Lesson Title	The Bounty of Bernoulli
Length of Lesson	1 hour 15 min
Created By	Chris Ruhs
Subject	Physics II
Grade Level	10-12th Grade
State Standards	Physics II: 3c
DOK Level	DOK 2
DOK Application	Explaining the meaning of Bernoulli's Principle as it applies to different phenomena.
National Standards	9-12: A (Inquiry)
Graduate Research Element	Wet chemistry practices include filtering, using a filter flask and aspirator (which relies on Bernoulli's Principle). Professionals in my field of research use aspirators frequently.

Student Learning Goal:

MS 9-12th Grade:

Physics II: 3 (c) Interpret and apply Bernoulli's principle. *Self-explanatory*.

National Science Education Standards of Content 9-12:

A: Inquiry: Communicate and defend a scientific argument. *Students will express concepts, develop diagrams, and design demonstrations related to Bernoulli's Principle.*

Materials Needed (supplies, hand-outs, resources):

Paper, writing utensils, dry erase marker/board, aspirator, filter flask, faucet adaptor, working faucet.

Lesson Performance Task/Assessment:

Formative:

1. Hand one blank sheet of paper to each student (printer paper is best). As the teacher, you should keep a piece of paper for yourself.
2. Demonstration 1: Hold your piece of paper vertically. Then, without changing the position of your hands, allow the majority of the paper to bend away from, hanging over your hands. Take a deep breath, and blow with a constant and forceful stream directly on the bend in the paper. If you do this correctly, you will notice that the part of the paper that was hanging down over your hands, rises up into the stream of air (you'll want to master this beforehand).
3. Now, have the students hold their pieces of paper by the bottom two corners, stretching the paper laterally taut, and ask them to follow your lead. Ask the students, "what do you notice?"
4. If everyone is doing this correctly, they will see the paper move upward into the stream of air, which is counterintuitive and unexpected to inexperienced students.

5. Ask the students "Why does the paper move upward into the stream instead of away from the stream?" Give them time to think about this.
6. Introduce Bernoulli's Principle, which in simplified form states that, "a faster flowing fluid (liquid or gas) creates a low pressure zone."
7. Have the class repeat this principle out loud.
8. Have the class write this principle at the top of the sheet that they were just using to demonstrate it, with the title "Bernoulli's Principle".
9. Tell the students that pressure always moves from High to Low (like on a weather map). Tell them that if you create a low pressure zone, then any higher pressure in the area will move into that lower pressure zone if it can.
10. Now, demonstrate the paper rising as you blow over it one more time, and ask the students again, "Why does the paper move upward into the stream instead of away from the stream?" (At least one student should make the connection that by blowing over the top of the paper, you've created a low pressure zone on top of the paper, and that the higher pressure underneath the paper wants to move upward into that low pressure zone, thereby causing the paper to rise).
11. Draw "before and after photos" of this phenomenon on the board, using arrows and labels to show the stream of air from your mouth, the paper, and a large arrow between the before and after diagrams to show the direction of the sequence in time.
12. Have the students draw these diagrams on their papers, including arrows and labels.
13. Have the students write the question, "why does the paper rise?" underneath their diagrams, then have them write an explanation for themselves in their own words using Bernoulli's Principle and the explanation of pressure moving from High to Low.
14. While they're writing, allow for questions. Make sure to give them enough time!
15. Now for each subsequent demonstration, instruct the students to draw, write the critical question for, and explain in their own words each phenomenon using Bernoulli's Principle and the understanding of pressure. Continue to follow the same sequence as before: demonstrate the phenomenon, ask the student why it happened, draw it with them on the board with arrows and labels, and explain it using Bernoulli's Principle and the idea of how pressure works.
16. These are the following demonstrations:
    a. Demonstration 2: ask the students if they have ever flown in an airplane (show of hands). Draw a cross-section of airplane wing on the board. You can draw the rest of the airplane for visual context. Explain how air moving over the curve of the wing moves faster because it must travel a longer distance in the same amount of time as air moving underneath the wing, which is flat and straight. (Faster air above the wing creates a low pressure zone above the wing, causing the higher pressure underneath the wing to lift the wing.

b. Demonstration 3: Turn on a faucet, and explain that you've created a fast flowing fluid. Tell them that in the stream of water is a low pressure zone, and that right now the air around that stream is moving into the stream. Show them an aspirator (used in chemistry with filter flasks). Hook the aspirator to the faucet and turn the water on again. Tell the student that the water moves straight down through the tubing, creating a low pressure zone in the tube, and the air in the room wants to get into that stream, but can only do so through the perpendicular tube. Explain that air moving from the room, through the tube, into the stream is suction. Place your thumb to seal the tubing, wait a moment, then remove your thumb to demonstrate the suction "pop" sound. Allow the students to come up and do the same. Hook the tubing to the filter flask and show them that the suction can be used to draw suction through a filter to separate a liquid from a solid (skip this if it does not relate to your subject matter or is too complex/unnecessary).

c. Demonstration 4: Reveal a ping-pong ball. Ask the students what it is. Throw it to one of the students. Let them bounce it and throw it back. Now, take the ping-pong ball and hold it above your heard at a 60 degree angle about 6 inches from your face. Take a deep breath and blow forcefully at the ping-pong ball. Maintain this stream as long as you can. If you do this correctly, the ping-pong ball will float in the air, shocking the class. This demonstration is difficult to achieve and requires practice, so if you cannot master it beforehand, then try using a blow dryer.

17. Remember to ask the students the critical questions, draw the demonstrations with them using arrows and labels, explain the demonstrations using Bernoulli's Principle and our understanding of pressure, have the students explain it to themselves in their own words, and allow for questions.

Summative:

1. Have the students take these drawings and explanations home. Have them redraw each demonstration neatly and clearly using arrows and labels, and have them write 5-10 sentences on each demonstration including what happened, what the critical question were, explanations for each using Bernoulli's Principle and our understanding of pressure, and any other thoughts or comments.
2. Have the students research one more phenomenon that includes Bernoulli's Principle. Have them design a demonstration for this phenomenon.
3. Test questions.

Lesson Relevance to Performance Task and Students:

Students will learn Bernoulli's Principle and ideas about pressure as integrated and scaffolded truths set firmly in their thinking. This will be accomplished by having the students experience unexpected phenomena, having them think about those phenomena, having them draw the phenomena, having the phenomena explained to them using

Bernoulli's Principle and ideas about pressure, having them teach themselves Bernoulli's Principle and ideas about pressure by having them explain the phenomena in their own words, and allowing them to see how Bernoulli's Principle and our understanding of pressure relates to several scenarios, most of which are familiar, commonplace, and easy to see. The use repetition, consistency in explanation, various learning styles, and everyday visual demonstrations will reinforce Bernoulli's Principle and our understanding of pressure in the students' minds.

Anticipatory Set/Capture Interest:
Every demonstration acts as an anticipatory set for explaining Bernoulli's Principle.

Guided Practice:
Students will walk through the demonstrations, the drawings, and the explanations with the teacher.

Independent Practice:
Students will write explanations in their own words; students will rewrite, redraw, and re-explain every demonstration for homework; students will find another phenomenon related to Bernoulli's Principle and design a demonstration around it for homework.

Remediation and/or Enrichment:
Remediation:
Individual IEP, fewer demonstrations.

Enrichment: Students could execute the demonstrations they designed for homework by collecting the necessary materials and leading the class.

Check(s) for Understanding:
What is a fluid?
Where do we see Bernoulli's Principle in our lives?
Does Bernoulli's Principle operate *every time* you accelerate a fluid?
What about wind? What about a water fall? Where else?

Closure:
A student-lead, teacher-guided summary discussion will bring closure to the lesson plan.

Possible Alternate Subject Integrations:
Physics could use all or part of this lesson plan as an introduction to fluid dynamics, pressure, or PV=nRT. It also fits nicely with Boyle's law and Charles' law.

Biology could use all or part of this lesson plan to have a foundation in physical laws that apply to biological systems.

Chemistry could use all or part of this lesson plan with Boyle's law and Charles' law, PV=nRT, and laboratory experiments that require students to filter samples.

Teacher Notes:
These demonstrations are fun if they are practiced and mastered ahead of time. Also, the more you get the students involved, the more they will pay attention and learn.