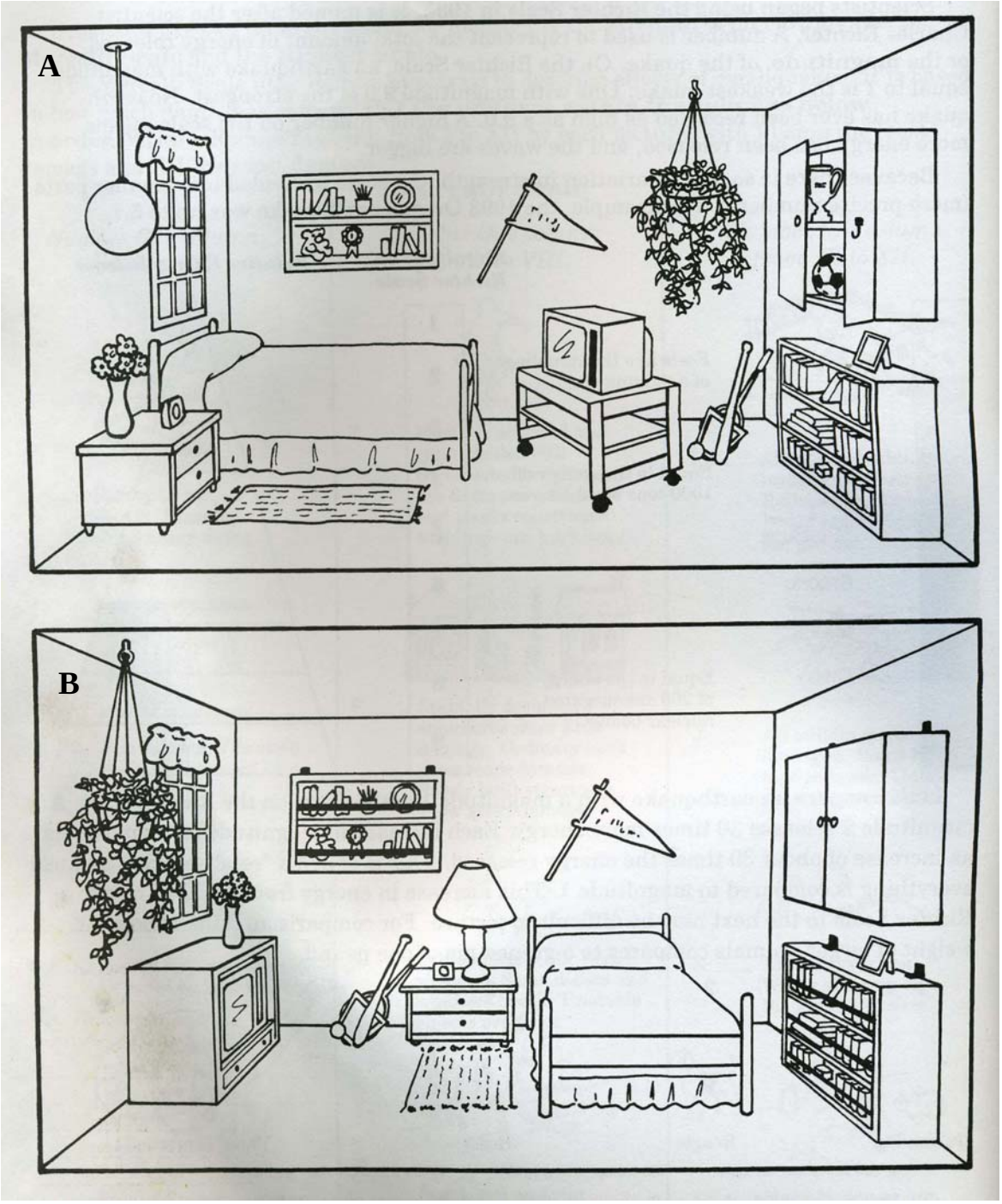
☐Yes ☐ No

Handout No. 10b: bedroom safety activity

Name: _____ Date: _____

Safe or Unsafe?

Compare the two rooms on this page. How are they different? Which one is safer and why? What are the dangers in the other picture?



From Discovering Earthquakes by Nancy Field (1995)