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PRACTICAL ACTIVITIES TO HELP GEOSCIENCE STUDENTS DEVELOP THE SKILLS THEY NEED TO SUCCEED

DR. LISA DONER

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INSPIRING THE **NEXT GENERATION**

PRACTICAL ACTIVITIES TO HELP GEOSCIENCE STUDENTS DEVELOP THE SKILLS THEY NEED TO SUCCEED

Traditional teaching methods that focus on the memorization and regurgitation of facts rarely lead to genuine learning. **Dr. Lisa Doner** and her team from **Plymouth State University** in the US have developed a program full of practical activities that allow their students to develop the skills needed for a successful geoscience career.

Dr. Lisa Doner

Associate Professor, Center for the Environment, Plymouth State University, USA

PROFILE

Field of research
Geoscience

Research project
Developing an educational research program to help students gain the skills they need for a successful career in geoscience

Funder
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TALK LIKE A ... GEOSCIENTIST

Albedo effect — the reflection of sunlight from the Earth's surface

Critical thinking — the analysis and evaluation of available evidence and arguments to reach a conclusion or create a new idea

Eutrophication — the process by which a body of water becomes enriched with nutrients, often leading to algal blooms and the creation of dead-zones

Watershed — an area of land that channels rainfall and snowmelt through streams and rivers and eventually into lakes, reservoirs or the ocean

Runoff — a major source of pollution, runoff occurs when excess water flows across the surface of land and into nearby streams, rivers or ponds, picking up toxic substances along the way. Nutrient-rich soil or water contains large amounts of nitrogen, carbon, phosphorus, sulfur and potassium

As all high school students know, learning new things can be challenging. Perhaps you have found yourself thinking, "Why would I possibly need to know about the second law of thermodynamics?" or "How is Pythagoras' theorem going to benefit me in the future?" Reciting facts, memorizing formulas and deciphering abstract concepts can feel tedious, confusing and pointless.

Traditional teaching methods that focus on the memorization and regurgitation of facts have bored students for centuries. These methods rarely lead to genuine learning, with students often forgetting what they have learned as soon as the exam is over or their coursework is submitted. However, there are other ways of teaching that can help students truly understand new concepts and apply them in a range of situations.

For example, taking part in practical activities that require students to use scientific concepts can be a great way for them to cement their learning. This is particularly true if the activity is related to topics that are relevant to the students' lives or local areas. This approach helps to ingrain knowledge and makes the concepts more accessible when students try to apply them in different situations.

The GeoPaths project at Plymouth State University in the US uses practical teaching methods to help its students learn. Led by Dr. Lisa Doner, the project also provides mentors for its students and helps them find internships and develop skills that can boost their resumes and career prospects.

What is GeoPaths?

GeoPaths is an educational project designed to cultivate the scientific knowledge and skills needed to start a successful career in the field of geoscience. Plymouth State University is a predominantly undergraduate institution (PUI), meaning that its main focus is on teaching undergraduate degrees, rather than facilitating the research of professors and lecturers. As a result, students at PUIs generally have fewer opportunities to gain experience and skills in the more niche areas of science.

"Students who dream of studying glaciers," says Lisa, "or exploring the deep sea or the moons of Saturn, might be discouraged with schools that don't have instructors who can teach glacial geology, physical oceanography or planetary sciences." These kinds of specialties are more common in schools that have a greater focus on research. The GeoPaths project is a way to give PUI students the practical skills and career opportunities they might not otherwise receive.

In Plymouth, New Hampshire, university students set up a field of mirrors and temperature sensors to explore the impact of changes in albedo on Earth's surface.

What are the aims of GeoPaths?

The overall goal of the project is to inspire students towards a career in geoscience whilst also building the critical thinking and technical skills that will help them along the way. Students enrolled in GeoPaths take part in a research project based around watershed areas. These are areas in which surface water converges at a single point, like a river mouth, or flows into another body of water, like a lake. Students in the GeoPaths project design, calibrate and analyze the data from monitoring devices that they use to study watersheds.

By engaging with the watershed research project, students are helping the local community understand more about their environment. The students gather and analyze essential data which helps to generate new knowledge about the local watershed system, such as how rainfall interacts with the land and how sediments are deposited in lakes.

GeoPaths students do not just gain practical skills from these activities. They can use these experiences to help them bolster their resumes and connect with other scientists, be that through their internships, post-graduate courses or professional careers. Students enrolled in the GeoPaths project are assigned mentors who help them make the most of these opportunities.

What role do mentors play in GeoPaths?

"Mentoring is about going beyond simple instruction when interacting with students," explains Lisa. "It includes being aware of, and sensitive to, challenges that students may have in their lives that limit their ability to learn at the same tempo as students with fewer challenges."

GeoPaths students come from a variety of backgrounds and so it is important that the mentors reflect this. "Students from non-white communities may not fully benefit from mentoring offered by an entirely white faculty," says Lisa. "A sense of connection may be more easily accomplished if the mentors come from diverse backgrounds."

> **"THINKING ABOUT THE ENVIRONMENT REQUIRES WORKING IN ALL OF EARTH'S SPHERES."**

The mentors engage the students in ungraded activities that are intended to build a student's confidence when working as a scientist. Much of this is done by developing basic skills such as collecting and analyzing data, performing calculations and using computer software such as Excel.

What other activities do GeoPaths students take part in?

The activities offered to GeoPaths students provide them with a range of practical skills and experiences. There are field trips led by expert hydrogeologists, on which students study river overflow; snowpack assessments, in which students examine the layering and stability of fallen snow; and electronics training, in which students program software for temperature sensors. The practical skills that the students cultivate whilst doing these activities are likely to come in handy when they start their careers.

The GeoPaths project also helps its students take the first steps into a successful career in geoscience. Mentors help their students make connections with major research agencies and guide them through the process of searching and applying for jobs. Students are shown how to tailor their resume to their desired job descriptions and pick out areas in which they are making good progress, as well as areas in which they may need to develop new skills.

What skills are important for a successful career in geoscience?

As well as the practical, technical and professional skills gained from these activities, one of the most important skills is critical thinking. Specifically, critical thinking from a geoscientific point of view. "Thinking about the environment requires working in all of Earth's spheres," says Lisa. "Most environmental textbooks focus almost entirely on the biosphere, but by deliberately bringing geology to the forefront, we can introduce aspects of the environment that are otherwise brushed over."

Take the problem of eutrophication, a process in which bodies of water are overloaded with nutrients that disrupt food webs and kill off wildlife. This is often seen as an entirely biological problem, but geoscience elements are also at work. For example, it is important to understand the role that soil plays in controlling nutrient-rich runoff from agricultural land, or what happens to nutrient-rich sediments when they are deposited at the bottom of lakes. Taking these elements of geoscience into consideration and thinking critically allows scientists to consider solutions more broadly.

What successes has GeoPaths had?

The success of the GeoPaths project is measured, in part, by the careers of its alumni. Of the six students who graduated from the first cohort, three progressed on to graduate school, one is working as a seasonal hydrologic technician, and another is a consultant at a geotechnical firm. Students from the second and third cohorts have completed internships and are well on their way to starting successful geoscience careers.

GeoPaths has also developed an exciting new research project that is used to help train students, teachers and the general public. This project, called MEERCAP, focuses on elements of geoscience that relate to climate change, and engages people from a much broader community than GeoPaths.

ABOUT *MEERCAP*

Mirror Exploration, Experimentation, and Reflection in Climate Adaptation Planning, or MEERCAP, is a field experiment developed by researchers at Plymouth State University. The project has been designed to investigate whether collections of mirrors can reflect enough sunlight to create a cooling effect in the surrounding environment, and potentially combat climate change.

"The earliest climate modelers understood that changes in Earth's reflectance, or albedo, was a primary factor in causing cooling or warming," explains Lisa. Light-colored surfaces, like snow and ice, have a high albedo and reflect a large amount of sunlight away from Earth's surface. In contrast, dark, non-reflective surfaces have a low albedo and absorb a lot of sunlight.

For decades, researchers have been investigating different ways of increasing the albedo effect, from painting roofs with white paint to releasing clouds of reflective particles into the atmosphere. MEERCAP's approach, using collections of mirrors, is an affordable and easy-to-implement method of increasing the albedo effect on a local scale. Lisa explains, "Using mirrors improves on the effectiveness of the white roofs idea because mirrors have over 95% reflectance and can be aimed at the sun in the most-effective angle."

MEERCAP has two field sites, each with six plots. These include control plots, which have no mirrors, and experimental plots, each of which have a different number of mirrors. All the plots have an identical network of sensors which capture changes in ground temperature and soil moisture.

How are students involved in the project?

The third cohort of GeoPaths students were involved in developing the MEERCAP project. "As we worked on the project with the students," says Lisa, "we realized how many additional, job-essential, training activities we could add to the student experience."

When taking part in the MEERCAP project, students help design the frames that hold the mirrors, set-up and repair the sensors, and write the programs that collect and download the data. "Going forward," continues Lisa, "we anticipate that students will create and test their own research questions dealing with the interaction of the sun and the mirrors." The MEERCAP project provides students with a chance to improve their critical thinking skills as well as develop additional practical skills.

Why are these additional skills important?

"Many children grow up without any practice in using tools," says Lisa. Learning how to hold a screwdriver, wield a hammer and cut and shape materials like wood are important skills. "Almost every job outside of a desk setting includes an occasional need to work with such tools," explains Lisa.

Most repairs to environmental monitoring sites are made by the researchers who use them. Students who know how to use hand tools will be able to apply these skills in problem-solving situations, which will make them valued employees. "Their knowledge in these areas can reduce maintenance delays and save the costs of hiring outside expertise," says Lisa, who speaks from personal experience in field work.

"THE EARLIEST CLIMATE MODELERS UNDERSTOOD THAT CHANGES IN EARTH'S REFLECTANCE, OR ALBEDO, WAS A PRIMARY FACTOR IN CAUSING COOLING OR WARMING."

Explore careers in *geoscience*

- Explore the Careers and Internships page on the US Fish and Wildlife Service webpage (www.fws.gov/careers). You can see the kinds of opportunities available to budding environmental scientists and apply for roles they are advertising.
- The US Fish and Wildlife Service also offers summer internships designed specifically for students. It provides a range of programs in locations all across the US.
- The US Geological Survey offers internships to students at all levels of their education: **www.usgs.gov/human-capital/students-and-recent-graduates**
- Many other organizations and universities offer summer schools that focus on geosciences. Contact organizations and universities in your area to see what opportunities they offer.
- Even if universities do not offer summer schools, it is worth getting in touch with professors to see whether they can provide work experience opportunities.

Meet two GeoPaths students

Emma Cox

Earth Sciences Student,
College of Earth and Mineral Sciences,
Penn State University, USA

When I graduate, I'd like to do research about current climate change, study ice cores and climatological records, and receive my doctoral degree.

I took part in GeoPaths and MEERCAP because I wanted to gain real experience in laboratory and fieldwork research for climate sciences, especially since this project has so much potential.

I gained extensive knowledge of how experimentation and research happen in the real world through constant problem-solving, developing conclusions to help further the experimentation, and learning how to use new tools and software.

The thing that sticks out for me the most is the importance of collaboration when doing research. Teamwork is important for solving problems, coming up with new ideas, and getting tasks done more efficiently.

I would recommend a career in geosciences. If you love to learn about Earth through both physical interaction and scientific analysis, geoscience is a great path for you.

My advice is to try to save your notes and textbooks from classes and make connections with professors you like. It's a wide field with many interesting niches. Explore the field of geosciences confidently, and don't be afraid to ask questions.

Emma shows fellow interns how to survey the mirror field using a total station.

Myles Sornborger

Former Environmental Science and Policy Student, Plymouth State University, USA

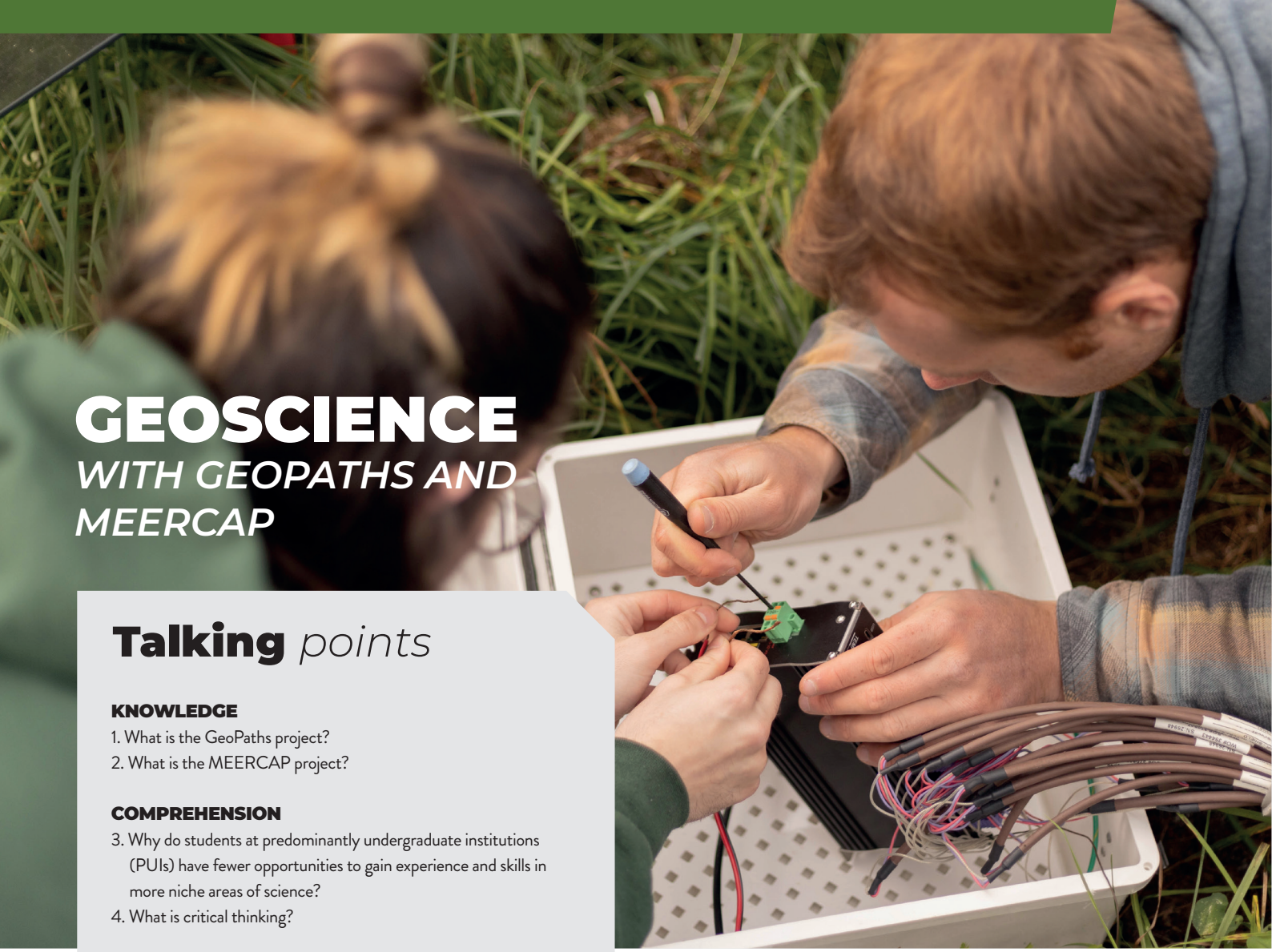
When I graduated, my goal was to start a science career in New England. I am achieving that as a hydrologic technician with the White Mountain National Forest. I took part in GeoPaths because I wanted to gain real experience early in my college career.

Thanks to GeoPaths, I gained a head start in developing soft skills that everyone needs for a successful career, as well as many other skills that make my resume more notable.

I also received guidance on finding a career path that would fit me, and my relationships with my mentors have continued beyond the project. I particularly enjoyed the time I got to spend with my mentors and cohort, both in the field and the classroom.

If geoscience interests you, I would absolutely recommend it. The career opportunities are there. Get as much practical experience as you can and don't specialize too early.

Myles at work on his GeoPaths internship, Franconia Ridge, New Hampshire.



GEOSCIENCE
WITH GEOPATHS AND MEERCAP

Talking *points*

KNOWLEDGE

1. What is the GeoPaths project?
2. What is the MEERCAP project?

COMPREHENSION

3. Why do students at predominantly undergraduate institutions (PUIs) have fewer opportunities to gain experience and skills in more niche areas of science?
4. What is critical thinking?

ANALYSIS

5. How would you define 'genuine learning'?
6. Why do you think teaching methods that rely on the memorization and regurgitation of facts may not lead to genuine learning?
7. In what ways do hands-on activities that are relevant to students' environments lead to genuine learning?

EVALUATION

8. How would you assess the success of GEOPATHS and MEERCAP?
9. Think back to an activity where you were asked to think critically. How effective were your critical thinking skills? What support did you need to complete the task?
10. Do you think we need help to develop our critical thinking skills? Why/why not?

Activities

Temperature and the albedo effect

Think about the temperature of different surfaces on a hot day. For example, wearing a dark shirt vs a light shirt, or sitting on a car seat vs a light car seat. What about a dark pavement in a car park? Have you observed any differences? Why do you think that is?

All matter absorbs, emits or reflects energy. Different types of matter absorb and reflect different wavelengths of energy, which leads to the different colors we observe. This also leads to differences in heat energy absorbed or emitted by the material. Surfaces that reflect more sunlight will emit more heat energy, and this is called the albedo effect.

MEERCAP is studying the relationship between temperature and albedo to investigate whether localized changes in albedo can help mitigate temperature increases due to climate change.

Task 1: The following experiment investigates how the albedo of different surfaces found on Earth affects temperature.

Materials

- Model surface materials: soil, sand, white sugar (to mimic snow), water with blue or green food dye added (to mimic ocean water)
- Four containers
- Four thermometers
- Four incandescent lights bulbs or heat lamps
- Stopwatch or timer

Activity

1. Fill separate containers with approximately 4 cm of a material: sand, soil, white sugar, dyed water
2. Place a thermometer into the material in each container, then place each container under a lamp. Do not turn on the lights yet (wait until step 5). Let the containers rest for 5 minutes.
3. Take an initial temperature reading of each material and record this in the data table on the right.
4. Make sure the containers will receive the same amount of light (i.e., the same bulb type and same distance from the light).
5. Turn the lights on and start the stopwatch. Record the temperature inside each container every 1 minute for 10 minutes
6. Turn the lights off and record the temperature every 1 minute for the next 10 minutes.

Temperature taken for each container

Time (mins)	1	2	3	4
0 (initial temperature)				
1 (after light on)				
2				
3				
4				
5				
6				
7				
8				
9				
10				
1 (after light off)				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Task 3: Use your data to respond to the questions below:

1. Which materials showed the greatest and least temperature gain when the lights were turned on?

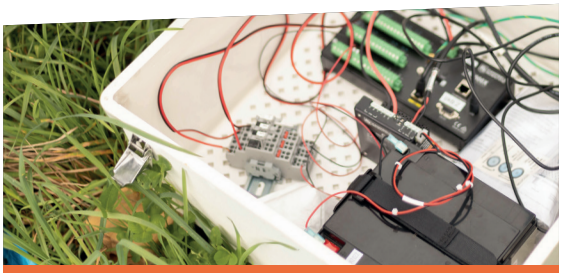
2. Which materials showed the greatest and least temperature loss after the lights were turned off?

3. Think about the Earth surfaces that your materials were mimicking (soil, sand, snow, oceans). Which of these surfaces will absorb, and which will reflect, the most sunlight? How might this affect temperatures around the planet? How might this change as the effects of climate change begin to occur?

4. MEERCAP uses collections of mirrors to reflect sunlight away from the Earth's surface. What affect do you think this will have on local surface temperature?

5. To what extent do you think that collections of mirrors will be effective at tackling both localized and global climate change?

MEERCAP interns Emma Cox, Cole Prescott and William Van de Veen (under sheet) discuss next steps for the mirror plot set-up.

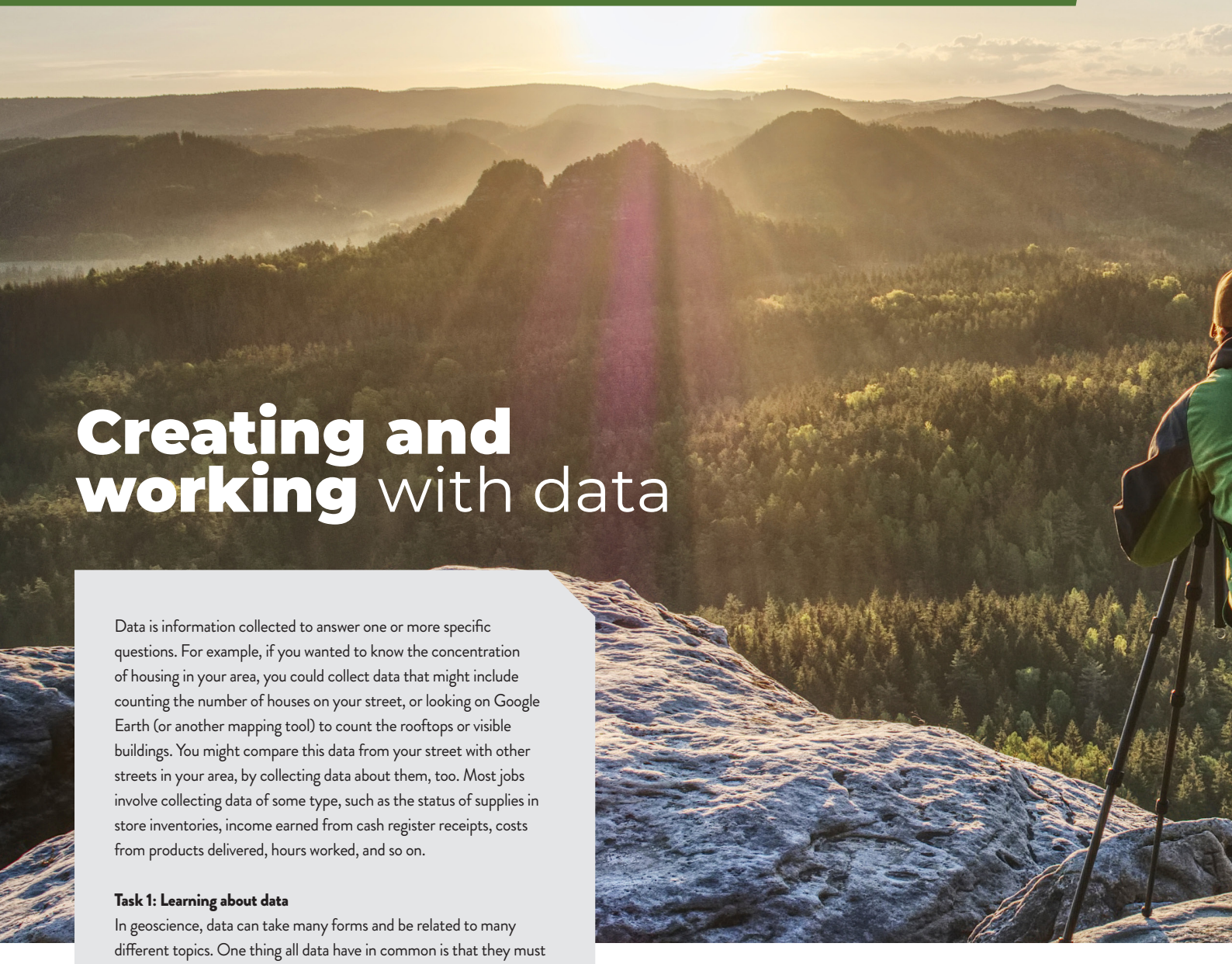


MEERCAP interns wired data loggers to record the temperature data coming from field sensors every 10 minutes.

Task 2: Once you have completed the experiment, use your data to fill in the tables below:

Material	Initial temperature	Temperature at 10 mins (after lights on)	Difference
Soil			
Sand			
Sugar			
Water			

Material	Temperature at 10 mins (after lights on)	Temperature at 20 mins (after lights off)	Difference
Soil			
Sand			
Sugar			
Water			



Creating and working with data

Data is information collected to answer one or more specific questions. For example, if you wanted to know the concentration of housing in your area, you could collect data that might include counting the number of houses on your street, or looking on Google Earth (or another mapping tool) to count the rooftops or visible buildings. You might compare this data from your street with other streets in your area, by collecting data about them, too. Most jobs involve collecting data of some type, such as the status of supplies in store inventories, income earned from cash register receipts, costs from products delivered, hours worked, and so on.

Task 1: Learning about data

In geoscience, data can take many forms and be related to many different topics. One thing all data have in common is that they must be a) recorded, b) stored and c) comparable to other data in order to be useful. This often involves data manipulation.

Think of a job or task that you have had and make a short list of the data that went along with it. Share this with others in your group.

Task 2: Recording data

This is often first done as a hardcopy in a notebook of some type (i.e., handwritten in a lab book or field book), but can also be done as electronic notes in a text file or data table. Hardcopies mean that you can look at the data without using an electronic device (smartphone, computer, etc.), which might run low on battery or require electricity. This is especially important for field work where an internet connection is unavailable and recharging is not an option.

Make a list of the different ways you record data in a typical day. Compare your list with that of the rest of the class by making a table on the board listing all the different ways you and your classmates record data. This is a great example of creating and recording data!

Task 3: Storing data

This is usually done in the form of electronic files, such as on a computer, but may also include a library of hardcopy reports. Storing data includes knowing where it has been put, so some sort of catalogue is needed. In a library, the Dewey Decimal System catalogs books and media according to topic. On your computer (or in cloud storage), data are stored in folders and cataloged according to file name, file date, file size or file type. You can control where your files go and how easy they are to find by following a few simple, standard protocols.

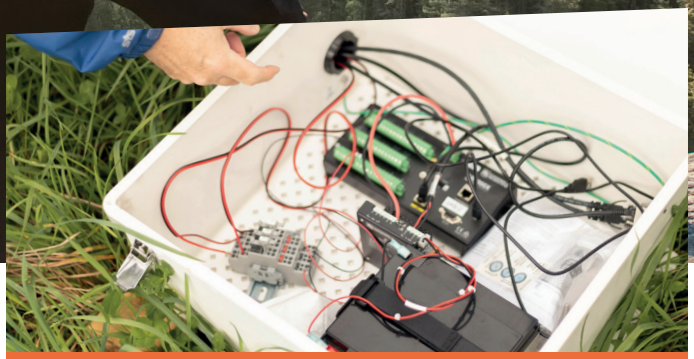
Your brain, while an awesome storage device for data that only you need, is a lousy storage place for data you need to share or keep for long periods of time. So where do you typically store data you intend to share? Make a list of places where you keep data that will be shared or stored for at least a few weeks.

Task 4: Saving data

Open a blank text document, such as Word, on your computer. Type in your name, save the file, and close the application. Start a timer. Then, send the file with your name in it to a student sitting next to you. Keep the timer going until they retrieve the file and open it, then stop the timer and record on a piece of paper the amount of time it took. Discuss ways to reduce the time required with your partner. Practice these ideas. See how quickly you can complete the task! Share your most successful method with the class.

Task 5: Comparing and manipulating data

This can only be done for data that is set up to be like other data. Often, when different people and groups collect data, the information is not collected and presented in exactly the same format or style. It is, therefore, important to standardize the way the data looks. This is called data manipulation and is often lumped into a job task called quality assurance and quality control (QA/QC). This can take a lot of time if the data comes in multiple formats. For instance, some data



Data loggers capture and store measurements from the sensors. This allows scientists to create charts of temperature change over time.

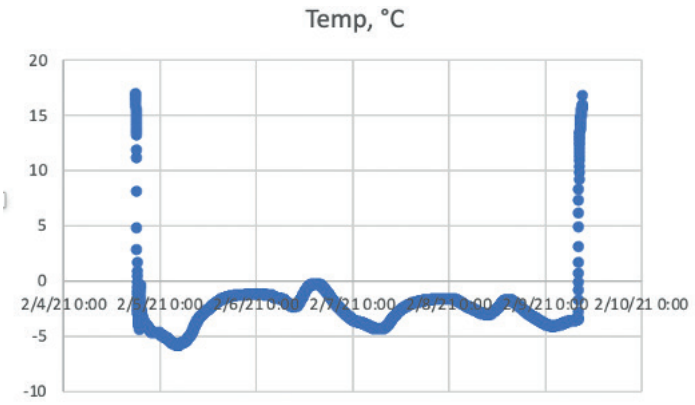
might be written notes organized by day of the month, as digital files organized by location, as text paragraphs or as tables.

Practice some simple data manipulation. First read the following instructions about importing csv data into Excel: **https://support.microsoft.com/en-us/office/import-or-export-text-txt-or-csv-files-5250ac4c-663c-47ce-937b-339e391393ba**. Now practice importing the following data files into Excel:

SnowData Example.csv
SnowData Example.txt
You will find these files, here: **futurumcareers.com/practical-activities-to-help-geoscience-students-develop-the-skills-they-need-to-succeed**

Save the data as an Excel file; note that the letters after the dot changes to xls or xlsx.

Task 6: Making graphs
Another aspect of QA/QC is to remove data that have no meaning. The easiest way to do this is to make a graph of the data to see what it looks like. If you make an xy scatterplot of the data in the SnowData example, it will look like the example graph on the right (temperature is on the vertical (side) axis, and the date and time is on the horizontal (bottom) axis.



In this example, the data were collected using sensors that were turned on inside a building, and then carried to a snowbank to be buried for a week. The sensor was then dug up and brought inside, and the data downloaded. The purpose of this data collection was to measure the snow temperature, but this dataset starts and ends with the temperature of a room. The room temperature data is known as 'garbage data' because that information is not meaningful.

In the SnowData.xlsx file, remove the garbage data and recreate the plot graph. Note what happens to the plot's vertical axis. When where the coldest and warmest temperatures?

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Careers in Geoscience

Task 1: Job searching
Use the following links to search for jobs and internships you think you might be interested in:

www.usajobs.gov
www.nsf.gov/crssprgm/reu
www.zintellect.com
www.earthworks-jobs.com/acad
www.usgs.gov/human-capital

You could also search on websites such as LinkedIn, Indeed or Glassdoor. Create a list of links to geoscience-related organizations, agencies, businesses or specific jobs that interest you. At the same time, create a list of organizations or jobs that you do not think would suit you. Sometimes, we need to figure out what is not a good fit for us before we figure out what is a good fit.

Find two jobs you think you would be good at, and two you think are not for you. Create a four-slide PowerPoint presentation to describe what does, or does not, appeal to you about each job. Think about the skills and experiences you already have and those you might need to develop before applying for the jobs.

Task 2: Resumes
Choose a job that you think you would like to do. Create a draft resume that captures your current skills and experience that would be of benefit for this job.

Once you have completed this, get creative and modify your resume, using a different color to add skills and experience that you do not have yet, but think that you might need in order to be an ideal candidate for that position. Imagine how you might get these skills (be creative!) and write a short cover letter that explains how you got this training. Have fun with this but include real skills that are suited to this particular position. Be sure to look closely at the qualifications and description for the job.

Dr. Lisa Doner shares her excitement about climate mitigation projects on a field trip to the MEERCAP site.

In the field, Dr. Lisa Doner trains students to wire sensor cables into data loggers.

More *resources*

- Watch a short animation about GeoPaths and MEERCAP: **futurumcareers.com/GeoPaths-and-MEERCAP_animation.mp4**

- To find out about MEERCAP, visit: **www.meer.org**

- Explore this article about 'agrivoltaics'. Think about the similarities between this project and MEERCAP. Using the knowledge you have gained from this article, why do you think agrivoltaics could be a successful practice? **www.nhpr.org/2021-11-14/this-colorado-solar-garden-is-literally-a-farm-under-solar-panels**

- Lisa recommends the following three websites for finding background information about geoscience:
  climate.nasa.gov/solutions/adaptation-mitigation
  www.nationalgeographic.com/climate-change/how-to-live-with-it/crops.html
  www.un.org/en/climatechange/climate-solutions

- These videos and websites can also help you explore different geoscience careers:

Hubbard Brook Ice Storm Experiment:
www.youtube.com/watch?v=GrWg9krspXQ

Hubbard Brook Experimental Forest:
www.youtube.com/watch?v=q63KgaWjNGc

Shell PLC Energy Careers:
www.shell.com/careers/renewables-energy-solutions.html

National Weather Service Careers: **www.weather.gov/careers**

Forensic Weather Consultants: **weatherconsultants.com/about-us/**

Geological Society of America Careers Presentations: **www.geosociety.org/GSA/Education_Careers/webinar/GSA/edu-career/webinars.aspx**

American Geosciences Institute:
www.americangeosciences.org

How to Become a Soil Testing Technician: Career Guide:
learning.americangeosciences.org

Environmental Science, Oceanography:
www.environmentalscience.org/career/oceanographer

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