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Using Elephant's Toothpaste as an Engaging and Flexible Curriculum Alignment Project

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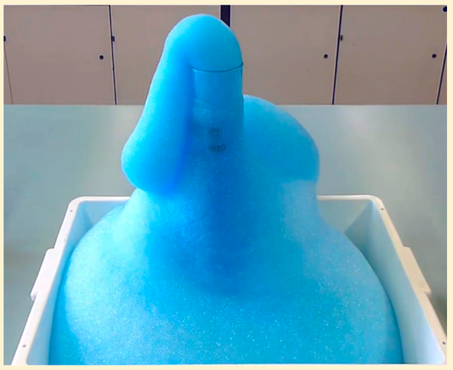
S *Supporting Information*

ABSTRACT: There is an increasing focus across all educational sectors to ensure that learning objectives are aligned with learning activities and assessments. An attractive approach previously published is that of curriculum alignment projects. This paper discusses the use of the fun and famous "Elephant's Toothpaste" experiment as a customizable curriculum alignment project that can be tailored to address a large number of learning activities and learning outcomes in chemistry suitable for students ranging from late high school through to first year university.



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■ INTRODUCTION

Modern pedagogy places a strong emphasis on the need for curriculum alignment. Mapping activities should be conducted in order to ensure that each learning objective has a linked learning activity in order to teach the objective and a corresponding assessment so that both the student and educators are able to see that the learning objective has been met.[1−4]

There are many ways of achieving these goals as part of an active, engaging learning environment. One appealing method for achieving this is the use of a Curriculum Alignment Project (CAP). A CAP was originally suggested as a demonstration or experiment conducted at the beginning of a course which demonstrated a multitude of learning objectives to be included as part of the unit of study. As the unit proceeds and the students' body of knowledge grows, they are able to readdress the CAP and comprehend or explain more and more of the activity.[5,6]

Previous researchers have surveyed students and found that many believe that learning involves the accumulation and memorization of information followed by exhibiting the ability to reproduce that information on demand for assessments.[7] Few students see new information as pieces to be incorporated into an ever-growing body of knowledge that they possess. A CAP allows students to observe how individual pieces of knowledge contribute to the whole. Showing students a link between a learning objective and a practical application increases student motivation.[8]

This paper demonstrates the use of a famous and entertaining experiment—Elephant's Toothpaste—as a CAP. Students thoroughly enjoy the spectacle of the experiment, making it an ideal choice for an activity to frequently relate content to. The experiment is simple to conduct, but grand enough that it can be done as a demonstration on a large scale, or scaled down and conducted by the students themselves. As such, variations of this experiment make for popular demonstrations.[9−13]

There are a large number of fundamental chemical concepts that can be discussed in relation to this experiment. Each concept can be explored or bypassed according to the learning objectives set by the instructor. As such, this flexible CAP is appropriate for students ranging from high school chemistry through to first year university.

■ SAFETY AND EXPERIMENTAL CONSIDERATIONS

A lab coat, safety glasses, and closed shoes should be worn at all times. The 30% w/v hydrogen peroxide (H_2O_2) solution is both corrosive and a strong oxidizing agent. Handle with care and wear gloves at all times.

The reaction is quite exothermic. To prevent heat burns, take care not to touch the measuring cylinder during the reaction.

If spills occur and result in staining with I_2, this can easily be cleaned up using ~0.1 M $Na_2S_2O_3$. In fact, this cleanup is also an excellent practical application of redox chemistry!

This method describes the decomposition of 100 mL of 30% w/v hydrogen peroxide solution. This is effective for a spectacular demonstration, presented to a classroom or small lecture theater. If the experiment is to be conducted by

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Table 1. Skills, Activities, and Assessment Points That Can Be Addressed during the Curriculum Alignment Project

Skill/Objective	Activity/Observation
Occupational health and safety	Observe the use of safety equipment, relate to SDS and/or risk assessments.
Reaction writing and balancing	Observe the occurrence of the reaction and, if possible, predict the products formed. More junior chemists could be encouraged to simply balance the equation.
Lewis structures	Draw Lewis structures for both the reactants and products of the reaction, giving experience with single and multiple bonds as well as lone pair electrons.
Mass and % w/v	Determine the mass of H_2O_2 present in a given volume of 30% w/v solution.
Molarity, volume, and molar mass	Use the molarity and volume to find the number of moles and/or mass of H_2O_2 used.
Gas stoichiometry and the ideal gas equation	Use the quantity of H_2O_2 available to predict/determine the mass or volume of oxygen gas produced through use of the ideal gas equation.
Comparing the density of solids and liquids to gases	Observe the fact that a very large volume of gas is created from a small quantity of solid and liquid. Note that this is true despite the fact that it takes 2 mol of H_2O_2 to produce 1 mol of O_2.
Endothermic and exothermic reactions	Measure the change in temperature and/or use this in conjunction with the observation of steam to conclude the nature of the reaction.
Calorimetry, enthalpy, and thermochemical equations[a]	Use the change in temperature during the reaction to calculate the amount of energy released by the reaction and/or the enthalpy of reaction.
Catalysts	Observe the rate of decomposition of H_2O_2 before and after being combined with KI.
Redox[b]	Observe the occurrence of the reaction upon the addition of KI. Potentially notice the subtle brown discoloration caused by the formation of I_2 from I^-. This is more pronounced in the absence of the food dye (see the photo provided in the Supporting Information).
Redox	Observe that any brown stains formed during the experiment do not easily clean off with water. However, upon application of $Na_2S_2O_3$ solution, the stain is easily cleaned as I_2 is reduced to I^-. $2S_2O_3^{2-}\ (aq) + I_2\ (aq) \rightarrow S_4O_6^{2-}\ (aq) + 2I^-\ (aq)$
Kinetics[c]	Repeat experiments can be used to determine the order of reaction and the rate law.

[a]A paper discussing this skill in great detail has been presented elsewhere.[10] [b]A paper discussing this skill in great detail has been presented elsewhere.[11] [c]A paper discussing this skill in great detail has been presented elsewhere.[11,12]

individuals or small groups of students, scaling down the volumes and/or concentrations may be appropriate in order to decrease the quantity of chemicals consumed and to diminish the chances of any chemical burns.

The experiment could even be conducted by students out of class, using yeast as the catalyst, dish soap as the surfactant, and 3% hydrogen peroxide solution, which can be purchased at a pharmacy. If the experiment is to be primarily conducted by students, other modifications have been suggested in the literature that would further minimize the risks associated with the handling of the chemicals involved.[9]

■ METHOD

A 100 mL portion of 30% w/v hydrogen peroxide is premeasured into a capped plastic bottle. To begin, the demonstrator may remove the cap to show that "nothing happens" because the decomposition is slow.

In a 500 mL measuring cylinder, place ~2.5 g of KI. This acts as a catalyst and is a substantial excess. If KI is unavailable, other simple iodide salts, yeast, or $Fe(NO_3)_3$ may be used instead.[10]

Next, add ~20 mL of concentrated surfactant (e.g., Pyroneg). If it is not of suitably high concentration, the volume of gas captured will be insufficient to carry the demonstration.

If desired, add ~3 mL of food coloring. This is purely for aesthetics.

Place the measuring cylinder in a sink or large container (at least 15 L is recommended). When ready, add the entire volume of H_2O_2 solution to the measuring cylinder. As oxygen gas is produced, a large volume of foam will be created that will very quickly exceed the capacity of the measuring cylinder and overflow into the container. The reaction proceeds according to the following chemical equation:

$$2H_2O_2\ (aq) \rightarrow 2H_2O\ (l) + O_2\ (g)$$

A video of the demonstration is supplied in the Supporting Information. If desired, a small variation can be applied where the catalyst is added as the final ingredient to highlight the role that it plays.

■ RESULTS AND DISCUSSION

The demonstration creates a large volume of foam, as the hydrogen peroxide decomposes to form water and half as many moles of oxygen gas, which, in conjunction with the surfactant, makes bubbles. Using these quantities, approximately 13 L of gas is produced, although the amount captured varies depending on the concentration of surfactant and hydrogen peroxide used (H_2O_2 goes "off"—decomposes—over time). Table 1 details the major learning objectives that the experiment could demonstrate, along with relevant observations or activities for students in order for them to capture the learning objective. There is great flexibility in which of these learning objectives an instructor may wish to use, as many of them are independent of one another.

In regard to how these observations and activities are aligned with an assessment, any number of possibilities exist. Assessment activities could be run on a weekly basis after the demonstration so that their knowledge of the reaction grows continuously. The assessment could be saved for the end of the unit, where a section of their final assessments could be dedicated to their understanding of the experiment. Alternatively, the CAP could be flipped around: the demonstration could be unveiled at the end of the unit of study before then asking students to use their new-found skills to describe the experiment. Regarding the nature of the assessment, conventional written tasks based on the key concepts could be employed, as authors have noted that problem solving exercises can themselves embody constructive alignment.[2] Furthermore,

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some students reflect on their performance on a written test as being an indicator of their understanding of the concepts, and sometimes more important than the success in terms of awarding marks.[7]

Alternative assessment techniques could include a verbal presentation of a given learning objective, an audio recording of the student's understanding, the development of a multimedia presentation which could then be uploaded and used as a student study resource, or really, any other mode that the instructor wishes. The degree of difficulty of the assessment can be tailored to suit the level of the students for most of the suggested objectives.

■ CONCLUSIONS

This paper outlines how the Elephant's Toothpaste experiment provides the possibility of a fun and engaging curriculum alignment project. No fewer than 13 key chemistry skills (learning objectives) have been identified as being observable, instructive, and, if desired, assessable within the demonstration.

■ ASSOCIATED CONTENT

Supporting Information

A video demonstration of the Elephant's Toothpaste experiment is supplied. An audio-free version of the same video is provided for those who may want to use it for a virtual demonstration. A photo of the experiment conducted in the absence of food coloring is shown to highlight the formation of I_2 to instructors interested in pursuing this learning objective. A few examples of learning activities and questions used in relation to this experiment are also provided. This material is available via the Internet at http://pubs.acs.org.

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Notes

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■ ABBREVIATIONS

CAP, curriculum alignment project; % w/v, percent weight-volume (grams per 100 mL)

■ REFERENCES

(1) Smith, C. Design-focused evaluation. *Assess. Eval. Higher Educ.* **2008**, *33*, 631−645.

(2) Biggs, J. What the Student Does: teaching for enhanced learning. *Higher Educ. Res. Dev.* **1999**, *18*, 57−75.

(3) Vanfretti, F.; Farrokhabadi, M. Consensus-based course design and implementation of constructive alignment theory in a power system analysis course. *Eur. J. Eng. Educ.* **2015**, *40*, 206−221.

(4) Sambell, K.; McDowell, L. The Construction of the Hidden Curriculum: messages and meanings in the assessment of student learning. *Assess. Eval. Higher Educ.* **1998**, *23*, 391−402.

(5) Pinkerton, K. Curriculum Alignment Projects: Toward Developing a Need to Know. *J. Chem. Educ.* **2001**, *78*, 198−200.

(6) Criswell, B. The Extraction and Isolation of Saltpeter from Nitered Soil. *J. Chem. Educ.* **2006**, *83*, 241−242.

(7) Watters, D.; Watters, J. Approaches to Learning by Students in the Biological Sciences: Implications for teaching. *Int. J. Sci. Educ.* **2007**, *29*, 19−43.

(8) Kember, D.; Hong, C.; Ho, A.; Ho, A. More can mean less motivation: applying a motivational orientation framework to the expanded entry into higher education in Hong Kong. *Stud. Higher Educ.* **2011**, *36*, 209−225.

(9) Trujillo, C. A Modified Demonstration of the Catalytic Decomposition of Hydrogen Peroxide. *J. Chem. Educ.* **2005**, *82*, 855.

(10) Marzzacco, C. The Enthalpy of Decomposition of Hydrogen Peroxide - A General Chemistry Calorimetry Experiment. *J. Chem. Educ.* **1999**, *76*, 1517−1518.

(11) Hansen, J. The Iodide-Catalyzed Decomposition of Hydrogen Peroxide: A Simple Computer-Interfaced Kinetics Experiment for General Chemistry. *J. Chem. Educ.* **1996**, *73*, 728−732.

(12) Carter, G. The Feasibility of Using Hydrogen Peroxide Decomposition Studies for High School Chemistry. *J. Chem. Educ.* **1986**, *63*, 159−161.

(13) Conklin, G.; Kessinger, A. Demonstration of the Catalytic Decomposition of Hydrogen Peroxide. *J. Chem. Educ.* **1996**, *73*, 838.

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