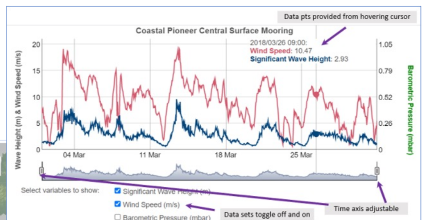
Guiding Students to Use Evidence to Support Their Scientific Reasoning: Research Results

Andrea Drewes, Kathleen Browne, Gabriela Smalley (Rider Univ.), and Sage Lichtenwalner (Rutgers Univ.)

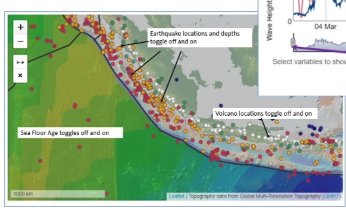
Need: Undergraduate science courses for non-STEM students can be the last opportunity of formal science education for many people. In these courses, students can improve their scientific reasoning if it is effectively integrated into learning experiences. This project seeks to fill a gap in the knowledge base by exploring the impact of instruction using an explanatory framework in introductory oceanography courses. Our focus has been on the interactions of data literacy and scientific reasoning skills to improve evidence-supported scientific explanations constructed by undergraduates.

Hypotheses: 1) Students who are guided to use a modified structure of "Data Description – Claim – Evidence – Reasoning" (DCER) will develop better explanations than if no explanatory structure is used. 2) The use of the DCER framework for writing scientific explanations positively influences the development of students' scientific reasoning and data literacy skills.

Example Web-based Interactive Data Sets



Waves & Weather



Tectonic Plate Boundaries

DCER Instructional Framework

Ocean Concepts — *Instruction to guide learning about ocean concepts.*

Data Descriptions — *Instruction to guide students to study data and **compose descriptions of patterns and variability in authentic data sets**.*

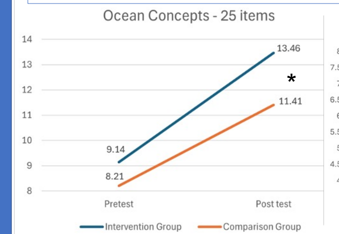
Claim — *Students collaboratively draw conclusions / **claims** from the data, discuss their ideas and reasonings to tie quantitative evidence to their understanding of relevant science concepts.*

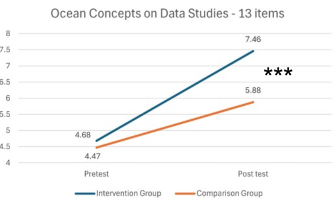
Evidence & Reasoning — *Finally, students individually compose higher-quality individual explanations / **reasoning** for in class "data studies" & on exams by linking **evidence** to their understanding of relevant science concepts.*

Methods: Our study has included comparison of students receiving direct, repeated guidance to develop scientific explanations using the DCER framework with students who completed sections of the same course with no intervention nor modification of traditional, lecture-based instructional approaches. Written scientific explanations from formative and summative assessments were evaluated to compare scientific reasoning for both groups. In intervention classes, we evaluated students' ability to read and make sense of time series and spatial data visualizations. Other research data sources include pre/post assessments and cognitive interviews with a subset of students from both groups.

Pre-Post Assessment Results

Outcomes of two-way mixed ANOVA tests





Ocean Concepts

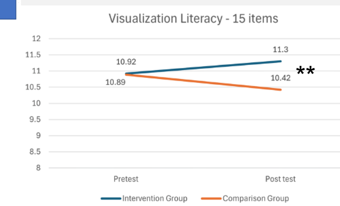
Intervention group: statistically significant higher gains than comparison group [group*time interaction of p = .036]

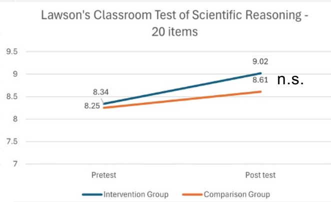
Both groups improve from pre to post, but when considering the impact of the intervention over time, we see a statistically significant difference in achievement of oceanography content knowledge.

Ocean Concepts – Widget Items Only

Intervention group: statistically significant higher gains than comparison group [group*time interaction of p < .001].

When only comparing achievement on ocean concepts items that were directly aligned to the data studies interactive widgets (the core instructional feature of the intervention), an even more drastic difference is observed between the groups.





Visualization Literacy:

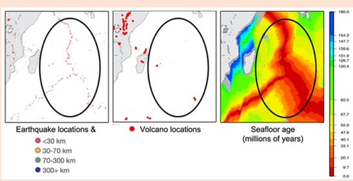
Intervention group: statistically significant higher gains than comparison group [group*time interaction of p = .010]

LCTSR

There are NO statistically significant differences in this test between the two groups [group*time interaction of p = .456]. We believe this is due to the more distal link to this test.

Exam Question 1

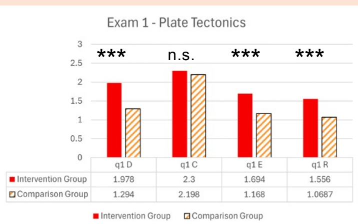
What type of plate boundary occurs in the circled region in the following maps? [*Only focus inside the circled region to complete this question.*] Each map shows the exact same geographic region on the globe with a different data set.



Outcomes of independent samples t-test:

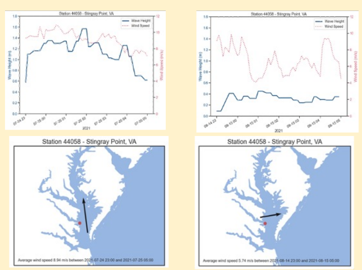
Intervention group: statistically significant higher scores than comparison group across most explanation components (D, E, R; but not C).

Both groups can make a correct claim, but ONLY intervention students are able to create evidence backed explanations with scientific reasoning while the comparison group struggles to do so.



	q1 D	q1 C	q1 E	q1 R
Intervention Group	1.978	2.3	1.694	1.556
Comparison Group	1.294	2.198	1.168	1.0687

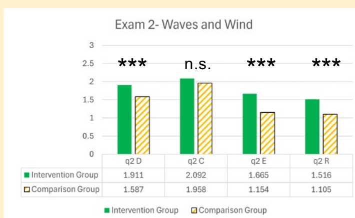
Semester Exams: Intervention vs. Comparison Groups



Exam Question 2

Why are there differences in wave height for the two different time periods?

Here are graphs that show data for wind speed and wave height from the same location for 2 different periods in time. The maps beneath each graph show wind direction for each different time period and the text along the south end of the maps note calculated average wind speed.



	q2 D	q2 C	q2 E	q2 R
Intervention Group	1.911	2.092	1.665	1.516
Comparison Group	1.587	1.958	1.154	1.105

Outcomes of independent samples t-test:

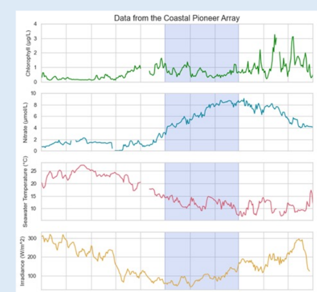
Intervention group: statistically significant higher scores than comparison group across most explanation components (D, E, R; but not C).

Both groups can make a correct claim, but ONLY intervention students are able to create evidence backed explanations with scientific reasoning while the comparison group struggles to do so.

Exam Question 3

What controls primary production during the winter season highlighted in light blue and why?

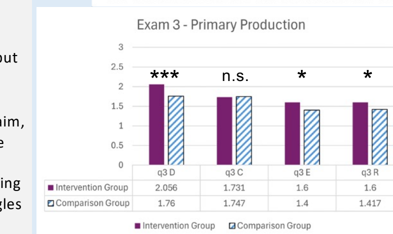
On the following page are graphs that show time series data for surface water Chlorophyll concentrations, Solar Radiation (irradiance) received at the sea surface, surface water Temperature, and concentration of surface water Nitrate (an inorganic nutrient) at a site offshore from NJ.



Outcomes of independent samples t-test:

Intervention group: statistically significant higher scores than comparison group across most explanation components (D, E, R; but not C).

Both groups can make a correct claim, but ONLY intervention students are able to create evidence backed explanations with scientific reasoning while the comparison group struggles to do so.



	q3 D	q3 C	q3 E	q3 R
Intervention Group	2.056	1.731	1.6	1.6
Comparison Group	1.76	1.747	1.4	1.417

n.s. = not statistically significant, * = p <.05 ** = p<.01, *** = p<.001

Acknowledgments

This material is based upon work supported by the National Science Foundation under Award No. DUE-2021347.