

Employing Popular Childrens Literature to Teach Elementary School Chemistry: An Engaging Outreach Program

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Abstract

Popular cultural themes or fads can provide an effective vehicle to enthuse students about science. The program described here uses current children's literature in a versatile chemical education activity. This activity generates excitement in elementary school students because of the integration of the popular *Harry Potter* literature series with hands-on experiments. Elementary school student participants are prompted to explore three main scientific topics during this activity: properties of solids, liquids, and gases; scientific ethics; and the scientific method. Undergraduate and high school student volunteer mentors are readily trained to conduct the activity within elementary schools via an introduction to the philosophy of the exercise in conjunction with working through the activity themselves. As an outreach activity it serves to connect undergraduate and high school students both with faculty and their community.

Keywords: Curriculum, Teaching/ Learning Aids, Learning Theory/ Practice, Outreach, Gases/ Liquids/ Solids

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Introduction

The current popularity of J. K Rowling's *Harry Potter* fictional literary series¹⁻⁵ provides an excellent and timely opportunity to enthuse students of all ages in the chemistry classroom. Utilizing a Harry Potter-like wizardry theme, we have designed a hands-on chemistry outreach program that addresses several Colorado Model Content Standards for Physical Science at the fourth- and fifth-grade elementary school levels (ages 9-11). The fictional wizardry theme serves as a "teaser" to engage students in chemistry. Realizing that the Harry Potter theme's popularity may be transient and likely to lose some of its effectiveness when dated or eventually passé, we assert that the chemistry instructional principles are essentially timeless and can be adapted to many emerging crazes. The Colorado Model Content Standards for Science relevant to this activity dictate that students understand the process of scientific investigations and design, conduct, communicate about, and evaluate such investigations.⁶ That students understand common properties, forms, and changes in matter and energy is a common elementary school science mandate and fundamental scientific expectation. Students are also expected to understand that science involves a particular way of studying,

investigating and knowing phenomena in our world through direct observation, recording and analysis of common connections among scientific disciplines.

Versatility built into this chemical education activity facilitates its use at several different instructional levels. It can be utilized by high school or university science programs for community layperson educational outreach, or elementary education enrichment activities. Alternatively, a motivated elementary school teacher can use the activity in their classroom with minimal prior experience. Supplies needed to conduct the experiments can be obtained from a chemistry stockroom, a mail order/online chemistry supplier, or even a grocery store. We provide explicit step-by-step directions to conduct these experiments in two formats: (1) for high school or college chemistry departments motivated to perform elementary educational outreach services, and (2) for the elementary school teacher who may not have a large budget, access to chemistry resources or scientific training. Both sets of instructions yield the same technical results, although the more common alternative reagents may yield less dramatic chemical reactions.

In-class Procedures

Our experience shows that elementary school students are excited about this activity because of the popularity of the Harry Potter literature series,¹⁻⁵ use of the wizardry theme as a context for experimentation, and because they perform hands-on experiments within this wizardry context.^{7,8} The flow of the instructional strategy and timeline for completing the chemistry activities are summarized in the flow chart in Scheme 1. The activity begins with the idea that J.K. Rowling's fictional characters

Harry Potter, Hermione Granger, Ron Weasley, and Draco Malfoy, (student characters who attend Hogwart's School of Wizardry and Witchcraft) have submitted their Final Projects for their Transfiguration class.¹⁻⁵ Their final project is to produce two substances that will transfigure through all three states of matter when mixed together. The elementary school students participating in this activity serve as "Official Hogwart's Wizard Graders" for these projects. The elementary school students analyze the Hogwart's students' submissions during the hands-on portion of the activity and complete a data worksheet that challenges them to determine whose project passes and fails the transfiguration test based on a specific scientific principle and experimentation.

Student participants are prompted to explore three main scientific concepts during this activity. First, they examine and determine the three states of matter (solid, liquid and gas) and some distinct properties of each, including phase transitions in real time. Second, students are introduced to scientific ethics: they are instructed not to let their personal biases or previous opinions of the characters (i.e., antagonist vs. protagonist) cloud their judgment as to the success or failure of each character's submissions for "the Test". Finally, students employ the classical scientific method of inquiry while performing the hands-on activities, observations, data recording, and analysis.

As shown in Scheme 1, the instructor begins the lesson by engaging the students to use science to observe, analyze and learn about matter and the phases of matter using the fictional Harry Potter theme. For example, the instructor could initially ask who has read any of the Harry Potter books,¹⁻⁵ and who has seen the movies, which characters they like and why. The classroom instructor defines appropriate terms including science, chemistry, data, observation, solid, liquid, and gas (see Figure 1) and also contrasts

science and chemistry with wizardry and magic, pointing out that science is not magic, nor must science or chemistry rely on wizardry or magic at all. Magic and wizardry imply the work of unknowable and mysterious non-human forces, while science and scientific processes can be explained through human-developed methods and knowledge. The chemistry behind each “test” of matter in this exercise is well-known and understood.

Students can rely on natural, not supernatural, observations and explanations for scientific processes. Next, the instructor introduces the idea that the students at Hogwart’s school take tests just like all elementary students do, but that they are slightly different in content and style. As justification for the experiments, the instructor explains that J.K.

Rowling’s Professor McGonagall (a teacher at Hogwart’s School of Wizardry and Witchcraft) has provided the classroom instructor with all of these substances submitted

by the Hogwart’s students for their transfiguration test, asking that the elementary students use their scientific skills to determine who passes the “Test” and who does not, based on specific scientific criteria. The elementary students base their “grading” of the

Hogwart’s students on whose submission (described below) passes successfully through the required three states of matter: solid, liquid and gas. The classroom instructor leads a

discussion of what constitutes scientific descriptions of solids, liquids and gases by describing some properties of each with the aid of posters and other visual aids (e.g., a rock for solid, a flask with colored water for liquid and a balloon for gas). Specific

criteria distinguishing each of the states of matter is important to produce descriptors for subsequent test assessments. A brief introduction to the ethics of science can then ensue, often accompanied by discussion of what it means to be objective, unbiased and a fair judge, using accurate observations and scientific data as criteria. Students receive their

official Hogwart's Wizard Grader Badges, shown in Fig.2, to commence the hands-on portion. For an outreach activity, small groups of elementary students are paired with college/high school student volunteer mentors. The activity works most efficiently if one volunteer is paired to mentor a group of four elementary school participants through the various activities.

Volunteers are readily trained by their own prior hands-on lesson with Scheme 1, the actual experiments, and introduction to the philosophy of the exercise (~30 min.). These volunteers mentor each group of elementary students, directing them to perform the tests submitted by each character. Volunteers pose hypothetical questions and encourage the elementary students to use concepts from the scientific method during their inquiry and exploration. Explicit but simple printed instructions (part of the activity kit) for each experiment are provided to each group of elementary school participants and processed with the volunteer mentor's assistance. Students record their observations as "data" on the data worksheet, shown in Fig. 1, using methods, terms and criteria presented in the instructor's introduction. The data worksheet designed to accompany the transfiguration activity directs the students to analyze and record their data in three different ways. Elementary students must fill in a data chart, record observations and finally explicitly draw each reaction (see completed example as Table 1). This helps the students learn to organize their observations as recorded data, process observations into records and retain the information while also reinforcing the concepts they have just learned regarding the three states of matter, and the scientific method. The data worksheet is designed to appeal to a variety of student learning styles and helps to stimulate learning through different processes. After all "tests" have been graded, the

instructor reconvenes class as a whole and the students discuss their findings and conclusions, following the scientific method.

Experimental Methods*

Materials Required to Make Solutions for 3 Complete Sets of Experiments

All reactions can be performed in 8 oz. clear plastic cups. Styrofoam and paper cups do not allow visual observation through the sidewall but could also be used for top-down observations.

Substance 1- Harry Potter's Foam

Solution A (blue): Contains ~1 g of any powdered laundry detergent and ~7 g aluminum sulfate hydrate $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$. These are ground together with a mortar and pestle and dissolved in 60 mL of water. A few drops of blue food coloring are added. 20 mL are needed for each reaction.

Solution B (clear): Contains ~6 g sodium bicarbonate NaHCO_3 (baking soda) dissolved in 30 mL of water. 10 mL are needed for each reaction.⁹

Alternative Substance 1- Harry Potter's Foam

Solution 1 (blue): Contains 3 tsp of any powdered laundry detergent dissolved in 3/4 cup of lemon juice. A few drops of blue food coloring are added. 4 tsp are needed for each reaction.

Solution 2 (clear): Contains 6 tsp baking soda dissolved in 3/4 cup of water. 2 tsp are needed for each reaction.

* Alternative substance listings are provided for classrooms lacking access to any chemical stockroom or chemical equipment (i.e., grocery store access only). Standard non-SI measurement units are therefore included for alternate recipe formulation.

Substance 2- Hermione Granger's Gel

Solution A (red): Contains ~25g of calcium acetate $[\text{Ca}(\text{CH}_3\text{COO})_2]$ dissolved in 60 mL of water. A few drops of red food coloring are added. 20 mL are needed for each reaction.

Solution B (clear): 30 mL of 2-propanol are needed. 10 mL are needed for each reaction.^{10, 11}

Alternative Substance 2- Hermione Granger's Gel

Solution 1 (red): Contains 3/4 cup of Elmer's white glue and 3/4 cup of water. A few drops of red food coloring are added. 4 tsp are needed for each reaction.

Solution 2 (clear): Contains 3 tsp of Borax (sodium tetraborate decahydrate) in 3/4 cup of warm water. 2 tsp are needed for each reaction. Stir the two substances together with a craft stick or plastic spoon.¹²

Substance 3- Draco Malfoy's Bubbling Potion

Solution A (yellow): Contains water and a few drops (~1 mL) of basic bromothymol blue. Solution will turn yellow/orange when the dry ice is added. 20 mL are needed for each reaction.

Solution B: Dry ice, crush with a hammer in the bag prior to adding it to the solution.¹³

Alternative Substance 3- Draco Malfoy's Bubbling Potion

Solution 1 (yellow): Contains 3/4 cup of water and yellow food coloring. 4 tsp are needed for each reaction.

Solution 2: Dry ice, crush with a hammer in the bag prior to adding it to the solution.

Substance 4- Ron Weasley's Warhead™ Fizz

Solution A (green): Contains 6 Warheads™ (Shocktarts™, or Cry Babies™ could also be used) sour candy dissolved in 60 mL of lemon juice. We recommend crushing the sour candy with a hammer in a plastic baggie. Heating the solution also helps them dissolve. If using more than one sour candy flavor, add green food coloring to mask brown color. 20 mL are needed for each reaction.

Solution B (clear): Contains ~6 g sodium bicarbonate NaHCO_3 (baking soda) dissolved in 30 mL of water. 10 mL are needed for each reaction.

Alternative Substance 4- Ron Weasley's Warhead™ Fizz

Solution 1 (green): Contains 6 Warheads™ (Shocktarts™, or Cry Babies™ could also be used) sour candy dissolved in 3/4 cup of lemon juice. A few drops of green food coloring are added. Crushing the sour candy with a hammer in a plastic baggie is recommended. Heating the solution also helps them dissolve. If using more than one sour candy flavor, add green food coloring to mask brown color. 4 tsp are needed for each reaction.

Solution 2 (clear): Contains 6 tsp baking soda dissolved in 3/4 cup of water. 2 tsp are needed for each reaction.

Safety Considerations. All chemicals and reactions are generally regarded as safe, non-flammable, non-volatile, and non-corrosive. Additionally, no violent reactions are anticipated. Hence, safety precautions are minimal beyond normal considerations for handling household chemicals. Ingestion or internal use should be avoided. If chemicals are spilled the hands should be washed well with soap and water. The use of safety goggles, gloves and lab coats/aprons is not necessary.

Discussion

After performing the activities, elementary students should be able to either verbally or, in writing:

- Explain the three states of matter, describe their properties, and give an example of each. (descriptive chemistry, technical communication)
- Express observations from each of the reactions in terms of whose “Test” exhibited which states of matter. (observation, descriptive chemistry, record taking)
- State who passed the “Test” and be able to explain why that character passed the test based on the criteria. (judgment, observation, objectivity)
- Describe the validity of their results based on the scientific procedures they followed. (scientific inquiry, pedagogy)
- Discuss scientific ethics and explain how they must be applied to this activity. (unbiased objectivity)

Elementary teachers can assess these outcomes through activities that might include class discussion, record keeping and scientific reporting or journaling. Outreach programs can assess elementary student comprehension through the use of an oral mini-quiz at the end of the activity. We have tested student retention by returning to a school three days after the activity, conducting a class discussion about the activity and also observing some writing activities conducted by the classroom teacher specifically oriented toward this activity. We assert that the activity seeks continual engagement through “doing” to spark interest in scientific inquiry; it builds student scientific confidence by actively involving

elementary students in a valid hands-on science investigation, involving all possible components of the process, including recording their judgment.

Scientific outreach programs conducted by colleges and universities often serve to enthruse or entertain younger students, while not necessarily teaching scientific concepts. For example, Colorado State University's Chemistry Club performs three different outreach activities including the Harry Potter transfiguration test, but depending upon the instructor's approach, elementary school students may or may not learn relevant scientific concepts. Also, common storyline, detective-show, mystery or magic show styles of activities may not focus on one specific scientific concept, but instead span many topics with unrelated experiments intended to entertain. The Harry Potter transfiguration test outreach activity focuses on teaching one specific scientific concept that of the states of matter. Criteria and process applied for determining who passes the "test" directly relates to the scientific concept while exploring other aspects of science. Our experiences indicate that elementary students comprehend and retain scientific concepts taught during this lesson: written assessments conducted three days after the outreach activity show that students processed and retained the information presented. The student assessment consisted of questions about what each characters test did and which states of matter were observed in each "test". The students answered these questions in writing and with pictures drawn from their own experiences with the activity.

Elementary school students are often engaged by this simple activity because it taps into a popular fictional craze familiar to the majority of them. One disadvantage to using the wizardry theme is the controversy that the literary series has encountered from conservative groups opposed to pedagogical endorsement of wizardry. While this activity

neither actively nor passively endorses wizardry, rather seeking to distinguish the scientific method from wizardry, a few students may be unable to participate because of their beliefs. Nevertheless, removing or altering the wizardry context of the activity to a different, intriguing theme would easily solve this contextual problem (ideological conflict). However, changing the present Harry Potter wizard context potentially lowers the enthusiasm level of the elementary students and would require some editing or modification of our resources. Likewise, the activity's theme could easily be changed to take advantage of any popular craze once the enthusiasm for Harry Potter subsides.

Because elementary school teachers frequently do not have strong science backgrounds to address science standards effectively or creatively, we have attempted to create an activity that they will find appealing, intuitive, popular and therefore easy to implement, while meeting mandated science-teaching standards. Activities, such as the one described here, make hands-on inquiry-based science learning convenient and attainable. To date, our entire experience with this activity comes from outreach visits by our chemistry club. We intend to provide kit-based, self-guided instructions for elementary teachers to implement the activity in their own classrooms. For this specific reason we provide the alternative substance list for experimental formulation.

This outreach activity also serves to connect high school students and college undergraduates posing as mentors with faculty interested in developing outreach activities, and provides a common focus and community service interest. Chemistry faculty or high school teachers can offer small amounts of "extra credit" to encourage students in their classes to participate in their departmental outreach activities. Initially, we have found that the extra credit points entice many of the high school and

undergraduate students into becoming mentors. However, after participating in the outreach activity, student volunteers often continue to participate without any added incentives. Exit surveys and interviews with student volunteers indicate their discovery of newfound skills as scientific “teachers”, with the excitement and infectious enthusiasm of their elementary school student audience leaves them feeling refreshed and energized. This activity also shows young volunteers that they actually know more about science than they thought as they answer elementary school students’ questions about what happens during the activity. Performing outreach activities also enhances the student’s academic service experience by connecting them with the community, promoting a positive community image for the local high school, college, or university, and breaking down stereotypes about college students and academia in general. Incidentally, we have found that many current undergraduate students have very little knowledge of the current J.K. Rowling Harry Potter literary series.¹⁻⁵ This is easily addressed by showing the Harry Potter movie series to student volunteers before the scheduled outreach activity and their training sessions.

Conclusions

To date we have conducted fifteen outreach visits using the Harry Potter transfiguration test in a variety of elementary schools in Colorado. We have trained more than 300 university undergraduate volunteers in 30-minute training sessions and we plan to continue to provide our outreach services to local school districts. We also plan to provide requisite materials and training to elementary school teachers, so that they might conduct these activities independently in their own classrooms without lead from

Colorado State University's Chemistry Club. We are also in the process of developing additional activities based on a similar theme that addresses additional Colorado Model Content Standards for Science for a variety of grade levels. Standard assessment protocols can be applied by education professionals to evaluate student retention and comprehension, and validate achievement of science standards.

Descriptive outreach activity lab packets containing explicit instructions to conduct this activity, insights and outcomes assessment and analysis for both college and high school science departments, and for elementary school teachers are available upon request through the Department of Chemistry, Colorado State University, Fort Collins, Colorado, 80523-1872 USA; <http://www.chm.colostate.edu>; tel: 970 491 6381.

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Scheme 1. Flow Chart of Transfiguration Activity Concept Development and Approximate Time Requirements.

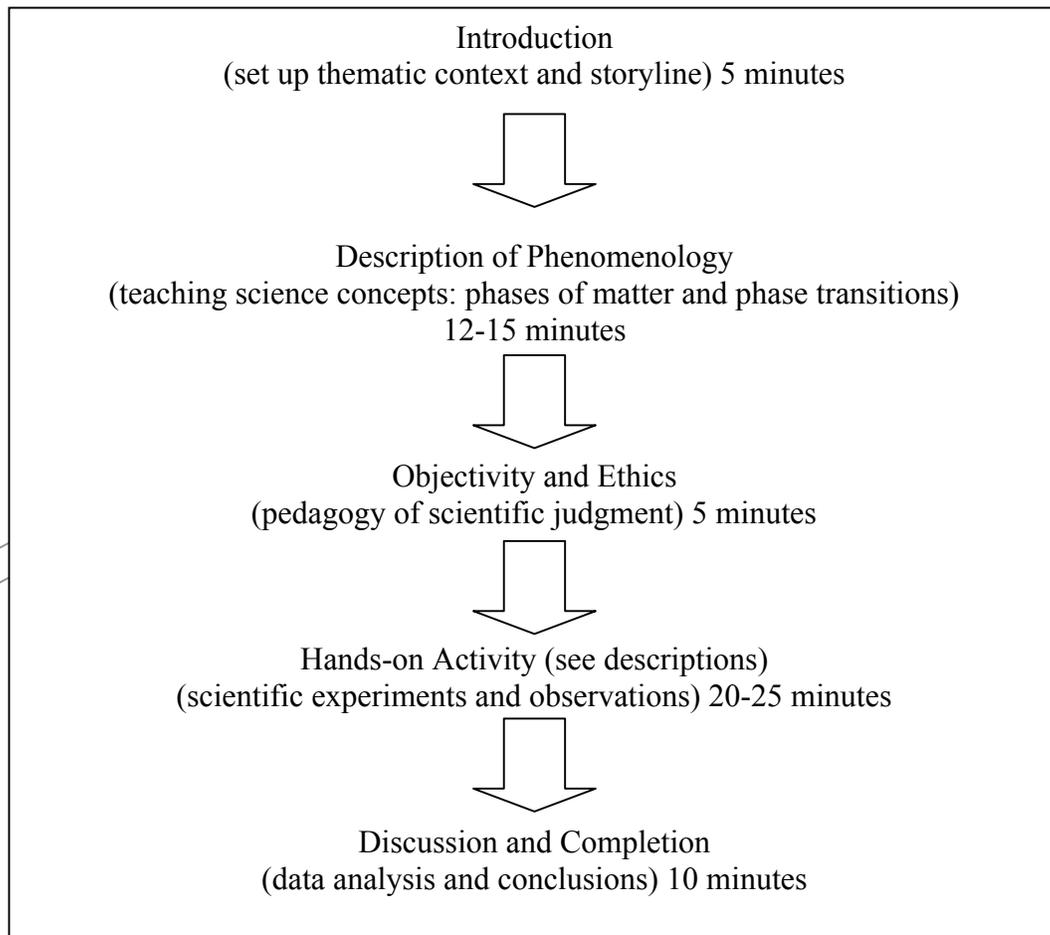


Figure 1. Student Data Worksheet for the Transfiguration Activity.

OFFICIAL CERTIFIED
HOGWART'S WIZARD GRADER
NAME _____



**Transfiguration Lab:
Properties of Substances**



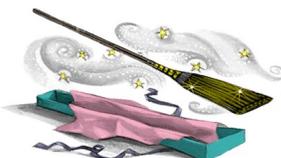
Teaching Keywords: phase change, states of matter, solids, liquids and gases. Professor McGonagall has instructed Harry Potter, Hermione Granger, Ron Weasley and Draco Malfoy to create two substances that transfigure through all three states of matter upon mixing. It is your job as official *Hogwart's Wizard graders* to determine and record, whether or not Harry Potter, Hermione Granger, Ron Weasley and Draco Malfoy have completed their transfiguration test.

Each student has submitted 2 substances that are supposed to transfigure upon mixing. Be sure to follow the directions given for each submission. You must record all observed phases of matter for each student's submission.

Put an X in the appropriate box below if you observe any state of matter in either the beginning substances or in the substance created by the transfiguration.

	Harry Potter	Hermione Granger	Ron Weasley	Draco Malfoy
Solid				
Liquid				
Gas				
Did they pass the test? Yes or No				

Keep in mind that students may not pass the test. It is even possible that no one will pass the test. If no one passes the test, you must decide who came the closest. You should base your decision on whose transfiguration went through the most phases of matter.



Observations:

Write down color changes, odors and anything else you notice about the beginning or ending substances.

	Harry Potter	Hermione Granger	Ron Weasley	Draco Malfoy

Draw a picture of each reaction below the students' name and indicate the phases of matter that are present. Use colored pencils, markers or crayons to indicate the colors of the solutions.

Harry Potter

Hermione Granger

Ron Weasley

Draco Malfoy

Figure 2. Official Hogwart's Wizard Grader Badges using 2160 Avery™ Mini Address labels and an inkjet printer.



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Table 1. Completed Sample Data Analysis Table for Elementary Student Activities.

	Harry Potter	Hermione Granger	Ron Weasley	Draco Malfoy
Solid		X		X
Liquid	X	X	X	X
Gas	X		X	X
Did they pass the test? Yes or No	No	No	No	Yes

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