Non-obvious controls:

- You will want to check the H_3O^+/OH^- ratio view to see how the particle number compare.
- When you use the slider to change pH on the pH meter or the arrows on the Water Component graph, the liquid automatically switches to custom. The color of the liquid will not change.
- If you are doing a lecture demonstration, set your screen resolution to 1024x768 so the simulation will fill the screen and be seen easily.

Important modeling notes / simplifications:

- The H_3O^+/OH^- ratio view is an attempt to help students visualize how the ion particles vary with pH. The number of particles displayed doesn't represent the actual number of particles in the volume shown.
- One of the learning goals is that the color of the liquid doesn't affect the pH, so we decided to keep the color of the custom liquid unchanging.
- We used 6.023×10^{23} particles/mole for calculations
- The significant figures were constrained to three for displays.
- For dilution, we assumed that the liquid was just a simple acid or base and that the only change in number of ionic particles comes from the addition of water. We did not use Ka calculations. For example, if students add ½ liter of water to an acid, then the number of H_3O^+ goes up by $(1 \times 10^{-7}$ mol H_3O^+ / L $H_2O)(0.50$ L $H_2O)(6.022 \times 10^{23}$ H_3O^+ / mol $H_3O^+) = 3.01 \times 10^{16}$ H_3O^+. This is added to the number of H_3O^+ in the original volume of liquid and then divided by the new total volume to get the new $[H_3O^+]$ (and then pH). The OH- concentration is calculated using K_w. If the liquid being diluted is a base, then the number of OH^- ions is increased (although, because the total volume is increasing, the net effect is lower $[OH^-]$ upon dilution). These calculations allow the simulation to take into account the leveling effect of water. The pH never goes above 7.00 when diluting an acid, or below 7.00 when diluting a base.

Insights into student use / thinking:

- We want to dispel the idea that pH can be used as a sole indicator of the concentration or strength of acids and bases.
- From having used indicators like litmus paper or pH paper, some students may think that the color of the substance is related to pH.
- *Others may be revealed later through interviews or class use.*

Suggestions for sim use:

- The Learning Goals that the development team used are available in the Teaching Ideas database http://phet.colorado.edu/teacher_ideas/view-contribution.php?contribution_id=566

- For tips on using PhET sims with your students see: **Guidelines for Inquiry Contributions** and **Using PhET Sims**
- The simulations have been used successfully with homework, lectures, in-class activities, or lab activities. Use them for introduction to concepts, learning new concepts, reinforcement of concepts, as visual aids for interactive demonstrations, or with in-class clicker questions. To read more, see **Teaching Physics using PhET Simulations**
- For activities and lesson plans written by the PhET team and other teachers, see: **Teacher Ideas & Activities**