

Hazard Literacy Center

Hazard Literacy Education Program

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Exploring Sinkhole Formation Through Simulation



1. Program Overview

This program was designed for middle school students to explore the mechanisms of sinkhole formation using an HTML-based interactive simulation. Students manipulate variables such as rainfall, pipe leakage and deterioration, soil type, surface load, and underground construction to observe how underground cavities form and eventually lead to ground collapse. The simulation visualizes changes in cavity size and ground instability in real time, helping students understand how sinkholes occur when critical conditions are reached. Through comparing different conditions, students learn that sinkholes result from the interaction of multiple natural and anthropogenic factors rather than a single cause. They also use scientific evidence to explore effective strategies for sinkhole prevention and risk reduction.

Grade Level	Grades 7-9 (Middle School)	Instructional Methods	Lecture, Simulation
Learning Environment	Classroom	Duration	50 minutes
Required Materials	Labtop		

2. Learning Objectives (Hazards Literacy Framework)

① Students can understand the mechanisms of sinkhole formation and explain the various factors that contribute to sinkhole occurrence.

② Students can use a simulation to investigate sinkhole risks under changing conditions and analyze the results.

③ Students can propose sinkhole prevention and response strategies based on their findings and explore practical actions for creating a safer society.

Learning Objectives	Knowledge & Understanding		Reasoning & Skills					Values & Attitudes			Psychology & Emotion			Behavioral & Practical Enagement		
	A1	A2	B1	B2	B3	B4	B5	C1	C2	C3	D1	D2	D3	E1	E2	E3
Objective ①	O	O	O													
Objective ②			O		O	O	O									
Objective ③								O		O				O	O	O

3. Key Concpets

· Ground Collapse and Sinkholes

· Erosion Caused by Water Flow

· Ground and Soil Properties

4. Program Sequence

Learning Activities	
Introduction	·Examine real-world sinkhole cases and share ideas about their causes. ·Recognize that sinkholes result from multiple interacting factors and define the inquiry problem.
Inquiry 1	·Learn the scientific principles of sinkhole formation, including groundwater, soil properties, pipe leakage, and underground cavities. ·Explore the roles of key variables affecting sinkhole formation.
Inquiry 2	·Use an HTML-based simulation to manipulate rainfall, pipe leakage and deterioration, soil type, surface load, and underground construction. ·Observe cavity growth and ground collapse and compare sinkhole risks under different conditions.
Inquiry 3	· Identify which factors have the greatest influence on sinkhole formation. · Propose evidence-based strategies for sinkhole prevention and risk reduction.
Conclusion	· Summarize how natural and anthropogenic factors interact to cause sinkholes. ·Discuss practical safety actions and prevention strategies for individuals and communities.

5. Theoretical Background and Activity Design for Disaster Education

Sinkholes are a representative ground hazard caused by the collapse of ground above a cavity formed underground. Naturally, they can occur in limestone areas where rock is dissolved by groundwater. In urban areas, however, they are caused by a complex combination of natural and human factors, including leakage from aging water and sewage pipes, heavy rainfall, underground construction, excessive groundwater extraction, and heavy surface loads. Therefore, sinkholes are difficult to explain by a single cause alone and need to be understood as a complex system in which multiple variables interact.

In recent disaster and safety education, building "hazard literacy" is being emphasized beyond simply memorizing safety rules. Hazard literacy refers to a civic competency that enables individuals to scientifically understand the principles and mechanisms of disaster occurrence, analyze and evaluate risks, and implement prevention and response measures at both personal and community levels. In sinkhole education as well, students are required to go beyond merely understanding the principles of occurrence; they need to engage in inquiry activities that analyze how various variables affect risk levels and propose prevention and response strategies based on their analysis.

To this end, this program utilizes an HTML-based interactive simulation developed through Gemini-assisted vibe coding. Students directly control variables such as rainfall, pipe leakage rate, pipe aging level, soil type, surface load, and the presence of underground construction to observe the formation and growth of underground cavities and the process of ground collapse in real time. In addition, by comparing and analyzing results for each variable, students evaluate sinkhole risk and explore preventive measures that consider the interactions among variables. These activities help students understand sinkholes not as simple natural phenomena, but as disasters resulting from a combination of scientific principles and social factors, thereby contributing to the development of scientific decision-making abilities and hazard literacy for a safer society.

In this simulation, students can directly manipulate variables such as rainfall, pipe leakage rate, pipe aging level, soil type, surface load, and whether nearby underground excavation construction is in progress. Through this, they can observe changes in cavity size and the progression of sinkhole occurrence. The specific interface of the simulation is shown in Figure 1 on the below.



Figure1. Sinkhole Simulation

6. Instructional Considerations

First, guide students not to explain sinkholes by a single cause. Since sinkholes occur through the interaction of various variables such as rainfall, pipe leakage, soil characteristics, and underground construction, this point needs to be emphasized. Second, guide students to understand simulation results as outcomes of a model rather than absolute facts. Because simulations are simplified models of real-world phenomena, inform them that a wider range of factors can exert influence in actual environments. Third, instruct students to explore by changing one variable at a time. Rather than changing multiple variables simultaneously, have them manipulate a single variable to compare and analyze the results, ensuring a clear understanding of each variable's effect. Fourth, place the guidance focus on the process of interpreting results rather than merely presenting them. Encourage students to explain why a certain variable had an impact based on scientific evidence, and share diverse interpretations through peer discussions. Finally, guide students to expand their learning into prevention and safety practices. Beyond understanding the principles of sinkhole formation, lead them to discuss prevention methods, safe behaviors, and community-level response strategies.

7. References

- Jeong, S., Jeong, Y., Kim, D. (2017). Trend of Physical Modelling For Ground Subsidence And Study of Its Application. Korean Society of Disaster & Security, 10(1), 1-10.

Exploring Sinkhole Formation Through Simulation

Theme	Exploring the Principles of Sinkhole Formation
What Will We Learn?	①Students can understand the mechanisms of sinkhole formation and explain the various factors that contribute to sinkhole occurrence. ② Students can use a simulation to investigate sinkhole risks under changing conditions and analyze the results. ③Students can propose sinkhole prevention and response strategies based on their findings and explore practical actions for creating a safer society.

1 Let's Think

- Why do 'sinkholes' occur, causing roads or ground in the middle of downtown to suddenly collapse? Write down your thoughts freely.



2 Learning the Causes of Sinkholes

- The following are key factors that affect sinkhole occurrence. Refer to them, investigate specifically how they influence sinkhole occurrence, and write down your findings below.

Rainfall, pipe leaks, pipe aging, soil type, surface load, underground construction, etc.

[Investigation] How do they affect sinkhole occurrence?

- Fill in the blanks.

1) If a lot of water seeps in, underground _____ can be washed away.

2) Old _____ leak water and weaken the ground.

3) The more buildings or vehicles there are, the more _____ increases.

4) Subway construction or excavation can change the _____.

3 Exploring with the Simulation

- Let's change the conditions and see how the risk of sinkhole occurrence changes.



• [Inquiry 1] Differences Based on Soil Type

- Set Conditions: Keep rainfall at 50 mm/h, leakage rate at 50%, and aging at 20 years fixed.
- Change the soil type (sandy soil, clayey soil, gravel–sand mixture soil) and compare the time it takes for a sinkhole to occur and the size of the cavity.

3 Exploring with the Simulation

- [Inquiry 2] The Relationship Between Building Weight (Surface Load) and Sinkholes

- Set Conditions: Keep gravel–sand mixture soil and leakage rate at 30% fixed.
- Q. How does the maximum cavity size the ground can withstand change when you change the surface load from 'Lightweight (compact car)' to 'Heavyweight (high-rise apartment)'?

- [Inquiry 3] The Impact of Underground Construction

– When other conditions are the same, how does the rate of change in risk level differ when the nearby underground excavation button is turned on versus off?

4 Summary

- Based on what you observed in the simulation, let's summarize the process of sinkhole formation.

1. Due to cracks in aging pipes or rainfall, _____ flows underground.
2. As the flowing water washes away soil, a _____ forms underground.
3. If the water flow continues or nearby _____ takes place, the _____ gradually grows larger.
4. If the roof of the underground cavity can no longer withstand the load on the surface, it collapses instantly, resulting in a _____.

- Imagine you have become the Safety Control Officer for sinkhole prevention in our city. Based on the simulation results, propose the first 2 projects to implement in our neighborhood to prevent sinkholes and write down the reasons why.

- Talk about anything new you learned or felt through today's lesson.