Best Bubbles – Teacher Notes

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Introduction:

It is hard to think of anything more mesmerising than bubbles! These free-floating translucent orbs which display rainbow colours are not only a lot of fun, but they exhibit some pretty interesting science.

This investigation is an exploration into what makes a good bubble mixture. It is at an open-inquiry level and therefore suitable for developing science inquiry skills for all grade levels. As students are engaged within a process of discovery, they develop a procedure and record data in their own way. This data is used to determine what the 'best' solution is. They also must evaluate the accuracy of their experiments.

This exploration can assist Year 7 students to recognise the difference between pure substances, mixtures, solvents and solutes, while Year 8 students will benefit from determining whether chemical or physical changes are taking place. Higher grade levels will benefit from the impressive display of refracting light and being able to observe the unusual properties of polymers (if using more advanced ingredients).

This investigation is safe and can be easily modified to be simple and inexpensive or complex enough to make a commercial grade product. Students can be further motivated by a class competition to see who has made the best bubbles!

Questions:

Students are given this general question: **what is the best mixture for creating bubbles?** However, they may want to think further about what makes a good bubble. For example: is it the ability to make bigger bubbles? Or perhaps it is the longevity of the bubble (time in the air before it self-pops)? Maybe it is the amount of rainbow colours that are displayed or the ease to which the bubbles can be blown? As one can see, there are many factors to a good bubble. A class discussion deciding on one or multiple factors to focus on may be beneficial.

Moreover, if there is going to be a class competition then certain "rules" will have to be decided on. For example: what type of plunger will be used? Do students want to create bubbles by blowing them or by swinging a larger plunger in the air?

Students will then write an Aim and a Hypothesis. All parameters decided upon can be incorporated into these sections in order to establish a well-defined scientific question.

Plan:

There is a wide range of possibilities when it comes to the planning of this investigation. Teachers may allow students to present a materials list that they have self-researched.

Alternatively, a pre-selection of materials could be made available at the front of the class. In order to increase the challenge, superfluous materials may be added.

Suggested materials are listed below:

- Measuring cups / beakers or test tube trays
- Scales
- Stop Watch
- Video Camera
- Lighting Source (to shine on bubbles)
- Plunger (plastic loops or string on sticks for larger type bubbles).
- Ruler

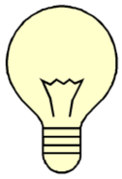
Below is a list of ingredients that have been reported as either essential or beneficial for bubble mixture:

Basic Ingredient List:

- Water
- Unscented Dish Soap (strong brands such as Dawn or Morning Fresh)
- Sugar or Starch

Advanced Ingredient List (OPTIONAL):

- Distilled Water
- Glycerine
- Natural Polymers such as: Guar Gum or Xanthan Gum
- Industrial Polymers such as: Polyethylene Oxide (PEO) or Hydroxyethyl cellulose (HEC)
- PH Adjusters such as: Baking Soda or Distilled Vinegar



Polyethylene Oxide (PEO) is a polymer with very long chain molecules that end up tugging on one another when dissolved in water. It can make very interesting visual effects when being poured from one container to another. This can make an exciting class demonstration or you may show students the following video, *The liquid that pours itself – Polyethylene Oxide*, on YouTube at this address: https://www.youtube.com/watch?v=bOSVX8zOPkc

Notes on Ingredients:

Chemicals such as sugar, starch and polymers are used to increase the viscosity of the water. This increases the bubble's integrity and its longevity as it takes longer for the water to evaporate.

Distilled water is considered superior to regular tap water as there are no minerals or other dissolved substances that reduce the consistency of the bubble.

Guar gum is usually available in health food stores as a replacement for gluten in cooking, and is a popular polymer used in home-made bubble mixtures. It is claimed to be more effective than Xanthan Gum.

PH adjusting chemicals may or may not be beneficial. This is on a case by case basis, depending on how the particular water and soap will mix.

Along with differing ingredients, there are additional considerations to be made with making a bubble mixture. Often people will go through the process of heating the water in order to more readily dissolve the solutes. Then the mixture is allowed to sit (sometimes up to a day) and/or cooled in a refrigerator. If time allows, then these steps may be taken, however using the water at room temperature should be sufficient if proper mixing steps are taken. For example, before adding any soap, dissolve your sugar/starch in the water by slowing adding the powder in order to prevent any clumping. Polymers may be added to the soap and mixed vigorously in order to prevent clumping when water is added.

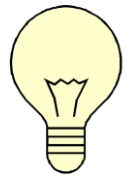
Time may be allocated for student lab groups to construct a method before commencing the experiment, or students may be allowed more freedom by at first playing around with the materials in a process of discovery. Students may then develop a method as they go along. Teachers may facilitate this by advising groups to allocate a note-taker for this task.

Conduct:

It is expected that there will be a wide range of methods and number of tests conducted between student lab groups. The following questions may be asked of students to assist in consolidating their procedures: What are you measuring? How are you measuring it? How many times will you be measuring it? What changes will you be making which are likely to have an effect on what you are measuring?

Time to complete the experiment for each group may vary significantly. In this time teachers may motivate students to make as many additional observations as possible. Guidance may be offered with the following questions: How can you reliably measure for the biggest bubble? How many (smaller) bubbles can be created with just one blow? How long do your bubbles survive in the air without popping? How can you utilise video recording of the experiment in order to increase the accuracy of these measurements?

Further qualitative observations can be made with the following questions: How easy are you finding it to blow bubbles? Are the bubbles transparent or can you see things reflecting back? Describe the surface of the film on your plunger. Can you see any colours or reflections? Are there any differences to the film that can make good bubbles versus the films that don't? Describe how the bubbles move. Do they fall to the ground straight away or do they float upwards for a bit at first? If blown outside, what are the effects of wind on the bubbles?

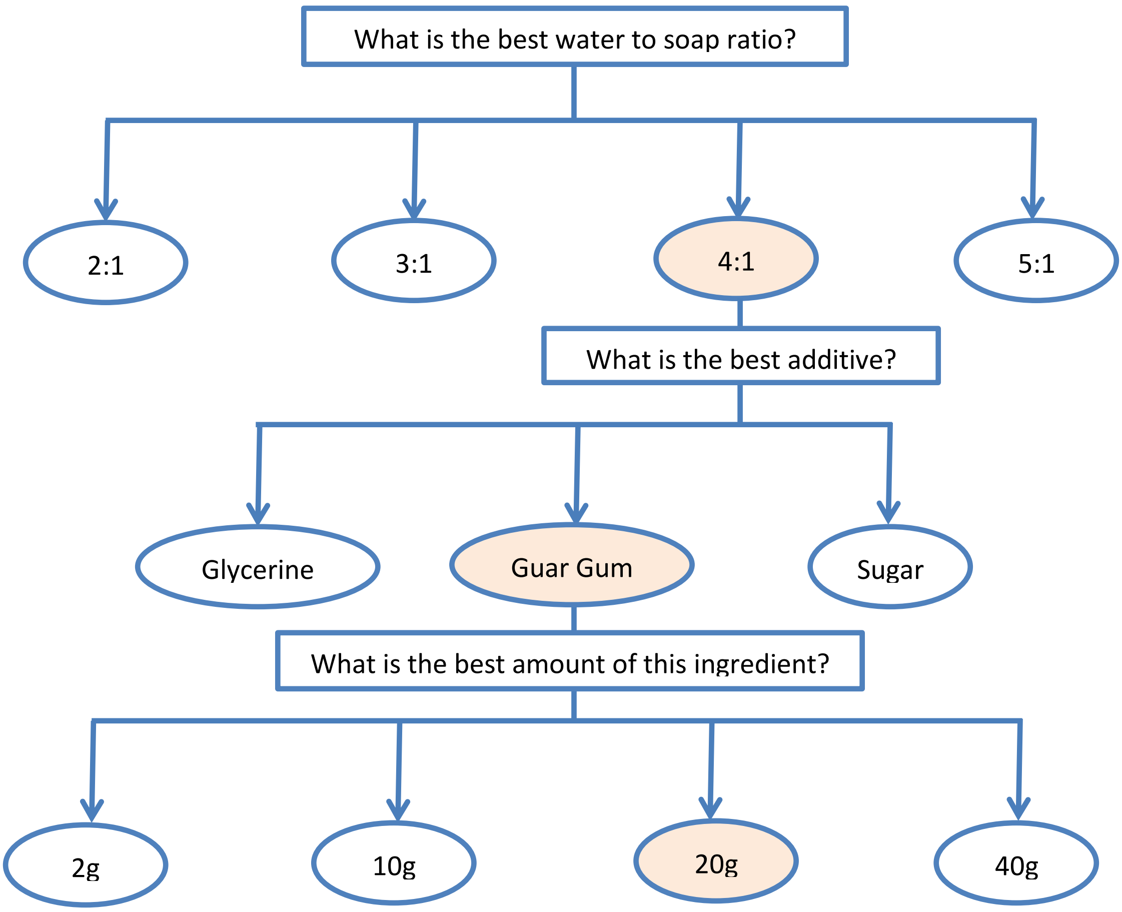


The colder the room, the more likely it is for the bubble to float upwards for a short time. This is because the human breath blown into the bubble is warmer than the climatic air. As hot air rises, so does the bubble!

It is expected that students find a reliable way to record their results. An example table is provided below for reference:

Water:Soap	Sugar/Starch/Polymer	Glycerine (X grams)	Largest Bubble Diameter (when being blown)
1:1	Not Added	Added	
		Not Added	
	5 grams	Added	
		Not Added	
	20 grams	Added	
		Not Added	
4:1	Not Added	Added	
		Not Added	
	5 grams	Added	
		Not Added	
	20 grams	Added	
		Not Added	
8:1	Not Added	Added	
		Not Added	
	5 grams	Added	
		Not Added	
	20 grams	Added	
		Not Added	

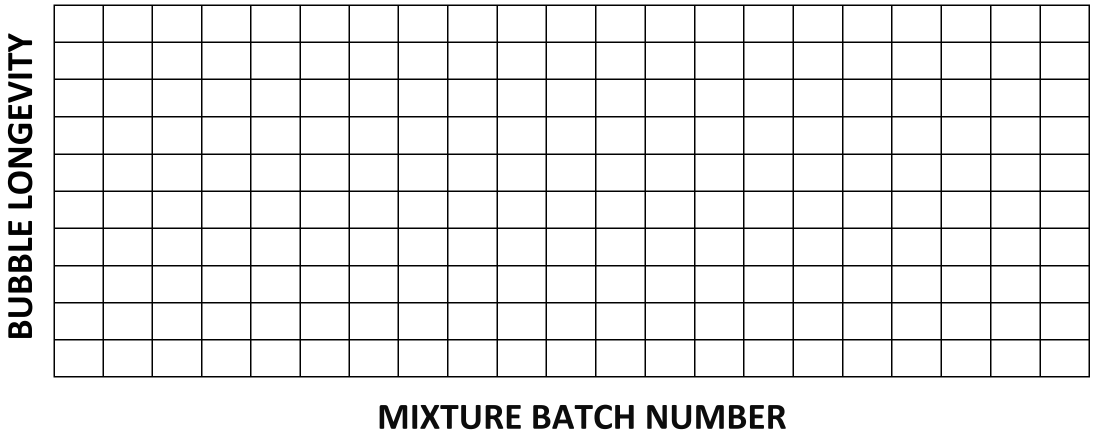
For more complicated recipes, students may get creative and create a work-flow system in order to end up with a better recipe in a shorter amount of time. An example is below:



When student lab groups are finished, they can present their best bubble mixtures to the class.

Analysis:

Students are asked to represent the data collected in a graphical form in order to better identify any patterns. Students may plot their results in a graph with the below axis, with the y axis being whatever dependent variable was used.



Why not conduct a meta-analysis? Input the results of all mixtures from all lab groups into excel. Order the mixtures from most effective to least. Examine the top 10. Are there any similarities in the recipes for these mixtures? Examine the bottom 10. What are their similarities? What are the noticeable differences of the top set from the bottom set? Can you bring all these findings together to learn something about what makes a good bubble mixture?

Problem-Solving:

At this stage students can evaluate whether their experimental design was satisfactory. Did they test the correct things in order to obtain an answer to their question? Did they conduct a fair-test? Did students ensure that the controlled variables remained consistent throughout, such as mixing technique? Did the same student blow the bubbles for each test? Were chemical measuring techniques consistent throughout, whether by weight or volume? Was enough information recorded so that recipe data can be collected for every mixture? Discuss these issues with students as they assess the reliability of their results.

Conduct a class discussion with students with the below focus questions:

Do they agree with any science you know?
What new things did you learn?
What did you find surprising?

Encourage students to explain the investigation using their theoretical knowledge, and allow students to ask questions about the features of a bubble that they do not yet understand. ***Content that could be covered in this discussion is offered below.***

Year 7 students may note that the bubble mixture is a solution. Students may be asked what ingredients are solutes (dish soap, sugar, glycerine) and which are solvents (water). Year 8 students may be able to identify which ingredients created a chemical or physical change. Apart from the PH adjusting chemicals, the changes will be physical. This is because none of the chemicals are changed into something new. The molecules which make up the solutes spread out and become suspended in the solvent, but they don't change their chemical structures. If the water was to be completely evaporated, the solutes would be left behind in their original form.

Year 9-10 students may benefit from understanding the chemical reaction that takes place when baking soda ($NaHCO_3$) is added to water (H_2O). They will react to give Carbonic Acid (H_2CO_3) which will then change to carbon dioxide (CO_2). Word equations are below:

$$NaHCO_3 + H_2O \longrightarrow H_2CO_3 + NaOH$$

$$H_2CO_3 \longrightarrow H_2O + CO_2$$

Additionally, the chemical reaction that takes place when vinegar (acetic acid) is added to water (H_2O) is an equilibrium reaction, meaning it moves between 2 states. The acetic acid (CH_3CHOOH) is transformed into an acetate ion and a H^+, which further combines with water to form hydronium ion (H_3O^+). Word equation is below:

$$CH_3CHOOH + H_2O \longleftrightarrow CH_3CHOO^- + H_3O^+$$

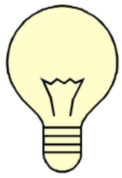
Chemistry of bubbles: Bubbles are able to be formed due to molecules in the soap having one end that is attracted to water (*hydrophilic)* and the other end repelled by water (*hydrophobic)*. This causes the soap to create a thin film over the water. A bubble is made up of two layers of soap molecules sandwiching a layer of water molecules.
The integrity of the bubble is held up due to the surface tension properties of water. Water molecules are attracted to each-other. Because of this they hold together to create a shape in the air. This is a sphere because the bubble uses the least amount of energy to contain its shape. A sphere has the smallest surface area in relation to its volume.

Bubbles burst in the air because the thin water layer quickly evaporates. Once enough of the water has gone, the integrity of the bubble collapses and the soap particles shoot off in all different directions. This process can be slowed down when bubbles are formed at colder temperatures because it takes longer for the water to evaporate. It is even possible for the water in bubbles to freeze, making an ice bubble. There are available videos of this on YouTube. A good example of this is *Soap bubbles @ -15 degrees Celsius*, located here: https://www.youtube.com/watch?v=b1Qrr50K0V0

Watch a video on the Discovery Channel's Slow Down show on YouTube, linked here: https://www.youtube.com/watch?v=blNe2Ae5a2c
This video will show bubbles popping in slow motion. It also shows that a hand covered in soap solution will not disturb the surface tension of the bubble,

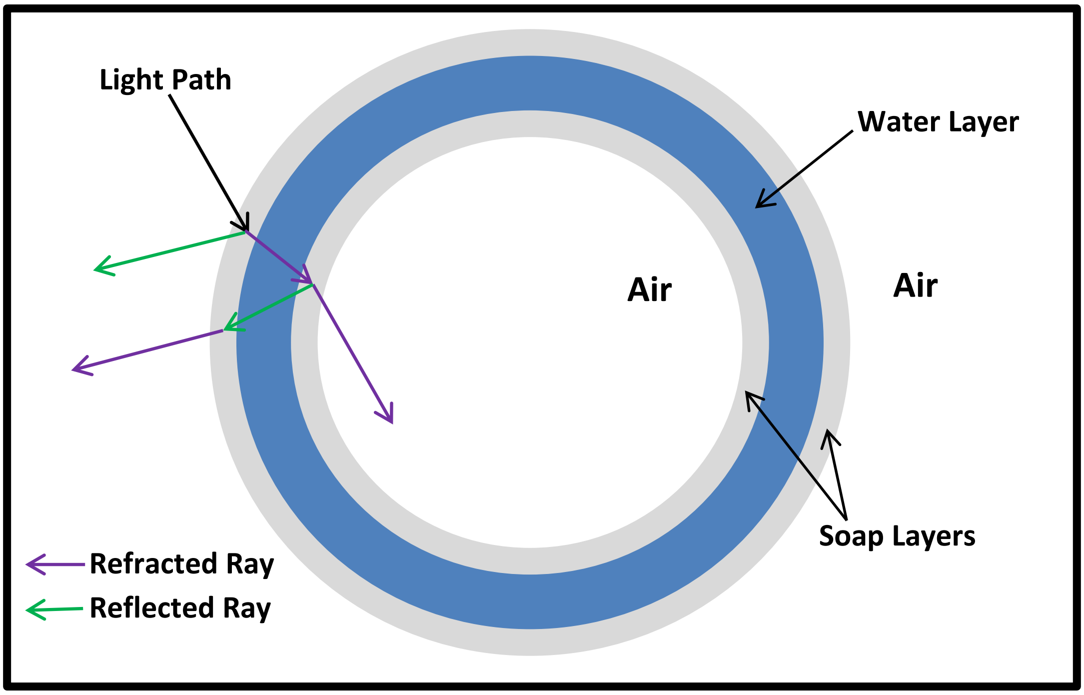
while touching the bubble with a dry hand will break the surface tension and immediately pop it.

The most effective additives in bubble mixture work because they optimise the level of surface tension and slow down the rate of evaporation. This causes the bubbles to be more durable and last longer.



Bubbles are big business! Did you know that there are patents for bubble mixtures? These patents don't just include specific ingredients, but also detailed manufacturing processes, such as heating and cooling steps. One of the more popular bubble mixtures in the market (BEEBOO®) has a top secret formula and claims to make record-breaking bubbles! It's even been used in performance art, like in Cirque de Soleil shows. Students may wish to compare a commercial bubble mixture with their own.

Thin-film interference: As white light hits the bubble at certain angles, the light wave refracts and reflects between the soap film's outer and inner surfaces. The white light is then broken into colours. This causes a rainbow effect as different colours will emerge from slight changes in the thickness of the film. That is why the colours move in a fluid like fashion over the bubbles.



Conclusion:

Students can now ask themselves if their Aim achieved. Were any of the student's predictions correct? Can the class now make a few conclusive statements about what makes a good bubble mixture? Include essential details in these statements such as water to soap ratios and any effective additives used.