ND EPSCoR Lesson Plan

Smart "PIGs" in Pipes

Lesson Title: Smart "PIGs" in Pipes

Lesson Overview:

In these lessons, students will learn about smart "PIGs" in pipes and their working principles. After these lessons, students are expected to have basic knowledge on pipes used in water and wastewater transportation and smart PIGs for pipe inspection. Problems being studied include but not limited to 1) pipe damages may be generated by different conditions; 2) different types of pipe damages; 3) how a simple smart pig works; 4) how to construct a "camera" based smart pig using provided DIY robot pieces; and 5) how to use the images obtained from the robot camera to develop a maintenance plan of pipes by analyzing the images.

Topic(s): pipe inspection, robotic technology, Smart PIGs

Grade or Grade Band: 9-12

Objectives:

- Students will understand how pipes work for transporting water and waste water.
- Students will describe typical damages pipes suffer under practical use conditions.
- Students will demonstrate how to build and operate a smart PIG using DIY robot and camera to document pipe damage.
- Students will develop a pipe maintenance plan.

National Next Gen Standards:

- **HS-ETS1-2 Engineering Design**: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- **HS-ETS1-3 Engineering Design:** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

North Dakota Standards:

- **HS-ETS1-2 Engineering Design**: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- **HS-ETS1-3 Engineering Design:** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Time Needed (estimate): Four 50-minute class periods

Lesson Author: Brittany Hagen
Dr. Brittany D. Hagen is an Associate Professor of Education and CAEP Accreditation Coordinator at Mayville State University in Mayville, ND. Dr. Hagen teaches courses related to foundations of education, educational technology, educational assessment, and elementary methods. Additionally, she has developed both online and classroom curriculums for a variety of age groups, including teach-the-teacher programs, assessment data

modules, and high school aviation facilitator guides and interactive student activities. Dr. Hagen is also a proud Mayville State alumnus, dedicated to developing highly effective teachers who share a passion for educating young learners.

Scientist/K12 Collaborator & University:

Dr. Ying Huang, Civil and Environmental Engineering Department, North Dakota State University (contact email: ying.huang@ndsu.edu, CIE201F).

Other Collaborators listed as below:

- Turtle Mountain Community College (TMCC)
- Sitting Bull College (SBC)
- Cankdeska Cikana Community College (CCCC)
- Nueta Hidatsa Sahnish College (NHSC)
- United Tribes Technical College (UTTC)

Scientist Bio:

Prof. Ying Huang currently is an associate professor and a Welch Faculty Fellow at the Department of Civil and Environmental Engineering, North Dakota State University. She obtained her Ph.D. from Missouri University of Science and Technology in 2012. Since 2012, Dr. Huang joined North Dakota State University as a faculty till now. Dr. Huang teaches or taught nine civil engineering undergraduate and graduate courses with high student rating, including CE204 (Surveying, offered in fall semester), CE303 (Materials, offered in spring semester), and CE303L (Materials Laboratory, offered in spring semester), etc., which have more than 100 enrollment each year, in addition to CE456/656 Railroad Planning and Design, CE452/652 Introduction to Pipeline Design, CE 458/658 Bituminous Materials and Mixtures, CE441/641 Finite Element Analysis, CE782 Introduction to Intelligent Infrastructure. She was or currently is a major advisor for 18 graduate students (12 Ph. D.s and 6 Masters), and more than 12 undergraduate research assistants, in addition to advisory committee member for 52 graduate students from civil engineering, computer science, electrical engineering, construction engineering, and statistics, etc. Dr. Huang's research backgrounds are in steel corrosion protection and mitigation, smart cities and autonomous systems, smart materials and structural health monitoring, intelligent transportation systems, pavement and traffic monitoring, railroad damage and defect assessment, big data for civil engineering application, and emergency evacuation for multi-hazards.

Summary of Research and/or Problem Being Studied:

In this project, we will present the students smart "PIGs" in pipes and their working principles. After these lessons, students are expected to have basic knowledge on pipes used in water and wastewater transportation and smart PIGs for pipe inspection. Problems being studied include but not limited to 1) pipe damages may be generated by different conditions; 2) different types of pipe damages; 3) how a simple smart pig works; 4) how to construct a "camera" based smart pig using provided DIY robot pieces; and 5) how to use the images obtained from the robot camera to develop a maintenance plan of pipes by analyzing the images.

Preparation/Materials

Background knowledge students must have to be successful:
Necessary knowledge about water and wastewater transportation, pipes and essential meaning to structural health inspection.

Essential Terminology:

- **Pipe smart PIGs**: acronym for Pipeline Inspection Gauge is a robot of sorts that helps pipeline companies identify potential problems before they happen or to pinpoint pipe damage and issues.
- **Water/wastewater transportation**: a system of pipes that transport wastewater to a treatment plan where clean water is transported out
- **Health condition inspection**: a visual inspection of the interiors of pipelines, plumbing systems, and storm drains to determine the health of the pipes.

Resources:

- See materials list and website below

Websites:

- https://primis.phmsa.dot.gov/comm/factsheets/fssmartpig.htm
- https://www.aboutpipelines.com/en/blog/inside-the-smart-pig-detecting-potential-pipeline-problems-before-they-happen-part-2/#:~:text=Quick%20pipeline%20pig%20facts&text=Pigs%20move%20with%20the%20product,have%20intelligent%20onboard%20flow%20control.
- https://www.ndt-global.com/?gclid=Cj0KCQjww_f2BRC-ARIsAP3zarEweLdUsSWmIsBYo4mA2nk_xPFnrDttEVF0MjA4YXzpDz2H9MMJ-30aAh17EALw_wcB

Materials needed:

- Computer and projector to facilitate the presentation and educational videos
- 2 PVC pipes (two different sizes including 8 inches diameter and 2-ft long, and 10 inches diameter and 12 inches long)
- PVC fittings (several different fittings such as elbow, T, or others available) connecting the two PVC pipes;
- Acetone
- Washable paint with different colors and paint brushes
- Different levels of grinding (4 levels)
- Electrical drill powered by battery (with different size of drill head).
- Option 1, DIY robot vehicles “nBot Ranger kit” and Wi-Fi camera with smartphone app, and glue to attach the camera to the robot
- Option 2, DIY smart video car kits which consist ranging and inspecting components.

nBot Ranger kit

SunFounder Smart Video Car Kit V2.0 PiCar-v

- Smart phones/pad for photographic needs with needs of Wi-Fi available
- Long pipe samples with known made damages for inspection.
- PowerPoint – found as separate attachment

Procedure/Activities

Lesson 1: Presentations on Pipes and smart PIGS (50 minutes)

Engage:

1. Ask students, "What does PVC stand for?" Allow time for responses. Record responses on the board. Explain that PVC stands for Polyvinyl Chloride and is the pipe likely used to bring water to and from their homes.
2. Have students discuss with a partner issues that may arise with the use of PVC pipes and share ideas aloud.

Explore:

3. Review PPT Slides 2-6 with students to provide an introduction to pipes, pipe health, PIGs, and pipe maintenance. These slides provide text, visuals, and videos to learn more about pipes and PIGs.
4. More information about smart PIGs can be found at the following websites:
    a. https://primis.phmsa.dot.gov/comm/factsheets/fssmartpig.htm
    b. https://www.aboutpipelines.com/en/blog/inside-the-smart-pig-detecting-potential-pipeline-problems-before-they-happen-part-2/#:~:text=Quick%20pipeline%20pig%20facts&text=Pigs%20move%20with%20the%20product,have%20intelligent%20onboard%20flow%20control.
    c. https://www.ndt-global.com/?gclid=Cj0KCQjww_f2BRC-ARIsAP3zarEweLdUsSWmIsBYo4mA2nk_xPFnrDttEVF0MjA4YXzpDz2H9MMJ-30aAh17EALw_wcB

Explain:

5. Share the goals of the activity found on PPT Slide 7. Ask students which goal they are most looking forward to and have them explain why.
6. To further explain the topic of smart PIGs, share the Fact Sheet 1: Fun facts of pipes and smart PIGs with students. Consider displaying on the projector for all to see or making a copy for each student to read and review. Once you have discussed the facts and what students learned, review the two questions found at the bottom of the fact sheet as a whole group to check for understanding. PPT Slide 8 will direct students' attention to the fact sheet.

Extensions for learning more about this topic:

7. To prepare for the activities that will be completed in the next three lessons, divide students into groups of four. Have each group select a team name. Record all team names on separate index cards and ensure they are visible to the whole group for reference.

Evaluation

8. Review some of the questions taken from the fact sheets to check for students' understanding of the topic of water/wastewater pipes and smart PIGs.

Lesson 2: Creating different inner surface conditions in pipes (50 minutes)

Engage:

1. Display different size PVC pipes to students. Ask students what they notice about the pipes (they are different sizes). Ask students how different sized pipes would affect pipe health, maintenance, and exploration. Allow time for students to discuss with a partner and respond. Consider writing responses on the board to refer to late.

Explore:

2. To further explain the topic of types of pipe damage, share the Fact Sheet 2: Facts of Pipe Damage with students. Consider displaying on the projector for all to see or making a copy for each student to read and review. Once you have discussed the facts and what students learned, review the two questions found at the bottom of the fact sheet as a whole group to check for understanding.
3. In this lesson, acetone, sandpaper, and electrical drills will be used. Remind students of the safety rules for these tools. For sandpaper, be careful not to rub abrasively on skin. For acetone, use only a small amount and use a wrap to put the acetone on the surface of pipe, also avoid direct contact of acetone on skin, eyes, mouth, etc. For electrical drills, remove the drill heads when not using and do not face the drill head close to hands, face, or any body parts.

Explain:

4. Next, use the directions on PPT Slide 10 for instructions on how to set up the Damage Activity. First, divide students into groups of four that were designated the previous day. Ensure name tents for each team are visible.
5. Have each team select one size of pipe and matching fitting to work with. Each team needs two 2-foot pipes and one fitting.
6. Instruct students to create six damages to their pipes, two of each of the following: sandpaper, drill, and acetone. More information and specific directions can be found on PPT Slides 11-13 and below. The damages need to be done inside the pipes and should be one of the following types:
    a. Damage #1: use one course grinding paper to make a rough surface on the inner surface of the pipe, the level of grinding can be selected from the available four levels provided and using your first paint color to mark this damage;
    b. Damage #2: use an electrical drill using different sizes of drill heads to be selected to make different sizes of damages (maybe small-sized holes), and use a different color to mark it.
    c. Damage #3: use acetone to chemically react with PVC inner surface, after the damage made, use another different paint color to mark this damage. Acetone can be left on the pipe until the next lesson.
7. Once all damages have been made, have students connect the two damaged pipes with the selected fitting. Have each team paint their selected team names on their pipe.

Extensions for learning more about this topic:

8. To extend this lesson and if time allows, teams can create more damages with combinations of the three tools. Encourage them to create a variety of damages that will be evaluated in the next lesson.

Evaluation

9. Randomly call on several students to share one thing they learned during today's lesson. Highlight key ideas students learned and reinforce important vocabulary from the lesson. Explain that they will exchange their damaged pipes with another group in the next lesson and create a robot to explore the pipe damage.

Lesson 3: Building smart PIGs using DIY robot (50 minutes)

Engage:

1. Ask students to recall the different types of damage they created in the previous lesson. Have each group predict which type of damage will be picked up by the Smart PIG robot they will build today. Record each group's response, along with their group name, one the board for reference at the end of this lesson.

Explore:

2. To further explain the topic of technologies used on a smart inspection PIG, share the Fact Sheet 3: Facts of technologies on a smart inspection PIG with students. Consider displaying on the projector for all to see or making a copy for each student to read and review. Once you have discussed the facts and what students learned, review the two questions found at the bottom of the fact sheet as a whole group to check for understanding.

Explain:

3. Instruct students to exchange their pipe with another team. Once teams have a new pipe, have them diagnose the damage and discuss how the damage of the new pipe compares and contrasts with the damage of their initial pipe. Have students share the similarities and differences among the damaged pipes.
4. Using the available or purchased DIY robot kits, have teams build the robot that will go through the pipes. The SunFounder Smart Video Car kit best fits students who are novice robot constructors. More advanced students with background knowledge about robot construction would likely be successful with the nBot Ranger Robot kit as this kit allows students to make the robot different shapes according to the size of the pipes. Pictures of the two robots can be found on PPT Slide 14.

Extensions for learning more about this topic:

5. Once the robots are built, install a camera on the robots to aid in viewing the inside of the pipes. Conduct a few trial runs and adjust the camera positions to best capture pictures inside the pipes.
6. Begin sending the robots through the pipes to capture pictures. Have students document the locations, size, and types of damage made on the pipes. A ruler may come in handy to measure depth and location of robots within the pipes. Specific directions for students can be found on PPT Slide 15.
7. Have students record their results on the Document Damage Graphic Organizer. Then, have students compare results of location, size, and types of damage with another group. Share all results, similarities and differences, with the whole group and discuss what students learned overall.

Evaluation

8. To evaluate students' learning, use the ten-word strategy to have students summarize how a simple smart PIG works. The ten-word strategy gives students 10 words, and only 10 words, to summarize their learning for the day. Have students write and share their own ten-word strategy or have them complete it in small groups. Save students' summaries to be used at the onset of the next lesson.
9. Preview the next lesson by telling students they will develop a pipe maintenance plan based on the pipe's conditions.

Lesson 4: Inspecting pipe conditions using the built smart PIGS and developing a maintenance plan for pipes (50 minutes)

Engage:

1. Re-read students ten-word summaries from the previous lesson. Highlight the key concepts that connect to this lesson where students will be developing a pipe maintenance plan. PPT Slide 16 provides a reminder to review the ten-word summaries from the previous lesson.

Explore:

2. To further explain the topic of pipe maintenance, share the Fact Sheet 4: Facts of pipe maintenance plan according to different damages with students. Consider displaying on the projector for all to see or making a copy for each student to read and review. Once you have discussed the facts and what students learned, review the two questions found at the bottom of the fact sheet as a whole group to check for understanding.

Explain:

3. If needed, reinstall and adjust the cameras on the robots to best capture pictures of damages within the pipe. Have students select a different pipe other than the one they damaged and the one they explored in the previous lesson.
4. Explain to students they will be using the robots to explore and document damage on a different pipe today.

Extensions for learning more about this topic:

5. The extension for today's lesson is that students will install LED lights or a flashlight on the robots to investigate the influence of different lighting when identifying pipe damage.
6. Have students send the robot, camera, and lights through their pipes, documenting damage location, size, and type. Consider using the Document Damage Graphic Organizer from the previous lesson to assist students.
7. Once pictures are taken, have students analyze the pictures and discuss how they would maintain the pipe in a real-world situation. Pipe maintenance techniques found on Fact Sheet 4 may be helpful for students as they write up their pipe maintenance plan.

Evaluation

8. Have each group share their maintenance plan with the class. Compare created plans with common practices used to address pipe maintenance needs. Ask students to share the most important thing they learned in this lesson. Highlight key information and clear up misconceptions as necessary.

Additional Lesson Resources / Materials

References:

- https://primis.phmsa.dot.gov/comm/factsheets/fssmartpig.htm
- https://www.aboutpipelines.com/en/blog/inside-the-smart-pig-detecting-potential-pipeline-problems-before-they-happen-part-2/#:~:text=Quick%20pipeline%20pig%20facts&text=Pigs%20move%20with%20the%20product,have%20intelligent%20onboard%20flow%20control.
- https://www.ndt-global.com/?gclid=Cj0KCQjww_f2BRC-ARIsAP3zarEweLdUsSWmIsBYo4mA2nk_xPFnrDttEVF0MjA4YXzpDz2H9MMJ-30aAh17EALw_wcB

Websites for purchasing materials

Materials for these lessons can be purchased at:

- www.menards.com
- www.amazon.com
- https://www.bhphotovideo.com/