Turbulence labs for middle school students

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Abstract: This document introduces middle school students to the fundamental concepts of turbulence and fluid mixing through four hands-on laboratory activities. Each lab isolates a key variable influencing turbulent behavior—flow rate, density, temperature, and mechanical stirring—allowing students to develop conceptual understanding through direct observation and simple measurements. Aligned with the Next Generation Science Standards (NGSS) and the Alabama Course of Study (ALCOS), these activities offer an accessible pathway for exploring laminar versus turbulent flow, Reynolds number effects, and mixing processes in gases and liquids. The materials are inexpensive, classroom-friendly, and adaptable for use as standalone demonstrations, station rotations, or full-period labs. Supported by the NSF CBET Fluid Dynamics Program, this resource aims to strengthen early STEM engagement and introduce real-world fluid dynamics concepts relevant to engineering and broader STEM fields.
This document is intended as a facilitator resource for middle school teachers; educators should establish and follow their own classroom-specific safety protocols when conducting these activities.
The authors declare that they have no conflict of interest.

About this Lesson

The four lab activities in this lesson plan provide a storyline to introduce the concept of turbulence and guide students toward its practical application in fluid dynamics and aerospace engineering. Each of these labs focuses on a different variable that affects the turbulence or turbulent mixing of a fluid, including flow rate, density, temperature, and mechanical agitation. This lesson can be introduced and taught with little background knowledge, with this video explanation for further information.

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Objectives
Students will:

- Measure and rank gases in order of their density.
- Use qualitative observations to argue for the role of density in turbulent mixing.
- Quantitatively measure the temperature of water.
- Use qualitative observations to argue for the role of temperature in the diffusion of liquids.
- Quantitatively record the time it takes for the food dye to mix with a cup of water fully.
- Use qualitative observations to argue for the role of movement in the mixing of liquids.
- Measure degrees of rotation using a protractor.
- Use qualitative observations to create an argument for the relationship between flow rate and turbulence.

Level
Middle Grades Chemistry 6-8

Alabama Standard (ALCOS 2024)	National Standard (NGSS)
MS-ESS-8b: Develop and use a model that illustrates how differences in heat and pressure affect density and the relationship between density and convection.	MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
MS-PS-2: Develop and manipulate models to explain changes in particle motion, temperature, and state of a pure substance when thermal energy is added to or removed from a system.	MS-PS1-4: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

Teaching Notes:
The provided labs can be performed as a demonstration, given as a single isolated lab, or performed as a series of stations or rotations. Teaching time in these formats can vary from 15 minutes to approximately 4 50-minute class periods.

Turbulence occurs when a fluid (such as air or water) starts moving in a chaotic (messy), unpredictable, and irregular way. Instead of flowing smoothly in straight lines, the fluid begins to swirl, twist, and mix with diffusive and circular motions.

The **Reynolds number**, usually written as **Re**, is a parameter scientists use to determine whether a fluid (air or water) is likely to flow smoothly or become turbulent. It is the ratio of the inertial and viscous forces observed in the flow, where

Low Reynolds number corresponds to a smooth, gentle flow (laminar flow)
High Reynolds number corresponds to a swirling, chaotic, irregular flow (turbulence)

Materials and Anticipated Costs with links:
For each group of 4 students

Flow-Rate Turbulence Lab
- Access to the sink with the turning faucet handle
- protractor

Reynolds Number Lab
- Three clear cups
- Access to water
- Spoon
- Water-based food coloring
- Stopwatch

Food Coloring Diffusivity Lab
- Three clear cups
- Access to water
- Ice
- Kettle
- Water-based food coloring
- Thermometer
- Stopwatch

Variable-Density Turbulence with Balloons
- Two Balloons
- Helium (from the tank or filled in a balloon from the local party store)
- Sharp needle
- Funnel
- Corn Starch

Name: **Date:**

Prelab:

1. List three factors that you think could cause two things to mix together more quickly.
2. What do you already know about the particle motion of a gas compared to a liquid?
3. In your own words, what is turbulence?
4. What do you know about the particle motion of hot liquids versus cold ones? Describe with words or by drawing a particle diagram.
5. Is it possible for food coloring to dye the water without stirring?
6. In your own words, what is diffusivity?
7. In your own words, what is momentum?
8. How long do you think it takes turbulence to dissipate from a fluid?
9. In your own words, what is momentum?

Lab Safety:

To be determined by the teacher, the following points are just providing examples:

- Wear protective goggles, gloves, and a mask at all times.
- Handle sharp items carefully when required to use them.
- Do not use lab materials outside of the directions given.
- Go immediately to your teacher if you have any questions or if there is an accident or spill.

Flow-Rate Turbulence

Procedures:

1. Ensure that the sink you are using is completely turned off.
2. Hold a protractor immediately beside the faucet handle. Use an erasable marker to note your starting position.
    a. If using a round knob, you can do this by making a tick mark on the handle at 0 degrees relative to the position of the protractor. If using a level handle, you can hold the protractor level with the sink and mark on the protractor where the handle lies.
3. Turn on the sink by turning the knob exactly two degrees according to the protractor.
4. Continue turning the sink on by two degrees at a time until the flow has changed from laminar to turbulent.
5. Check the turbulence of the water by placing a sheet of paper with writing on it behind the water stream. If the words are legible, the flow is laminar.
6. Repeat steps 1-4 two more times, recording your results.
7. Turn off the sink and wipe off the reference marks made.

Data: Record at what point the flow became turbulent in the table below.

	Trial 1	**Trial 2**	**Trial 3**	**Average**
Degrees from the start point				

Analysis:

1. What evidence did you see that there was laminar flow coming out of the sink at first?
2. What changed in your observations when the flow became turbulent?
3. Did the flow become turbulent at the exact same point each time?
4. Why do you think this was the result?
5. Make a claim relating the flow rate of a fluid to its degree of turbulence.
6. Suggest one way that turbulence could be directly measured in this or a related lab.

Reynolds Number Lab

Procedures:

1. Fill a cup with room-temperature water.
2. Stir the water clockwise 10 times with the spoon.
3. Immediately add a single drop of food coloring in the middle of the cup. DO NOT STIR
4. Begin your timer when you add the food coloring.
5. Record your immediate observations, then continue to record at each time given in the table.
6. Repeat steps 1-5, but wait 10 seconds before adding the food coloring.
7. Continue to repeat for all times listed in the data table.
8. Pour your dyed liquids into a sink or waste bucket and clean up all materials.
9. Repeat steps 1-8 with corn syrup.

Data: Record written observations in the table below for water, then corn syrup.

Time	**Immediately after stirring**	**10 seconds after stirring**	**20 seconds after stirring**	**30 seconds after stirring**
0 min				
1 min				
3 min				
Time	**Immediately after stirring**	**10 seconds after stirring**	**20 seconds after stirring**	**30 seconds after stirring**
0 min				
1 min				
3 min				

Analysis:

1. What evidence did you observe of turbulence after the dye was added?
2. In which test did the dye fully mix the quickest?
3. Did you observe a large or small amount of turbulence with this test?
4. Which liquid mixed the most slowly after the dye was added?
5. What property of the corn syrup caused it to behave differently from the water?
6. Make a claim relating to the effect that stirring the water had on the dye’s diffusion.
7. Based on these results, how long do you think it will take for the turbulence in the water to fully dissipate?

Food Coloring Diffusivity Lab

Procedures:

1. Fill a cup with room-temperature water.
2. Record the temperature of the water in the cup.
3. Place the cup on a solid surface and wait for it to become completely still.
4. Add a single drop of food coloring in the middle of the cup. DO NOT STIR
5. Begin your timer when you add the food coloring.
6. Record your immediate observations, then continue to record at each time given in the table.
7. Repeat steps 1-5 with ice water (ice removed) and hot water.
8. Pour your dyed liquids into a sink or waste bucket and clean up all materials.

Data: Record written observations in the table below.

Time	**Room Temperature Water ___**℃	**Ice Water ___**℃	**Hot Water ___**℃
0 min			
1 min			
3 min			
5 min			
7 min			

Analysis:

1. What evidence did you observe of turbulence after the dye was added?
2. In which liquid did the dye fully mix the quickest?
3. Did you observe a large or small amount of turbulence with this liquid?
4. Which liquid mixed the most slowly after the dye was added?
5. Did you observe a large or small amount of turbulence with this liquid?
6. Make a claim relating the temperature of a fluid to its amount of turbulence.
7. Do you think that it is possible for mixing to occur without turbulence, but with laminar flow instead? Why or why not?

Variable-Density Turbulence with Balloons

Procedures:

1. Using a funnel, add 1 tsp of cornstarch to an uninflated balloon and shake gently to coat the inside.
2. Fill a balloon with helium, or take a helium-filled balloon from your teacher.
3. Make sure you are in a well-ventilated, preferably cold environment and outside. Wear goggles and a mask if you are within 5 feet!
4. (Optional) Set up a slow-motion recording device to review your results.
5. Stand in front of a dark wall, or have a group member hold a sheet of dark poster paper behind the balloon.
6. Extending your arm out, hold the balloon still as you pop it from the side using a sharp object.
7. Observe the visible movement as the gas from inside the balloon mixes with the air around it.
8. Repeat steps 1-5, this time using your breath to fill the balloon instead of helium.
9. Clean up all balloon waste and return materials.

Data: Record written or drawings of your observations in the table below.

Gas Inside of Balloon	**Observations After Popping**
Helium	
Breath	

Analysis:

1. What evidence did you see that there was turbulence after the balloon popped?

2. Which gas mixed the most quickly with the air after the balloon popped?

3. Did you observe a large or small amount of turbulence with this gas?

4. Pure oxygen is denser than helium but less dense than carbon dioxide. Predict what you would expect to see if a balloon full of oxygen were tested.

5. Make a claim relating the density of a gas to its amount of turbulence.

6. Suggest one way that turbulent mixing could be measured in this or related experiments.