Using everyday language to explain scientific concepts could help students learn, study finds

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(PhysOrg.com) -- To talk about photosynthesis, you need to know a little Latin, a bit of French, some Greek, a word coined by a pair of French chemists in the 19th century, and a word of ancient origin that has been adopted and adapted by scientists around the world.

There's photosynthesis—New Latin. And glucose—a French modification of a Greek word. There's chlorophyll—coined by French scientists Pierre-Joseph Pelletier and Joseph Bienaimé Caventou. And chloroplast—part of the so-called International Scientific Vocabulary.

Those words are just part of the scientific vocabulary teachers will soon be writing on blackboards in fifth-grade classrooms across the country to explain the process by which green plants convert water, carbon dioxide and sunlight into carbohydrates and oxygen.

Usually, elementary school students are expected to learn the concepts and lexicon of photosynthesis—and other scientific subjects—simultaneously.

But according to a recent study by Bryan Brown, an assistant professor of education at Stanford, and Kihyun Ryoo, a doctoral candidate in Stanford's School of Education, students who learned the basic concepts of photosynthesis in "everyday English" before learning the scientific terms for the phenomenon fared much better on tests than students taught the traditional way.

Brown and Ryoo, who published the results of the study in the April 8 online issue of the Journal of Research in Science Teaching, called their method the "content-first" approach.

"The results reveal that although learning the language of science remains a primary hurdle, students taught using our content-first approach demonstrated an improved conceptual and linguistic understanding of science," they write.

"Furthermore, as we examined each groups' differential performance [the students were randomly divided into two groups], it became clear that students' ability to communicate using scientific language was significantly impacted by this treatment."

Brown and Ryoo said the approach offers a way to tap into the rich intellectual resources of children and potentially reduce their anxiety about using scientific language.

The traditional approach

To help students master scientific lingo, teachers usually build word walls—interactive displays of the lingo, with graphics illustrating their links to photosynthesis. They hand out vocabulary lists. They use flash cards. They ask students to make up their own definitions.

But Brown and Ryoo say those techniques do not take into account that children learn new words as those words become valuable and meaningful to their lives.

"We knew what an apple was before we said 'apple,'" Brown said during a recent interview in his office at the Center for Education Research at

Stanford. "We were hungry and saw an apple, and we were able to say, 'Give me that apple.' Need drove language acquisition."

In their article, "Teaching Science as a Language: A 'Content-First' Approach to Science Teaching," Brown and Ryoo write that the vocabulary of science presents unique challenges.

"In contrast to foreign language instruction, where students are learning new ways to express familiar ideas, science instruction often involves the presentation of new ideas expressed through new language," they write.

In a Spanish class, for example, students learn that mesa means table and silla means chair. But when fifth graders are studying plant growth, they learn that green plants make glucose inside a chloroplast filled with chlorophylls in a process known as photosynthesis.

"In science class, students get new words and new ideas simultaneously," Brown said. "We wanted to break that paradigm."

Testing a new approach

To test their theory that a "content-first" approach would boost comprehension, Brown and Ryoo designed an interactive software program that paralleled the activities of an actual science lesson on photosynthesis, a required subject in fifth grade.

They created two versions of the program, called Science of Wizardry.

One version, given to the treatment group, used alternate words and phrases to teach the basic concepts of photosynthesis. For example, it used "sugar" at the beginning of the program and segued into glucose later. It used "energy pigments" at first, and subsequently introduced chlorophylls. It used "energy pouch" as a temporary stand-in for chloroplast.

The second version of the software, which was given to the control group, used the alternate words once and then switched to scientific vocabulary for the rest of the lesson.

Except for the differences in language use, the software was identical in content and presentation, including drag-and-drop quizzes and experiments.

Brown and Ryoo gave the program an adventurous twist by adding a narrator for the first two parts of the lesson—a mandrake plant on a heroic quest.

"I need your help to save my friend Wendy," says the mandrake, which was depicted as a smiling sprite with leafy hair. "Wendy needs the healing powers of a full-grown mandrake plant. If you can help me grow, we can save my friend Wendy."

In the first part of the lesson, everyone studied the basics of photosynthesis and conducted three experiments. In one experiment, the kids "grabbed" an umbrella off a bookshelf in a virtual classroom and placed it over a potted plant on a desk to deprive it of sunlight, and "opened" a window shade in the classroom to provide light to the one standing next to it.

They observed the plants for a week—shown by small calendar pages flying off the computer screen—as one thrived and the other withered.

In the second part of the lesson, students first took quizzes on the basics. Students in the treatment group were asked to correctly place boxes—containing a sun marked "light," droplets of air marked "air humans breathe out" and "good air that humans breathe in," and a white cube marked "sugar"—into blank boxes arrayed around a plant. Once they completed that task, the scientific terms—photons, carbon dioxide, oxygen, glucose—appeared in bold letters in the boxes. By clicking on each one, students got more detailed explanations of each concept.

During parts one and two of the lesson, the mandrake "grew up" to age 18, sprouted more leaves on its head and danced—to the sound of children cheering—as kids mastered the concepts and scientific language of photosynthesis. By the end of part two, they have saved Wendy.

In the final part of the lesson, students conducted seven experiments relying solely on scientific language. In one experiment in a virtual science lab whose shelves were filled with beakers, the students tested for the presence of carbon dioxide in water by using a dye that changes from blue to yellow when carbon dioxide is present.

While conducting the experiments, the kids recorded their hypotheses and observations on virtual blackboards on the computer screen, and in real workbooks at their desks.

The 49 students, who were randomly divided into two groups, worked at individual laptops and wore headsets. Brown and Ryoo did not provide any instruction. The students, including 28 boys and 21 girls, attended a K-6 public school in San Lorenzo, Calif.

Before starting the program, Brown and Ryoo tested the class to see how much they already knew about photosynthesis. The students then spent about four hours over the next two school days using the interactive software.

At the end of the second day, the students took the test—18 multiple-choice questions and eight open-ended questions—again. Brown and Ryoo also interviewed the students about their understanding of photosynthesis.

Promising results show need for more study

When they compared the pre-test and post-test performances of the students, Brown and Ryoo were elated by the results.

"The thing that we're most excited about is that the students in the treatment group"—which learned the basics in everyday English first—"got higher scores on every type of question—multiple choice and open-ended," Brown said. "They got higher scores when questions were asked in everyday language. They got higher scores when questions were asked in science language. And when they were asked to write answers to open-ended questions, they were much better at writing their ideas in science language."

Brown and Ryoo cautioned that the results are tentative because the test was short, the sample size was small, and they did not have as much information as they would have liked about each individual student's English language proficiency.

They said the findings suggest the need for further study in a larger population of students.

For her dissertation, Ryoo is studying the impact of the content-first approach and the use of computer simulation on science learning among 240 students attending four elementary schools in the Bay Area.

Brown said some people who have learned about the "content-first" approach have responded by asking, "Isn't that just good teaching?"

"My response to that is that there's no research to document what happens if you teach in this particular way, so how do teachers know it works?" he said. "And in the classrooms I've seen, teachers are not sophisticated in the way they teach good scientific language consistently."

Teachers often talk to students about the connection between words they know and the ones scientists use, Brown said. For example, a teacher might explain that "sorting" the animal kingdom into two major categories—invertebrates and vertebrates—is the same thing as "classifying" them to a scientist.

"This 'modeling' is a common practice," he said. "But putting students in situations where they're required to use the language, which is what we did in this study, is absolutely not common."

Provided by Stanford University

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