Ordering Components of a Class Session: Application of Literature to Design of a Module on Analysis and Modeling of Dynamical Systems in Biology

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The ordering of components of a class session affects the effectiveness of instruction. For example, choosing to start with a real-life example could get students motivated to learn about a concept, or choosing to end with a worked example could prepare students to do homework problems. Ordering learning activities should reflect an understanding of the steps that people go through in a learning cycle. One way of thinking about how best to sequence learning activities is the BSCS 5E Instructional Model, in which activities follow the order, Engagement, Exploration, Explanation, Elaboration, and Evaluation. The 5E Model is in an philosophical lineage following Herbart and Dewey. It is based on the "guided discovery" model of Atkin and Karplus; the significance of each phase in the model and the ordering of the phases has been studied extensively.

I present how I apply the literature on ordering learning activities to improve a module on biochemical oscillators. The module is part of a course on mathematical modeling in biology for life science majors. Prior to the module on biochemical oscillators, students use discrete difference equations, implemented in Excel and MATLAB, to model oscillations in predator-prey systems. One of the overall learning goals is for students to be able to synthesize biological behavior, mathematical analysis, and computational solutions. In the case of biochemical oscillators, a key biological phenomenon (two-component oscillators working via selectively autocatalytic reactions) can be studied analytically (by applying formulas to the reaction network) and computationally (modeling how kinetic parameters affect time-varying concentrations of molecules). Students have prior knowledge of cell biology, calculus, and modeling using difference equations. The major assessment for this module is a lab exercise in which students use analytic techniques to predict whether particular kinetic parameters lead to oscillations in a biochemical reaction network, and confirm these predictions by adapting MATLAB code to model the system. To prepare for the lab activity, students must learn the qualitative requirements on reaction kinetics for biochemical oscillations to take place, and how to perform eigenvalue analysis to predict whether oscillations would be possible.

Based on assessments of student learning from the first time this module was offered, I was able to identify aspects of the lesson that could be improved by ordering activities under the 5E Model. To predict whether oscillations are possible in a system, students must be able to follow a mathematical procedure, but, while students were capable of following the steps, they reported not understanding the significance of the procedure in predicting the behavior of the system and its relevance to biology. I developed an activity in which students can explore eigenvalue analysis by sketching reaction trajectories. Following the 5E Model, I revised the lesson plan to place this exploration of the eigenvalue analysis after engaging students in consideration of how chemical kinetics enable oscillations and prior to explanation and elaboration steps.