BIOLOGY BOTTLENECK LESSON
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CONTEXT	Biology L112, Foundations of Biology: Biological Mechanisms, is one of two foundational courses students take if they are planning on careers in one of the health professions or graduate studies. This course is taught in a flipped format with 60 students enrolled.
STEP 1: THE BOTTLENECK **WHAT ARE STUDENTS UNABLE TO DO?**	Memorization versus visualization. Students can memorize the components of particular biological processes, but no matter which mechanism is involved, students do not know how to visualize biological processes. Visualizing a three- dimensional process such as translation of RNA is difficult, and if you can't visualize it, you can't make predictions.
STEP 2: THE MENTAL ACTION **WHAT MENTAL ACTIONS DOES THE EXPERT PERFORM TO GET PAST THE BOTTLENECK?**	I visualize the components of processes---I do this all the time. To watch the process in my mind, I have to first know the components and their functions, and then go back and forth between what happens to the process and what happens to the components, which is iterative. This is a mechanistic visualization. [She starts sketching chromosomes and chromosome pairs on a sheet of paper, using arrows, bars, and boxes to indicate the process going forward, being interrupted. This shows another part of visualization--- turning the objects and processes into symbols in order to symbolically manipulate them.] In my work, there's a process and the chromosomes and the different stages that the process is in. If it arrests at a certain phase, in my head I am watching the chromosomes go through their movements and seeing the effects of them freeze at a certain stage or if they switch from one process to another. I'm visualizing whether a protein makes something happen or stops it. I have the chromosome behavior so firmly in mind, I can apply the effects of other things on this process. (And you can say this for every process I visualize.)
STEP 3: MODEL THE THINKING **WHAT ANALOGY WILL YOU USE TO MODEL THESE MENTAL ACTIONS?**	Translating RNA to a protein is like building a car out of LEGO starting from the written instructions. This analogy works because the LEGO car has an active function along with being three-dimensional---colors and shapes that make up the parts that move.
STEP 4: PRACTICE AND FEEDBACK **HOW WILL THE STUDENTS PRACTICE THESE MENTAL ACTIONS? HOW WILL THEY RECEIVE FEEDBACK TO MAKE IMPROVEMENTS?**	• At Week 2 in the semester students draw the course vocabulary words instead of memorizing them (as in concept maps or process maps). • At Week 3, students draw pictures of movements across the membrane. • At Week4, students practice visualizing in their learning groups using the Human Tableau CAT that I learned from my colleague Roger Innes (Zolan, Strome, & Innes, 2004) (though this CAT is NOT for assessment but for practice). Students act out the

	process of RNA translation with their bodies so they have to know what the components are and what they do; plus ---it's iterative. • Afterward, the teams reflect on the human tableau scenes in writing to reinforce their understanding of the process.
STEP 5: MOTIVATION **WHAT WILL I DO TO HOLD STUDENTS ACCOUNTABLE AND DISRUPT RITUAL WAYS OF LEARNING?**	• I use some mnemonic phrases, repeating them for emphasis: "Close your eyes and visualize," and "Less memorize, more visualize." • I have "flipped" the class so there is less of a tendency for passive memorization and more active explanation and visualization by students. While there are prerecorded lectures, students spend most of their in-class time in learning groups facilitated by teaching assistants. The once-weekly whole-group meetings are teacher explanations interspersed with clicker questions. Students constantly seek out someone they don't agree with on the clicker questions to explain their understanding to and listen to the explanations of others.
STEP 6: ASSESSMENT **HOW WILL YOU ASSESS STUDENT MASTERY OF THE MENTAL ACTION?**	Students (n=54) scored 89% correct on an item on the final exam that assessed students' ability to visualize by drawing and explaining transport in plant cells. By the time we realized it would have been good to collect a pretest, it was too late in this course. But the next semester, we "pretested" the students in an even larger section of the same course (300 students, with n=124 signing IRB permissions to participate in study) on a similar task (drawing and explaining the process of transport). While this was not the same class, it did give us an idea of what the typical class can do in regard to visualizing a biological process prior to it being taught explicitly---24% answered it correctly. The students who could not answer correctly went wrong in interesting ways: Some students could draw the visualization but could not explain it (8%). Some students could explain it (were they just parroting words?) but could not draw it (7%). The incorrect responses gave us ideas for further study., as we try to better understand how to help students develop visualization and the skills to represent their mental processes. (Thanks to Professor Megan Dunn for the pretest study and Natalie Christian for data analysis.)
STEP 7: SHARING **HOW WILL YOU SHARE WHAT YOU LEARNED?**	I teach a pedagogy course for biology graduate students based on Decoding the Disciplines---every student develops a bottleneck lesson and teaches it with feedback. I occasionally present to faculty groups about how decoding affected my teaching (Zolan, Strome, & Innes, 2004).