

Synthesizing Magnesium Oxide Through a 3D Experience

JTILT
Competition
Honorable
Mention

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This lesson received an Honorable Mention in the 2023 JTILT Lesson Plan Competition and was peer-reviewed.

OVERVIEW

This lesson is from the Types of Reactions unit in a High School Chemistry class and focuses on the synthesis of magnesium oxide. The purpose of this lesson is for students to conduct a lab experiment, and understand, at an atomic level, how the reaction occurs. In collaboration between a Chemistry teacher and Educational Technology faculty member, one three-dimensional (3D) experience was created to support the visualization of the reaction and minimize the students' misconceptions.

Topics: 3D Experiences, Chemistry, High School, Practical Lab Work, Safe Lab Experiences, Types of Reactions

Time: One 50-60 minute class

MATERIALS

- [Synthesis of Magnesium Oxide Worksheet](#) (DOCX)
- [Safety Briefing Outline](#) (DOCX)
- [Synthesis Instructions for Lab](#) (DOCX)
- Mobile device or computer per student
- Link or QR code to Synthesis Reaction 3D experience (see Support Materials)
- Lab Materials:
 - Safety goggles
 - Crucible
 - Strip of Magnesium
 - Tongs and/or heat proof glove
 - Bunsen burner
 - Clay triangle
 - Ring stand or tripod

CONTEXT-AT-A-GLANCE

Setting

This lesson took place at a suburban, all girls, Independent High School in the Northeastern United States.

Modality

Face-to-face

Class Structure

After an introduction of the content, a lab was facilitated. Then students completed a worksheet, which included a 3D experience about the reaction.

Organizational Norms

The school is bring your own device. Student cell phone use in class is teacher dependent. Students have access to an LMS and Office 365.

Learner Characteristics

Learners were 10th grade high school students between the ages of 14-16. 95% of the students had iOS devices (iPhones).

Instructor Characteristics

The Chemistry teacher has a master's degree and 15 years' experience teaching science. The Educational Technology faculty member has 17 years' experience teaching PK-12 and higher education and specializes in multimedia and emerging media design.

Development Rationale

The lesson objective is to engage students in the exploration of a synthesis and combustion reaction, to introduce chemical equations, and to write balanced equations.

Design Framework

Social Constructivist Design Theory

STANDARDS

The Next Generation Science Standards (2017) utilized in this lesson include HS PS1-1, HS PS1-2, and HS PS1-4. Core ideas around bonding and formula/equation construction in addition to cross cutting ideas about predictions, models, and patterns of reaction.

The International Society for Technology in Education ([ISTE], 2016) Standards for Students were utilized in this lesson, including 1.6.c.

The ISTE (2017) Standards for Educators were utilized in this lesson including 2.1.c, 2.4.a, 2.5.c, 2.6.b.

CONTEXT AND SETTING

This lesson was facilitated at a suburban, all girls, Independent High School in the Northeastern United States by a Chemistry teacher who has 15 years of experience teaching science and has a master's degree. The class is a year-long, college preparatory Chemistry class, which all sophomore's take at the school.

The Chemistry teacher and an Educational Technology faculty member at an Institute of Higher Education collaborated over a year to create 3D experiences to enhance the traditional lab work and support the abstract, submicroscopic concepts with detailed examples. Submicroscopic Chemistry concepts are often difficult for students to grasp (Bakar et al., 2019), and various strategies such as lab experiments, 2D images, and models (e.g., ball and stick) are used to support these concepts (Muljana et al., 2020, 2023; Summerlin & Borgford, 1989; Tatli & Ayas, 2012). Unfortunately, these strategies lack specific information about the atomic interactions (Harrison & Treagust, 2000; Muljana et al., 2020), and existing 3D models, aimed at teaching theoretical Chemistry concepts, are inaccurate or not designed for HS levels of understanding (Muljana et al., 2020). Due to these limitations, we decided to design 3D experiences for various Chemistry units that specifically address student misconceptions identified by the Chemistry teacher (see next section).

This lesson is a face-to-face lesson that combines lab work and a 3D experience to make links from

observed phenomena (lab work) to atomic rearrangement (3D experience) and the chemical equation. This lesson occurs in the third quarter of the year, typically in April. At this point, students have been enrolled in the Chemistry course with the same teacher for six months.

STUDENT MISCONCEPTIONS

Students develop misconceptions when they struggle to link macroscopic observations with the behavior of atoms and ions as they react. Some of these include:

- Failure to link oxidation (addition of oxygen) with combustion reactions.
- Failing to link the creation of an oxide to an increase in mass-students often believe that gases have no mass, so they assume that adding oxygen has no effect.
- Struggling to link the lab observations and the chemical equations that represent them.
- Struggling with the concept of conservation of mass/atom economy-atoms and gases have no mass is a common misconception to carry from early childhood.

The aim of this lesson sequence was to address the content and the misconceptions through the supplementary addition of a 3-dimensional (3D) interactive experience. This 3D experience aimed to mimic the lab experiments and allowed students to witness the ionic/atomic level interactions and make a conscious link to the chemical equations that represent what they are witnessing.

STUDENT USE OF TECHNOLOGY

At the beginning of the year, the students were asked about using technology for their learning. Questions were focused on the technical skills of the students and preferences for using technology for science (Table 1). Overall, the students knew which apps to use on their phone for QR codes and how to access a link after scanning a QR code. Students primarily preferred a physical piece of paper for their work, but did like having access to the digital version, with most students preferring to handwrite their answers.

Table 1

Student technical skills and preferences for using technology for their science learning.

Question	Agree	Disagree
I know which application to use for QR codes on my phone.	82.86%	17.14%
I know how to access the link after scanning a QR code.	88.57%	11.43%
I prefer to handwrite my answers in science class. ^a	65.71%	25.71%
I prefer a physical piece of paper for my work.	82.86%	17.14%
I like having access to a digital version of the worksheet.	88.57%	11.43%

^a8.57% of students responded with "either works" or "it depends."

Note. Percentages are based on consenting participants ($N = 35$; 79.55%) with IRB approval.

PRIOR INSTRUCTION

At the beginning of the year, students learned about the expectations of safely working in a lab. Students received written and verbal instructions, were introduced to the lab materials, and had worksheets and other activities to demonstrate lab safety. The specific safety concerns for the lab portion of this lesson should be reiterated to the class to ensure no confusion (see Safety Briefing Outline).

At the time of this lesson, the students were also familiar with the appropriate use of technology in the classroom, including when to use their phones and when not to, and how to scan QR codes to access the 3D experiences. At the beginning of the year, students received coaching on technology use in the classroom and lab and how to scan QR codes and access QR code content. These technology skills were then utilized in each unit leading up to this lesson, so, by the time of this lesson, the students were familiar with the appropriate use of technology in the classroom.

DETAILED SETUP

LAB SETUP

For this lesson, lab equipment was set up in stations around the practical experiment area of the room (Figure 1). Each station had the equipment needed for the lab experiment, which includes:

- Crucible
- Strip of Magnesium
- Tongs and/or heat proof glove
- Bunsen burner
- Clay triangle
- Ring stand or tripod



Figure 1. Image of the lab equipment set up in a station. Safety goggles should be included.

Instructions and safety briefings were provided both on paper and verbally (see Safety Briefing Outline). Safety equipment includes:

- Safety goggles for each student,
- Heat proof gloves for each group,
- Access to a safety shower and cold water in case of burns, and
- Dustpan and brush in case of breakages.

Set up for the lab takes about 10-15 minutes before class begins. The safety briefing and instructions (see Safety Briefing Outline) take about 7 to 10 minutes depending on the nature and experience of the students.

WORKSHEETS

The Synthesis of Magnesium Oxide Worksheet was handed out and discussed before the lab began and completed after the practical work was finished. The Synthesis of Magnesium Oxide Worksheet should be reviewed by the teacher prior to the lesson to ensure all the information is correct and links/QR codes to the 3D experience is working.

3D EXPERIENCE

The 3D experience was designed and developed, in the Vectary platform, collaboratively between the HS Chemistry teacher and an Educational Technology faculty member using Rapid Prototyping (Tripp & Bichelmeyer, 1990). This experience is linked in the worksheet with a QR code (see Support Materials a link to the 3D experience). Students were expected to access this experience using their mobile devices once the lab work was completed and they were focused on the worksheet. The worksheet and 3D experience take about 15 to 20 minutes and could be completed at home or at the start of the next class if necessary.

SOCIAL CONSTRUCTIVIST DESIGN THEORY

Collaborative learning allows students to discuss what they observe, make sense of it, and draw conclusions about what has taken place. The three social constructivist design theory elements, "personal interpretation of experience," an "active process," and "multiple perspectives" (Richey et al., 2011, p. 130), supports Chemistry learning in both the lab work and classwork.

The lab work, which is completed in pairs or small groups, supports active learning, and allows the students to gain each other's perspectives as they complete the experiment. The 3D experience supports the students in visualizing the interaction of atoms/ions in the reaction. The students can construct their own interpretation of the reaction, which is then assessed through peer discussion of their responses and the equation representing the reaction, and by the teacher through submission of lab worksheets. This collaboration gives students confidence about sharing their answers as the work is dissociated from them and is a shared responsibility.

LEARNING REPRESENTATION

SEQUENCE OF LESSONS IN THE UNIT

This lesson is part of a unit on types of reactions in Chemistry. The unit is an engaging exploration for students and can be used to introduce more complex chemical equations and the process of writing balanced equations. The sequencing of reactions in the unit is immaterial, but this lesson involves the use of a Bunsen burner, so it is not usually first in the sequence of lessons in the unit, as the students are unfamiliar or nervous of the Bunsen burner. Placing this lesson later in the sequence ensures students' confidence in prior lab work. This unit is taught to students around April of the school year, so they are experienced in lab work and following safety protocols.

BELL WORK

The class begins with a review of the reactions the students have met so far in the unit. This bell work takes about 5-15 minutes of the 50-60 minute class. The students are asked some quick to answer recall questions about a previous reaction type or accompanying equations to stimulate thinking about Chemistry. The questions used depend on the content taught prior to this lesson. A short activity or demonstration can also be used such as a simple combustion (e.g., a candle flame) and eliciting prior knowledge of combustion reactions. This time should be used to introduce the lab, review safety procedures, and equipment handling (see Safety Briefing Outline).

LAB WORK

Once the bell work is complete, transition the pairs or small groups of students to the lab. Ensure that students have a suitable place to record their rough observations and a copy of the Synthesis Instructions for Lab that outlines the written procedure. Students could be provided with or acquire a small notebook at the start of the year where they record all rough notes and data. The small notebook has the advantage of avoiding lost single sheets of paper, protects their formal lesson notes from potential damage in the lab, and teaches students about the value of rough work

before completion and submission of the polished final version.

The lab equipment is laid out in stations around the room (Figure 1). Each station has all the items the group will need for their experiment except the magnesium ribbon which is kept in one place to facilitate control of access and ensure safe handling (see Lab Setup section for materials).

Distribute the magnesium strips to the pairs or small groups of students once the equipment is correctly set up. Refer to the Synthesis Instructions for Lab for specific details on the experiment. The pairs or groups of students carry out the combustion of a strip of magnesium in a porcelain crucible lifting the lid occasionally to allow an improved air supply (Figure 2). This is being done qualitatively not quantitatively so a 2-3 cm strip of magnesium ribbon will show the effect. This allows students to experience the macroscopic (visible) reaction at first hand and then discuss the phenomena observed to make sense of what was seen.

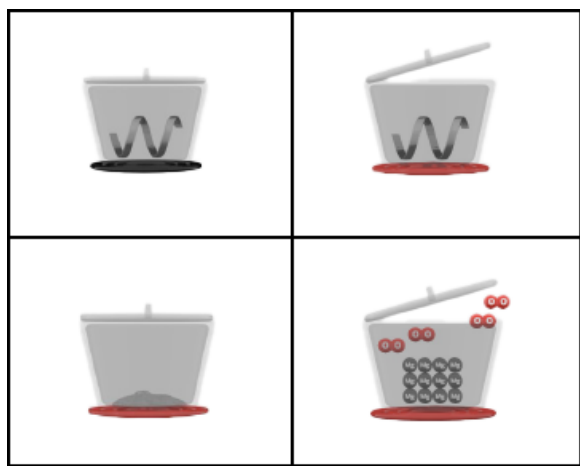


Figure 2. Four panel image of the lab from the 3D Experience.

Ensure safe working with students using tongs to move the hot crucible lid and then leave the hot crucible to cool at the end of the lab. The lab runs for about 15 to 20 minutes.

3D EXPERIENCE/WORKSHEET

Once the lab is complete and the students recorded the observations in their rough notes, students work collaboratively in their lab groups on the Synthesis of Magnesium Oxide Worksheet. The worksheet has a

QR code that gives students access to the 3D interactive experience on their mobile device. The questions on the worksheet ask about their macroscopic (lab) observations first. Students interpret their observations and experiences of the reaction in these questions.

The questions then ask students to think about combustion and the presence of oxygen. Students continue to work in their pairs or groups to create the word equations identifying the chemicals that are reacting (magnesium [Mg] and oxygen [O₂]) and write the chemical equations to represent the reaction. At this point, encourage the students to access the 3D experience on their mobile devices, and follow the instructions in the 3D experience to see a digital representation of the reaction. Instruct students to zoom in to see the ions reacting. This 3D experience is designed to help students make the link between observed phenomena and the chemical equations that represent the reaction. This follows on from previous work that has been done on patterns of reactions in the periodic table caused by changes in the valence electron arrangements to form ions. It is not essential that students balance the equation unless that has been previously taught, but it is essential to create correct formulas for the elements and compounds involved and be able to identify the types of bonding in each.

ENDING DISCUSSION

After the students finish the lab work and worksheet, gather the class for students to share out the answers from the groups. This provides students with reassurance that the experiences and observations between groups were similar. Reviewing the word and chemical equations together allows the teacher to reinforce the use of the 3D experience and help guide the connection between macroscopic and atomic level thinking, as well as question the students on patterns of reactivity, energy storage changes, bonding, and formula construction. The aim is to ensure students connect the interaction between the reactants (Mg and O₂) and the products being formed (MgO) at the atomic level with the observed disappearance of metal (magnesium strip) and formation of gray ash (MgO). This is an area where students often struggle, so stressing the connection of the submicroscopic, atomic version that the 3D experience shows with the macroscopic observation during the lab with the final chemical equation created by the students is a

worthwhile investment of time. Further examples of synthesis (i.e., combustion) reactions are given on the worksheet and could be completed for homework with the expectation of students creating word and chemical equations for each.

CRITICAL REFLECTION

CHEMISTRY TEACHER REFLECTION

This is the sixth time I have implemented this unit of learning at my current school. For the Bell Work, a more constructivist approach would be followed if the questions focused on the concept of a combustion or synthesis reaction. I suggest using this Bell Work activation time to look at observations around the candle flame example by demonstrating how it can be relit from the hot wax vapor rather than the wick, the chemicals involved in and produced by combustion, and the various components of the flame. When implemented again, I plan to ask students about their prior knowledge of combustion reactions generally and engage them in a discussion of how combustion reactions occur and the witnessed energy storage changes. During this discussion, I will check for student understanding of the concepts by considering and asking questions such as:

- Can the students give examples?
- Can the students identify the 3 parts of the fire triangle, so they know how to extinguish a combustion reaction?
- Can the students explain how the actions to extinguish a fire work and relate this to energy storage changes?
- Can the students discuss the removal of fuel, removal of oxygen, or cooling and what these looks like in action?
- Can the students identify the chemicals involved in their combustion reaction example?

Although these questions are not directly connected to combustion reactions, they would help students realize that combustion is something with which they are familiar and relate the use of oxygen in reactions to this activity.

After the lesson, I find that students continue to struggle with chemical equations into the next unit, but this seems to stem from an earlier misconception

about the construction of ionic and covalent formulas, which manifested when writing equations. In future I will alter how the concept of ionic and covalent formulas are introduced to try and prevent this confusion. The timing of when to introduce the idea of atom economy and balanced equations is a topic of discussion every year amongst the faculty. I find introducing these items is easiest when students notice that the atom counts are not equal on each side. When that occurs, I encourage them to focus on having the correct formulas for the compound, and then to start balancing the number of atoms in the equations.

In the past, the combination of lab and worksheet in one lesson required 60 minutes. Due to schedule changes this year, we have 50 minute blocks, so the lesson will need to be modified. Modifications could include holding the collaborative equation writing and discussion in a subsequent lesson or having the equation writing become an individual activity assigned for homework with an asynchronous discussion on a technology tool such as Flip.

EDUCATIONAL TECHNOLOGY FACULTY REFLECTION

I was not present for the teaching of this lesson but supported the design of the 3D experience before the lesson and made updates to the design after the lesson. This was the 15th 3D experience built between the Chemistry teacher and me. After the initial discussion and 3D build, the only update completed was the equation at the end of the experience. The original equation was not balanced, which supported the students' confusion of balancing equations. This equation was updated to the balanced equation, $\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$, displayed on the screen at the end of the 3D experience.

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SUPPORT MATERIALS

The link is for the Synthesis Reaction 3D experience and appears in the Synthesis of Magnesium Oxide Worksheet: <https://app.vectary.com/p/4R19D9Z9QVtrnpGp7cm8sY>

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