Recent Research in Science Teaching and Learning

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ABSTRACT

The *Current Insights* feature is designed to introduce life science educators and researchers to current articles of interest in other social science and education journals. In this installment, I highlight three diverse research studies: one exploring classroom talk and how it impacts conceptual learning; one identifying a unique influence on evolution acceptance: statistical understanding; and the last a genetics lesson that reduces racial bias.

CLASSROOM TALK AND CONCEPTUAL LEARNING

Boden, K. K., Zepeda, C. D., & Nokes-Malach, T. J. (2019, October 28). Achievement goals and conceptual learning: An examination of teacher talk. *Journal of Educational Psychology*. Advance online publication. <https://doi.org/10.1037/edu0000421>

Biology educators are asked to create courses that go beyond memorization of details and lead to conceptual learning of the big ideas of the discipline. Perspectives on how to encourage this type of learning abound, but Boden and colleagues found a simple method: how instructors talk to their students and reinforce a mastery goal structure for a course.

Specifically, these researchers draw on the theory of achievement goal orientation. Achievement goals are the underlying reasons why a person pursues an academic task. They are generally divided into two categories of goals: mastery and performance. Mastery goals involve taking on a task to understand it and to improve oneself. Performance goals involve taking on a task to do better than others on it or earn a good grade. Interactions between students and teachers have the potential to influence student goal orientations, because teachers, in their position of authority, determine what behaviors are valued and what success looks like in a course. Boden and colleagues summarize how perceiving a class to be mastery oriented is correlated with a suite of positive outcomes for students, including positive affect, persistence on difficult tasks, and the use of more complex metacognitive strategies that all should benefit learning. Perceiving a class to be performance oriented, on the other hand, is related to anxiety and lower persistence on challenging tasks. Surprisingly, given these findings, the researchers found in their review of the literature that performance goal orientation is consistently correlated with higher performance on assessments, while mastery is not. They hypothesize that this is because most assessments are at the recall level and do not really test conceptual learning. Thus, they set out to measure whether the goal structure of a class as established in classroom talk can predict conceptual learning.

Boden and colleagues had access to an impressive existing data set of videos of 111 middle school mathematics classrooms where instructors were covering ratios, rates, or proportions. This data set also included student performance on an assessment that measures conceptual growth in four areas of mathematics (using the Balanced Assessment of Mathematics) for all these classrooms. Using these scores, researchers identified 40 classrooms with the highest ($n = 20$) and lowest ($n = 20$) conceptual growth from this sample after controlling for differences in student backgrounds and instructional practices.

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This feature is designed to point CBE—Life Sciences Education readers to current or noteworthy articles for life science educators and education researchers. We invite readers to suggest current themes or articles of interest in life science education as well as influential papers published in the more distant past or in the broader field of education research to be featured in *Current Insights*. Please send any suggestions to Julia.Gouvea@tufts.edu.

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Coders transcribed what instructors said in each of these classroom videos and coded instances of three dimensions of instructor statements: task, recognition, and evaluation. Task statements were any time an instructor stated expectations or goals related to learning or math. Recognition statements were any time an instructor acknowledged student performance on a task or in the class. Recognition could be positive or negative (praise, criticism, reward, or punishment). Evaluation statements focused on feedback on student mistakes, comparing students to one another, and any instances in which the instructor asked students to evaluate one another's or their own work. Each of these three categories of instructor statements could be further coded as mastery or performance oriented. For example, if a teacher states that he or she expects high grades on an assignment, that would be a task statement oriented toward performance. On the other hand, if a teacher said that the goal of a task was to be able to justify the steps you took to complete it, that would be a task statement coded as mastery oriented. Counts of mastery- and performance-oriented statements in each dimension were used as outcomes to see whether they were distinguished by classrooms with low or high conceptual growth.

Overall, among the three categories of classroom talk, Boden and colleagues found that there was more evaluation talk occurring than task and recognition talk across all 40 classes. High conceptual growth classrooms were characterized by more instances of both mastery oriented task and evaluation talk. Classes with low conceptual growth had more performance talk in the evaluation dimension. The researchers did not find that recognition talk predicted conceptual performance, as both high and low conceptual learning classrooms had mostly performance recognition talk (i.e., recognition based on achievement or correctness, not explanation or effort). The researchers hypothesize that, by emphasizing understanding and learning as a goal, teachers influence student study behaviors to focus on those that help with conceptual understanding. In addition, evaluation statements that provided explanation (as mastery statements would) role model these study strategies for students, again reinforcing them. On the other hand, the researchers hypothesize that evaluation statements that simply correct students may communicate that failure reflects ability and lead to less adaptive study strategies.

On the basis of this research, practitioners should consider classroom talk involving the instructor and how it can impact learning. Using mastery task talk and mastery evaluation talk can improve student understanding of concepts.

EVOLUTION UNDERSTANDING AND ACCEPTANCE INFLUENCED BY STATISTICAL UNDERSTANDING

Fiedler, D., Sbeglia, G. C., Nehm, R. H., & Harms, U. (2019). How strongly does statistical reasoning influence knowledge and acceptance of evolution? *Journal of Research in Science Teaching*, 56(9), 1183–1206.

Understanding what factors influence a student's knowledge and acceptance of evolution is a growing area of research in biology education. In this paper, Fiedler and colleagues briefly review factors known to impact these outcomes, which include many affective, conceptual, and situational factors. One of the conceptual factors that seems to influence evolution knowledge is understanding of statistical concepts like randomness and

probability. Probability is clearly linked to evolution, as it underlies the key features necessary for natural selection to occur (variation, heritability, and differential survival and reproduction). Randomness is important in evolution for understanding the ultimate source of heritable variation (mutations) as well as genetic drift. Fiedler and colleagues focus on statistical reasoning and examine how context may influence this understanding: Does understanding these concepts in a math context versus an evolution context influence evolution knowledge and acceptance in a large sample of introductory biology students at a large research university in the United States?

To gather information about students' statistical reasoning ability, Fiedler and colleagues used the recently developed RaPro instrument, which measures students' understanding of randomness and probability using evolution examples (in the context of evolution) and using mathematical examples (in the context of mathematics). This instrument was recently developed and still needed to be validated for diverse population of students in the United States. Thus, this validation was the first step in this study. Using Rasch analysis, the authors found support for a two-factor model demonstrating that statistical understanding in these two contexts measures two different aspects of the same concept. So, statistical reasoning in a mathematics context and in an evolution context are related to each other, but each also offers distinct information, and they are treated as two separate variables in the following analyses.

Fiedler and colleagues used the Conceptual Assessment of Natural Selection (CANS) to measure evolution understanding and the Inventory of Student Evolution Acceptance (I-SEA) to measure evolution acceptance. Four hundred sixty-eight undergraduates in introductory biology completed the RaPro, CANS, and I-SEA survey instruments.

To test the relationship between statistical understanding and evolutionary knowledge and acceptance, the researchers took a forward-selection approach to model selection: They ran three models for the outcome of evolution knowledge and four models for the outcome of evolution acceptance. In each model, they added a new variable while keeping all the original variables in the model. In the first model, they included statistical reasoning in an evolution context alone, in the second, they added statistical reasoning in a math context, and in the third, they added in a block of seven student demographic and background variables. These variables included gender, race, age, class level, major, and English reading and writing skills. Finally, when they were testing the outcome of evolution acceptance, they ran a fourth model adding the variable of evolution knowledge.

This model selection technique allowed the researchers to demonstrate that statistical reasoning is still a predictor of evolution knowledge and acceptance, even when student background is accounted for. Statistical reasoning in evolution and in mathematical contexts together explained almost 28% of the variance in evolution knowledge and 19% of the variance in evolution acceptance. In comparison, at least in this sample, student background did not explain any variance in evolution understanding and only 7.6% of the variance in acceptance. Thus, statistical reasoning seemed to have a larger impact on both acceptance and understanding than student background. Finally, in the model for evolution acceptance,

statistical reasoning seemed to explain some unique variation in acceptance beyond what was explained by evolution understanding.

These results suggest that effective evolution education should incorporate statistics education specifically around the topics of probability and randomness, possibly through collaboration with statistics educators or through units taught in evolution classes. The integration of mathematics into biology has been suggested for improving biology education generally, but this article speaks to its unique impact on evolution education.

A HUMANE GENETICS EDUCATION

Donovan, B. M., Semmens, R., Keck, P., Brimhall, E., Busch, K. C., Weindling, M., ... & Kowalski, S. (2019). Toward a more humane genetics education: Learning about the social and quantitative complexities of human genetic variation research could reduce racial bias in adolescent and adult populations. *Science Education*, 103(3), 529–560.

Many people hold the misconception that human racial groups are distinct from one another both physically and behaviorally and that the basis of these distinctions is genetic, a concept called “racial essentialism.” This conception perpetuates prejudice, whether intentional or not. In their introduction, Donovan and colleagues review evidence demonstrating that the way genetics is sometimes taught in introductory biology has the potential to reinforce racial essentialism. They proceed to test whether the biology curriculum also has the potential to reduce racial essentialism by teaching accurate science about human genetic differences.

Donovan and colleagues developed a curriculum that emphasized scientifically accurate information about race. They employ the technique of contrasting cases in their lesson. First, they provide students with a visual breakdown of what it would look like if races were distinct from one another genetically and a visual breakdown of what it would look like if races were not genetically different from one another. Then they present students with actual human data in the same visual format and have them develop an argument for whether the hypothesis that “different races are genetically alike” is supported or refuted by comparing the new data with the scenarios they were provided. Thus, this lesson breaks down two common misconceptions related to prejudice belief: People of the same race are genetically uniform and people of different races are genetically different from each other. The full lesson is available to educators in the Supporting Information of the article.

This curriculum was delivered to three different groups of participants through two methods: a weeklong face-to-face intervention and a 45-minute computer-based lesson. The three samples were middle and high school students (weeklong lesson; $n = 166$), adults through Mechanical Turk (computer-based lesson; $n = 176$), and a sample of high school students from across five schools (computer-based lesson; $n = 721$). The majority of these participants identified as white and female.

Researchers took an unusual approach to the control condition for these experiments. Rather than teaching human genetics in the “classical” manner (teaching about human genetic diseases), they chose to compare the new genetics unit with a unit on climate change, another politically controversial topic. They argue this is a better control, because existing evidence suggests that teaching genetics the classical way increases genetic essentialism, so they would overestimate the impact of their treatment. In addition, climate change as a control should also control for ideology that may influence student experiences with both topics. Both lessons spent the same time on task, used the same instructional framework, and taught the concept of variation.

To measure the impact of the treatment, Donovan and colleagues used the Perceptions of Biological Variation instrument, which measures perception of genetic variation within and between races. They also employed a racial stereotyping instrument with items focused on the genetic essentialism of race. Participants completed these surveys before the experiment and immediately after the experiment; participants in the third sample completed the surveys a third time, 3 weeks after the experiment, to examine longitudinal persistence of the effects.

Compared with the control (climate change), the new genetics unit reduced participants’ beliefs about genetic essentialism of race as well as racial stereotyping significantly more. Across all three experiments, the treatment reduced participants’ beliefs about racial essentialism by 0.75 SD, classically considered a moderate to large effect size. The impact on racial stereotyping was more variable, with the largest study resulting in only a small reduction in bias, and the two smaller studies having moderate effect sizes. This reduction lasted for at least 3 weeks, as the effect of the treatment was still significant at the third time point.

Finally, using a mediation analysis, researchers tested whether learning about human genetic variation was what drove the reduction in racial stereotyping. They specifically tested whether it was learning about genetic variation within racial groups (within group items on Perception of Biological Variation instrument) or learning that there are few distinct genetic differences across groups (between group items) that drove the reduction in racial stereotyping. They found that learning about human genetic variation explained 19–45% (depending on the sample) of the reduction in stereotyping when exposed to the genetics intervention; specifically, it was learning about how little distinct genetic variation there was across racial groups that drove this reduction, not learning about within-race variation.

This set of experiments was proof of concept that how educators teach genetics can impact racial beliefs. Teaching accurate science that reflects how little racial groups vary genetically from one another and that most of the variation in human genetics occurs within and not across groups could address common misconceptions about race and lead to a “more humane genetics education.”