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Yes, You Can Do NGSS
How I Learned to Love the Standards, Thanks to a Little Professional Development and a Lot of Help from a Prehistoric Fish.
By Katherine Bryant

INTRODUCTION
As the standards in education change, veteran teachers sometimes struggle to change with them. The Next Generation Science Standards, along with the Michigan Science Standards, are a case in point. I am sure I am not alone in being intimidated by Three-Dimensional Learning and trying to incorporate Science and Engineering Practices (SEPs), Cross-Cutting Concepts (CCCs), and Disciplinary Core Ideas (DCIs) in every lesson. The only element most of us feel comfortable with is the DCIs, because we know our science.

To help teachers implement NGSS and MSS, plenty of training sessions have been offered across Michigan during the last four years, some of which I have attended. Nevertheless, at the end of the day when I sat at my desk and tried to plan lessons, I admit I still felt lost. True, Michigan Technological University’s Michigan Science Teaching and Assessment Reform program (Mi-STAR) is working hard to complete a middle school curriculum aligned with the standards, but as we await those Mi-STAR units, what is a science teacher to do? In my case, I decided to get out there and take advantage of more in-depth professional development. It turned out to be one of the best decisions I’ve made as a teacher. By the time I was done, I had created a unit worthy of the NGSS, reached more people than I could have ever imagined, and partnered with a wonderful organization devoted to saving one of Michigan’s most iconic—and threatened—species. Most importantly I enjoyed teaching this content, and the students enjoyed learning it. It was the most fun I had all year.

ANYONE CAN DO THIS
Before I proceed, I want you to understand that there is nothing special about me or my school. We are not a wealthy school, nor are we a magnet school of some sort. We are an urban school in a city that has been in decline since the crash of the auto industry in the 1970s. About 46 percent of our students qualify for free or reduced-cost lunches. Thus, while you
may not be able to recreate this particular unit, there is no reason you cannot develop equally amazing units of your own. I’m a regular teacher just as you are, and I believe any teacher can find success the way we have.

In summer 2017, frustrated with my apparent inability to incorporate the NGSS into my science classes, I signed up for Research Experiences for Teachers: Promoting Learning About Computational Tools and the Environment (RET:PLACE). Yes, it was a big commitment—six weeks in all—but the shorter NGSS workshops I had taken didn’t give me confidence that I could develop a unit aligned with the standards. RET:PLACE is held at Michigan Technological University, in Houghton, and led by Dr. Alex Mayer, chair of the Department of Civil and Environmental Engineering, and Noel Urban, professor of civil and environmental engineering. It paired secondary teachers with graduate students to create place-based units with a research component that would meet the NGSS and MSS. Our team included Tricia Benkert, also of the Saginaw Township Community Schools, and Ashley Hendricks, who was earning her M.S. in Environmental Engineering from Michigan Tech. Our goal was to create a research-based unit that had an actual impact on the place we live.

First and foremost, we had to choose a research topic, one that was interesting, place-based, and conducive to the use of modeling tools. Though we had several ideas, we finally settled on the lake sturgeon and named our unit Sturgeon Stewardship in the Saginaw Bay.

The sturgeon is a prehistoric fish that is native to Michigan—including our own school district—and has been around millions of years longer than the Great Lakes (Lake Sturgeon Biology, undated). It also offers a textbook example of the negative impact humans have had on the environment and wildlife, the consequences of those impacts, and what people can do to mitigate the harm they have done.

As we did our RET:PLACE research, we discovered Sturgeon for Tomorrow, a Michigan nonprofit based in Cheboygan County which is devoted to protecting and expanding lake sturgeon populations. Its Sturgeon in the Classroom program provides sturgeon fingerlings to teachers, who keep the sturgeon in their classes until spring of the school year. Then they are released into the waters where they were hatched. We decided to try to work this program into our unit. The application process was rigorous, but our principal was very supportive. We were thrilled when we were finally granted permission to raise a sturgeon. When it arrived, my students named it Bubbles.

**INCORPORATING THE THREE DS**

**Science and Engineering Practices (SEPs)**

We used many NGSS Science and Engineering Practices through this unit, including Developing and Using Models, which was a focus of RET:PLACE. To predict how long it would take the population of sturgeon at Black Lake to become self-sustaining, we used the free, web-based modeling tool Insight Maker. This was important both as a science lesson and as a research tool, because the students could use the information to forecast when extra sturgeon from the Black Lake area could be used to stock other areas of the state. For us to determine best management practices, we needed to know how often and how many sturgeon we should stock.
Another SEP we used was Analyze and Interpret Data. One of the biggest challenges to increasing the sturgeon population is that the fish don’t reproduce until they are at least 10 years old. Furthermore when they do start reproducing, they do so sporadically, perhaps every four or five years. To illustrate this concept, we created a handout using real data (Michigan State University, undated) about sturgeon reproduction, including the zone where the fish was located, the sex of the fish, and the year the data was gathered. The students plotted data collected on several sturgeon to determine when a male and female were in the same location. The students found that over a 10-year period there were only four times when a male and female fish were in the same location during the same year. Analysis revealed that the sporadic occurrence of male and female fish in the same location and the scarcity of the fish themselves contribute to the decline of the sturgeon population and hinder its rebound.

The third and final SEP we used was Obtaining, Evaluating, and Communicating Information, which was fulfilled in the final product of this unit: a public service announcement created by the students. They were given a choice of audience, including Michigan’s fisherman, the general public, or people interested in sturgeon in the classroom. The students created these PSAs and shared them with each other and the director of Sturgeon for Tomorrow, Brenda Archambo.

**Cross Cutting Concepts (CCCs)**

We incorporated several Cross Cutting Concepts into the unit, the first being Cause and Effect. Students needed to learn the causes of the decline in sturgeon population. While the scope of this unit did not allow us to determine a precise cause, students did have the opportunity to learn about overfishing, poaching, pollution, habitat fragmentation, and the sturgeon’s slow reproductive rate, which all contribute to the sturgeon’s decline (Lake Sturgeon Biology).
Scale, Proportion, and Quantity is another CCC that was integrated into this lesson. Students learned about the time scale in which these creatures thrived. According to a local news article in the Bay City Times (Rogers, 2013) in the 1700s, schools of sturgeon were observed swimming in the Saginaw River. This prehistoric fish had a large, flourishing population until human factors reduced their numbers by 99 percent.

Lastly, the third CCC we addressed was Stability and Change. The sturgeon turned out to be an excellent model for this CCC, since its population was stable for many millions of years, thanks to its long life and slow reproductive rate. Then change happened quickly with European settlement, about 150 years ago.

**Disciplinary Core Ideas (DCIs)**
The Disciplinary Core Ideas we covered included MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem service, and MS-ESS3-3 Apply scientific principles for monitoring and minimizing human impacts on the environment.

As the unit progressed, students learned about the sturgeon’s place in the evolutionary time scale. They learned that it has existed for about 136 million years, which means that it was here at the time of the dinosaurs (Lake Sturgeon Biology). Students learned about the human factors that decimated the population. They created and analyzed graphs of sturgeon populations over roughly 100 years. Students learned about the reproductive slowness of the sturgeon and what has been done throughout Michigan to help mitigate the damage done to the sturgeon. They learned about the current state of the sturgeon population, and they created their own PSAs to share their knowledge.

**RELEASING BUBBLES**
During the unit, our sturgeon grew from seven inches to about 14 inches. Finally the time came to release it back into the wild. We were originally supposed to return our fish to Black Lake, where it was hatched, but the Michigan Department of Natural Resources (MDNR) granted us permission to place Bubbles into the Saginaw River watershed. We were delighted to be the first class to be allowed to stock a sturgeon in our local waters, because this meant that part of our goal, to mitigate the harm people had done in our own area, was going to come true. The bonus: all our stakeholders could be there for the big event.

We carefully planned the release. We invited our board of education, principal, sponsors, and, most importantly, the parents of our students. The students and teachers were bused to the release site along with Bubbles, who rode with us in a plastic container. We met Sturgeon for Tomorrow director Archambo; the MDNR representative; and all the guests at the boat ramp. Once the water in the container matched the temperature of the river, I waded out to the end of the dock and let Bubbles go into the Tittabawassee to join about 400 other sturgeon the MDNR had stocked the previous fall. I imagined our sturgeon happy to be able to swim as far and as much as it wanted. After the release we had a pot luck and played in the park. It was the best day of the year for me.

**CONCLUSION**
Looking back, the magic of this project was sharing it with others; even my parents were there. We told other educators, friends, and colleagues about our sturgeon. People at the release
were touched, including the staff at Imerman Park who arranged for us to use a pavillion for the occasion. One man said he caught a sturgeon once and his grandfather said to put it back, that it was old and deserved to live out its life.

This fish is a fighter, and through this unit we have educated not just our students, but also their families, and not just about one species of fish, but about the importance of caring for all our natural resources. In the process we were able to meet the NGSS and have a wonderful time doing it. Yes, it was a lot of hard work, but the results were more than worth it. I wholeheartedly recommend the RET:PLACE program to anyone looking to develop their own place-based NGSS unit. If I can do it, you can too.

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Bay City Times article by Dave Rogers, published April 25, 2013 STURGEON HERE? Scientists Study Lake Sturgeon Spawning in Saginaw River "Giant Prehistoric Fish Reproduce Every Decade April-June; Is This The Year?"

SUPPLEMENTARY MATERIALS
Research Experiences for Teachers: Promoting Learning About Computational Tools and Environment (RET:PLACE), accessed at https://sites.google.com/a/mtu.edu/ret-place/

Unit Poster: Sturgeon Stewardship in Saginaw Bay

Unit overview and lesson plans are available at https://sites.google.com/a/mtu.edu/ret-place/lesson-plan-units/2017---2018 via the “Sturgeon Stewardship in Saginaw Bay—Let’s Bring ’Em Back, Baby” portal. If you would like the original files, we will be happy to provide them.
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Student Research: Analyzing Positronium Annihilation in Entangled Photons

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ABSTRACT

One of the most enigmatic discoveries in modern physics is entanglement. Entanglement is a special phenomenon in which two quantum systems are said to be “linked” together after interacting or being generated in particular ways. The use of this theory comes from the idea that one system tells us something about the other across large distances. This experiment entails conducting a simple way to detect quantum entanglement by recording and analyzing the data of opposite simultaneous Geiger counter readings. By placing the Geiger counters in different orientations, different results are expected, indicating which directions the photons are traveling and if they travel in the direction predicted by quantum entanglement.

Entanglement is currently one of the most actively researched areas in modern physics. Erwin Schrödinger first coined the term “entanglement” in 1935 in order to describe a strange phenomenon in which quantum systems appear to be interdependent across large distances (Danforth, 2018). In that same year, Albert Einstein extended this idea with Boris Podolsky and Nathan Rosen (Blair, 2017). Unlike Schrödinger’s view, they attempted to disprove the idea that there was some sort of connection between particles across arbitrary distances.

In order to explain away this behavior, they attempted to add hidden variables to quantum systems to help account for entanglement without allowing for “spooky action at a distance,” which was how Einstein described this process (Fine, 2017). Their work is still cited today.

Fig. 1: Spin states of nonlocal systems, A and B, from a source; part of Bohm’s EPR experiment (Cavalcanti, 2007)
However, John Stewart Bell’s 1964 paper — “On the Einstein-Podolsky-Rosen Paradox” — showed that “no physical theory of local hidden variables can ever reproduce all of the predictions of quantum mechanics” (Bell, 1964). In other words, Bell’s theorem showed that Einstein’s work could not be used to describe entanglement classically; e.g., using the laws of classical mechanics such as $F = ma$.

Quantum mechanics requires a special perception of the universe. For example, a single system can exist in two states at once until it is measured, and only then does the system take on one state or the other. For entanglement, the quantum state for pairs or groups of particles cannot be described independently; i.e., if you measure the spin state of one particle, the other particle will automatically have the opposite spin state. One of the most mind-breaking consequences of all is the idea that the speed of light may not actually be the ultimate speed limit.

![Visual representation of entanglement between quantum states](rowen2015)

This particular experiment was inspired by and built upon the work of George Musser. Musser published an article in *Scientific American* in 2013 — “How to Build Your Own Quantum Entanglement Experiment” — in which he described an elegant and inexpensive way to observe entanglement. Our objective was to replicate Musser’s experiment as a high school physics research project.

The equipment for this experiment included two RM-60 Geiger counters from Aware™ electronics, a small disk of radioactive sodium-22 (which has a half-life of 2.6 years), a coincidence box also from Aware electronics along with corresponding cables, a lead tube contraption (including lead tape), and two aluminum bars. We also used an Aware interface box and an iOS Geiger bot app. The lead tube device was formed by cutting a standard water bottle and shaping it roughly an inch in diameter. Then two layers of lead tape were wrapped both on the inside and outside of the tube. This arrangement was used to reduce axis radiation which, in turn, dramatically increased accuracy.
Theory predicts that an emitted pair of entangled gamma-ray photons will have perpendicular polarities. In order to verify this during the experiment, aluminum blocks were placed in front of both Geiger counters. These act as parallel plate ionization chambers that cause the charges with perpendicular polarities to be re-emitted in perpendicular directions due to Compton polarity effects (Abdel-Rahman et. al, 2006). In other words, photons emitted from the sodium-22 decay will travel in opposite directions and have perpendicular polarities if they are entangled. Thus, when the Geiger counters are set up orthogonal (perpendicular) to each other, there would be a higher rate of measured simultaneous coincidence compared to when the counters are set up directly opposite to each other.

The process itself was quite simple, yet time-consuming. It involved placing the sodium-22 source roughly centered inside the lead tube. Then Geiger counters were plugged into the C-Box, the C-Box to the interface box, and then the interface box to the iOS device with Geiger bot downloaded to our computer. Finally, the aluminum bars, which act as gamma-ray prisms, are set on the ends of the tube with the Geiger counters placed against the aluminum bars in their corresponding orientations (opposite/orthogonal). The Geiger counters begin recording —“clicking”— at each instance where it records a photon. The entangled gamma photons are produced when anti-electrons, or positrons, are released by the decaying sodium-22 source. They then collide with electrons in the air and form opposite angular velocities to each other while being linearly polarized, thus producing entangled gamma rays scattering in opposite directions to each other (Musser, 2013). The coincidence box records the instances where the Geiger counters’ clicks are simultaneous. The iOS Geiger bot app records the data received by the coincidence box, which is the data used for this experiment. Figure 4 provides a picture of the setup labeled “Opposite” for this experiment, since the Geiger counters are set up directly opposite one each other while Figure 5 depicts the "Orthogonal" orientation due to the fact that the Geiger’s are set up perpendicular to each other.
Gamma-ray incidences were recorded simultaneously from the two Geiger counters with different orientations over approximately 48 hours. The occurrence of simultaneous gamma-ray detection increased by around 0.05 CPM (counts per minute) when the Geiger counters were placed orthogonal to one another in comparison to when they were placed opposite of one another, as shown in Figure 6. This difference is not dramatically significant but it does appear to show that in the orthogonal orientation, simultaneous detections of photons are recorded consistently higher compared to the opposite orientation. This matches the prediction by quantum mechanics (Musser, 2013). The reason that the particle detection count for orthogonal and opposite orientations was still somewhat close is likely due to the inherent randomness of the sodium-22’s emission of positrons and the fact the accidental counting rate does not completely account for all randomness. There is no guarantee that the source will only release one positron in one direction at a time. Instead, it is likely that the source produces multiple gamma-ray photons that are not originating from the same positronium system but still traveling simultaneously orthogonally or oppositely. Hence, due to the fact that this project was created as inexpensive as possible, there is still a reasonable amount of error unavoidable in this experiment. However, it does follow the predicted outcome of quantum entanglement, and it does so at this extraordinarily cheap price.

The accidental counting rate is supposed to account for the majority of the error in this experiment. This relationship is depicted in the formula $R_2 = 2N_1N_2t$; where $N_1$ and $N_2$ are the individual Geiger rates and $t$ is the downtime of the counters (Jánossy, 1944). $N_1$ was approximately 308 CPM, $N_2$ was 294 CPM, and for the RM-60 Geiger counters the downtime is recorded as 50 ± 5 µs. This value worked out to roughly 9.1 CPM and is depicted in Figure 6 by the error bars shown.
Our results show orthogonal setups resulting in a higher CPM which is clearly indicative of quantum entanglement.

We also identified various topics that we would investigate further along with finding some things we would’ve done differently. First off, we would like to point out that entanglement was depicted in this project in the simplest way, so we would love to partake in an experiment that provides a more accurate depiction of entanglement. That said, to improve upon this project we would increase our accuracy by verifying the accidental coincidence equation stated previously by testing on a radioactive source that does not produce entangled photons, which results in most, if not all, accidental coincidences (this was mentioned in one of our talks with George Musser). It may also be useful to have a more “powerful” radioactive source of entangled photons. With a higher overall incidence-rate, more accurate data could be obtained from the same type of experiment. The problem inherent in such an approach is that a more radioactive source of entangled particles would likely be unsafe to handle without proper protection, further increasing the price of the experiment along with the risk. Another line of inquiry would be the testing of different materials as photons scatters. We’re curious as to what material would improve scattering and how different materials would impact results.

One of the main areas of focus for scientists is creating one “uniform” set of physics that combines quantum and classical physics that explains the theories such as general relativity, entanglement, and many more. These real-world connections give a foundation for the growth in this process, and we hope to someday be a part of that discovery.

Finally, we would like to thank the Michigan Science Teachers Association for providing a grant to make this project possible. We would also like to thank Mr. Michael Sinclair for guidance in this project, Mr. Mark Cardwell for his tireless work behind the scenes to make our research work, Mr. George Musser for his endless support in aiding us with our project, Mr. Frank Dowd for helping construct our apparatus, and finally our parents for their support in our endeavors.

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Basic Reaction Chemistry, the Next Generation Science Standards, and Green Chemistry: Making Connections

By Steve Kosmas, Grosse Point North High School, and Mark Benvenuto, University of Detroit Mercy.

INTRODUCTION

Chemistry courses in high schools, and first chemistry courses in community colleges and four-year colleges often emphasize writing proper chemical reactions. Indeed, one can claim that knowing how to write and balance chemical equations is one of the hearts and souls of the science (we can claim that writing proper Lewis structures may be the other).

Curiously, although what is now called green chemistry can trace its roots back to what is called The Brundtland Report, in 1987,(1) there are still no standards in either the Next Generation Science Standards (NGSS) or the American Chemical Society that dictate specific places or subjects into which the principles of green chemistry can be inserted.(2,3) We feel it is important to take some steps in this direction now, even before governing bodies dictate what students should learn, simply because a high school chemistry class, or a college general-level chemistry class, is usually the place that a young person will hear about the subject of green chemistry in a structured learning environment. Put in somewhat more colorful language, these chemistry courses represent the last line of defense at which student can be educated about one of the most pressing issues of our time.

To help rectify this perceived lack, we present here two industrial chemical processes that have connections to both the NGSS and the 12 principles of green chemistry, and that can be used as discussion points in any chemistry lecture. The goal of such examples is to get students to develop a sustainability mindset or a green chemistry mindset. What do you do if a medication that helps people battle cancer also creates undesirable by products? Should we be teaching students about how to calculate atom economy versus percent yield? How do teachers find the time to integrate green chemistry principles into the curriculum? How many science teachers understand the ramifications of industrial chemistry well enough to lead a discussion on sustainability? We would argue that it does not matter how much one knows at this point in time; the goal is to move in the direction of developing a Green Chemistry Growth Mindset or a Sustainability Growth Mindset. All of the preceding questions may spark an interest in the green chemistry process.(4)

REACTION CHEMISTRY

The production of sulfuric acid.

Sulfuric acid is the single largest commodity chemical produced on Earth. The global production of sulfur, its starting point, is tracked each year by the United States Geological Survey’s Mineral Commodity Summaries, a free, downloadable document published annually. (5) as can be seen in Figure 1, sulfur is first reacted with oxygen, the resulting sulfur dioxide
is then reacted with oxygen (this second reaction requires a vanadium pentoxide catalyst), then the resulting sulfur trioxide is reacted with water to produce sulfuric acid. This forms as a mist if allowed to do so, and so it is reacted with further sulfur trioxide to make what is called oleum, which is reacted with more water to form the final product, sulfuric acid.

It can be seen that these five reactions can be discussed in terms of addition reactions, as well as in terms of oxidation or reduction, in that sulfur goes through three oxidation states, from 0, to +4, ultimately to +6. Likewise, oxygen is reduced in two different steps, from 0 to -2.

Figure 1: Reactions for the production of sulfuric acid.

\[
\begin{align*}
S + O_2(g) & \rightarrow SO_2(g) \\
SO_2(g) + \frac{1}{2}O_2(g) & \rightarrow SO_3(g) \\
SO_3(g) + H_2O(g) & \rightarrow H_2SO_4 \\
H_2SO_4 + SO_3(g) & \rightarrow H_2S_2O_7 \\
H_2S_2O_7 + H_2O & \rightarrow 2 H_2SO_4
\end{align*}
\]

The production of iron.

Like the production of sulfuric acid, the production of iron is a massive undertaking that is tracked by the Mineral Commodity Summaries, as well as by professional organizations, such as the American Iron and Steel Institute.(6) Tens of millions of metric tons are produced each year in the United States and several other nations. What can be called the simplified reaction chemistry for this is shown in Figure 2. We state that it is simplified because different ore batches produce different amounts of iron and of by-products.

Figure 2: Reactions for the production of iron

<table>
<thead>
<tr>
<th>Reaction</th>
<th>temperature range (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 C(s) + O_2(g) → 2 CO(g)</td>
<td>200 – 700</td>
</tr>
<tr>
<td>3 Fe_2O_3(s) + CO(g) → CO_2(g) + 2 Fe_3O_4(s)</td>
<td>600 – 700</td>
</tr>
<tr>
<td>CO(g) + Fe_3O_4(s) → 3 FeO(s) + CO_2(g)</td>
<td>850 – 900</td>
</tr>
<tr>
<td>CaCO_3(s) → CaO(s) + CO_2(s)</td>
<td>850 – 900</td>
</tr>
<tr>
<td>FeO(s) + CO(g) → Fe(l) + CO_2(g)</td>
<td>1,000 – 1,200</td>
</tr>
<tr>
<td>C + CO_2(g) → 2 CO(g)</td>
<td>1,300</td>
</tr>
<tr>
<td>SiO_2(s) + CaO(s) → CaSiO_3(l)</td>
<td></td>
</tr>
</tbody>
</table>

We have listed the temperature ranges for each reaction here because the NGSS does address the idea of reaction temperatures. Additionally, once again, this set of reactions can be thought of in terms of addition reactions as well as oxidation-reduction reactions. It is noteworthy here that reactions are in the list which do not include iron at all. These
represent the use of carbon to combine with the oxygen originally in the iron ore, and the production of what is called slag from the silicates that invariably are co-located in iron ores. But traditionally this set of reactions is used to show how an iron ore can start with iron in a +3 oxidation state, and end with it reduced to a 0 oxidation state.

THE GREEN CHEMICAL CONNECTIONS

Sulfuric acid production.

According to the Mineral Commodity Summaries, sulfur, from which sulfuric acid is produced, is mined, recovered from oil operations, and produced as a by-product of other operations to a total of millions of tons per year. The product, the sulfuric acid, is used in a wide variety of further reactions, including the large-scale production of fertilizers. Regulations are in place in most developed countries that limit the amount of any effluent from a sulfuric acid plant during any step of the operation. In the United States, a past limit was no more than $\frac{1}{2}$ pound of emission for every ton of product. But when 1 million tons of product are made, this means ½ million pounds of some effluent can be allowed to escape. This can be a point of discussion, as the first of the twelve principles of green chemistry is to “prevent waste,” and the eleventh is “real-time analysis for pollution prevention.” Additionally, the ninth point is “catalysis.” The vanadium pentoxide catalyst mentioned above is an amazing one, as it generally last 10 – 20 years during production.

Iron production.

The production of CO2 in the reactions which produce iron is often overlooked, or given minimal attention when these reactions are used in class. Yet once again, this is an example of the first of the twelve green chemical principles: prevent waste. Carbon dioxide is invisible; so it’s difficult to imagine it as tangible waste. Yet this can be an excellent teaching and discussion point.

The heat involved in producing iron is an aspect of the production that can engender a discussion about the sixth of the green chemistry principles: design for energy efficiency. It may seem odd to say it, but this is as efficient as iron production has ever been, even though it requires enormous amounts of energy.

As well, the production of calcium silicates, the slag, in an iron production process is related to both the fourth green chemistry principle: design benign chemicals, and the tenth principle: design for degradation. At first this may seem laughable, in that slag does not seem benign, nor does it degrade. But there is enough of it produced that a National Slag Association exists,(7) which tries to find uses for this material, such as lining road beds, and as filler in other building projects.

CONCLUSIONS:

Both sets of reactions in Figures 1 and 2 can be used to teach the basics of reaction chemistry. Both can be used to show how equations are balanced. Both can be used as examples of addition reactions, or as examples of oxidation and reduction, in alignment with the NGSS. And importantly, these two sets of reactions show students real life chemistry in which the principles of green chemistry can be imported and discussed. If students and teachers do not understand the industrial processes, then how can such process be made greener? The term “cradle to cradle” is a new term for many. How do we give students the opportunity to discuss
the life cycle of a process and what to do with undesirable by product? The first step is to give students the opportunity to discuss these topics. As a parallel example, we believe teratology should be discussed in high school classes, since the relevance factor may increase student interest(8). How thalidomide was kept out of the United States is a great, educational story (thank you Dr. Frances Kelsey!). Perhaps it is time to balance the content with societal issues that impact everyone. Besides, if students learn a large amount of content, but do not apply that to bettering society, what is the purpose of knowing the content? We find examples and open-ended questions like this prove useful in our own classes, and hope readers will be able to do the same.

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Growing Capacity: The Power of Place in Project-Based Learning

Erica R. Hamilton, Grand Valley State University; Kimberly Pawelka, Grand Valley State University; Sue Blackall, Sparta Public Schools; Lisa Marckini-Polk, Civic Research Services, Inc.

There are more than 1.5 million K-12 students enrolled in public schools across Michigan (Michigan Department of Education, 2017). These students have opportunities to learn in urban, suburban and rural settings, all rich with unique histories, cultures, and environmental phenomena. According to the state of Michigan’s website, the state is comprised of 58,110 square miles of land, which includes forests, hills, wetlands, dunes, farmland, oil and gas fields, and developed town and urban centers. The state also has 11,037 inland lakes, 36,350 miles of rivers, and 3,288 miles of Great Lakes shoreline (Michigan Government, 2018). Michigan’s natural resources, history, cultural narratives, and its relationship to the Great Lakes provide rich and diverse settings in which K-12 students can engage in place-based education and project-based learning.

PLACE-BASED EDUCATION

Place-based education focuses students’ learning on local built and natural environments, and connecting student learning to local contexts is central to place-based education (Sobel, 2004). According to Greenwood (2013), “local places provide the specific contexts from which reliable knowledge of global relationships emerge” (p. 94). We also know from research that when students engage in inquiry-based, experiential learning they are more likely to remain actively engaged in the learning process (van Uum, Verhoeff, & Peeters, 2017). Thus, engaging students in hands-on learning in their own real-world contexts provides opportunities to generate knowledge about local places and phenomena as well as engage in environmental stewardship (Great Lakes Stewardship Initiative, 2016; Semken & Freeman, 2008). According to Sparta Public Schools’ teacher, Sue Blackall “When engaged in place-based education students become personally and emotionally connected to specific places, which serves to motivate environmental stewardship” (May 2018).

Findings from studies of six place-based education programs conducted by the Place-based Education Evaluation Collaborative (2010), which included more than 100 urban, rural and suburban schools, clearly indicate that place-based education encourages students to make connections to local places and generates mutually beneficial partnerships between students, schools, and their communities. Place-based education pedagogy also positively impacts student achievement and serves to advance local environmental, social, and economic interests. “In short, place-based education helps students learn to take care of the world by understanding where they live and taking action in their own backyards and communities” (p. 2). Separate studies of place-based education have demonstrated improvements in cognitive engagement (Athman & Monroe, 2004a) and critical thinking skills (Athman & Monroe, 2004b). Place-based education also promotes “action competence” (Barratt & Barratt Hocking, 2011), in which students are empowered to use and apply their learning to make a positive difference in their local communities.
PROJECT-BASED LEARNING

According to the Buck Institute for Education (2018), project-based learning offers students choice and responsibility regarding their learning, provides standards-based concepts and inquiry-based activities, and challenges students to engage in learning that is authentic and relevant to the world in which they learn and live. Project-based learning also encourages students to share their learning with a real-world audience. Project-based learning (PBL) is used to deepen students’ understanding of science and other subjects through examination of real-world problems (Hmelo-Silver, 2004). Because project-based learning is student-driven, with teachers serving as guides and facilitators, students are more likely to actively engage in their learning and transfer their learning to new content and challenges.

Zhang, et al. (2016) conducted an experimental study of more than 760 fifth graders across eight schools in low-income areas. They found that students engaged in inquiry-based learning through peer interaction and collaboration and centered on a real-world problem demonstrated better decision-making skills and were more likely to transfer these skills to a new task than peers who experienced a traditional model of direct instruction. Finkelstein et. al. (2010) studied more than eighty teachers at the secondary level from Arizona and California. Their study focused on the impact of PBL on student learning in high school economics, and found that high school students who engaged in project-based learning demonstrated an increase in problem-solving skills and capacity to apply their learning to real-world problems.

COMBINING PLACE-BASED EDUCATION AND PROJECT-BASED LEARNING

When project-based learning is partnered with place-based education, powerful learning experiences can unfold in which students use new knowledge and problem-solving skills to become change agents in their communities. These dual learning goals directly align with the Michigan Science Standards (2015), in which students are expected to not only learn about but also “do” science. Through place-based education and project-based learning students actively engage in Michigan’s Science and Engineering Practices (Figure 1) by addressing real-world issues in their local communities. In addition, they are given the opportunity to investigate and practice the core concepts of the discipline, also known as enduring understandings (i.e., patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter in systems; structure and function; stability and change of systems).

Listed below are the Science and Engineering Practices from the Framework:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Figure 1. Michigan Science Standards Science and Engineering Practices
COMBINING PLACE-BASED EDUCATION AND PROJECT-BASED LEARNING: A CLASSROOM EXAMPLE

Michigan teacher Sue Blackall’s work with her elementary students provides an example of how to integrate place-based education and project-based learning to build understanding of both science content and the scientific processes. Sue and her students have had opportunities to make a lasting impact in their community and, at the same time, expand what they identify as their place. In the following sections, we highlight how Sue and her students collaborated with local community partners to address several real-world problems in their community. We also offer suggestions and resources for teachers who want to support and extend student learning through place-based education and project-based learning.

Sue is an active participant in the Groundswell program, a place-based environmental education initiative of the Great Lakes Stewardship Initiative (GLSI). The Groundswell program is housed in and supported by Grand Valley State University. Through project funding, ongoing professional development, and site-based support, Groundswell helps schools and teachers develop K-12 students’ awareness of their local place and works to promote lifelong environmental stewardship. The funding Groundswell teachers receive is grant-based and centered on implementing student-led, community-based stewardship projects aimed at supporting and extending students’ academic development. During the 2017-2018 school year, more than 120 Michigan teachers in 36 schools engaged in the Groundswell program, including Sue and her students. Through the Groundswell program, teachers and students are connected with local partners who provide additional expertise, guidance, and resources.

IDENTIFY A PROBLEM AND DEVELOP SOLUTIONS

Sue’s work with 3rd-5th graders provides an example of using the power of place to enrich project-based learning. Sue is an experienced elementary science teacher for Sparta Public Schools, a rural district located in the heart of fruit orchard country in the western Lower Peninsula. After attending a local workshop, she learned that her school district’s grounds had been stripped of native plants and wildflowers over the course of multiple building renovations. Working with a local master naturalist program and a high school biology teacher in the district, Sue and her students learned how grass-only monocultures, including ones on their school grounds, support very little biodiversity. Students also learned about native plants and the role they play in the ecosystem. Subsequently, students talked about what they could do to improve the situation. They chose to install a substantial rain garden (36’ x 190’), plant a variety of native trees and shrubs, and install a perennial garden around the perimeter of their school, Appleview Elementary (Figure 2).

Figure 2. Appleview Elementary students planting native plants on their school grounds
COLLABORATE

Inspired by the success of their perimeter native plantings, the following year Sue wrote a grant in partnership with the local office of the U.S. Fish and Wildlife Service, to install a 15-acre prairie behind the district’s high school. Sue’s third graders and her colleague’s 10th graders first worked together to pick up rocks to ready the field for planting. They then installed the new plants, including native grasses (i.e., big and little bluestem, Indian grass, and switchgrass) and wildflowers (i.e., gray-headed coneflower, common evening primrose, black-eyed Susan, New England aster, bergamot, compass plant, coreopsis, tick clover, etc.). Building on their success, the next year they planted native bushes around an already existing holding storm water retention pond on the school grounds, installed when the school was built in 2006. By that time, homeowners at the bottom of the hill reported that their basements were no longer flooding, because - as Sue’s students now knew - roots of prairie plants controlled and cleaned storm water and then diverted it to the water table. Sue noted, “the high schoolers loved it because they could see all kinds of wildlife right behind their school.” In addition to the improved aesthetics, through project-based learning and place-based education Sue’s students also made a profound difference in the ecosystem in which they lived. According to Sue, “For me, the whole purpose of planting native plants is for people to see why and how we have to put nature back in our communities because we’ve taken it out, destroying the very foundation of the food chain.” As Sue reflected on these experiences, she explained that many times people have to first see how beautiful native plants are before they begin to understand how important these plants are to the environment, including supporting a location’s biodiversity and wildlife.

As a result of encouragement from the Groundswell program staff to expand their work beyond their school grounds, Sue established a partnership with a local branch of the national organization, Trout Unlimited and involved a district middle school science teacher, too. This branch of Trout Unlimited was interested in restoring Nash Creek, which runs through the Sparta Public Schools’ community and is as tributary of the Rogue River. At the time Sue began working with Trout Unlimited, however, elected officials in their village had not been particularly interested in investing in the creek. But, with local students’ involvement that dynamic changed. Trout Unlimited taught the middle school students to measure the water quality of Nash Creek. Sue’s elementary students stood on the bridge and mapped storm water runoff from adjacent parking lots and parks into the creek. They learned that planting native plants is an effective way to clean the runoff water, provide habitat, and stabilize the banks (Figures 3 and 4).

Figure 3. Appleview Elementary students planting native plants on along Nash Creek

As Sue noted, “this work directly engages students’ scientific thinking and understanding. We have lessons about restoring the banks and the watershed while we’re standing near Nash Creek. They’re meeting the standards and engaging in the types of
work environmental professionals do. When they’re outside working, they’re talking about which plant is theirs and this helps them further understand how to take care of their surroundings.” After observing Sue’s students working and learning in the field, local leaders were so impressed that the village manager asked if Sue and her students would be willing to restore additional parts of Nash Creek if the village funded the restoration. He included it in their village’s upcoming budget for parks and recreation. In the Spring of 2016, Sparta Public Schools’ middle school and elementary students began restoring another section of Nash Creek.

The ongoing work along the creek led to the discovery of a strip of land along Nash Creek that had been invaded by Reed Canary Grass. In September 2017, Sue’s classes focused on the devastating effects an invasive species can have on a watershed ecosystem. To address this issue, the area was professionally sprayed, then students planted native plants (i.e., fox sedge, cardinal flower, blue lobelia, blue iris, and mountain mint) along the edge of the stream.

INQUIRE
As part of their ongoing inquiry into invasive species, students learned how settlers unknowingly brought invasive species to their region. They also learned about how today’s stewards of the environment - including K-12 students - can address the negative impacts of invasive species in their communities. Students’ work during the 2017-2018 school year included planting bushes and trees along Nash Creek in two separate parks as well as along the banks of the Rouge River. They also planted wildflowers in a flooded plain of Nash Creek and installed a new wildflower garden at their local elementary school.

COMMUNICATE FINDINGS
As noted earlier, students should be “doing” science, not just learning about science (Michigan Science Standards, 2015). Sue helped her students identify a local problem and then empowered her students to take ownership of their learning which also impacted their community. As a result, Sue readily sees how place-based education and project-based learning pedagogies engage students in doing science. “We cannot assume that children have the opportunity or are motivated to connect with nature. Our school and village are giving them an opportunity. These opportunities can change their lives.” Sue continues, “I read a long time ago, that if kids aren’t connected to nature by age 11, they won’t be connected when they are older - when they are decision makers who impact the environment. But, now - even as elementary students - they can express how important it is to take care of their watershed and every living thing in it, including themselves. Not only can they say it, they really live it, and they want to convince others, too.” To share their learning, Sue and some of her students recently participated in Groundswell’s 2018 Student Showcase event in which

Figure 4. Appleview Elementary students planting native plants on along Nash Creek
they presented their work to community members, including area business and education leaders, project partners, parents, teachers, and students (Figure 5).

Sue’s experience reinforces the benefits of project-based learning and place-based education and shows how these pedagogies can be used in concert to develop 21st century and next-generation skill sets as well as emotional resonance (Anderson, 2017). It has been proven that K-12 students have better, long-term retention and increased ability to apply new learning if instructional methods actively promote ongoing engagement and provide opportunities for students to put their learning and ideas into action (Wirkala & Kuhn, 2011; Zhang, et al., 2016). As Sue’s experiences demonstrate, this is what happens when teachers draw on place-based education pedagogy and combine it with project-based learning to support and extend students’ capacity to “do” science. Engaging students in science and engineering practices (Figure 1), Sue helps her students relate required content to their everyday lives, which she expects will lead to greater retention of the information. According to Sue, “Teachers are under so much pressure to have students ready to take tests by specific dates, many feel they don’t have time to take their students outside.” However, when students use the local places where they learn and live as contexts for learning they learn more deeply and can actively apply their learning in their community.

SUGGESTIONS FOR TEACHERS
As explained in the introduction, the state of Michigan has an amazing amount of resources and places which can be used to support and extend student learning. There are also a number of local issues facing communities which K-12 teachers and students can learn more about and work to address. To implement project-based learning and place-based education in local communities we encourage teachers to consider the following strategies, aligned with the Michigan Science and Engineering Practices (Figure 6).
<table>
<thead>
<tr>
<th>Michigan Science and Engineering Practices (SEP)</th>
<th>Principles of Place-based Education (Great Lakes Stewardship Initiative, 2016) and Project-based Learning (Buck Institute for Education, 2018)</th>
<th>Strategies and Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions and defining problems (SEP #1)</td>
<td><strong>Identify a problem.</strong> Address a real-world problem in your community and make a meaningful difference.</td>
<td>As a means of identifying a problem around which to organize student learning, begin by collaboratively taking inventory of neighborhood problems and issues. Students can lead a literal or virtual tour of their school or community where they point out problems and challenges that affect them. One teacher we know built a project around piles of abandoned tires after her students showed them to her and explained how dangerous they could be.</td>
</tr>
<tr>
<td>Planning and carrying out investigations (SEP #3)</td>
<td><strong>Investigate and inquire.</strong> Develop student voice and consult stakeholders as part of the inquiry</td>
<td>Or, teachers and students can reach out to area parks and recreation agencies, water quality groups, or similar non-profit organizations to generate a list of neighborhood issues. These professionals and organizations can also present specific issues to the students for their consideration. Both methods create interest: the first taps into students’ experiences and concerns, while the second ensures the work has an audience beyond the school and establishes its importance beyond the classroom.</td>
</tr>
<tr>
<td>Analyzing and interpreting data (SEP #4)</td>
<td><strong>Collaborate with others.</strong> Work closely with peers and community partners (i.e., nonprofits, units of government, higher education) to better understand the array of problems in the community, their impacts, and options to resolve or address one or more issue. Ask for feedback throughout the project and use feedback to inform future investigations and decisions.</td>
<td>Reach out to the Department of Public Works or a city, township, or village manager to ask what needs they may have noticed in their local parks or natural areas. These organizations and individuals often have understanding of local needs, especially those they might not be able to address due to lack of funds and/or workforce.</td>
</tr>
<tr>
<td>Using Mathematics and computational thinking (SEP #5)</td>
<td><strong>Develop a solution.</strong> Through collaboration, investigation and inquiry develop a solution to the identified problem. Test, reflect and seek feedback to modify and refine solution.</td>
<td>As part of the inquiry process, include stakeholders as collaborative partners. One or more partners from the community can help identify legitimate and manageable opportunities in which to get involved, cut through potential red tape, and identify ways to make the project of maximum benefit and impact in the community. Partnerships increase student interest, engagement, and career learning by exposing them to professionals already at work in their community. Partners may also be able to bring additional content and contextual knowledge and provide resources such as delivering materials and providing necessary tools.</td>
</tr>
<tr>
<td>Constructing explanations and designing solutions (SEP #6)</td>
<td>Use classmates to peer review solutions and provide critical feedback. This can be done by having student teams present their solution, ask classmates what they liked about their presentation and identify areas of growth. Students can then provide additional ideas or resources the team may not have thought of. The team then can reflect on the feedback and make any changes they feel are appropriate.</td>
<td></td>
</tr>
<tr>
<td>Engaging in argument through evidence (SEP #7)</td>
<td></td>
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</tr>
</tbody>
</table>
Engaging in argument through evidence (SEP #7)

Obtaining, evaluating and communicating information (SEP #8)

**Share findings.** Communicate findings to stakeholders, including community partners, stakeholders and interested community members. This process enables students to participate in public discourse and engage in environmental stewardship.

An authentic audience heightens value for students. As Pittman (2016) notes, “Sharing products and performances with the public creates a purpose for top-quality work” (p. 47). While engaging a beyond-the-school audience often comes at the close of a project, community partners and community members should be students’ audiences as they work, too.

Place-based education - when also aligned with project-based learning - provides an emphasis on supporting and enhancing local communities. As a result, these learning opportunities often bring students into contact with professionals in the field. They also have opportunities to work with elected or appointed community officials, and in the best instances, students can then participate in public discussions around their community’s needs and opportunities.

**Figure 6. Implementing Michigan Science and Engineering Practices through Place-based Education and Project-based Learning**

When this type of integrated learning occurs in the places students learn and live, it engages them in their community and adds relevance to their work. As Demarest (2015) notes, “when students work with members of their community on real issues, the solutions they generate have the potential to effect real and lasting change” (p. 15). Sue and her students’ work on their school grounds and in their local community demonstrate the power of combining place-based education and project-based learning. As they engage in the “doing” of science, Sue’s students’ understanding of a local place expanded from their school grounds to their community and planted seeds - literally - for the next generation of environmental stewards. As Sue explains, “using place-based education and project-based learning ensures that my students not only understand science but they are also motivated to do science and are empowered to make a difference in their community.”

**REFERENCES**


Whether it’s a biomedical breakthrough or an archaeological discovery, students and professors in Wayne State University’s College of Liberal Arts and Sciences work side by side to change our understanding of the world. WSU gives undergraduates the chance to learn across disciplines, combining the personal experience of a small college with the global advantages of a major research university.

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When the Norse Became the Vikings
Analyzing Climate Change in History
Phil Gersmehl, Michigan Geographic Alliance, Central Michigan University

History is not “just one thing after another.” On the contrary, many of the major trends in history are the direct effects of causes that we can identify, describe, and sometimes quantify. Applying science to history can offer insights that can help us predict the effects of changes going on today.

In this short note, I will describe some changes in technology, geopolitics, and climate that enabled the Norse people to become the Vikings – a tribe of successful raiders whose impact reached as far as Russia, Constantinople, Spain, and North America.

It is an interesting trivia fact that “viking” was originally a verb, not a noun. It means, basically, “to raid.” For this reason, the short sentence, “Some Norse people went viking” is a more accurate statement about the late 8th century than something like: “The Vikings began to raid other countries.”

Here’s our question: what changed to persuade these people become raiders at this time in history?

One important change was technological – the invention of boat-construction methods that allowed Norse sailors to travel far into shallow, rocky rivers as well as the open ocean. The Viking solution involved a number of ingenious inventions. I mention it here because it is an important part of the picture, but this story has been well told elsewhere.

www.pbs.org/wgbh/nova/ancient/viking-ships.html
https://www.asme.org/engineering-topics/articles/history-of-mechanical-engineering/engineering-the-viking-longboat
https://regia.org/research/ships/Ships1.htm

A second change was political. The success of Norse raiders was partly due to the disorganization and weakness in most of Europe after the disease-aided collapse of the Eastern Roman Empire. Again, this is an important part of the story, but it is not something that merits much analysis in a science journal.

My focus here is on the environmental changes that occurred at roughly the same time. A careful look at those changes can give us information that is directly applicable to the 21st century.

Let us begin by acknowledging the efforts of hundreds of 20th- and 21st-century investigators who have meticulously gathered huge amounts of information from tree rings, cave deposits, lake sediments, pollen profiles, ice cores, and ancient court records and other documents. Let us especially note the efforts of two Scandinavian scholars, who compiled evidence from 91 independent investigations. Their compilation can be summarized with a deceptively simple graph (Figure 1).

The vertical bars on this graph show the general range of average temperatures in each 20-year period from the dawn of the Common Era to the end of the 20th century. Temperatures from
different places are made comparable by expressing all temperatures in terms of deviations from the long-term average at the place of measurement. This mathematical procedure is common, but it has to be explained in sufficient detail that students can describe the process in their own words and even apply it to a different data set (e.g., in the MEECS unit on climate change, available for download at https://www.michigan.gov/deq/0,4561,7-135-3307_3580_29678-00.html)

For our purposes, the curving line on this graph is more important. Any point on this curving line represents the average temperature for a 50-year period of time around a specific year. Like the 20-year bars, this kind of curve smoothing is a common analytical procedure, but it also requires careful explanation for students to understand fully.

The mathematical intricacies, however, are not needed to gain the main message of the graph, which is that average temperatures have indeed risen and fallen at different times in recorded history. Teachers can help students see this point by asking them to describe the line in their own words (or even by having them choose among options, like “Average temperatures went down over time – the line goes lower as you go toward the right side of the graph,” “Temperatures went up and down, . . .” and “Temperatures generally went upward, . . .”).

This abstract conclusion can be made more concrete by focusing on one particular period of time. For example, let us look at a warm period that helped farms in northern Europe become very productive.

Start by inspecting the curved line more carefully. Ask students to identify which three years seemed to mark “turning points” in the trend line: 100, 500, 800, 1000, or 1200. They should conclude that a long-term downward trend seemed to end at roughly the year 800. Beginning then, average temperatures rose about a degree and a half Celsius (nearly three degrees
Fahrenheit) in less than two centuries.

What does this mean in practical terms? Three degrees does not sound like much, but it becomes significant when we look at what it does to the growing season. Around the year 800, the frost-free season in Denmark was between 100 and 110 days long. This seems like enough, when you compare it with the 70 to 90 days that different varieties of grain require. The illusion of safety disappears, however, when you look at the numbers through the eyes of people who actually farm for a living. They know that an average season of 105 days means that one year out of 10 might have several weeks less, due to a late or early frost. You never know in advance what year will have that unexpected frost!

Moreover, farmers want at least a few weeks of unfrozen soil to prepare the ground and plant seed in the spring. It also helps to have a margin of error in the fall, to ensure timely harvest. In short, it takes an average frost-free season of at least 120 days to grow grain reliably, year after year.

And it is a biological fact that people cannot eat enough in one year to survive a year without food!

Meanwhile, by the year 1000, the frost-free season in Denmark was longer than 150 days, more than enough for wheat, beans, and most fruits. In short, between 800 and 1000 CE, the environment in Denmark changed dramatically. It was no longer a place where grain-crop failures could be expected every two or three years. It became a land with good yields in at least 19 out of 20 years. For awhile, however, people still produced babies at an average rate of more than seven per mother, as if they were still destined to lose more than half of their children to starvation or malnutrition-aided disease. When childhood deaths became less frequent, population boomed.

This is when demography became destiny. If several sons survive in each family, but only one can inherit the farm, there will be a surplus of able-bodied young men with nothing better to do. Migration to the Americas was not an option, yet, and the industrial revolution was still many centuries in the future. Raiding could easily become an ever-more-popular way to gain fame and fortune.

![Norse Settlements and Viking Raids](http://ss.oaisd.org/bi9-europe.html)

*Figure 2: Spread of Norse (Viking) influence between 750 and 1000 CE. Adapted from online interactive maps available for projection or printing at [http://ss.oaisd.org/bi9-europe.html](http://ss.oaisd.org/bi9-europe.html)*
How can we make these historic trends in temperature even easier to appreciate? One approach is to have students look at a modern data table and find analogous locations in Michigan. One good source is the NOAA website:

www.ncdc.noaa.gov/climatenormals/clim20supp1/states/MI.pdf

This table lists the growing season in dozens of Michigan towns. Some are quite short, such as at Sault St. Marie, with 119 days, or Newberry with 114, Gaylord with 115, and so forth. In other words, Denmark in the year 800 had a frost-free season that was shorter than in many northern Michigan towns that are largely surrounded by forest, with very few successful farms anywhere nearby. Then, by the year 1000, Denmark had a growing season that was as long as places like Holland, in a prosperous fruit-and-dairy area, or Bad Axe, in the Thumb county that leads the state in corn and bean production.

In other words, the climate in the land of the Vikings went from being like the pine forests of the Upper Peninsula to the best croplands in the Lower Peninsula, in less than 200 years.

Why is this worth knowing? One reason is historic - the Viking raiders had an outsized impact on Europe (which may explain why at least half the residents of Michigan have some Viking DNA in their ancestry!) An equally important reason is climatic – this kind of thing is happening again, but much faster. Among easily available public sources, the USDA Soil Survey for Isabella County noted that the average frost-free season at Mt. Pleasant was 142 days long, based on the record from 1950-1979. More recently, the NOAA website noted above says that the frost-free season at Mt. Pleasant is 159 days long, based on the record from 1971-2000. And for the period 2013 through 2017, it was an average of 163 days, as reported by another useful site for individual student inquiry:


One might think that a longer growing season would be a good thing for Michigan, where half of the state was clearly too cold for successful farming in the 20th century. That assumption, however, is questionable for at least four reasons. First, a lot of soil in northern Michigan is infertile sand, a result of centuries of pine forests growing on coarse material left by glaciers. Second, many fruit trees require a period of chilling weather for proper flowering. Third, a longer growing season can bring weeds, insects, and other pests that have few natural enemies here. Fourth, and perhaps most important in the near term, Michigan’s farm region has experienced slightly higher temperatures in July, slightly stronger rainstorms in summer, and slightly longer periods of dry weather between storms. This combination of changes has a direct financial consequence: supplemental irrigation is often needed to maintain crop health through a summer period that is hotter (more evaporation) and dryer than in the mid-20th century. Stated another way, Michigan farmers may have already spent many millions of dollars installing irrigation systems that might not have been needed 60 years ago.

This last statement needs a lot more evidence before I will be comfortable removing qualifiers like “may” or “might” from it. In short, the changing need for irrigation is a good subject for future inquiry. Here, let me just conclude that the rise and fall of the Vikings in Europe coincided with a change in climate that turned Denmark from a European UP into a European Thumb – from a cold forest that could support only marginal grazing when cleared, to a place where grain and milk production could be highly profitable. This kind of thing seems to be
happening in Michigan today – a rise of “just a degree” can have significant economic effects in a state where the frost-free season is between 110 and 160 days long.

One last statement: I hope no one reading this article is tempted to conclude that the current rise in temperature is “just one more of nature’s normal ups and downs.” The data also clearly show that the current warming is much faster than it was during the “Viking warm period,” and it has already taken us far outside of the “normal” range of variation for the current position in the earth’s orbit. To suggest otherwise is to be either willfully ignorant or intentionally misleading. Climate change is happening, humans are largely responsible for the current rise in temperature, and we need to do a better job of linking climate change to history and economics, in order to help future citizens identify ignorant and misleading statements about climate change.
Winter Tips From the GVSU Groundswell Project

Joanna Allerhand, Assistant Director, Center for Educational Partnerships, Grand Valley State University, College of Education. Amanda Syers, Groundswell Project Assistant, Center for Educational Partnerships, Grand Valley State University, College of Education.

Outdoor education can happen in any season – even winter. The quiet of a snow-blanketed field or forest creates an exploration wonderland. Try these tried and tested activities and resources to spark the winter curiosity with your students:

• Generate inquiry about Earth’s energy budget with an investigation about the reflectiveness of snow using the MEECS Climate Change Guide (https://wgvu.pbslearningmedia.org/resource/meecsclimate3/investigating-energy-balance)
• Make snowfall measurements and determine the snow water equivalent using GLOBE protocols (https://www.globe.gov/documents/348614/3e7ff179-fca0-4eae-8c4e-279f4da03592)
• Look for animal habitats in deciduous trees once the leaves have fallen. Bird nests and leafy squirrel nests are much easier to see in the winter.
• As snow melts, look for evidence of animals that had inhabited the subnivean zone. For more information on the subnivean zone and what to look for: http://msue.anr.msu.edu/news/the_subnivean_zone_life_under_the_snow_part_1
• Make phenological observations and do data collection using a citizen science program like Project Budburst (https://budburst.org/)
• It can be easier to identify deciduous trees without their leaves! Have students look at bark, twigs, and buds and use a winter tree guide to help with identification.

In the great words of Dr. Scott, paleontologist, on PBS series Dinosaur Train, “Get outside, get into nature, and make your own discoveries!” (http://www.pbs.org/parents/dinosaurtrain/more-dinosaur-train-fun/nature-trackers-club/)

All photos are by Joanna Allerhand, co-author of the article.
The expression “seeing is believing” is usually true. But in science education, many of the concepts can be quite difficult for students to observe because they can be very small, very large, very fast or very slow. So how can we provide students with an experience of science phenomena in the confined 45 to 90 minutes of a class period?

One option is to use simulations to give students the ability to slow down the really fast, speed up the really slow, and see the very large or very small. Simulations enable students to build a mental framework for how a “hard to see” system works. They can change variables in a simulated system to observe how each effects the system; and by doing so, students build a conceptual understanding. Simulations are tools that can be embedded within a science lesson to provide a memorable experience for students in the context of all of the background vocabulary, equations, rules, laws, or theories associated with the phenomenon.

Try these 5 simulation-based lessons with your students:

1: ‘FRESHWATER CHEMISTRY’ FROM EARTH SCIENCE

This lesson explores a hypothetical aquatic ecosystem where students can change the pH and temperature of the water. They can see a possible effect on the diversity and population size of the fish that live there.

For more information, download the Teacher Notes (pdf). You can view and download the full TI-Nspire CX activity on our website.

2: ‘IT’S JUST A LUNAR PHASE’ FROM EARTH SCIENCE

Observing moon phases takes weeks and students can usually only see them after school has ended and from Earth. This simulation allows students to see how and why the phases of the moon happen – with a view from space!

For more information, download the Teacher Notes (pdf). You can view and download the full TI-Nspire CX activity on our website.
3: ENERGETIC COASTERS FROM PHYSICAL SCIENCE

Many students may not have the opportunity to visit an amusement park or may be too nervous to ride a roller coaster. They aren’t just missing out on the thrills of amusement park rides – those rides also involve a lot of awesome science! Use this simulation to help students explore the concepts of kinetic and potential energy.

For more information, download the Teacher Notes (pdf). You can view and download the full TI-Nspire CX activity on our website.

4: ‘DNA REPLICATION’ FROM BIOLOGY

DNA replication is one of those concepts that students simply cannot see. The process is too fast and too small to observe directly. This simulation allows them to slow down the process so they can see how DNA replication works.

For more information, download the Teacher Notes (pdf). You can view and download the full TI-Nspire CX activity on our website.

5: ‘BUILD AN ATOM’ FROM CHEMISTRY

Atomic structure is just about as small of a phenomenon as you can get! Explaining to students how atomic structure works will only get them so far. Having them see it by building atoms through the addition and subtraction of sub-atomic parts will help them gain a better understanding of structure and charge. This simulation is an adaptation of the very popular PhET simulations from the University of Colorado.

For more information, download the Teacher Notes (pdf). You can view and download the full TI-Nspire CX activity on our website.

Even the very best simulation doesn’t always accurately represent natural processes as they happen in reality. It’s always a good idea to make sure students know that when simulations are being used, they are very good estimates of reality but they are not absolute representations of reality.
Citizen Scientists for All Ages -
A Celebration of the Migrating
Monarch Butterfly

By Nancy Berg, Educational Specialist and Naturalist, DeGraaf Nature Center, Holland, MI. and Nature Education Center, Hemlock Crossing Ottawa County Parks, West Olive, MI.

INTRODUCTION
The monarch butterfly is one butterfly that is highly recognized for its extended and generational migration route. This journey comes complete with many natural obstacles along the southward route to Mexico from Michigan. The monarchs’ overwintering site in Mexico was first and only discovered through the efforts of passionate volunteers who used a tagging device which then led to the 1975 discovery that the Monarchs from as far as the northern states of Michigan and Minnesota, as well as Canada, were overwintering in central Mexico. The term, citizen scientists, was then given to these individuals. The tradition of tagging and learning about the tracking of these beautiful insects continues for citizen scientists of all ages at a Michigan-Based Outdoor Educational Farm in Clarkston, Michigan, The Clarkston Family Farm.

WHAT IS A CITIZEN SCIENTIST?
The term, citizen scientist, has been around since the late 19th century to define untrained, yet passionate citizens, willing to conduct and monitor intensive and investigative scientific research. These volunteers are passionate but not professional scientists, yet much of the data collecting and processing is done by the citizen scientist. Over the years, citizen scientists have been called on to collect data on migrating birds, invasive species, mammal populations, and insect behavior and migration. One such insect is the monarch butterfly.

Recently, I was able to participate along with butterfly expert, Deborah Jackson, and other volunteers in a Monarch Butterfly Festival held at Clarkston Family Farm in Clarkston, Michigan, on September 8, 2018. This event involved a variety of citizen scientists activities for all ages and experience. Clarkston Family Farm’s CEO and outdoor educator, Chelsea O’Brien, coordinated activities which included identification and tagging of monarch butterflies and then releasing them on their long journey. This effort was an opportunity for many in the Clarkston community to become citizen scientists.

HOW DOES MONARCH TAGGING WORK?
Due to loss of habitat and its native plant species, the common milkweed, along with shifting climate and unfavorable environmental conditions, the monarch butterfly has decreased by approximately 1 billion butterflies over the past 15 years. Efforts by gardening organizations, such as The Wild Ones, located in Grand Rapids, Michigan, have influenced planting habits of local gardeners throughout Michigan. Planting native milkweed species along with other butterfly plants such as the Purple...
Coneflower, Wild Bergamot, and Butterfly Weed, help support the comeback of the Monarch butterfly. Tagging the monarch plays an important part in identification of a particular butterfly. The purpose of tagging monarchs is to connect the original location of capture to the point of recovery of each butterfly. This tagging process helps researchers understand the migration route, the influence of weather and food conditions along the route, and the overall survival rate of the monarchs. Small coded tags are recorded by citizen scientists including the date, the location, the gender of the monarch, and a specific tag number. Placing the tag on the butterfly wing does not harm the butterfly in the least nor does it impede their flight. The tags do, however, provide important information to questions regarding monarch biology and conservation. Organizations like Monarch Watch, and Monarch Alert have regularly scheduled tagging programs and are always looking for more citizen scientists to help in the effort.

CHELSEA O’BRIEN ANSWERS THE CALL

Working with butterfly expert, Deborah Jackson and her team of butterfly enthusiasts, Chelsea O’Brien thought it would be extremely beneficial for the Village of Clarkston and her Clarkston Family Farm community to work together as citizen scientists in the effort to educate, instruct, and involve residents in this unique opportunity. The Monarch Festival was held on September 8 with over 800 people in attendance. Various stations were set up around the farm property and near the milkweed meadow to excite learning about the monarch butterfly, its lifecycle, its migration, its native food source, and the tagging process. Participants learned about planting a butterfly garden, marveled at the miracle of the metamorphosis of the monarch caterpillar, and were given a caterpillar to raise. Practicing the art of tagging a monarch wing and setting it free was the final experience as a citizen science.

GET INVOLVED

Public involvement in Monarch Butterfly Citizen Science programs have been on the rise since 1990. Some of the programs focus on different aspects of the monarch biology. These include lifecycle study, migration, population dispersal, disease control, gardening techniques, and overwintering. School groups and science classes are a key component to spreading information and effort toward this worthy cause. A recent
international art-related project entitled, The Mother Earth Parachute Project, could be one such avenue to get educators fired up about monarch butterflies. I have included a website with more information about this particular project. Whichever aspect you choose to use, get involved! It is a worthy environmental project that will turn your students on to being the next generation of citizen scientists!

RESOURCES:
https://www.monarchwatch.org/
https://rivercitygrandrapids.wildones.org
https://motherearthproject.org/parachutes
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