Water Balloon Heating

Subject Area	Physics or chemistry.
Age or Grade	Elementary high school physics or chemistry.
Estimated Length	20 minutes.
Prerequisite knowledge and skills	Rudimentary knowledge of specific heat and the relation between heat and temperature change ($Q = m \cdot c \cdot T$).
Lesson Goals and New Content	Students must obtain a feel for what heat capacity means, and understand how the number relates to heat absorption and temperature change. Students will see that having a large heat capacity means a material can absorb a lot of heat without a large increase in temperature.
Materials Needed	Round latex balloons. Matches. 1 mL measuring spoon. Candles. Cup of cool water. Balloon stand. (This can be crafted from a paper cup with some tape. The tip of the flame should be about 1 inch under the balloon.) Stopwatch or other form of timer. Slides for discussion after the demonstration (pdf format).
Procedure	**Opener** (5 min.) Set up the experiment before class, having the materials out and ready for the students to see as

	they walk in. As class starts, ask for some volunteers to help you. Have one student be in charge of lighting the candle, and let another inflate a balloon to about 6 inches in diameter. Most will have guessed what's about to happen! Ask them to guess for how long the balloon can survive if you put it in the flame. **Development** (5 min.) Ask for someone to be the timer, and have him or her measure the time the balloon can survive in the flame. Then give the go ahead and let your volunteer place the balloon in the flame. As most of your students probably guessed, it pops right away! Thank your volunteers and have someone else come up to try again, only this time, pour a few milliliters of water into the bottom of the balloon before inflating it. (Try a few times before class to figure out exactly the right amount for your setup, so that the balloons don't pop too quickly, or not at all.) As before, have the students guess for how long the balloon will survive, and time it in the flame. This time, it should survive about a minute. (Make sure all the water stays at the bottom of the balloon as it is placed on the fire, as it otherwise will pop pretty quickly.) **Closure** (10 min.) Now, open up a discussion to the class. Start the discussion slides and go through the slides, stopping at slide 6. At this point, ask for an

	explanation as to why the second balloon survived for so much longer. Most of them will suspect the water, and some might even guess the specific heat capacity has to do with it. (If not, nudge them along by asking what was different between the two balloons, and by asking what happens to the water as it sits in the flame.) Some often think the water evaporates, but you will notice the water splashing onto the table as the balloon pops, disproving this. Move on to slide 7-9, and ask why, when the specific heat capacity of water is only 4 times that of air, did the balloon not just live 4 times longer. (The mass must be taken into account.) This is done in slides 10-12. (To as large extent as possible, have the students deduce the answer before revealing the slides.) The mass of air in the balloon is about 1 g, if you inflated it to 6" diameter. At this point, however, it still looks like 2 mL of water would only absorb 8 times the heat of the balloon as it contained just air. Yet, the balloon lived more than 8 times longer. The remaining slides explain this. In fact, only the bottom portion of the air gets heated, after which it has to move out of the way for new, colder air. This convection is slow compared to the conduction of heat in the water. (This conclusion is much more difficult and advanced, but you can lead the students along by asking them if they think all the air in the original balloon was heated up, and if they know what hot air does - most will know it rises.)

	As an alternative closer, leave out the slides until after the class has had time in groups to discuss what happened, and to try and explain it on their own. (Adds more time to the lesson.) **Variation** Set up several little rigs and have students volunteer for a competition. Have each of them compete against the "cool teacher" to see who can best inflate their balloon to withstand the fire. Inflate yours with a few milliliters of water in the bottom without letting them know ahead of time. Then, present it as a puzzle to them to figure out what about your balloon made you win.
Evaluation	In addition to the initial evaluation during the closure discussion, this basic homework assignment has two problems which test the students' understanding of the concept of heat capacity.
Extensions	Other uses of water, such as calorimetry, can be the center of a follow-up demonstration. If they have not already done so in previous classes, a lesson to determine the energy content in food products by burning them (a cheese puff works well) can be done with calorimetry.