# Exploring Nondestructive Testing

## Companion Lesson to X-STEM All Access Episode "Nondestructive STEM Detectives"

| **Grade Band**: Middle School-High School | **Topic:** Nondestructive Testing |
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**Brief Lesson Description**:
This lesson plan introduces students to Nondestructive Testing (NDT) technology, including its principles, methods, and applications in various industries. Students will engage in hands-on activities and collaborative projects to deepen their understanding of NDT techniques.

**Performance Expectation(s):**

**HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
**HS-ETS1-2:** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering
**MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
**MS-ETS1-2:** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem

**Specific Learning Outcomes:**
Students will learn five major procedures in Nondestructive Testing, analyze case studies to determine the cost, safety, and ethical impact of such testing, and explain how NDT impacts our lives.

**Narrative / Background Information**

Nondestructive Testing (NDT) is a critical field in engineering and manufacturing that focuses on evaluating the properties of materials, components, and assemblies without causing any damage. This technology is essential for ensuring the safety, reliability, and quality of products across various industries, including aerospace, automotive, construction, and nuclear energy. NDT methods, such as ultrasonic testing, magnetic particle testing, liquid penetrant testing, and radiographic testing, allow engineers and technicians to detect internal and external flaws, assess structural integrity, and prevent catastrophic failures. By identifying defects early in the production process or during routine inspections, NDT helps mitigate risks and ensures compliance with safety standards.

This lesson assumes that students have basic knowledge in material science (including that materials are defined by their properties) and basic physics principles (sound travels in waves and magnetic fields interact with materials). Basic familiarity with the scientific process, the engineering design process and problem solving is also helpful.

| **Science & Engineering Practices:** | **Disciplinary Core Ideas:** | **Crosscutting Concepts:** |
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| **Analyzing and Interpreting Data**<br>Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)<br><br>**Constructing Explanations and Designing Solutions**<br>Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2)<br><br>**Engaging in Argument from Evidence**<br>Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MTS-ETS1-2)<br><br>**Planning and Carrying Out Investigations**<br>Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much and accuracy of data needed to produce | **PS1.A: Structure and Properties of Matter**<br>The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3)<br><br>Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2)<br><br>**PS2.B: Types of Interactions**<br>Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS1-3)<br><br>Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different | **Patterns**<br>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-3)<br><br>Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2) |

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| reliable measurements and consider limitations on the precision of the data (e.g., number of trails, cost, risk, time) and refine the design accordingly. (HS-PS1-3)<br><br>**Connections to Nature of Science**<br>**Science Knowledge is Based on Empirical Evidence**<br><br>Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2) | properties from those of the reactants. (MS-PS1-2)<br><br>**ETS 1.B: Developing Possible Solutions**<br>There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2)<br><br>**ETS1.C: Optimizing the Design Solution**<br>Criteria may need to be broken down into simpler ones that can be approached systemically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2) | |

**Possible Preconceptions/Misconceptions:**

Students might come in with several common preconceptions or misconceptions about Nondestructive Testing (NDT), such as:

1. **NDT is always 100% accurate. They** may believe that nondestructive tests never miss flaws or give false results, overlooking the limitations and need for multiple methods or repeat testing.
2. **All testing damages the material.** Some might assume any kind of testing must harm or alter the material, not realizing that NDT methods specifically avoid damage.
3. **NDT is only used in big industries. Students** may think NDT applies only to large-scale fields like aerospace or construction, missing how it's used in everyday products or smaller-scale applications.
4. **NDT is simple and quick. They** could underestimate the complexity, skill, and time required to properly perform and interpret these tests.
5. **Safety is always guaranteed if NDT is done.** Students might assume that once something passes NDT, it's completely safe without ongoing monitoring or maintenance.

**LESSON PLAN – 5-E Model**

**ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:**

Start the lesson by asking students to answer the following questions individually: ***"What do you predict Nondestructive Testing is?"*** and ***"What might be some ways to test a material without destroying it?"***. Have students share their answers with a partner and then discuss as a whole class.

Next, show the X-STEM Video **"Nondestructive STEM Detectives"** to introduce students to this topic. After the video, discuss the questions ***"How were your predictions correct? incorrect?"*** and ***"How does NDT make your life better?"***

**EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:**

Students will complete lab stations to learn about various types of NDT. Each of the five stations should take about 10 minutes.

Teacher preparation for the lab stations:

1. Print off one set of Station Directions and post at each station.
2. Gather the materials needed for each station and set up around the room.
    a. For Station1: You may prepare the tubes for students to test ahead of time to shorten the time needed to complete the task.
    b. For Station 2: Old/used metal objects work best to find flaws. If Vaseline is not available, vegetable oil or thick lotion can also be used.
    c. For Station 3: You should prepare the "flawed" objects ahead of time. You can scratch/poke holes in plastic spoons for an easy, low-cost option.
    d. For Station 4: Select/Prepare objects that have different shapes and densities. For example, you can use a cereal box compared to corrugated cardboard. To change densities within a sample, you can use sandpaper to "thin" out areas of the sample as well.
    e. For Station 5: The empty can can be replaced with a small cardboard box or other device to promote sound.

Students should complete the Student Handout as they complete stations.

**EXPLAIN:**

As a class, you will discuss each of the five different NDT procedures that were explored during the stations. After hearing from students about their observations and thoughts of each station, provide direct instruction on each of the five tests using this NDT Summary. They can take notes (on the blank organizer in the notes) or you can hand out the information for later reference.

**ELABORATE: Applications and Extensions:**
Divide class into six groups. Provide each group with one of the NDT Case Studies. Direct groups to read the case study and then create a poster/slide with the following information:

1. Summary of Scenario
2. How NDT is used
3. How would the absence of NDT affect human safety in this scenario?
4. How would the absence of NDT affect costs in this scenario?
5. What ethical considerations would arise in this scenario?

**EVALUATE:**

**Formative Monitoring (Questioning / Discussion):**
Throughout the lesson, formative questions are found bolded and italicized. Student handouts can be used in the Engage/Explain section to check for understanding.

**Summative Assessment (Quiz / Project / Report):**
Each group should present its poster to the class. Following presentations, discuss the benefits and consequences of using NDT. Students can then formally be assessed using the following constructed response question:
***Reflect on the importance of Nondestructive Testing (NDT) in various industries. In your response, discuss how NDT methods contribute to safety, reliability, and cost-effectiveness. Use specific examples from the activities or case studies to support your points.***

Students can be assessed using the rubric:

| Criteria | Meets Expectations |
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| **Content** | Response thoroughly explains the importance of Nondestructive Testing (NDT) with relevant examples from activities or case studies. |
| **Clarity and Organization** | Ideas are well-organized and clearly articulated, making the response easy to follow. |
| **Use of Examples** | Specific examples effectively support the points made about NDT's importance. |
| **Grammar and Mechanics** | Writing is polished with few to no grammatical or spelling errors. |

**Elaborate Further / Reflect: Enrichment:**
Challenge students to invent a new nondestructive testing technique for a specific material or industry. They should:

1. Identify the material and potential flaws to detect
2. Describe how their method works (e.g., using sound, light, magnetic fields)
3. Explain the benefits and limitations
4. Present their idea to the class with a diagram or prototype sketch

**CAREER CONNECTIONS**

There are a wide variety of careers students can pursue in the Nondestructive Testing field. From testing infrastructure in the field as a NDT technician to developing new technology in the lab as a NDT researcher, there are many interesting careers for students to learn about. The following activity will provide students an opportunity to learn about these careers.
Go to https://usasciencefestival.org/resources/ to access the Student Career Resources.

Select the Nondestructive Testing Field.

Have students browse the careers within your chosen cluster. Select one career that they would like to learn more about. They should then gather the following information using the student graphic organizer or in a class notebook:

- Job description and typical responsibilities
- Education and training required
- Skills and qualities needed
- Average salary
- Work environment and schedule
- Professional Organizations, Educational Programs, and Internship & Apprenticeship Opportunities

Choose a Choice Board Activity and use the information gathered to complete the chosen activity.

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| **Career Profile**<br>Research the job description, required skills, and average salary for your chosen career. Summarize your findings in a blog entry. | **Career Path Match**<br>Create a visual timeline or flowchart showing the education, training, and steps required to enter and advance in this career. | **Day in the Life**<br>Write a diary entry or create a video/blog describing a typical day for someone in this career. Use research to make it realistic. |

Provide students an opportunity to share their findings with peers or with you.

**SOCIAL EMOTIONAL LEARNING ACTIVITY**

**CASEL Competency Addressed:** Social Awareness, Responsible Decision Making

**Objective:** Students will understand the importance of ethics in scientific testing and engineering practices, reflect on ethical dilemmas related to Nondestructive Testing, and practice responsible decision-making.

Start the lesson by asking the students to consider the Prompt: ***"What does ethics mean to you? Why is it important for scientists and engineers to act ethically?"*** Let students share briefly with a partner, then discuss as a class. Highlight key ideas: honesty, safety, fairness, responsibility.

Divide students into groups of 3-4. Then**,** present a simple scenario related to NDT:
***"Imagine a company finds a flaw in a bridge using NDT. Repairing it will be expensive and delay traffic, but ignoring it risks safety. What should they do?"***

Ask the small groups to discuss: ***What are the ethical issues involved? Who is affected by the decision? What would be the responsible choice? Why?***

Circulate and listen, then lead a brief whole-class reflection: ***How do ethics affect safety and trust in science and engineering? How might ethical lapses impact people's lives? How can we apply ethical thinking in our own work and decisions?***

Complete the lesson by having students individually complete an exit ticket reflecting on the prompt:
***"Why is ethics important when using tools like Nondestructive Testing?"***

| Materials Required for This Lesson/Activity | |
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| **Quantity** | **Description** |
| 1 set | Clear plastic straws or test tubes of various lengths |
| 1 | Test Tube Rack |
| | Water |
| 1 set | Small stones or marbles |
| 1 | Tuning fork or solid object to create sound vibrations (a ruler or wooden block) |
| 1 | Vaseline |
| 1 | Jar of Iron filings |
| 1 | Strong Magnet |
| 1 set | Various metal objects with known surface flaws (small screws, bolts, used pieces, etc) |
| 1 per group | Small plastic or metal part with intentionally created surface flaws (Plastic spoons are recommended) |
| 1 | Dropper of food coloring |
| | Paper Towels |
| 1 | Flashlight |
| 1 Set | Various objects with different densities and shapes |
| 1 | Wall or Screen to project shadows |
| 1 set | Rubber bands of various sizes |
| 1 | Clean Soup/Vegetable can without top |
| 1 | Stopwatch |
| 1 | Recording device or audio app (optional) |

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