Runaway Carbon Cycle: Reducing Carbon Emissions through Understanding and Action

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Abstract

Students in rural schools can produce substantial gains in environmental literacy through engaging activities on the carbon cycle and stewardship activities. The following article describes a NOAA Planet Stewards project that was intended to be one year in duration but is on-going into its second year due to the pandemic. Survey results document that substantial attitudinal and behavioral changes can be gained in areas of the country not normally served by curbside recycling programs through stewardship activities focused on recycling, reducing, and reusing materials in relation to saving atmospheric carbon. While the pandemic initially disrupted and delayed the project, it also forced the project to explore new ways to recycle materials that provided interesting insights into future approaches concerning environmental stewardship.

Introduction

It can be a challenge to relate something as complex as the carbon cycle to climate change, and it can be an even bigger challenge to relate a tenuous understanding of the carbon cycle to environmental stewardship that retains a meaningful, long-lasting impact on a student to motivate attitudinal and behavior change. While it may be easier to relate carbon cycle issues to students in a community that is well served by recycling and conservation programs, the potential gains in places that are lacking such programs provide remarkable opportunities to substantially shift opinion. If one really wanted to move the needle toward climate literacy, perhaps, there is no place better than rural South Dakota with its limited availability of drop-off recycling, nearly non-existent curbside pickup of recyclables, and, not surprisingly, low rates of recycling. Now, more populated regions of the country may wonder why this is the case. Think of all the times there was a bin for a certain type of recyclable conveniently placed there for you or neatly arranged curbside bins for sorting recyclables or various drops-offs located nearby for your convenience. Now imagine taking all of that away. You may think you would still recycle, and you would probably be wrong. The reality is that if you did not have these programs and convenience, recycling would be just as alien to you as it is to most of my students. I, myself, and my family used to burn our trash along with all of my burnable

recyclables since I lived in a farmhouse during my early years of teaching and did not have trash pickup services like many rural residences. Because of these limitations, the tradition of a burn pit or burn barrel is engrained in many parts of rural America. When we moved to town and burning was no longer an option, we decided to save recyclables and drop them off in the nearest recycling center 85 miles away in Aberdeen, South Dakota. Recyclables were dropped off before the beginning of shopping trips in town making our trip carbon neutral many times over. This is a cumbersome means of recycling but is the only available option to many rural South Dakotans. Replicating this strategy among students was a key aim of the stewardship component of this project made possible by funding from NOAA Planet Stewards.

The Three Rs

The stewardship activity was coupled with an education component tied to our textbook's unit on ecology and environmental science to relate carbon emissions to climate change for 7th grade Life Science students and 10th grade Biology students; however, components of the stewardship project were implemented in all grades in 6-12.

Table 1. Earth and Human Activity

Performance Expectation

MS ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Dimensions	Classroom Connections
Science and Engineering Practices	
Asking Questions and Defining Problems • Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.	• Students collect and analyze materials to determine the amount of carbon dioxide produced in the production of various items and how much carbon dioxide from the atmosphere will be saved if it is recycled.
Disciplinary Core Idea	
SS3.D: Global Climate Change • Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming).	• Students identified an act of reducing and reusing in their daily life, document it, and calculate its impact over the course of a month and project that impact into a full year in terms of atmospheric carbon dioxide saved.
Cross-Cutting Concepts	
Cause and Effect • Cause and effect relationships are routinely identified, tested, and used to explain change.	• Students investigated the relationships of carbon dioxide emissions and climate change.

This education component was paired with stewardship activities that focused on how students could individually decrease their carbon footprint through the three Rs of reduce, reuse, and recycle. While the concept of the three Rs in conservation may seem a bit worn out, in reality for those students who are at the beginning of their environmental stewardship, this is actually an ideal place to start. The concepts of reduce, reuse, and recycle are not tired phrases for students who are not actively engaged in environmental stewardship. In fact, one will find that students unfamiliar with stewardship often get these concepts confused. That is why each student that participated in the project had to identify at least 10 items that could be recycled at home. These items would need to be brought into school, approved for local recycling drop off in Aberdeen, and weighed to determine the environmental impact of its production and its recycling.

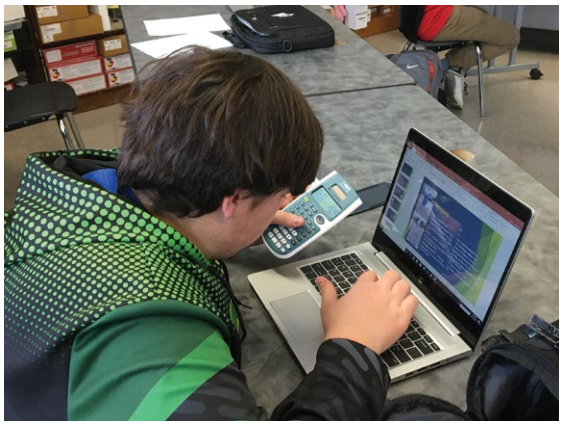

Figure 3. A sophomore biology student calculates the amount of carbon dioxide produced for the production of each of his recyclable items and how much atmospheric carbon dioxide would be conserved if these same items were recycled.

Photo credit: Spencer Cody

Having students bring in their recyclables for documentation allows the teacher to verify what is being recycled and allows students to apply specific calculations to determine the amount of carbon dioxide produced in the production of various items and how much carbon dioxide from the atmosphere will be saved if it is recycled. It has been my experience in working with middle and high school students that there is little awareness of what is thrown out in their homes and even more confusion over what is and is not locally recyclable. Frequently, when students bring in items to be vetted and measured, they bring in items such as single-use plastics or plastics that

Figure 4. Sophomore Biology students weigh their recyclable items in order to calculate the environmental impact production and recycling of each item.

Photo credit: Spencer Cody

have resins that are only recyclable in a few circumstances beyond our local means. These do not count toward their ten items.

The goal of the project is not to fix the issue of all of our non-recyclables or de facto non-recyclables but to get recycling items that are relatively easy to recycle such as cardboard, paperboard, paper, newspaper, magazines, resins #1 and #2 plastics, aluminum, and steel/tin cans. This alone should reduce trash by roughly half in most cases. The trick is to get students to recognize what they throw away, what could be recycled, what the environmental impact is, and get them in the practice of recycling.

Discovering Reducing and Reusing

Additionally, students were required to identify an act of reducing and reusing in their daily life, document it, and calculate its impact over the course of a month and project that impact into a full year in terms of atmospheric carbon dioxide saved. Again, documentation and verification by the teacher was important. Frequently, students demonstrated their perception of reality about what could be reduced and it was not realistic. For example, a student trying to explain how much carbon dioxide they are going to save by using a cold-water cycle to wash a load of towels versus a warm-water cycle can yield almost comedic level responses from a student who obviously has never washed clothes. It is important to cut through this perception gap since, unlike most adults who have had to stretch resources for financial means at some point through reducing or reusing, these thoughts do not come naturally to many students. It can be a difficult process for them to brainstorm ideas for reducing and reusing, but when they start to realize the many different possibilities and what could be saved environmentally and financially, it becomes valuable information to them.

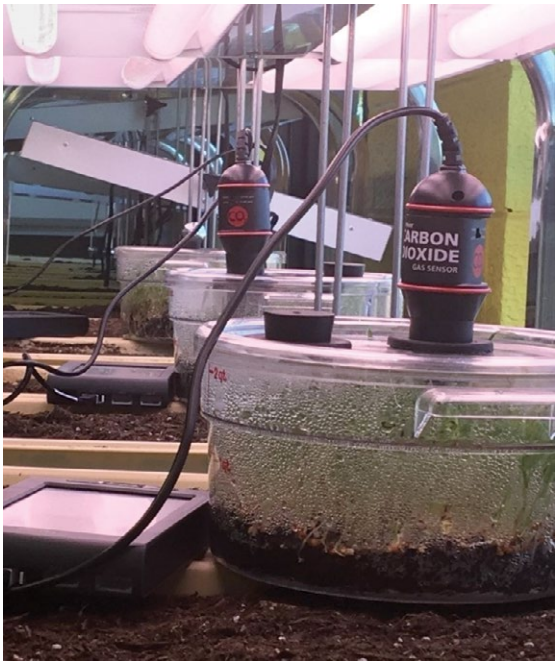

Figure 5. Students experiment with sealed environments by monitoring carbon dioxide levels over a three-week period to document levels as seeds germinate using cellular respiration and then begin to utilize photosynthesis.

Photo credit: Spencer Cody

Contained Environments and Biosphere 2

Our Planet Stewards project started without a hitch in October of 2019 with the initial administration of pre-surveys to capture pre-knowledge of climate literacy (Climate, 2009) and levels of environmental stewardship. As the pre-surveys cycled through the classes, there were many misconceptions concerning the carbon cycle and climate change. The surveys were based on similar surveys administered in a prior NOAA Planet Stewards project by the same investigator but now with an expanded set of questions on the carbon cycle, reducing, and reusing. Additionally, recycling was sporadic to nearly non-existent depending on what was being recycled. Practices of reducing and reusing were limited. Since there were a lot of misconceptions and questions surrounding the carbon cycle and sources of greenhouse gases, students began projects relating research into Biosphere 2 and developing their own contained environment while monitoring carbon dioxide levels. Students were given a 2-liter Vernier gas chamber and allowed to fill the chamber with potting soil and a variety of seeds then watered the chamber before placing the sealed lid back on. A Vernier carbon dioxide probe was

attached to the sealed environment allowing for students to monitor levels within the container without opening it.

As one would expect, the container initially registered carbon dioxide levels comparable to what would be found in a classroom, about 400-1,000 ppm, depending on how long and how many students had been in the classroom. The sealed environments and carbon dioxide probes were placed under grow lights that were left on for 24 hours a day. Within a day the carbon dioxide levels would usually spike due to microbial activity in the soil. Then within two to three days when cellular respiration from the germinating seeds began, a massive increase carbon dioxide levels would be detected. Bird seed often works well for cheap and quick germinating plants for many investigations, including this one. Once germination is fully underway, it is not unusual to have some containers peak beyond 20,000 ppm, levels that would cause serious health problems in humans. The carbon dioxide levels do not begin to level off until photosynthesis overtakes the cellular respiration rate. Usually, this happens about one to two weeks into the experiment. The level then declines to an elevated level of a few 1,000 ppm. These results usually shock students into realizing how delicate and complex the carbon cycle really is and why carbon is always at the forefront of environmental issues. The project then related these results to the Biosphere 2 and the human experiments on contained scientists from the early 1990s. To heighten the interest level of students in the results of the Biosphere 2 experiments (Zimmer, 2019), 13 students were selected among applicants in grades 6-12 to visit Biosphere 2 in March of 2020 to work with scientists on site and tour the facility to learn about current and past research relating to climate issues. These selected students became the motivational core around our stewardship and research efforts. Of course, March of 2020 had other plans.

Pandemic of Possibilities

Sealed environments, Biosphere 2 research, and carbon dioxide levels would pave the way toward the stewardship aspect of the project. As has been described before, students would need to document recyclable items, apply that recycling to a 30-day time period, and project the carbon dioxide savings out over a year. The same would need to be true with their documented acts of reducing and reusing. Stewardship activities began in December of 2019 and went well until March 13, 2020. It was a Friday, of course, when it was announced that schools throughout the state would be closed indefinitely. This canceled our field trip to Biosphere 2, which was to be the next week during our spring break. This also halted our recycling efforts since all drop off sites were closed to the public. Even aluminum cans were temporarily no longer recyclable. While we were able to continue with most of our efforts of reducing and reusing, our recycling stewardship ground to a halt. All the recyclables that we had collected were held in storage until later that fall once drop off sites started to open. What were we to do in the meantime to meet our recycling goals? In looking at our options, I noticed that a scrap metal recycling facility in Aberdeen was still accepting scrap metals with no aluminum cans. With this information I discussed scrap metals with

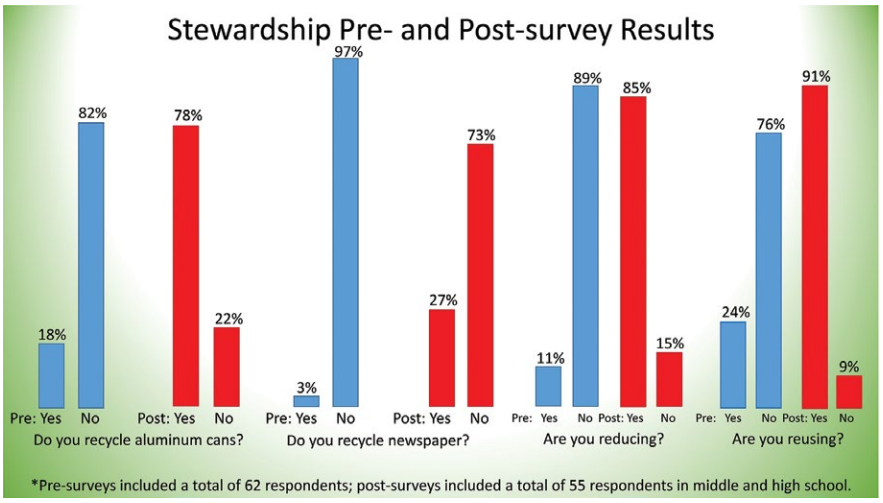

Figure 2. A sampling of the data collected from the pre- and post-surveys from the project indicate a significant shift in reducing, reusing, and recycling behavior. While data on a wide range of recyclables was collected, aluminum cans and newspapers represented the two extremes in what was already and what was not recycled. Similar shifts were experienced in all other areas of recyclables.

Photo credit: Spencer Cody

those students still trying to meet recycling goals. With a little socially-distanced coordination, we were able to easily exceed our recycling conservation goals by recycling scrap aluminum from junked ramps, platforms, rails, posts, siding, gutters, and downspouts. In fact, students were very interested in the idea of taking in scrap for money. The idea of finding shelterbelts (linear plantings of multiple rows of trees or shrubs) filled with junk, a typical place for rural families to discard old equipment, having profit potential and a major impact on conserving carbon really got their attention and may be a key area to explore for stewardship activities in the future. Without our participation in NOAA Planet Stewards, we would never have organized such an effort and would not have discovered such useful insights into recycling scrap through students' stewardship.

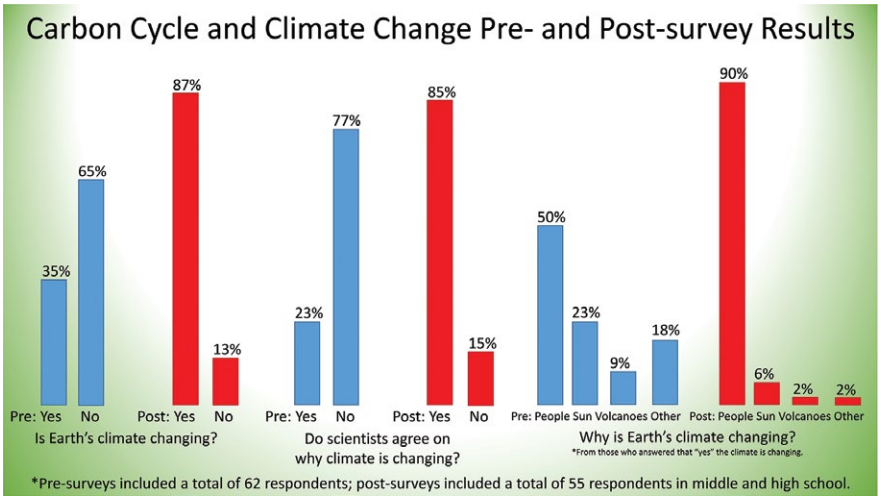

Figure 1. A sampling of the data collected from the pre- and post-surveys from the project indicate a significant shift in understanding the carbon cycle and climate change.

Photo credit: Spencer Cody.

Conclusion

Our goals of conserving at least 466 kg of carbon dioxide from the atmosphere through acts of reducing, reusing, and recycling were met. While the stewardship component has been restarted and will run until our rescheduled Biosphere 2 field trip in June, we have successfully conserved 952 kg of atmospheric carbon through documented acts of reducing, 556 kg through reusing, and 7,125 kg through recycling. Additionally, short-term shifts in attitudes concerning climate change and stewardship were documented. Some key documented gains included a more than doubling of students indicating that the Earth's climate is changing, a nearly quadrupling of those indicating that climate change is caused by human activity, and a 65% increase in students indicating that carbon dioxide is a greenhouse gas.

References

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About the Author

Spencer Cody teaches 7-12 Science at Edmunds Central Middle and High School in the Edmunds Central School District in Roscoe, South Dakota. He holds a BA degree in Middle School and Secondary Biology Education from Concordia College in Moorhead, Minnesota, and an MS degree in Chemistry Education from South Dakota State University in Brookings, South Dakota. He has taught for 15 years in the middle and secondary sciences and is the recipient of numerous awards for his teaching including the 2018 Sanford Inspire Teacher of the Year for South Dakota, 2020 North Central Section Outstanding Earth Science Teacher, 2020 EPA Presidential Award for Environmental Education, and 2021 Region Four Teacher of the Year for South Dakota. Spencer can be reached at Spencer.Cody@k12.sd.us.