Building science knowledge, identity, and interest using place-based learning to engage diverse urban undergraduate and high school students

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Introduction

New York's glacial history and landforms were used to engage a diverse, urban population of undergraduate and high school students heavily impacted by remote learning. These settings all had:

- High ethnic and racial diversity
- High proportion of English Language Learners (ELLs)
- Populations underrepresented in STEM fields
- Limited science literacy
- In the case of the two-year college (2YC), first generation college students

Goals

The goals of this work was to increase student

science knowledge,
science identity,
and
science interest.

We used pedagogical strategies that provided equitable ways of learning and demonstrating knowledge such as place-based learning (Semken et al., 2017).

These activities and lessons were developed for synchronous remote learning.

The authors are two professors at the American Museum of Natural History Master of Arts in Teaching program (AMNH - MAT), and two former MAT graduate students, now HS teachers. We created a professional learning group to develop the materials and conduct this study.

Theoretical Framework

To increase students' science knowledge, identity, and interest we used pedagogical strategies that provided equitable ways of learning and demonstrating knowledge to validate and reflect the diversity, identities, and experiences of all students, and communicate to students that they are valued and their varied experiences are an asset in learning (Moll et al., 1992). These strategies included:

- **Place-based learning** which boosts student engagement, is more relevant for students, and attracts underrepresented groups to science (Semken et al., 2017). We focused on local glaciation history to increase student connections to the lesson content.
- **Active learning** opportunities applying the 5E instructional model and engaging in multiple science practices (Bybee, 2015).
- Incorporating **fun in lessons** to elicit positive emotional responses, thereby increasing effective processing of information and the transfer to long-term memory storage (Willis, 2007; NRC, 2000).
- Providing **multiple ways to demonstrate skills and understanding** such as sketching, storytelling, developing analogies.
  - Students **sketched** at multiple points throughout the lessons which is shown to enhance student engagement, reveal understanding, and aid in organizing knowledge (Ainsworth et al., 2011).
  - Students created **analogies** from their own lives to describe local glacial landforms and processes which is shown to enhance meaning-making and student connection to scientific content and processes (Rivet & Kastens, 2012).
- **Building scientific skills** by emphasizing practices such as observing, measuring, interpreting data, sketching, and map reading during virtual field trips (NRC, 2012).

Methods

Who we are

- MAT professors in science education and science
- Former MAT graduate students, now public high school teachers

Who our students are

- **Garnet 2YC:** 29% Latinx, 28% Black, 28% Asian, 14% White; 53% Female, 47% Male; 54% Receive financial aid
- **Deep Valley HS:** 54% Latinx, 10% Black, 8% Asian, 26% White; 49% Female, 51% Male; 6% ELL; 18% Students with disabilities; 54% Economically disadvantaged
- **Douglass HS:** 36% Latinx, 10% Black, 36% Asian, 16% White; 41% Female, 59% Male; 28% ELL; 15% Students with disabilities; 82% Economically disadvantaged

What we did

- We co-developed a 5E lesson sequence, with pre- and post-surveys that measured the development of content understanding (Fig. 1; Keeley & Tucker, 2016), student science identity (Pugh et al., 2010), and interest in science (Lamb et al., 2012).
- The mini-unit took 2 weeks to 1 month to teach (6 hours total).

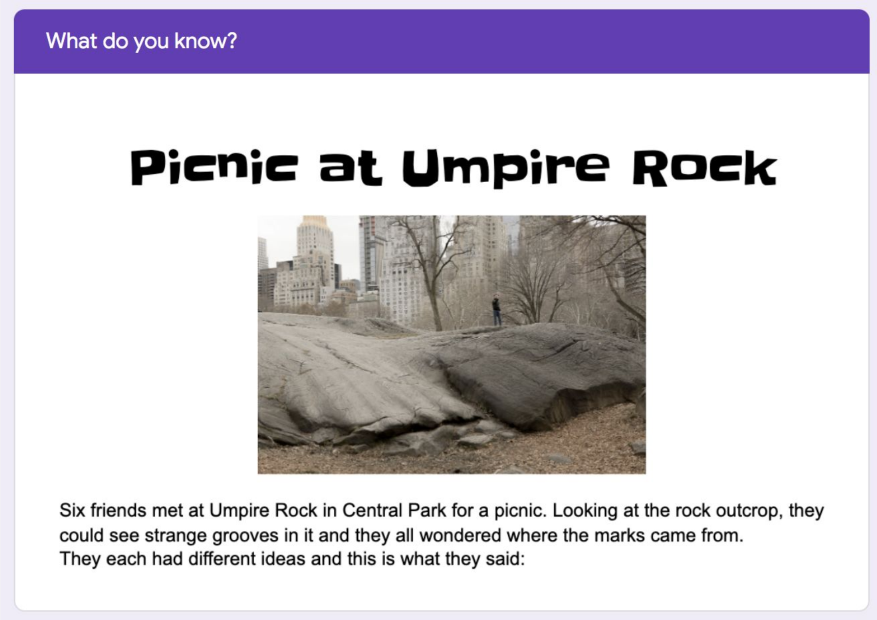


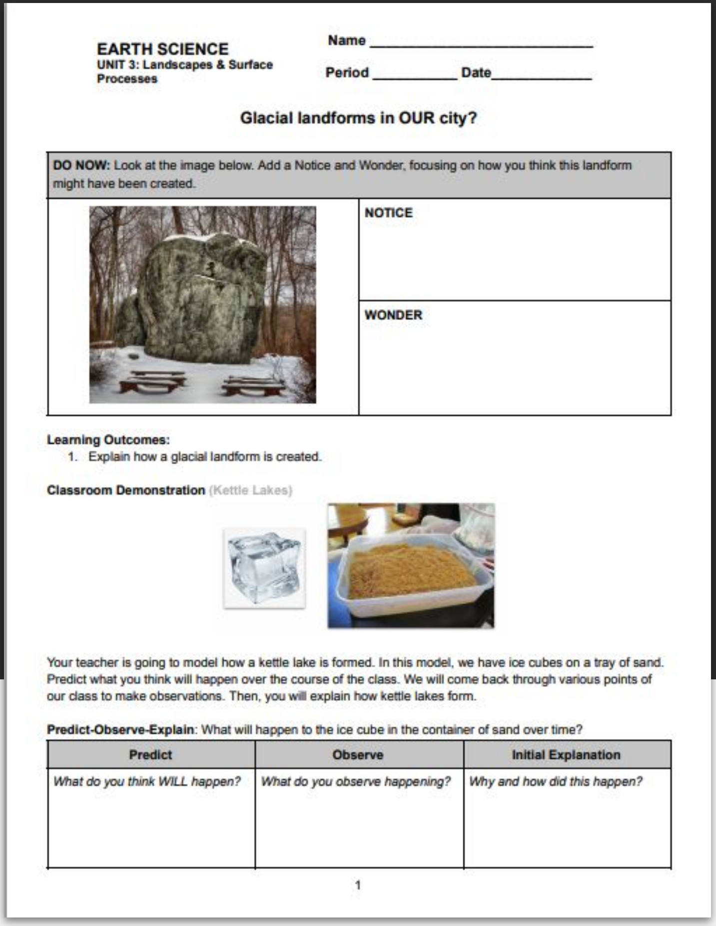
Figure 1. Content assessment based on Keeley and Tucker (2016)

Methods

Lesson materials were modified by each teacher to suit the needs of their students.

Adaptations included:

- Formatting to match each teacher's teaching style
- Use of graphic organizers (Fi
- Translated materials for ELLs
- Simplification of lessons to fit pacing needs and remote learning setting
- Conversion of short answer questions to multiple choice



EARTH SCIENCE
UNIT 3: Landscapes & Surface Processes

Name ______________________
Period __________ Date ___________

Glacial landforms in OUR city?

DO NOW: Look at the image below. Add a Notice and Wonder, focusing on how you think this landform might have been created.

NOTICE

WONDER

Learning Outcomes:
1. Explain how a glacial landform is created.

Classroom Demonstration (Kettle Lakes)

Your teacher is going to model how a kettle lake is formed. In this model, we have ice cubes on a tray of sand. Predict what you think will happen over the course of the class. We will come back through various points of our class to make observations. Then, you will explain how kettle lakes form.

Predict-Observe-Explain: What will happen to the ice cube in the container of sand over time?

Predict	Observe	Initial Explanation
What do you think WILL happen?	*What do you observe happening?*	*Why and how did this happen?*

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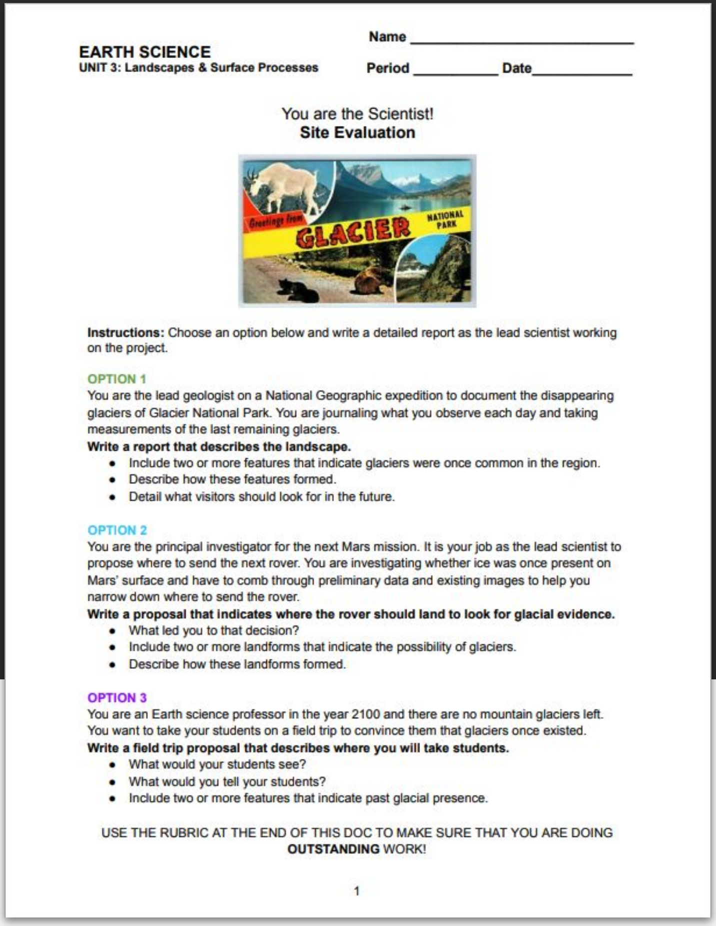


EARTH SCIENCE
UNIT 3: Landscapes & Surface Processes

Name ______________________
Period __________ Date ___________

You are the Scientist!
Site Evaluation

Instructions: Choose an option below and write a detailed report as the lead scientist working on the project.

OPTION 1
You are the lead geologist on a National Geographic expedition to document the disappearing glaciers of Glacier National Park. You are journaling what you observe each day and taking measurements of the last remaining glaciers.
Write a report that describes the landscape.
- Include two or more features that indicate glaciers were once common in the region.
- Describe how these features formed.
- Detail what visitors should look for in the future.

OPTION 2
You are the principal investigator for the next Mars mission. It is your job as the lead scientist to propose where to send the next rover. You are investigating whether ice was once present on Mars' surface and have to comb through preliminary data and existing images to help you narrow down where to send the rover.
Write a proposal that indicates where the rover should land to look for glacial evidence.
- What led you to that decision?
- Include two or more landforms that indicate the possibility of glaciers.
- Describe how these landforms formed.

OPTION 3
You are an Earth science professor in the year 2100 and there are no mountain glaciers left. You want to take your students on a field trip to convince them that glaciers once existed.
Write a field trip proposal that describes where you will take students.
- What would your students see?
- What would you tell your students?
- Include two or more features that indicate past glacial presence.

USE THE RUBRIC AT THE END OF THIS DOC TO MAKE SURE THAT YOU ARE DOING **OUTSTANDING** WORK!

1

Figure 2. Adapted Explore and Evaluate lesson material used at Deep Valley HS. Scaffolds included here are graphic organizers and color coding to separate concepts.

Results **Science Content**

- 92 students completed both the pre- and post-surveys. This represents less than two thirds of students participating in the 5E mini-unit.
- 44 students were from Douglass HS, 30 were from Deep Valley HS and 18 were from Garnet 2YC.
- Initially, 25% of students selected the correct answer (Fernando) which increased to 66% during the post-survey for a gain of 41% (Fig. 3 & 4).
- Overall, all groups moved toward “more correct” by selecting the correct answer or second closest choice (Fernando & Mayumi):
  - 65 out of 92 or 71% chose one of the two most correct answers in the pre-survey.
  - 79 out of 92 of 86% chose one of the two most correct answers in the post-survey.
- 8.7% of students chose one of the two least correct answers in the pre-survey (Reginald & Lupe). This was lowered to 5.4% in the post-survey.

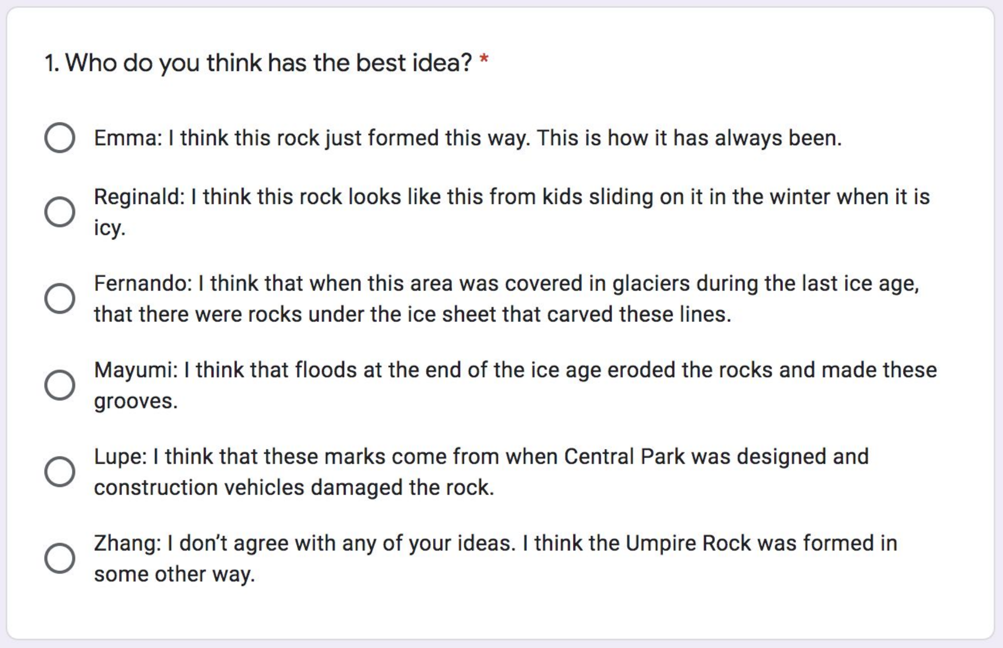


Figure 3. Answer options given to students for the content knowledge portion of the survey.

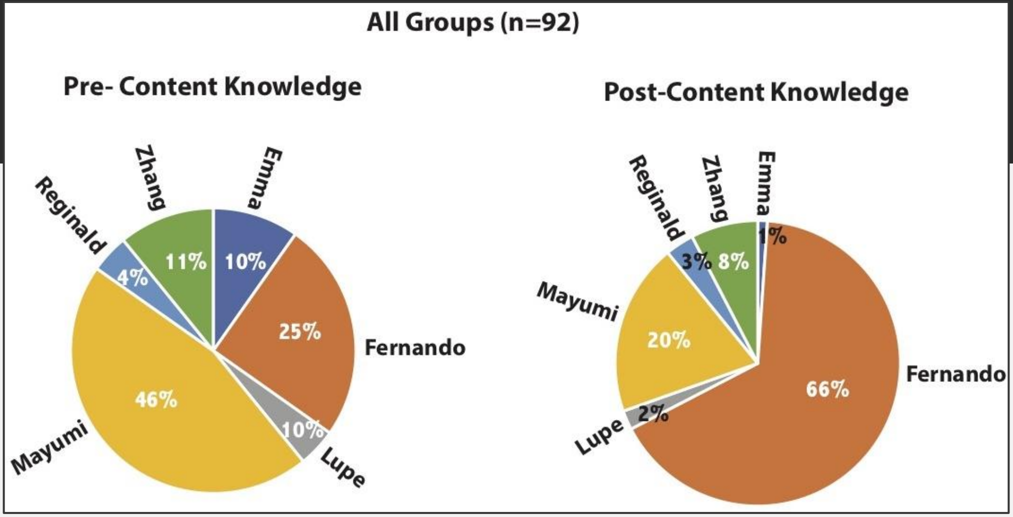


Figure 4. Chart showing percentages of answers selected by student from all three schools.

Results **Science Content**

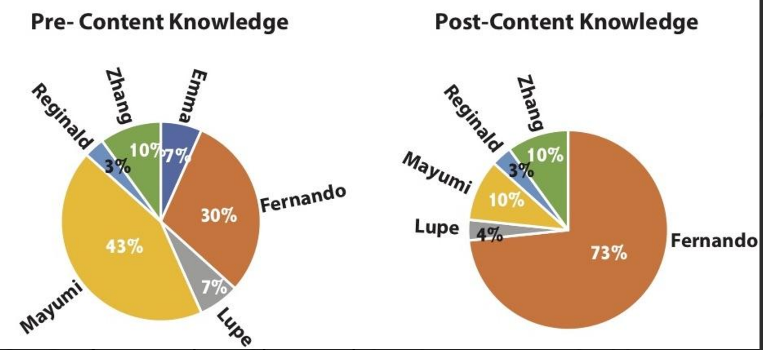


Figure 5. Answers selected by students at Deep Valley HS (n = 30).

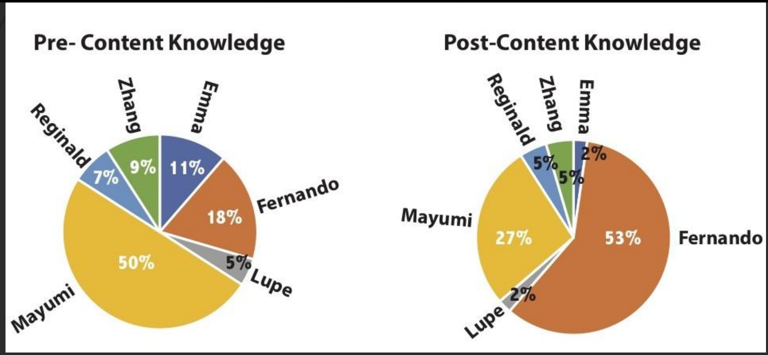


Figure 6. Answers selected by students at Douglass HS (n = 44).

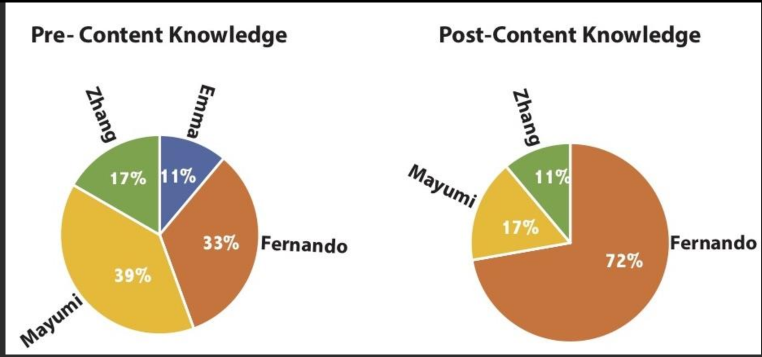


Figure 7. Answers selected by students at Garnet 2YC (n = 18).

Deep Valley HS
(n = 30)

Students from Deep Valley HS selected five out of six answers in the post-survey, deciding one option was not possible. The three least correct answers (Lupe, Reginald, Zhang) stayed almost the same in the post-survey.

Douglass HS
(n = 44)

In the pre-survey, 2YC students showed the highest content knowledge, while Douglass HS students, with the highest ELL population, scored the lowest.

Garnet 2YC
(n = 18)

2YC students only selected four of the answers in pre-survey, deciding two were not possible. This was reduced to three selections in the post-survey.

Many post-survey responses showed a strong understanding of glacial processes:

I think glacial grooves and striations are gouged or scratched into bedrock as the glacier moves. Boulders and coarse gravel get trapped under the glacial ice and abrade the land as the glacier pushes and pulls them along, so grooves are formed in the worn rock.

Results **Science Identity**

- Student science identity was determined using four science identity statements (Pugh et al., 2010) to measure students' evolving perceptions of themselves as scientists in the present and in their futures as a part of the pre- and post-survey (Fig. 8).
- Averaged data shows an increase of 0.24 (4.8% increase) on a Likert scale for Deep Valley HS students and a slight increase for the Douglass HS and the 2YC students of 0.01 (0.3% increase).
- Although slight, the increase in scores between the pre- and post-surveys is statistically significant when averaged for all schools (P value = 0.04044).

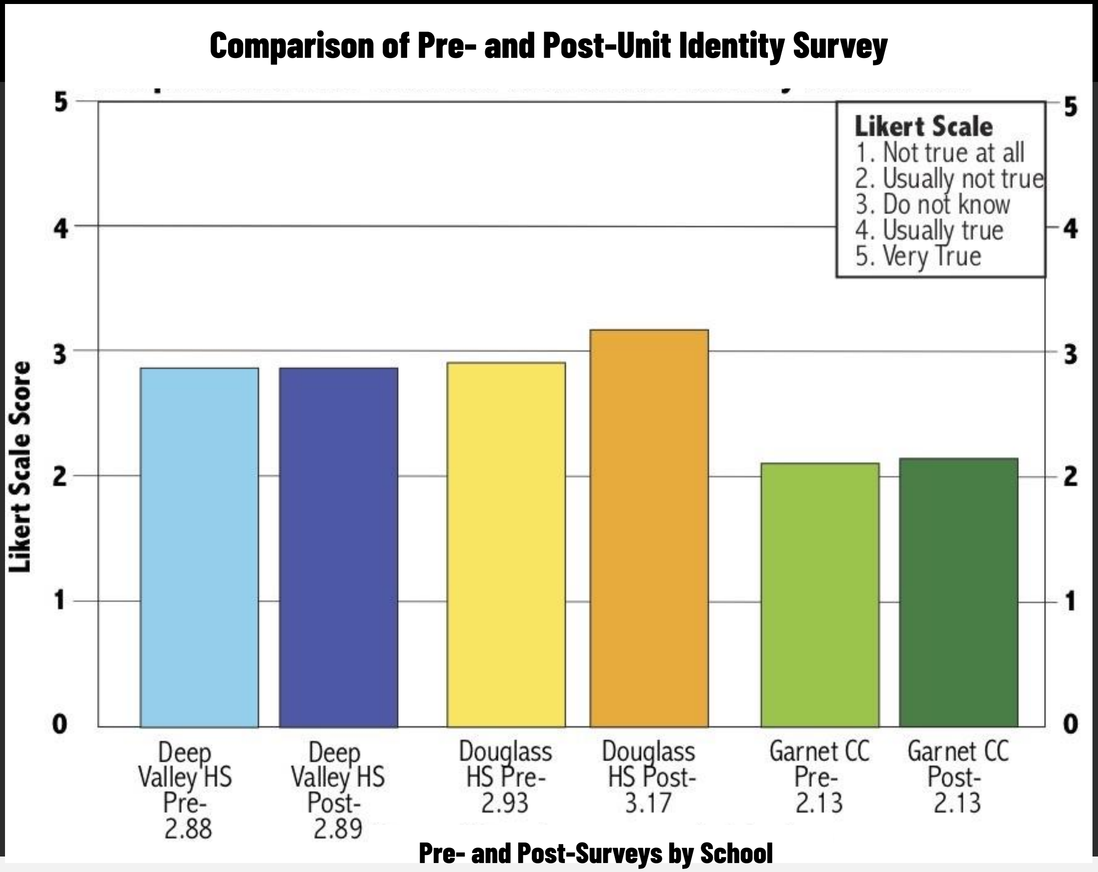


Figure 8. Comparison of science identity portion of pre- and post-surveys.

Science Identity statements used in the survey:

1. I see myself as a science person.
2. Being involved in science is a key part of who I am.
3. I can see myself doing science in the future.
4. I can imagine myself being involved in a science-related career.

Results **Science Identity**

- Standard deviations were highest for Deep Valley HS students indicating a wider variation in student responses (Table 1).
- The identity statements can be broken into two categories: present and future.
  - **Present:** (1) I see myself as a science person;
    (2) Being involved in science is a key part of who I am.
  - **Future**: (3) I can see myself doing science in the future;
    (4) I can imagine myself being involved in a science related career.

- Grouping students' responses by present and future shows students' evolving senses of themselves as scientists.
  - For statements about the present, there is a mix of upward and downward movement.
    - Deep Valley HS: -1.8%
    - Douglass HS : +6.6%
    - 2YC: -3.0%
  - For statements about the future, the scores all increased.
    - Deep Valley HS: +2.6%
    - Douglass HS : +3.0%
    - 2YC: +3.6%

Table 1. Comparison of present and future categories of science identity statements in the surveys at the three schools.

	DEEP VALLEY HS		DOUGLASS HS		GARNET 2YC		All Pre/Post Mean	All Pre/Post Standard Deviation
	Mean	SD	Mean	SD	Mean	SD		
Present Pre	2.78	1.16	3.08	0.91	2.18	0.77	2.68	0.95
Present Post	2.69	1.12	3.41	0.99	2.03	0.92	2.71	1.01
Future Pre	2.97	1.17	2.78	0.93	2.08	0.76	2.61	0.96
Future Post	3.1	1.18	2.93	0.8	2.26	0.87	2.76	0.95

Results **Science Interest**

- Determined using the Science Interest Survey (Lamb et al., 2012).
    - Includes 21 items that are broken into five subscales: F (Family Encouragement), P (Peer Attitudes toward Science), T (Teacher Influence), I (Informal Learning Experiences), and S (Science Classroom Experiences).
- Highest values were recorded for Teacher Influence followed by Science Classroom Experiences (Fig. 9).
- For all three settings, Family Encouragement and Informal Learning Experiences increased from pre- to post-survey.
- For averaged data, we see:
    - Family encouragement, Informal learning experiences, and Science classroom experiences increased from pre- to post-survey
    - No change for Peer attitudes
    - A slight decrease in Teacher influence
    - A t-test determined only the change in Family encouragement was statistically significant (Table 2)

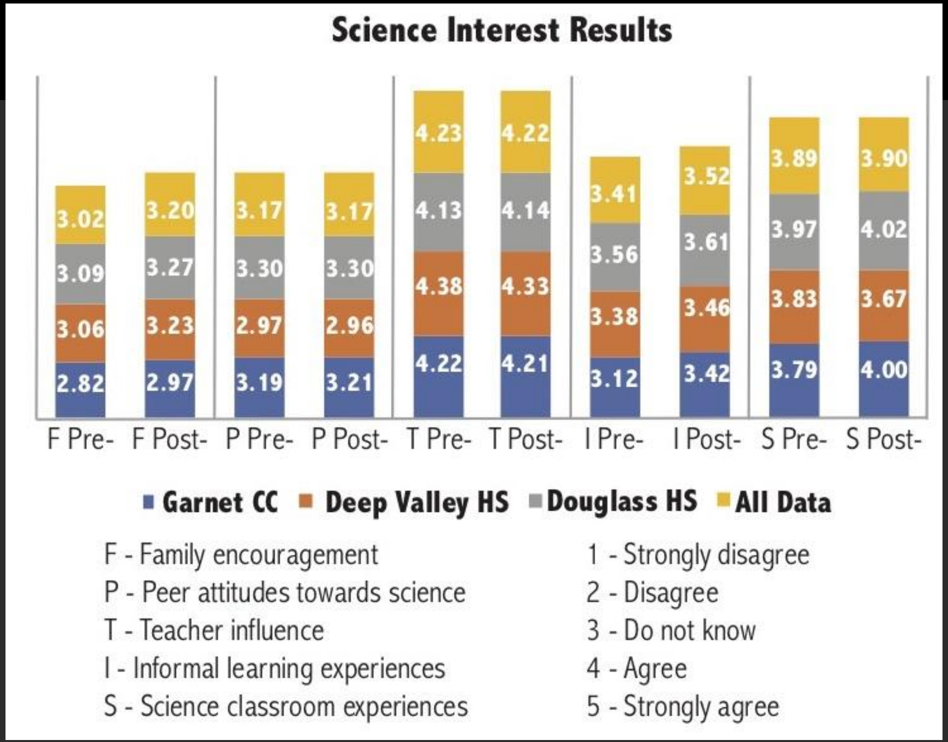


Figure 9. Comparison of all pre- and post-science interest survey results grouped by subscale.

	F	P	T	I	S
Sig. (2 tailed) P value for all data	0.006	0.961	0.806	0.137	0.179

Table 2. Paired t-test results for Family encouragement.

Discussion
Science Content

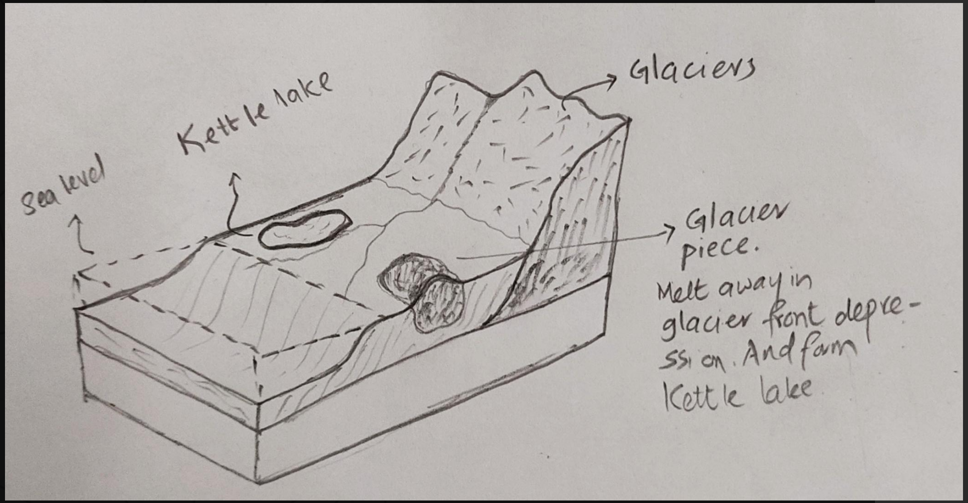


Figure 10. Student work showing their understanding of how a kettle lake is formed. (Garnet 2YC)

- All student groups showed a similar increase in content knowledge. Their written reflections showed improvements in understanding and explaining how glaciers change the landscape.
- 5% of students showed little change in selections for the least right answers between pre- and post-survey. This may indicate low engagement.
- Garnet 2YC students showed the highest content knowledge, only selecting a subset of the best answers in the pre- and post-survey. This may be because some of these students took high school Earth science and have greater prior knowledge.
- The student group consisting of many ELLs showed the lowest prior content knowledge. Equal learning gains suggests our use of equitable pedagogical methods was successful.

Discussion
Science Identity

Which option are you choosing? ___________Option 2____________________

After careful evaluation of the data I've been sent, I have come to a conclusion as to where on Mars the rover should land. The images below were selected from the preliminary data I was given, and they both display places worth investigating. From the images themselves, I can infer that ice was once present on Mars' surface. In fact, not only was it just present, but it was in the form of a glacier.

The first image shows a surface on Mars that has very clear parallel lines etched into it. These lines can be compared to the striations we see on some rocks on Earth. Striations are formed when rocks and/or boulders get trapped underneath a glacier, and they scrape against the rock under them as the glacier moves. As they do this, the rocks leave parallel lines on the surface.

The second image displays an almost beach-like area on Mars. There is a small decline in the land, and at the bottom of it is an area filled with rocks and boulders varying in size. The best explanation for how all those rocks got deposited there is to say that it's a moraine. Moraines are formed when material like rocks and boulders fall off a glacier, or get in it's path. The glacier pushes this fallen material and deposits it elsewhere.

In conclusion, there is too much evidence that glaciers once existed on Mars to ignore. The rover should be sent to these two locations to further investigate them, and to see if there's any other glacial evidence close to them.

Figure 11. Student work from the Evaluate lesson. (Deep Valley HS)

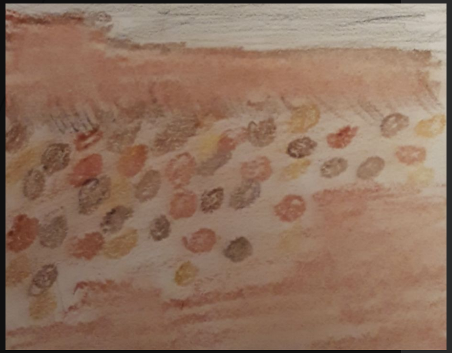
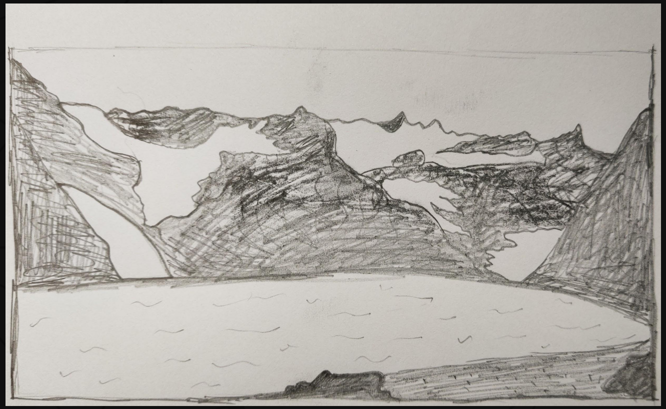


Figure 12 and 13. Student drawings of imagined Martian evidence of glaciation from the Evaluate lesson (striations and moraine). (Deep Valley HS)

- Students from both high schools had above average science identity scores while 2YC students had a below average score. This may be attributed to the 2YC students being non-science majors.
- Science identities increased for questions related to a career path (future category) in science. The last lesson in the mini-unit asked students to imagine themselves as a scientist to complete a task which may have influenced this result (Figs. 11-13).
- A possible explanation for decreases from pre- to post-survey may be that this occurred at the end of the year and students may have been feeling burned out after a year of remote learning during a global pandemic.

Discussion
Science Interest



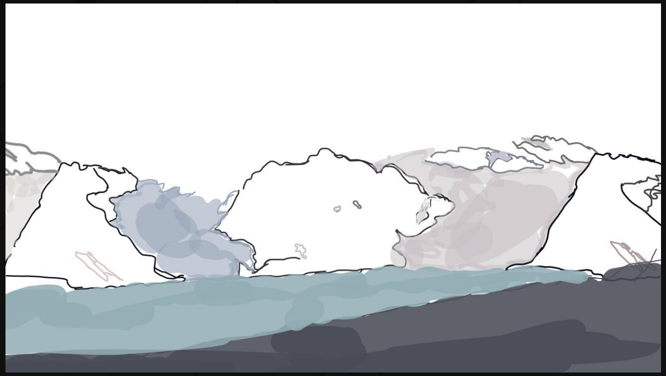


Figure 14 and 15. Student drawings of Alaskan glaciers. (Garnet 2YC)

- The highest science interest scores are in the subscales of Teacher Influence and Science Classroom Experiences, indicating the importance of teachers and classroom environments.
- For the pre- and post-survey, the Family subscale was the only category that was statistically significant (increase from 59% to 63%; P value = 0.006). We speculate remote learning from home may have facilitated discussion about science with family members.
- Despite having an average lower science identity, 2YC students had a very similar post science interest score (2YC: 3.54, HS: 3.61); this may reflect 2YC students having decided on a non-STEM related career path, while high school students are unlikely to have made this choice yet.
- Conducting the pre- and post-survey in the space of as little as two weeks may explain the small variation in values.

Conclusions

- The place-based 5E mini-unit conducted for a diverse group of urban 2YC and high school students showed an increase in content knowledge, and aspects of science identity and science interest.
- Our study found the high school students in this study to have a moderate to high science interest and science identity, while the 2YC students have a moderate to high science interest, but lower science identity.
- We developed a rich resource that uses equitable pedagogical methodologies that can be shared with high school and college educators.
- The collaboration and professional interaction between high school and college educators and scientists was a beneficial professional development experience.

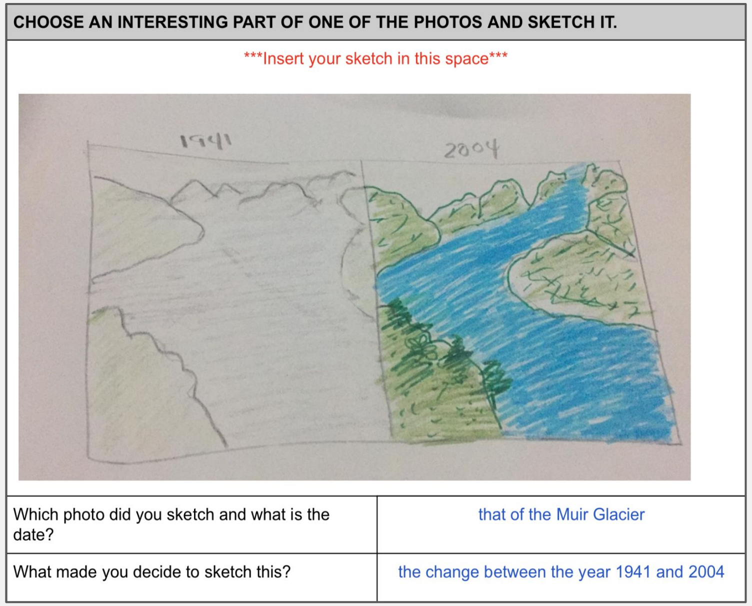


Figure 16. Student work from the Engage lesson showing the retreat of the Muir Glacier over time. (Deep Valley HS)

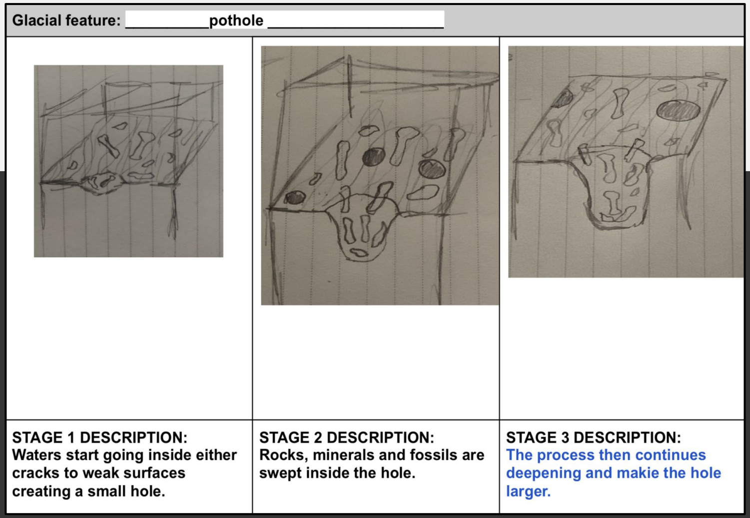


Figure 17. Student work from Explain lesson showing how a pothole is formed. (Deep Valley HS)

Next Steps

- Teach this mini-unit in a non-pandemic setting and compare student outcomes to remote setting
- Continue collaboration to adapt lessons for in-person use
- Align to NGSS Performance Expectations
- Measure science identity and interest over semester
- Create deliberate opportunities to build science identity and interest
- Foster further collaboration between high school and college educators

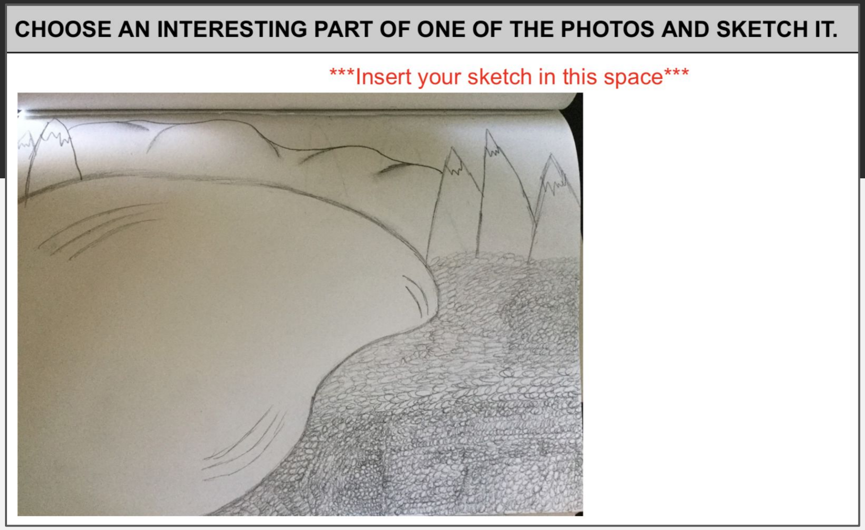


Figure 18. Student work from the Engage lesson showing an Alaskan glacier. (Deep Valley HS)

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