THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Electromagnetism

What is the effect of the number of windings of wire on the strength of an electromagnet?

GRADES 6–8

Physical Science

VAN ANDEL EDUCATION INSTITUTE
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INQUIRY-BASED SCIENCE

Physical

Electromagnetism

Grade Level/ Content	6–8/Physical Science
Lesson Summary	In this lesson students learn how to make an electromagnet out of a battery, nail, and wire. The students explore and then explain how the number of turns of wire affects the strength of an electromagnet.
Estimated Time	2, 45-minute class periods
Materials	D cell batteries, common nails (20D), speaker wire (18 gauge), compass, package of wire brad nails (1.0 mm x 12.7 mm or similar size), Investigation Plan, journal
Secondary Resources	How Stuff Works: How Electromagnets Work Jefferson Lab: What is an electromagnet? YouTube: Electromagnet - Explained YouTube: Electromagnets - How can electricity create a magnet?
NGSS Connection	**MS-PS2-3** Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
Learning Objectives	• Students will frame a hypothesis to predict the strength of an electromagnet due to changes in the number of windings. • Students will collect and analyze data to determine how the number of windings affects the strength of an electromagnet.

What is the effect of the number of windings of wire on the strength of an electromagnet?

Electromagnetism is one of the four fundamental forces of the universe that we rely on in many ways throughout our day. Most home appliances contain electromagnets that power motors. Particle accelerators, like CERN's Large Hadron Collider, use electromagnets to control the speed and direction of these speedy particles. Historically, scientists believed that electricity and magnetism were two different forces. However, by the late 1800s, research had shown that positive and negative charges were controlled by only one force—magnetism! Since this revelation, electromagnets have been constructed using electrical currents to produce and control magnetic fields.

Electromagnets differ from permanent magnets due to the fact they require an electrical current to pass through them to attract metallic objects. An advantage of an electromagnet is that its magnetic strength can be controlled and turned on and off at will. In this lesson, students will create an electromagnet and determine how changing the number of windings of a wire affects the magnetic strength.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Students will need the following materials to complete this investigation:

- 5 speaker wires
  - Separate the two halves of speaker wire so you have a single wire. Cut these into 1.5 meter lengths. Strip one-half inch of the plastic insulation of each wire segment.
- 1 Common nail (20D)
- 1 D cell battery
- Container of wire brad nails (1.0 mm x 12.7 mm)
- Compass
- Investigation Plan
- Journal

Part 2

INVESTIGATION FACILITATION

Before you introduce the investigation question, have students conduct a **Messing About** to develop the knowledge and skills required to perform the investigation. Instruct students to build an electromagnet using the long (common) nail, a speaker wire, and D battery. Have them test their electromagnet by picking up the wire brads or using a compass to check for a magnetic field.

If students struggle, provide hints so that they are all confident in their ability to build an electromagnet. (Example hints could be: *wrap the nail with the wire in the same direction, each wrapping should be parallel and tight, connect the wire to each end of the battery, pick up metal objects with the end of nail closest to the windings.)* Have students share their completed electromagnets.

Electromagnet Example

? Question

Introduce the investigation question.

What is the effect of the number of windings of wire on the strength of an electromagnet?

Personal Knowledge

Students capture what they already know about electricity and magnetism.

- Allow students to list prior knowledge about electricity, magnets, or electromagnets.
- Come together and create a class list. *(List may include: electricity makes the lights go on, magnets have two poles–a north and south, electricity needs a conductor to move, magnets are attracted to all metals.)*

DISCOURSE

Conduct a *Think, Write, Pair, Share*. Ask students to think about what they already know about electricity and magnetism and then write down their thoughts. Then, have them share with a partner and/or a small table group. Have a variety of groups share examples and write a class summary.

Prediction

Students write a hypothesis about what they think will happen based on prior knowledge.

Have students write a hypothesis based on the investigation question using the following format:

If *[independent variable]* **then** *[dependent variable]* **because** _____.

If I add more wire windings around a nail then its strength as an electromagnet will increase. I think this will happen because I have put regular magnets together and their strength increased. Even though I'm not sure why, I think winding more wire around the nail will increase the strength.

Investigation Plan

Students perform trials to determine the effect of windings on electromagnet strength.

- Divide students into teams of two. Give each team their materials and their Investigation Plan.
- Review the materials as a whole class.
- Have students follow the **Investigation Plan**.*
- Students conduct at least 3 trials for the various numbers of windings and record their data.

(Caution: Remind students not to leave the wire connected to the battery for more than 30 seconds at a time. Leaving the battery connected will rapidly shorten the life of the battery as well as cause the wire to heat.)

CRITICAL THINKING

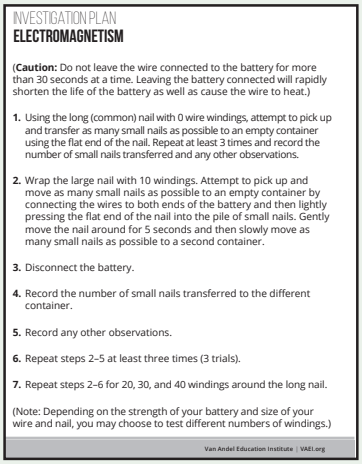
Use the Fair Test checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plan, the more confident they can be in their results.

HABITS OF MIND

Ask students which of these habits of mind they think will help them most with the investigation:

- Curiosity
- Openness to new ideas
- Creative thinking
- Critical thinking
- Perseverance
- Adaptability
- Self-direction
- Integrity

They should review their choice when the investigation is over and determine if this was the habit of mind that helped them the most or if it was another.



INVESTIGATION PLAN

ELECTROMAGNETISM

(**Caution:** Do not leave the wire connected to the battery for more than 30 seconds at a time. Leaving the battery connected will rapidly shorten the life of the battery as well as cause the wire to heat.)

1. Using the long (common) nail with 0 wire windings, attempt to pick up and transfer as many small nails as possible to an empty container using the flat end of the nail. Repeat at least 3 times and record the number of small nails transferred and any other observations.
2. Wrap the large nail with 10 windings. Attempt to pick up and move as many small nails as possible to an empty container by connecting the wires to both ends of the battery and then lightly pressing the flat end of the nail into the pile of small nails. Gently move the nail around for 5 seconds and then slowly move as many small nails as possible to a second container.
3. Disconnect the battery.
4. Record the number of small nails transferred to the different container.
5. Record any other observations.
6. Repeat steps 2–5 at least three times (3 trials).
7. Repeat steps 2–6 for 20, 30, and 40 windings around the long nail.

(Note: Depending on the strength of your battery and size of your wire and nail, you may choose to test different numbers of windings.)

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Investigation Plan

* Depending on the strength of your battery and size of your wire and nail, you can negotiate with your students on how many windings you want to test.

Observation

Students document their observations.

Have students create a data table to record their findings.

PERSEVERANCE

Encourage students to remain focused throughout the investigation. Curiosity may drive them to do additional trials (beyond the minimum of 3).

Example Data Table

Part 3

INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIM

Data Analysis

Students make sense of their data by organizing it and representing it visually.

Have students analyze their data. They may wish to use the Data Analysis prompt as a guide.

- Have students **evaluate** their data for trustworthiness. Have students highlight any data that they wonder about. Ask them to reflect on their confidence level of their data.
- Then, have them analyze their data to find patterns and trends. They may **organize** the data and/or **represent** it visually to construct meaning. Have students use math where appropriate *(average number of nails for each winding, etc.)*. They should show that the number of small nails transferred increases as the number of windings increases.
- Have students **interpret** what the identified patterns or trends mean.
- Ensure they have enough data that it can be used as evidence to support a claim.

DISCOURSE

If your students are new to the process, it may be helpful to have students share examples with a *Research in Progress*. After each of the steps of data analysis (evaluation, organization, representation, and interpretation), have groups share their progress.

Secondary Knowledge

Students use secondary sources to understand how electromagnets work.

Use these resources (or your own) to develop students' understanding of electromagnetism. Ask students to write down 4-5 things that they learned. After reviewing these resources, students should understand how electromagnets work and see some examples of electromagnetism in everyday life.

Continued

How Stuff Works: How Electromagnets Work
Jefferson Lab: What is an electromagnet?
YouTube: Electromagnet - Explained
YouTube: Electromagnets - How can electricity create a magnet?

COLLABORATION AND CONSTRUCTION OF MEANING

Jigsaw the reading and viewing of the secondary resources. Place students in a "home" group and have each student choose a different article or video to view. After reading or viewing, the groups divide into new "expert" groups consisting of students who viewed the same article or video. The information is discussed and then students re-form into their home groups and share in the construction of meaning. After reviewing secondary sources, students should understand that electricity flowing through wires produces a magnetic field and each winding acts like a mini magnet.

Explanation

Students write a claim and provide evidence and reasoning to support it.

- Have students use what they've discovered from their analyzed data to write an explanation that answers their investigation question. Students may wish to use the Explanation prompt as a guide. Have them write their explanation in their Lab Journal.
- Have students develop a **Claim** to answer the question: What is the effect of the number of windings of wire on the strength of an electromagnet?
- Then, have them add **Evidence** (the analyzed data) to support their claim.
- Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as science principles they have learned.

Claim

I claim that by increasing the number of windings around the nail, the strength of the electromagnet is increased.

Evidence

For every trial, the number of nails picked up increased as the number of windings increased. For example, in trial 3 we saw that 7 nails were picked up at 10 windings, increasing to 51 nails at 40 windings.

Reasoning

Investigation: We did a fair test. We conducted 4 trials with consistent results. We followed the investigation plan. We were sure to carefully make connections and consistently press the electromagnet lightly into the nails while slowly moving the nail before picking up. Each of the 3 other groups supported our results although two of the groups had drops in their 40 winding test. We are not sure why.

Science: Science concepts support our results. Our reading indicated that each winding is like a mini magnet and each winding that is added increases the strength of an electromagnet.

- Once the explanation is written, have students discuss their results using a Present and Defend.

DISCOURSE

Have students conduct a Present and Defend to develop presentation skills as well as audience participation. Research teams present a summary of their investigation to the class. The class analyzes the information presented and asks clarifying questions, challenges and/or supports the arguments made, and even presents alternative explanations as appropriate. Research teams defend their explanation with evidence and reasoning. If students are doing the same investigation plan, choose 1 or 2 groups to share.

Continued

HABITS OF MIND

Earlier, you asked students which habit of mind they felt they would need to utilize in this investigation. Revisit this idea by asking students which habits of mind were most useful after all. Ask students to explain their choices.

Evaluation

Students reflect on the investigation.

- Ask students how confident they are in their results.
- Ask students what surprised them.
- Ask students what questions they have as a result of this investigation.

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Students demonstrate understanding of electromagnets by designing and conducting an open investigation.

- Ask students to brainstorm a list of variables that could impact the strength of electromagnets. Make a class list together.
- Together, choose 4 variables from your list and turn them into questions for an experimentally designed investigation.
- Student teams design and conduct an investigation from 1 of the 4 questions.

EXAMPLE IDEAS

What affect does the type of battery have on electromagnetic strength?
What affect does the size of the common nail have on electromagnetic strength?

Assessment

1. Students provide an explanation (**claim, evidence,** and **reasoning**) that clarifies the cause and effect relationship between the number of wire windings and the strength of an electromagnet.
2. Students generate an investigation question that clarifies the cause-and-effect relationship between magnetic force and electric current.
3. Students design and conduct an investigation that clarifies the cause-and-effect relationship between magnetic force and electric current.

For additional lessons or to customize this lesson, go to www.nexgeninquiry.org.

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INVESTIGATION PLAN
ELECTROMAGNETISM

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