The Use and Abuse of the Haber-Bosch Process

by Jessica Young, 2022 CTI Fellow
Cochrane Collegiate Academy

This curriculum unit is recommended for:
7th Grade Social Studies - The Modern World

Keywords: PBL, project based learning, DBQ, data based question, World War I, World War II, fertilizer, Haber-Bosch reaction

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: Scientific discoveries are neither positive nor negative. Most scientists, in fact, set out to help the world. However, with every new discovery comes a new risk. Technological advances can be utilized for good or evil, depending on who is in charge. The Haber-Bosch reaction, discovered and refined before World War I, is one such example. Haber, a Jewish scientist, set out to make nitrogen from the air useful as a fertilizer. Without his invention, the world would have starved within 30 years. Bosch, another Jewish scientist, engineered a way to produce ammonia, the usable form of nitrogen, in mass quantities. However, at the start of World War I their process was used to produce explosives. The labs they led researched synthetic rubber and gasoline. Haber, a nationalist, discovered and weaponized deadly mustard gas. And, to bring it back around, elements in mustard gas were found to eliminate white blood cell cancers. So, throughout history, have scientific advances helped or harmed the world? Do they promote equality, or just bolster those in power? Using an inquiry-based model, students will analyze the benefits and consequences of the Haber-Bosch process. Students will use a variety of readings about the process, World War I, and current events to answer the data-based question.

Introduction

Rationale

In the middle grades, students continue to expand their understanding of the past and of historical concepts and inquiry. They also begin a more in depth study of World History which begins with the study of early humans in sixth grade and extends up to to modern day current events in the seventh grade. In eighth grade, students focus on the study of United States History from exploration through modern day current events. Students begin to understand and appreciate differences in historical perspectives by recognizing that individual experiences, societal values, and cultural traditions influence interpretation of historical events. They discover that science and technology bring changes that can affect values and beliefs.[1]

Demographics

I teach 7th grade science and social studies at Cochrane Collegiate Academy. Cochrane is a Title I middle school in East Charlotte that shares a campus and resources with iMeck High School. They have access to CTE and AVID programs as well as a career and college readiness track. Cochrane received and 'F' on it's most recent school report card, indicating low student achievement and growth on standardized tests.

The student population of CCiA is 66.00% hispanic/latino, 26.90% black or African American, 3.40% Asian, 2.70% caucasion or white, 0.30% native Hawaiian or other pacific islander, 0.20% native American, and 0.40% two or more races. In addition, 90% of students receive free/reduced lunch, 36% have limited English proficiency, and 8% receive special education. There are 56 classroom teachers to serve grades 6-12 grade levels and a total of 959 students.[2]

Unit Goals

Seventh grade social studies focuses on patterns of continuity and change in world history from the Great Global Convergence (1400-1800) to the Present. In this unit, students will apply critical thinking skills to form their own conclusions about the pros and cons of technological advances throughout history. Often, advances are meant to help the general populous but are easily misused by those in or seaking power.

The use of project based learning, specifically the data-based question format, will allow students to read and evaluate primary sources and learn through inquiry. After learning about background information and researching the topic more thoroughly in a variety of documents, students will decide if technological advances help or hinder humanity's quest for equality throughout history.

In this particular unit, students will focus on the Haber-Bosch reaction and its effects on World Wars I and II. They will read about the science behind the development, and well as its positive

---

[1] *Charlotte-Mecklenburg Schools.*

[2] Summary report.

and negative effects. Ultimately, students will create a project supporting their point of view. This project may be an essay, slideshow, infographic, speech, or video.

For more detailed information about standards, please see Appendix 1.

The Issue: Starvation

In 1898, the president of the British Academy of Sciences, Sir William Crookes, announced that the world was in peril. The population was increasing at such a rapid rate that there would not be enough food to sustain humanity by 1930. While traditional farming methods across the world had so far managed to replenish nitrogen in the soil through crop rotation and fertilization, there was only so much land available and the more it was farmed the less fertile it would become. In addition, there were fewer farmers to work the land, and more mouths to feed in cities, due to the industrial revolution.

Natural Solution: Sources of Nitrogen

Phosphorus, potassium, and nitrogen, especially, are essential for healthy crop development. Nitrogen is a limiting factor for plant growth; more nitrogen in the soil means potential for more plants, less nitrogen means fewer plants. Nitrogen is found naturally in manure, compost, and the air. In fact, nearly 80% of the air is nitrogen but is not accessible to plants. Before nitrogen could be processed synthetically, nitrogen-rich fertilizer was difficult to come by. In addition to compost and manure, nitrogen was available in the more concentrated form of saltpeter. Saltpeter was white salt collected from stone walls, especially underground. It was slow to form and tedious to collect. Saltpeter plantations formed, where heaps of manure, soil, ashes, and garbage were wetted with urine and left to crystallize in the sun. Saltire, a similar crystal found in the Tarapaca desert of South America, also made adequate fertilizer and gunpowder. By the 1830s, seabird manure, or guano, became a popular fertilizer in Europe and a valuable commodity. Peruvian guano, the most nitrogen-rich manure available, had formed over generations and would eventually run out. Germany, as a mostly landlocked country, had difficulty reaching South America, even if guano supplies weren't dwindling by the 1870s.[5]

Scientific Solution: Haber's Process

Nitrogen in the air forms a triple bond, which is extremely difficult to break. Ammonia, on the other hand, has three single covalent bonds which are much easier to break. In order to synthesize ammonia (NH3) from the air, Haber needed extreme pressure, heat, and a catalyst. were that they needed a catalyst that was readily available and created enough ammonia to make the whole endeavor worthwhile. At first, Haber found that the method needed extreme pressure and a rare element called osmium as a catalyst. The nitrogen from the air combined with hydrogen from other natural gasses to create ammonia. His machine had worked, but only on a very small scale. The chamber was carved out of a single piece of quartz.

Haber: The Man

Fritz Haber was a fiercely nationalistic German, Jewish chemist. Even before the Nazi's took control of Germany, German jews were ostracized by polite, Christian, society. As scientists, bankers, and jewelry makers, German Jews could achieve some renown, but they were never quite accepted as fully German.

Haber's process for harvesting nitrogen from the air, developed just before World War I, may well be the beginning of the modern era.[2] Haber, a German chemist, patented a process for creating synthetic ammonia, from nitrogen, in 1908 and won the Nobel Prize for it in 1918.[3] While Haber invented the process, Carl Bosch, industrialized it so that it could be used on a large scale.[4]

Industrial Scale: Bosch's Machinery

To increase the scale of the operation, Bosch not only needed to change the catalyst, but build a machine that could withstand extreme pressure. Bosch had experience with machinery and was able to engineer such a device. Bosch tried to enhance the size and output of the chamber, but later decided that the strength of the metal did not matter quite as much as the pressure. In turn, the flexibility of the steel walls was allowed. so long as the process still worked. The steel liners would eventually need to be replaced.

Immediate Implications

During World War I, maritime blockades made it impossible for Germany to trade with South America, but the Germans were able to produce their own fertilizer using the Haber-Bosch process.[5] The process enabled Germans to feed their country and military without relying on Peruvian Guano or Chilean nitrates. The Haber-Bosch process and the nitrogen it produced increased the length of the war by an estimated one to two years. Without it, Germany would not have been able to survive the international embargo.[8]

In addition, the nitrates necessary for fertilizer could also be used to make explosives. Before World War I, three-quarters of every barrel of gunpowder was saltpeter. South American saltire could also be turned into a true saltpeter by switching just one atom. From there, another small chemical alteration turned it into nitric acid, the basis for a whole new generation of powerful explosives. Nearly half of Germany's munitions in WWI evolved from the Haber-Bosch process. This combination of industrialization and scientific advance continued during WWII with nuclear weapons.

Haber and his inventions powered Nazi Germany (p.262) In fact, the Haber-Bosch process for synthesizing ammonia was used to make both fertilizer and gunpowder.[3] In addition, Haber invented lethal chlorine, also known as mustard gas. These chemical weapons already fell into the gray area of war at their creation. Since the gas was released by canisters, already used for other wartime weapons, they were technically not against the Hague Conventions. Plus, the

[3] Janes, Lauren

French and British were already using tear gas. However, using deadly chemical weapons set a dangerous precedent. Even German generals were reluctant to use the weapons that depended upon a favorable wind and impeccable timing. After months, the weapons were eventually released, destroying a portion of the forward French troops, but Germans were so scared of the gas that they did not take full advantage of the break in the front line. In addition, Germans worried about enemies utilizing the same innovations against them. In this way, the combination of science and industrialization that produced mustard gas and the Haber-Bosch process is often referred to as the precursor to the Manhattan Project and the creation and use of nuclear bombs during World War II.

The factory run by Baden Aniline and Soda Factory, or BASF, to produce ammonia could also be used to make synthetic gasoline and artificial rubber. Without these innovations, Hilter would not have been able to wage his war on the rest of Europe.

Future Implications

Since 1898 the human population has doubled and doubled again. The increased crop yield due to nitrogen from the Haber-Bosch process made populations boom in many countries later in the 1900s. For his contributions to feeding the world, Fritz Haber was awarded the Nobel Prize in Chemistry in 1918.[4] We are now on the brink of 8 billion people, and eating more average calories than people of the late 1800s. Half of our current population would not survive, even cutting back calories and eating a vegetarian diet, if not for the nitrogen provided by the Haber-Bosch process. The rest of the population would starve. However, we have created an unsustainable population. There is no way to naturally feed everyone.

There is also a world-wide obesity epidemic made possible by the Haber-Bosch process. In 35 years, China went from the extreme famine of the cultural revolution to the current obesity epidemic. The rest of the world too, has more readily available calories from meat, oil, and fatty foods supported by the Haber-Bosch process.

The Haber-Bosch process requires a great deal of energy and fuel, with an enormous carbon footprint. Excess nitrates from fertilizer are responsible for damaging much of our planet's waterways and ecosystems. As nitrate levels rise, aquatic animals and plants are suffocating. Algae blooms kill crustaceans, plants, and fish that do not flee. A dead zone the size of New Jersey continues to grow in the Gulf of Mexico. At least 150 more dead zones exist around the world. Even in areas not yet considered a dead zone, the excess nitrogen permeates soil, water, and air. It comes back down as acid rain, and destabilizes ecosystems.

Instructional Implementation

Teaching Strategies:

[4] Naufal, P.

- DBQ[5]
- PBL[6]
- Inquiry Based Learning[7]
- Paideia and Socratic Seminars[8]

Classroom Lessons/Activities-
The activities below can be completed in three to four 90 minute class periods. Steps 1-3 can be completed in one block, steps 4-5 in another block, and step 6a, the socratic seminar, and step 6b, the essay, can be covered in one or two blocks.

Student resources:
Background Video: https://www.youtube.com/watch?v=hK4vXKaBJko&t=30s
Extended War:
https://medium.com/discourse/the-germans-created-gunpowder-food-from-thin-air-a2729f8148f8
Advancement:
Nobel Prize
Haber was a smart, ambitious scientist
https://link.springer.com/chapter/10.1007/978-3-319-19357-1_6
Haber controversial
https://blogs.unimelb.edu.au/sciencecommunication/2016/10/06/fritz-habers-legacy-the-good-and-the-bad/

haber, wife, chemistry, fed billions, death is death, mustard gas, chemotherapy
https://timeline.com/the-father-of-chemical-warfare-had-a-wife-who-tried-to-stop-him-65fc37a10357

poison gas made at his lab post death used on jewish relatives in concetration camp, wife
https://www.smithsonianmag.com/history/fritz-habers-experiments-in-life-and-death-114161301/

war ended sooner w chemical weapons, lives saved (though like drowning on land) Hague Conventions
millions of shells remain (alchemy of air)

Unit 6: World Wars / Conflict **Topic:** The Use and Abuse of Technological Advances WWI - Present	
Standards	7.C&G.1.1 Explain how the power and authority of various types of governments have created

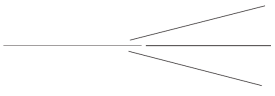
[5] *The DBQ Project*.
[6] *What is PBL?*
[7] Khalid Khalaf, B.
[8] Our approach.

	conflict that has led to change. 7.E.1.4 Explain how competition for resources affects the economic relationship among nations. 7.H.1.1 Distinguish specific turning points of modern world history in terms of lasting impact. I.1.5 Identify evidence that draws information from multiple perspectives.	
Essential Question	Have technological advances like the Haber-Bosch reaction, helped or harmed the world?	
Lesson Component[9]	**Directions**	**Resources**
Step 1: The Hook Exercise Engages students and orients them to the question.	To warm up, students will answer the question: Do you feel technological innovations are helpful or harmful…? Explain. Students will share their thoughts with partners or small groups, then with the whole class.	Hook: "Did you realize that one-third of the nitrogen atoms in your body did not come from nature? That the food that we eat contains amino acids, that nitrogen originally came from fertilizer, and most of that fertilizer, almost all, came from chemical factories? They, in turn, extract that nitrogen from the atmosphere using a process called the Haber Process – so the fact that we and billions of other people are not starving to death is a direct result of the invention of the Haber Process."[10]
Step 2: The Background Essay	Define terms 5Ws questions ● Who ● What	Background material: The Haber-Bosch Process: Nitrogen Fixing the World.

[9] Lesson components and their descriptions are from the DBQ website. https://www.dbqproject.com/.

[10] *Is science morally neutral?*

Further orients students to the question and provides essential context that helps make sense of the documents.	• When • Where • Why Teacher will ask students to choose a side, then present background material. After the video, review arguments in favor and against the Haber-Bosch process. Have students revisit personal opinion: Do you feel technological innovations are helpful or harmful…? Explain.	Arguments in favor: 1. fertilizer supports population, prevented starvation, started green revolution 2. Haber, the inventor, won a Nobel Prize 3. Many other scientific advances, like nuclear power and chemotherapy, evolved from Haber's contributions Arguments against: 1. Dangerous: created gunpowder and lengthened the war 2. Led to unsustainable population growth 3. High energy needs / carbon footprint
Step 3: Understanding the Question and Pre-bucketing Helps students plan so they can target their investigation of the documents. Clarifying the question motivates students to start reading their sources to find answers.	Helps students plan so they can target their investigation of the documents. Clarifying the question motivates students to start reading their sources to find answers. Understanding the Question 1. What is the analytical question asked by this DBQ? 2. What terms in the question need to be defined? 3. Rewrite the question in your own words.	Graphic Organizer: 

	Pre-Bucketing Directions: Using any clues from the DBQ question, create possible analytical categories and label the buckets. Examples: The Haber-Bosch Process: 1. Saved people 2. Elongated war 3. Caused environmental issues	
Step 4: Analyzing the Documents It's like you're a detective! The documents provide clues and evidence students need to support their thesis or claim. They provide the knowledge and information students need to answer the question.	Read and annotate documents.	Document Analysis Sheet Documents (see Appendix 2)
Step 5: Bucketing: Getting Ready to Write	Helps students get organized. Buckets become containers for evidence that students use to categorize or group evidence from the documents. Look over all the documents and organize them into your final buckets. Write labels under each bucket and place the letters of the documents in the buckets where they belong. Thesis Development and	Bucket Graphic Organizer:  Chickenfoot Graphic Organizer: 

	Road Map On the chickenfoot below, write your thesis and your road map. Your thesis is always an opinion that answers the DBQ question. The road map is created from your bucket labels and lists the topic areas you will examine in order to prove your thesis.	
Step 6A: The Thrash-Out and Preparing to Write	Socratic seminar or debate Students prepare to write by debating or "thrashing-out" their answer to the question. Students practice using evidence from the documents to support and verbally validate their claims. They use what they learn to outline their final project.	Socratic Seminar Graphic Organizer[11]
Step 6B: Final Project	The project or performance task may be an essay, slideshow, infographic, speech, or video. Student projects should be evidence-based using their documents, buckets, and outlines to support and explain their reasoning.	DBQ Graphic Organizer[12]

Assessments

[11] Socratic Seminar Template and Samples.
[12] Thinking Nation.

Notes and participation in class discussion may be used to assess learning throughout the unit. The final project will serve as a test grade. The project or performance task may be an essay, slideshow, infographic, speech, or video.

Bibliography

Brown, Erik. "The Germans Created Gunpowder & Food from Thin Air." Medium. Dialogue & Discourse, June 9, 2019. https://medium.com/discourse/the-germans-created-gunpowder-food-from-thin-air-a2729f8148f8.

Charlotte-Mecklenburg Schools / Homepage. / Homepage. (n.d.). https://www.cmsk12.org/

Hager, Thomas. *The Alchemy of Air*. *Amazon Kindle*. New York, NY: Crown, 2009. https://read.amazon.com/?ref_=dbs_p_ebk_r00_pbcb_rnvc00&_encoding=UTF8&asin=B001EUGCTS.

Is science morally neutral? The curious case of Fritz Haber. Sinai and Synapses. (2022, September 15). https://sinaiandsynapses.org/content/is-science-morally-neutral-the-curious-case-of-fritz-haber/.

Janes, Lauren, April Merleaux, Helen Zoe Veit, Alice Weinreb & Samuel Yamashita (2019) World War I and the Origins of the Modern Food System, Global Food History, 5:3, 224-238, DOI: 10.1080/20549547.2019.1666647.

Khalid Khalaf, B., & Bt Mohammed Zin, Z. (2018). Traditional and Inquiry-Based Learning Pedagogy: A Systematic Critical Review. International Journal of Instruction.

Naufal, P. (2016, October 6). *Scientific scribbles*. Scientific Scribbles. https://blogs.unimelb.edu.au/sciencecommunication/2016/10/06/fritz-habers-legacy-the-good-and-the-bad/.

O'Connor, A. (2014). Arsenal Of Chemistry: The Haber Bosch Process and the Great War. *The Undergraduate Historical Journal at UC Merced*, 2(1). http://dx.doi.org/10.5070/H321025693 Retrieved from https://escholarship.org/uc/item/4d1768q0.

Our Approach. National Paideia Center. (n.d.). Retrieved November 19, 2022, from https://www.paideia.org/our-approach.

Ritter, Steven K. "The Haber-Bosch Reaction: An Early Chemical Impact On Sustainability." cen.acs.org. Chemical and Engineering News, 2008. https://cen.acs.org/articles/86/i33/Haber-Bosch-Reaction-Early-Chemical.html.

Socratic Seminar Template and Samples. (n.d.). https://www.ccsoh.us/cms/lib/OH01913306/Centricity/Domain/207/Socratic%20Seminar%20Template%20and%20Samples.pdf.

Summary report. (n.d.). https://www.indistar.org/app/Reports/SummaryReport.aspx.

The DBQ Project. The DBQ Project. (2020, March 11). https://www.dbqproject.com/.

"The Nobel Prize in Chemistry 1918." NobelPrize.org. https://www.nobelprize.org/prizes/chemistry/1918/summary/.

Thinking Nation. (2022). DBQ Graphic Organizers. https://www.thinkingnation.org/wp-content/uploads/2022/02/CCSS-Blank-HTS-Graphic-Organizers.pdf.

What is PBL? PBLWorks. (n.d.). Retrieved November 19, 2022, from https://www.pblworks.org/what-is-pbl.

"What Is the Haber Bosch Process and Its Ecological and Human Impact?" Youmatter, June 2, 2020. https://youmatter.world/en/definition/what-haber-bosch-process-ecological-impact/.

Appendix 1: *Teaching Standards*

7.E.1 Understand the economic activities of modern societies and regions.
- 7.E.1.1 Explain the factors and conditions that contribute to the development of economic systems.
- 7.E.1.2 Explain how national and international economic decisions reflect and impact the interdependency of societies.
- 7.E.1.3 Summarize the economic activity fostered by various economic systems. 7.E.1.4 Explain how competition for resources affect the economic relationship among nations.
- 7.E.1.5 Explain how economic systems have led to the transformation of various regions around the world and indigenous ways of life.

7.B.1 Understand how individual and group values and beliefs have influenced various cultures.
- 7.B.1.1 Compare major elements of culture in various modern societies around the world.
- 7.B.1.2 Explain how values and beliefs affect human rights, justice, and equality for different group sof people.
- 7.B.1.3 Compare how individuals and groups respondto stereotypes, oppression, human rights violations, and genocide.

7.H.1 Evaluate historical and current events from a variety of perspectives.
- 7.H.1.1 Distinguish specific turning points of modern world history in terms of lasting impact.

7.H.1.2Summarize the influence women, indigenous,racial, ethnic, political, and religious groups have had on historical events and current global issues.
7.H.1.3 Compare individual and societal responses to globalization in various regions and societies.
7.H.1.5 Explain how slavery, xenophobia, disenfranchisement,ethnocentrism, and intolerance have affected individuals and groups in modern world history.

7.G.1 Understand ways in which geographical factors influence societies
7.G.1.1 Explain how push-pull factors of forced and voluntary migrations have affected societies around the world.
7.G.1.2 Explain reasons why societies modify and adapt to the environment.
7.G.1.3 Explain the influence of demographic shifts on societies using geographic tools and data.