QUANTITATIVE ANALYSES OF STUDENT LEARNING FROM *CARBON TIME* UNITS

WHAT IS *CARBON TIME*?

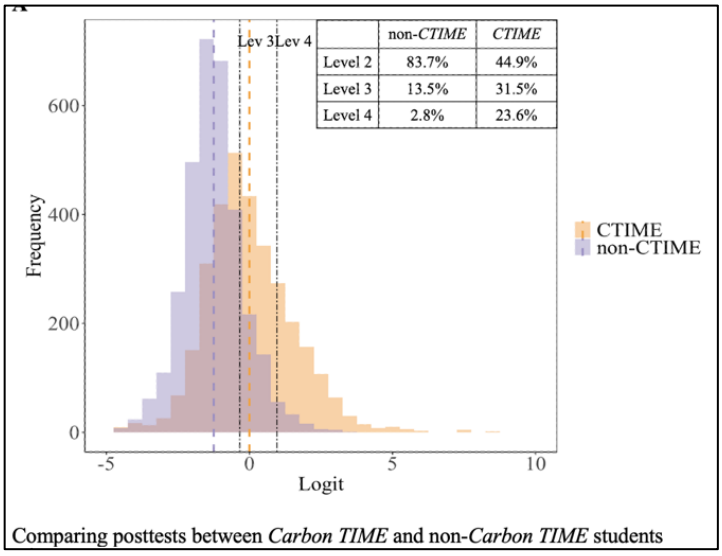
Carbon: Transformations in Matter and Energy (*Carbon TIME*) is a design-based implementation research (DBIR) project focused on developing students' environmental science literacy. It includes six MS/HS teaching units and coordinated assessments focusing on processes that transform matter and energy at multiple scales—in cells, organisms, ecosystems, and global systems. These units have been developed and revised over a 12-year period based on research about how students make sense of these processes.

Student learning outcomes are from a large and diverse quantitative data set, including 59,654 student assessments of three-dimensional learning aligned with *Next Generation Science Standards* collected in classrooms of 133 middle- and high-school teachers over a four-year period. Our findings are organized around three research and design goals.

GOAL 1: DESIGN CURRICULA AS FLEXIBLE "TOOL KITS" FOR STUDENTS' THREE-DIMENSIONAL SENSEMAKING.

The *Next Generation Science Standards* (and *Michigan Science Standards*) define goals for students' science classroom performances as *three-dimensional sensemaking about phenomena*. To reach these goals, teachers need curricular tools that support them in assessing and scaffolding their students' three-dimensional engagement with phenomena while also enabling them to respond to their own students in rigorous and responsive ways.

So, one core goal of the *Carbon TIME* project was to design a flexible set of curricular resources that teachers and students in diverse schools could use to support three-dimensional learning in their own circumstances. ***Did it work? If so, how well, and for which students?***



Comparing posttests between *Carbon TIME* and non-*Carbon TIME* students

- **Finding 1a:** *Students studying Carbon TIME units showed significantly higher achievement than students studying curricula previously used by participating teachers.* For example, ninety-one percent of students who studied *Carbon TIME* scored higher on the overall posttest than the median of students who studied the teachers' previous curricula.
- **Finding 1b:** *Within classrooms, students with lower pretest scores had higher learning gains.* In other words, *Carbon TIME* helped reduce the achievement gap within classrooms.
- **Finding 1c:** *Student learning increased from the first unit (Systems and Scale) to the third unit (Plants).* Students' learning gains were cumulative over time.

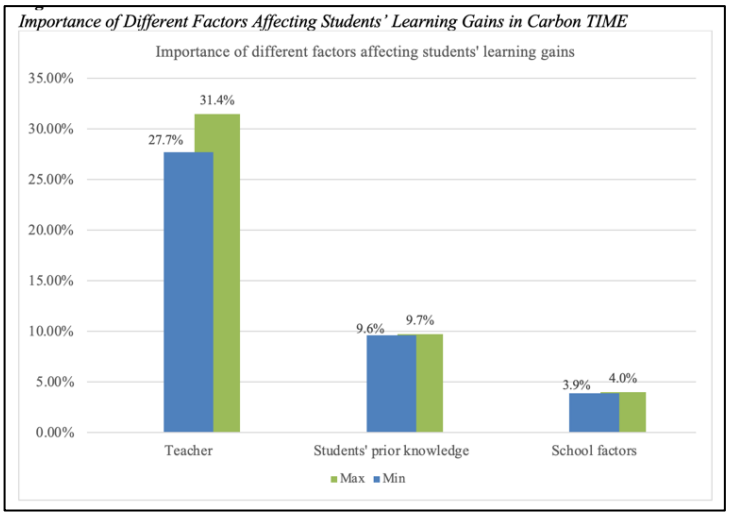
Our answer is, YES, the *Carbon TIME* "tool kit" works. Students showed substantial learning gains after studying *Carbon TIME.* Not only that, but *Carbon TIME* works to close gaps within classrooms; students with lower pretest scores gained more.

GOAL 2: SUPPORT PROFESSIONAL AND ORGANIZATIONAL LEARNING.

Comparing learning data from different schools and classrooms allows us to answer questions about differences among teachers and schools so that we can better support schools as learning organizations. ***What factors – including individual teachers and school demographics – affected students' learning?***

These research findings on *Carbon TIME* student learning are from: Lin, Q., Frank, K. A., Bathia, S., Draney, K., Thomas, J., & Anderson, C. W. (2021). *Factors Affecting Students' Learning from a Design-Based Implementation Research Project in Diverse Education Systems*. Manuscript submitted for publication.

- **Finding 2a, b:** *The differences in learning gains across teachers' classrooms (controlling for student pretests and school demographic variables) were both statistically and educationally significant.*
- **Finding 2c:** *Students in schools with higher percent of free and reduced lunch, or higher percent of marginalized students of color, showed smaller learning gains.*
- **Finding 3:** *Teachers were more important than students' prior knowledge and school demographic factors in explaining variation in students' learning gains.*



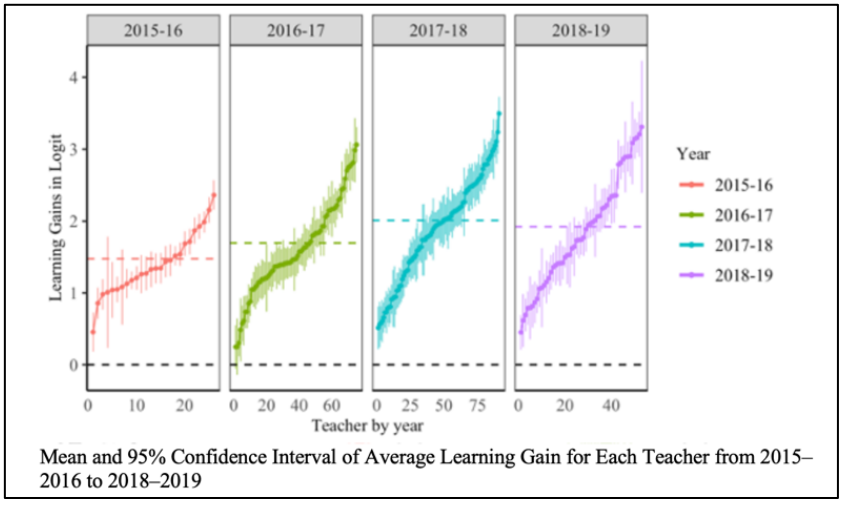
Our answer is teachers make the largest difference. Every teacher used *Carbon TIME* units differently and those differences were consequential. The differences among teachers were large and not attributable to other factors such as students' prior knowledge or the racial composition of schools.

School demographic factors (percent free and reduced lunch and percent marginalized students of color) also made a difference but accounted for much less of the variance in student learning than teachers. This suggests that *demography is not destiny;* working with schools to improve their curricular and assessment resources as well as their social infrastructures—policies, practices, and norms for professional communities—can support sustained improvement in student learning.

GOAL 3: IMPROVE THROUGH ITERATIVE DESIGN CYCLES IN RESEARCH-PRACTICE PARTNERSHIPS.

The current versions of the curriculum units, assessments, and professional development are the product of many years of iterative development involving both teachers and researchers. ***Did our curricular resources or individual teachers improve over time?***

- **Finding 4:** *Student learning increased (a) as Carbon TIME units and professional development improved over time, and (b) as teachers gained experience and learned from professional development.*



Mean and 95% Confidence Interval of Average Learning Gain for Each Teacher from 2015–2016 to 2018–2019

Our answer is, YES, we see improvement over time. Average learning gains for all students improved significantly across the first three years of the project. Individual teachers also improved their students' learning across years.

We note that administrators often value "flexibility" in teaching assignments, with teachers moving among different subjects or courses in response to student demand or administrative priorities. Similarly, teachers value freedom to choose materials and activities that they like. These data indicate that this flexibility and freedom comes with a price. Students, teachers, and organizations all benefit when they can work collectively with other professionals, when curricula and teaching assignments are stable, and when iterative revision cycles enable cumulative learning.