Cultivating active learners: How instructors can change their teaching to help students engage with formative assessments

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Because formative assessments (FAs; e.g., clicker questions, in-class group activities, Just-in-Time-Teaching, homework assignments) are known to improve student learning and retention in STEM, national reports have called for instructors to adopt these techniques. While the use of FAs has increased in STEM courses, it has also been accompanied by challenges, including students who are resistant toward them or use them in ways that may undermine learning (e.g., not taking FAs seriously, searching the internet for answers). Student buy-in and utilization thus represent critical factors that potentially limit the adoption and efficacy of FAs. Furthermore, instructors often adapt these techniques, and these changes could lead to variation in learning gains. Thus, instructors need guidance about how to implement FAs to encourage student engagement and support learning. Moreover, while the FA literature provides many general insights, more work is needed to fully understand how to optimize student engagement with specific FAs that are commonly used in undergraduate biology. To address this gap and provide more specific guidance for instructors, we have investigated the overarching research questions of how students buy-in to and utilize specific FAs as well as how instructor implementation characteristics influence student FA buy-in and utilization.

Our research is grounded in two theoretical frameworks. First, we applied Prosser and Trigwell’s model of teaching and learning to establish an FA Engagement Model, in which implementation characteristics affect student perceptions about the FA (i.e., buy-in) and student behaviors during and after the activity (i.e., utilization). In turn, FA engagement (i.e., buy-in and utilization) influences subsequent learning gains. Second, we used Black and Wiliam’s five objectives for how FAs improve learning to scaffold our investigations of each component of the FA Engagement Model (i.e., implementation, buy-in, and utilization). Our work has yielded multiple data streams. First, we collected mixed-methods survey data from over 1,000 students in 12 biology courses and 38 student interviews from 8 biology courses at a large midwestern university. We used factor analyses and mixed effects statistical models to analyze our quantitative data and thematic content analysis involving a combination of a priori and emergent processes to analyze qualitative data. We combined our insights from these quantitative and qualitative data to build and validate a diagnostic survey tool, the Formative Assessment Buy-in and Utilization Survey (FABUS), that instructors can use to monitor student buy-in and utilization. The development of FABUS involved an iterative process of piloting and revising based on student think-aloud interviews, feedback from instructors, and statistical analyses (i.e., exploratory and confirmatory factor analysis and reliability statistics). We administered the final version of FABUS to over 4,700 students in 55 biology courses at 9 institutions of varying types. This talk will synthesize the overarching findings from our 5 years of research reported in several published manuscripts. Throughout this research, we have catalogued the range of variation for each of the three components of our FA engagement model for several FA types. We have catalogued 72 different characteristics across 8 categories of FA implementation, characterized how student buy-in aligns with
the five FA objectives, and outlined the range of student FA utilization behaviors within categories of approach, discussion, resources, and later use. In addition, we have tested the relationships among the model components. In general, we have found that the majority of students buy-in to commonly used FAs, and our mixed effects models have identified factors that predict increased FA buy-in. Instructional implementation differences along with student beliefs about ownership of learning and behaviors have consistent significant influences on buy-in, while student demographics, previous experiences, and incoming GPA do not. In addition, our models have shown that higher buy-in toward FAs predicts deeper learning approaches and improved exam and course performance, even when controlling for student demographics and GPA. Taken together, these results suggest that instructors should care about student buy-in and that they have the power to improve it. Through in-depth analysis of student interviews, we have further fleshed out relationships between specific implementation characteristics and student buy-in and utilization, yielding a comprehensive resource that distills recommendations across each implementation category about how instructors can improve student FA engagement. These recommendations support those of previous research while also providing deeper insights from the student perspective and generating new recommendations for implementation characteristics that have received little attention in the literature. For example, we identified deliberate steps instructors should take to ensure student engagement with pre-class FAs. Other novel findings include insights about activity messaging, out-of-class peer learning, and grading policy. Additionally, we found that implementation characteristics have interacting effects on student engagement and that students will tolerate a degree of “acceptable discomfort.” This research refines the FA literature and provides important information for undergraduate biology instructors by systematically outlining implementation, buy-in, and utilization for several commonly-used FAs and demonstrating the connections among these variables and student performance. Moreover, FABUS represents a powerful tool that instructors can use to gain feedback about specific aspects of their FA implementation. Prior to FABUS, there have been no other instruments that directly assess student perceptions and behaviors regarding specific FAs within a course. In addition, we will share how we have used FABUS to scaffold a professional development workshop in which faculty reflected on their FABUS results and identified implementation changes they planned to make to improve student buy-in and utilization. These efforts provide a model for how faculty can use data from their own classes to improve FA implementation in ways that are aligned with best practices.
Classroom as genome: using genomics research methods to assess the student and instructor behaviors associated with clicker questions

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In this presentation, we address two problems in biology education. First, how do we achieve fine-grained analysis with classroom observation protocol data? Often, classroom observation data is compressed through summary statistics, meaning that only a coarse-grained perspective on the underlying instructional data is revealed. This results in the loss of potential insights on patterning within observed classrooms. Second, how can researchers measure the level of fidelity of implementation for an instructional technique within a broad source pool of observations, while minimizing the need for arduous manual analysis? It is difficult to target professional development efforts without a detailed accounting of current practices, and developing creative methods to extract such information from data collected for other purposes would be of great value to the research community. Here, we present the results of two projects that together address these problems. We have established a methodology for the analysis of observation data streams termed “classroom as genome” (CAG). Following that, we deployed CAG on a large population of classroom observations in order to analyze the implementation of Peer Instruction. Classroom observation data may provide a variety of insights to individual instructors looking to understand and improve their own classroom practices, while for education researchers, the analysis of classroom data at large scales can provide a big picture perspective on instructional practices. There are a growing number of published classroom observation protocols, each with its own focal points. These protocols have been broadly used in efforts to characterize the spectrum of instructional practices at individual colleges and universities, as well as to compare and contrast hundreds of class periods from sets of higher education STEM classrooms spanning multiple institutions. However, analyzing classroom observation data at large scales can be fraught with difficulty. Many of the above studies rely heavily on summary statistics to compress and restructure the underlying data prior to downstream analyses. These summary outputs can obscure meaningful patterns and differences within a pool of observations. A challenge for the field is to fully take advantage of the fine-grained data provided by many observation protocols. In order to address this challenge, we developed a new philosophy of classroom observation data structuring and analysis that leverages the many parallels between genomes and classrooms, including the layering of multiple forms of information, the meaningfulness of directionality, and underlying patterns within a larger superstructure. Taking this analogy to its logical end, we are enabled to draw upon the tools of a bioinformatics scientist, with the intent of repurposing genomics analysis approaches for education research. CAG approaches allow researchers to address a wide-ranging set of potential questions, from the dispersion and clustering of individual classroom behaviors to the sequencing of different classroom behaviors relative to one another. CAG methods have the potential to enable analyses that would otherwise be much more difficult, and should be of interest to biologists writ large who have an interest in seeing the tools of biology research being applied within the educational realm. Second, we apply CAG methods to the study of Peer Instruction (PI) within the STEM classroom. PI is a pedagogical technique characterized by individual student responses to an instructor’s conceptual question using clickers or other personal response systems, followed by discussion of the question among peers and a second response to the question. Researchers have detailed a framework for the fidelity of implementation of PI, which highlights both the individual
thinking/response step and the peer discussion step as critical for high fidelity usage of the technique. Research on PI and clicker usage has described implementation at small to medium scales, but large scale studies of the detailed implementation behaviors of PI have remained difficult to execute. To address this problem, we repurposed a data set of 412 classroom recordings (representing over 70 faculty members at over two dozen institutions) that had been coded using the Course Observation Protocol for Undergraduate STEM (COPUS). Using CAG, we were able to isolate and analyze 457 distinct occurrences of the “clicker question” code found across 177 of the classroom observations. We found that 382 of the clicker question episodes overlapped with the “group discussion of clicker questions” code, but that only 47 of these 382 episodes also incorporated the “independent thinking” code. Meanwhile, 64 of the clicker question episodes were found to overlap “independent thinking” without overlapping “group discussion of clicker questions.” We found that there was a statistically significant different between the mean percentage of time spent lecturing between class periods containing a clicker question and those without (unpaired T-test, p < 0.0001), but that there was not a significant difference in class time spent lecturing or listening between class periods containing different forms of clicker question implementation. Our results suggest that, as a community of instructors, we are missing out on many opportunities to encourage better peer discussion episodes through the use of preceding individual thinking and responses. In addition, we describe the usage of ends analysis to describe patterns across clicker questions. In ends analysis, the starting end and the closing end of every instance of a code/feature of interest are lined up, while all other codes are plotted relative to those aligned ends, enabling the visualization of features that proceed, follow, or overlap other features of interest. Applying ends analysis to the 457 clicker question episodes, we uncovered distinctive patterns in the time leading up to, during, and after clicker questions, which shed additional light on the ways in which clicker question usage aligned (or didn’t) with the high fidelity practices suggested by PI. Altogether, these results provide with a much broader, yet simultaneously more detailed, view of the PI “character” of instructor questioning in a broad range of classrooms, in a way that was not possible using traditional analysis techniques. This represents a streamlined approach to determining fidelity of implementation in a way that uses off the shelf data and can be a complement to specialized research instruments for the study of a given pedagogical technique. Citations: “Classroom as genome: Using the tools of genomics and bioinformatics to illuminate classroom observation data.” CBE – Life Sciences Education, 18:es1, 1–12, Spring 2019. “Clicker usage in postsecondary STEM classrooms: a quantitative analysis of correlated student and instructor behaviors.” In preparation.