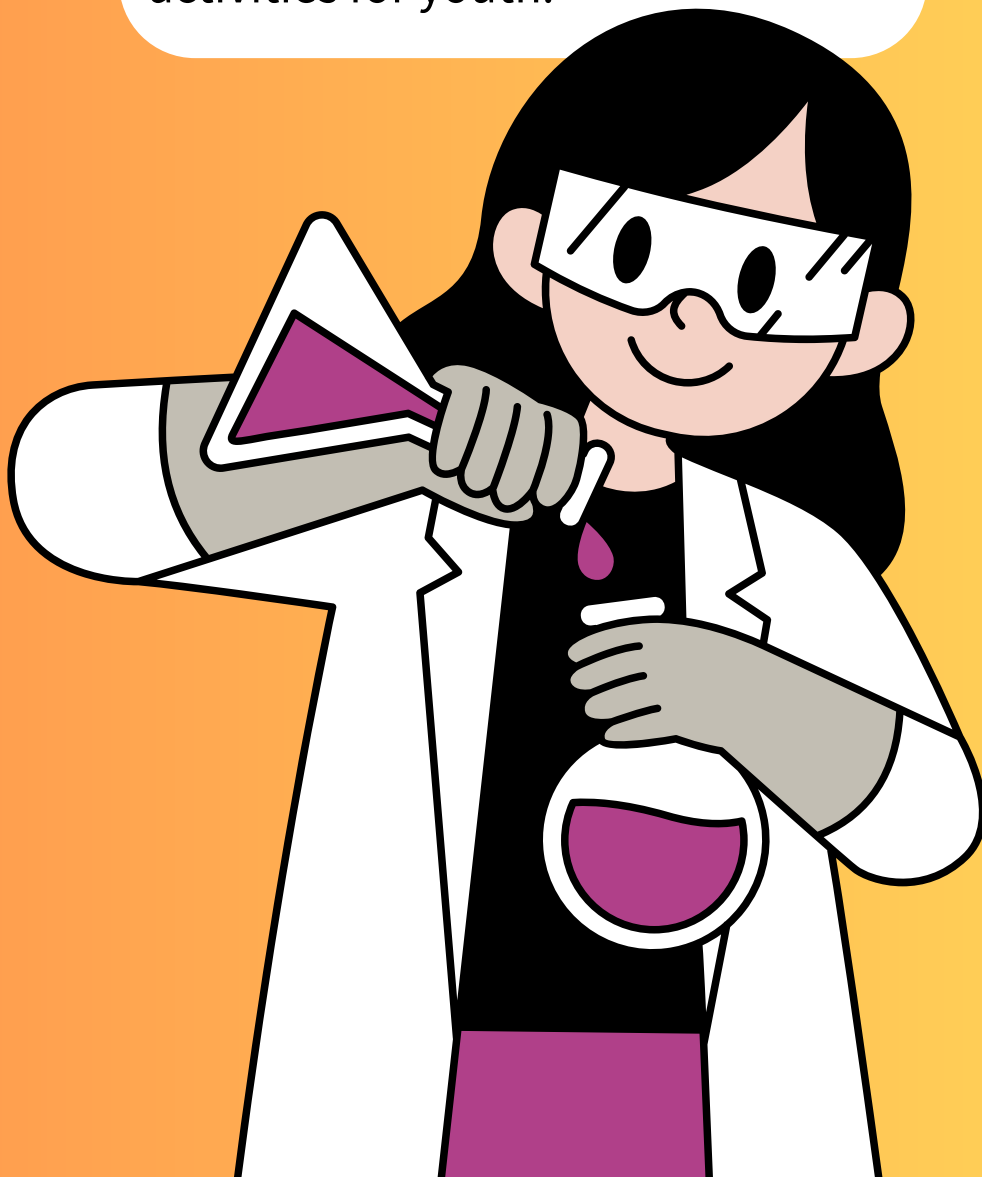


PHANTOM WRITING WITH INVISIBLE INK

**STEM²D Topic:
SCIENCE**

**Target Population:
Students, ages 8-14**

PHANTOM WRITING WITH INVISIBLE INK is part of the Student Activities Series developed by FHI 360 for Johnson & Johnson's WiSTEM²D initiative (**W**inning in **S**cience, **T**echnology, **E**ngineering, **M**athematics, **M**anufacturing, and **D**esign). The series features interactive and fun, hands-on activities for youth.



PHANTOM WRITING WITH INVISIBLE INK

STEM²D Topic: Science

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ACTIVITY DESCRIPTION

In this activity, students will explore the science of invisible ink by writing hidden messages and revealing them through chemical and thermal reactions. Using reactive substances that remain concealed until activated, they'll engage in a hands-on investigation to uncover the secrets behind phantom writing, making chemistry both fun and memorable.

ESTIMATED TIME



This session typically takes **10 to 15 minutes** to complete.

STUDENT DISCOVERIES

Students will:

- Learn how STEM²D – science, technology, engineering, mathematics, manufacturing, and design – disciplines contribute to solving real-world challenges.
- Build important STEM²D skills, such as problem-solving, creativity, curiosity, communication and adaptability.
- Consider STEM²D concepts including chemistry, physics and material science and how these concepts connect to various STEM²D occupations.
- Have fun experiencing STEM²D!

GETTING READY

Materials:

- Pre-Activity Checklist
- Tell My Story Form, *optional*



STEM²D Skills

- Problem-Solving
- Creativity
- Curiosity
- Communication
- Adaptability

- Activity materials, 1 set of the following items per pair of students:
 - White, medium weight (65 lbs or 175 gsm) cardstock paper, *2 sheets*
 - Measuring spoons, *tablespoon, teaspoon and ½ teaspoon*
 - 3, 8-oz Plastic cups
 - 2 Stirring spoons
 - 2 Cotton swabs
 - Old newspaper or cardboard, *1 sheet*
 - Paper towels for cleanup

Method 1

- 1 Tablespoon of baking soda
- 1 Tablespoon of water
- ½ Teaspoon of turmeric powder, *handle with care as turmeric easily stains fabric; avoid contact with clothing*
- 3 Tablespoons of rubbing or isopropyl alcohol, *40% alcohol or more*

Method 2

- ½ Teaspoon of water
- 1½ Tablespoons of lemon juice
- Clothes iron or hair dryer, *from a safety perspective a hair dryer may be preferable*

Estimated Materials Cost:

Activity leaders can expect to incur \$25 in materials costs when completing this activity with approximately 25 students. This estimate does not include the cost of a clothes iron or hair dryer.

ACTIVITY LEADER PREPARATION

- Read **Spark WiSTEM²D**. This is essential reading for all volunteers interested in working with youth, as it provides important background knowledge about STEM²D, strategies for engaging students, and tips for working with groups of students.



Engaging Students

- Circulate and answer questions during the activity.
- Check frequently for understanding by asking open-ended, topic-specific, or process questions.
- Encourage students to ask questions to gain deeper understanding.

- See the STEM²D Student Activities Overview for additional information.
- Review the Pre-Activity Checklist (at the end of this document) for details and specific steps for planning, preparing, and implementing this activity.
- If time is limited, you can simplify the activity by focusing on just one method—either chemical or heat.

STEP-BY-STEP INSTRUCTIONS

1. Welcome & Introductions (3 minutes)

- Greet the students as they arrive.
- Tell the students your name, title, and organization/company.
- Explain why you love STEM²D, and how your work is connected to various STEM²D areas.

2. Learning Activity: Phantom Writing with Invisible Ink (10 minutes)

- Explain that today, students will dive into the captivating world of chemistry by uncovering the secrets of invisible ink! They'll experiment with chemical and thermal reactions to write and reveal hidden messages. Show the students the supplies they will be using to write their secret messages. See the Pre-Activity Checklist for more details. Ask:
 - If you wanted to send a secret message, how would you do it?
 - Do you think science plays a role in making invisible ink work?
 - What are the differences between chemical and thermal reactions?
 - Can you think of real-world applications for invisible ink besides secret messages?
- Let students know that they will be exploring two distinct methods for conducting invisible ink experiments. The first method explores chemical reactions, while the second highlights thermal reactions.
- Guide students through Method 1 of phantom writing, emphasizing the role of chemical reactions.
 - Combine 1 tablespoon of baking soda with 1 tablespoon of water in a cup. Use a stirring spoon to mix the two together.



STEM²D Concepts:

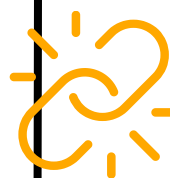
- **Science:** Understanding chemical reactions (e.g., acid-base interactions) and exploring physical processes like heat activation.
- **Technology:** Utilizing heat sources for revealing invisible ink and applying modern techniques for innovation in invisible ink designs.
- **Engineering:** Problem-solving and optimizing experimental setups.
- **Manufacturing:** Creating invisible ink using accessible materials like turmeric, baking soda, or lemon juice.
- **Design:** Experimenting with creative ways to craft invisible messages and combining aesthetics with functionality, such as patterned designs or secret scripts.

This activity beautifully bridges creative thinking with scientific inquiry, offering hands-on exploration in multiple STEM²D fields.

- Dip the cotton swab into the baking soda mixture. The cotton swab will serve as the students' writing tool.
- Place the old newspaper or cardboard under the cardstock to protect the writing surface and keep it clean. Use the damp cotton swab to write a secret message on the white cardstock. *Tip: Do not soak the paper too much!*
- Have students evaluate the visibility of their message—does it become more hidden as it dries, or remain visible?
- Allow the written message to dry completely.
- Prepare the second mixture by combining $\frac{1}{2}$ teaspoon of turmeric powder with 3 tablespoons of rubbing alcohol. Use a stirring spoon to mix the two together. Note: Turmeric fully dissolves in rubbing alcohol, but if you use isopropyl alcohol, some turmeric may remain undissolved. This will not impact your results.
- Dip a second cotton swab into the turmeric solution.
- Paint the whole paper with the turmeric mixture. Make sure to cover the secret message previously written with the baking soda mixture.
- The reaction between the baking soda mixture and turmeric mixture allows the hidden message to be revealed!
- Guide students through Method 2 of phantom writing, emphasizing the role of thermal and chemical reactions.
 - Combine $1\frac{1}{2}$ tablespoons of lemon juice and $\frac{1}{2}$ a teaspoon of water. Use a stirring spoon to mix the two together.
 - Dip the cotton swab into the lemon juice mixture. The cotton swab will serve as the students' writing tool.
 - Place the old newspaper or cardboard under a second sheet of cardstock to protect the writing surface and keep it clean. Use the damp cotton swab to write a secret message on the new piece of white cardstock. *Tip: Do not soak the paper too much!*
 - Ask students to assess how invisible their message is. Does it become more invisible over time? Why might this be?



- Allow the written message to dry completely.
- With adult supervision, plug in the iron and set to high. Gently glide the hot iron over the paper multiple times. If using a hair dryer, move the hair dryer back and forth over the paper to avoid burning it. It might take a bit longer than using an iron, but it should work effectively. This method is a safer alternative, especially for younger students.
- The heat from the iron or hair dryer triggers a reaction in the lemon juice mixture, making the hidden message visible!
- Use paper towels to clean up any spills.
- Explain the chemistry behind both methods of invisible ink. Some types rely on heat-induced carbonization or oxidation, where heating exposes chemical changes that reveal the hidden message. Others remain invisible until they undergo a chemical reaction, triggering a transformation that makes the message appear.
- The Science behind Chemical Reactions and Invisible Ink:
 - Baking soda is an alkaline substance, meaning it has a high pH. Mixing the baking soda with water allows it to be “painted” onto the paper but it will be colorless and not leave any indication of where it is as it dries.
 - Turmeric is a pH indicator. A pH indicator changes color when exposed to acidic or alkaline substances.
 - When turmeric comes into contact with the baking soda, the turmeric will change from deep yellow to bright red revealing the hidden message!
- The Science behind Heat-Activated Invisible Ink:
 - Carbohydrates from the lemon juice, including the citric acid and sugars, are absorbed into the paper.



STEM²D Connections

- *Security and Anti-Counterfeiting:* Invisible ink is used in industries like banking and government for fraud prevention, document authentication, and anti-counterfeiting measures.
- *Forensics and Law Enforcement:* Scientific principles behind invisible ink are relevant to crime scene investigation, where forensic scientists may uncover substances invisible to the naked eye – for example, ethidium bromide making DNA fluorescent under UV light, and luminol reacting with iron to help investigators find blood at crime scenes.
- *Technology and Innovation:* Modern technologies incorporate invisible ink in advanced printing techniques, QR codes, and data encryption for secure communication.
- *Entertainment and Gaming:* Invisible ink finds a place in escape rooms, treasure hunts, or interactive games, enhancing mystery and engagement.

- When you apply a heat source to the paper, the carbohydrates begin to carbonize. This process releases carbon, which reacts with oxygen in the air through oxidation, causing the paper to darken in the area where the juice was applied making your hidden message appear!

3. Student Reflection (2 minutes)

- Wrap up the activity by asking the following reflection questions:
 - Why do you think the hidden message was invisible at first?
 - What surprised you the most about the chemical reactions in this activity?
 - Which invisible ink do you think worked better? Why?
 - What other kinds of substances do you think you could use as invisible inks?
 - What other surfaces do you think you can write on with invisible ink?
 - Is it difficult to write in invisible ink without being able to see where or what you have already written?
 - Can you think of other real-world applications where similar chemical reactions or processes might be used?
- Ask students to consider what kind of careers people with an interest/degree in this area would have?

Examples include:

- Invisible Ink: Forensic Scientists, Chemists, Security Experts, Graphic Designers and Printers, Historical Archivists and Conservators, Spy Agencies and Intelligence Operatives
 - Chemical Reactions: Chemical Engineers, Food Scientists, Materials Scientist, Cosmetic Chemists, Research Scientist, Pharmacologists
- Thank students for joining you today and encourage them to continue exploring careers in STEM²D.
 - Encourage students to take the STEM Career quiz and explore how a career in STEM²D can help to shape their future.

<https://www.stem2d.org/stem2d-at-home>



EXTENDED LEARNING

You can extend student learning by having students or teams:

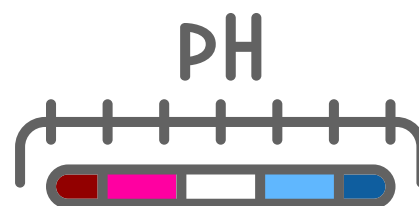
- **Watch** the following videos that demonstrate invisible ink with lemon juice and turmeric.
 - Lemon Juice Invisible Ink:
https://youtu.be/poCnU_crpjQ?si=GVPaTyKjkZb-lwGF
 - Turmeric Invisible Ink:
https://youtu.be/4BHGD_tuBjE?si=kNOvjKAa-JSTfJUg
- **Explain** that hidden messages are sometimes used in cinema. Watch the short clip from the movie National Treasure, where they use thermal and chemical reactions (method 2) to uncover a secret message on the Declaration of Independence.
 - <https://www.youtube.com/watch?v=YSbyB4O5hyA>
- **Experiment** with different ways to send and reveal hidden messages.
 - Try using different colors and types of paper. The paper you choose must be absorbent enough to hold the ink yet doesn't react chemically with your invisible formula.
 - Consider changing the surface material to wood, fabric, or plastic, each creating varied effects. Testing different materials could yield fascinating results if you aim for creativity in your projects.
 - Try using different acids to write your secret message. Experiment with lime juice, orange juice, milk or vinegar to see how they interact with the surface material.
- **Discuss** how certain inks remain invisible in regular light but emit a glow when exposed to ultraviolet (UV) or black light. Try using a blacklight to uncover these hidden messages.



KEY WORDS

- **Acid.** An acid is a compound with a pH of less than 7. Acids can be organic or inorganic that are both corrosive and reactive, especially with metals.
- **Alkali.** A substance that has a high pH greater than 7, indicating that it is basic rather than acidic. Alkali are a type of base that dissolves in water. All alkalis are bases, but not all bases are alkalis.

- **Base.** A base is a substance with a pH higher than 7. A base is a substance that can neutralize an acid by reacting with hydrogen ions.
- **Carbonize.** To convert a substance into carbon or a carbon-containing residue, usually through the process of heating in the absence of oxygen.
- **Chemical Reaction.** A process where a set of substances undergo a chemical change (the breaking and/or forming of chemical bonds) to form a different substance.
- **Citric Acid.** Citric acid is a weak organic acid that is naturally found in many fruits, particularly citrus fruits like lemons, limes, and oranges.
- **Heat Reaction.** A broad term referring to any chemical reaction influenced by heat. In these reactions, heat provides the energy necessary to break chemical bonds in the reactants, allowing new bonds to form and create new products. A heat reaction can also be a consequence of energy transfer.
- **Neutral.** A substance is neutral if it has a pH of 7, meaning it is neither acidic nor alkaline.
- **Organic Acid.** An organic acid is a type of acid that contains carbon atoms and is typically derived from organic compounds. Organic acids are often weak acids, meaning they don't completely dissociate into ions in water.
- **Oxidation.** Process where oxygen combines with another element to form a compound.
- **pH.** Quantitative measure of the acidity or basicity of a solution. The term translates the value of the concentration of the hydrogen ion in substances into numbers between 0 and 14. If a substance has a pH less than 7, it is said to be acidic. If its pH is greater than 7, then it is said to be basic or alkaline. A pH of 7 is neutral.
- **Thermal Reaction.** A specific type of chemical reaction where the chemical change is initiated by heat energy, often as a reactant or a result of the reaction. Often involves thermal decomposition, where a compound breaks down when heated.



RESOURCES AND REFERENCES

Activity concepts and real-life connections adapted from:

- Science Buddies, Secret Messages With Invisible Ink!
<https://www.sciencebuddies.org/stem-activities/invisible-ink>
- STEAM Powered Family, Invisible Ink Project.
<https://www.steampoweredfamily.com/invisible-ink/>
- Learning Mole, DIY Invisible Ink: Unveiling the Secrets of Chemical Reactions and pH Balance.
<https://learningmole.com/diy-invisible-ink-chemical-reactions/>
- Science Notes, How to Make Invisible Ink and Reveal Secret Messages.
<https://sciencenotes.org/how-to-make-invisible-ink-and-reveal-secret-messages/>
- American Chemical Society, Write Secret Messages with Disappearing Ink.
<https://www.acs.org/education/activities/secret-messages.html>



PRE-ACTIVITY CHECKLIST

PHANTOM WRITING WITH INVISIBLE INK

The following checklist helps activity leaders plan and prepare to conduct the *Phantom Writing with Invisible Ink* activity with students.

DID YOU . . .

- Read Spark WiSTEM²D? This is essential reading for all volunteers interested in working with youth. It defines the STEM²D principles and philosophy and provides research-based strategies and tips for engaging and interacting with youth.
- Visit the event venue (optional) and/or finalize logistics with the organizer? Ask:
 - What is the date, time, and location of the event?
 - How will the room be arranged? Do I have access to tables? How big are they?
 - How many students do you expect? How will the students be organized/participate in the event? Knowing this will help you determine the quantity of materials to purchase.
- Recruit additional volunteers, if needed?
- Prepare for the activity? Did you:
 - Read the entire activity text prior to implementation?
 - Customize the activity, if desired, to reflect your background and experiences, as well as the cultural norms and language of the students in your community?
 - Complete the **Tell My Story Form**, which will prepare you to talk about your educational and career path with the students? (*optional*)
- Obtain the required materials? See the Materials and Estimated Materials Costs sections.
- Set up the site appropriately for the activity?
- Practice your presentation? *Make sure you can explain the concepts to students, if needed, and that you know the correct answers.*
- Bring a camera, if desired, to take photographs?
- Obtain and collect permission slips and photo release forms for conducting the activity, if applicable?
- Have fun!

TELL MY STORY FORM

This form will help activity leaders and other volunteers prepare to talk about their STEM²D interests, education, and career path.

ABOUT YOU

Name: _____

Job Title: _____

Company: _____

When/Why did you become interested in STEM²D? _____

What do you hope young people will get out of this activity?

FUN FACT

Share a little about your background. Ideas:

- Share a memory from childhood when you first had your “spark” or “interest” in STEM²D.
- Detail your journey, highlighting what you have tried, what you learned, steps to success, etc.
- Failures or set backs are also great to talk about—difficulties, and/or challenges, and how you overcame them.

EDUCATION AND CAREER PATH

What classes/courses did you take in secondary school and in college that helped or interested you most? _____

How did you know you wanted to pursue a STEM²D career? _____

What was your postsecondary path, including the institution you attended and your degree? If you switched disciplines, make sure you explain why. _____

What does your current position entail? Be sure to include how you use STEM²D during a typical work day. _____
