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Title: Diagnosing Students' Mastery of Concepts in Biology: An Examination of Mastery States Before and After Instruction Based on 3-D Animations

The topics at the beginning of high school biology classes are about inner workings of cells and organs, and students mostly learn these topics from reading texts, 2-D figures, or diagrams. For many students, these abstract science concepts and processes are difficult to learn and understand. Through a collaborative grant-funded effort, learning modules based on 3-D animations were developed to improve teaching and learning of these abstract concepts. This study focuses on diagnosing high school students' mastery of three biological concepts (i.e., Osmosis, Diffusion, and Filtration) at two time points in the context of these learning modules: before instruction with the 3-D modules and after instruction. The test administered to determine mastery was developed such that each item measured one of the three concepts. We modeled the data using a diagnostic classification model (DCM) in order to statistically classify students according to mastery levels (i.e., mastery or non-mastery) of each separate concept.

In our study, we addressed two main research questions. First, how well does the 3-dimensional DCM represent the data? In other words, is the DCM an appropriate model for these data in terms of model-data fit? Once we established an adequate model-data fit, our next question of interest was to compare the prevalence of mastery before and after instruction to quantify the extent to which the 3-D animations were effective. We viewed a student's transition from non-mastery on the pre-test to mastery on the post-test as evidence for learning.

Three forms (Form A, B, and C) of assessment were developed to evaluate the effectiveness of the 3-D animations, and these assessments were administrated to 473 high school students. Students were randomly assigned to two groups (Group A and Group B). At the beginning of the semester, students who belonged to Group A took the Form A, and students who belonged to Group B took the Form B as a pre-test. After using the 3-D animations, students who belong to Group A took the Form B and Form C, and students who belonged to Group B took the Form A and Form C as a post-test. Thus, items in Form C could be treated as anchor items for scaling of Forms A and B. This data structure is described in Figure 1.

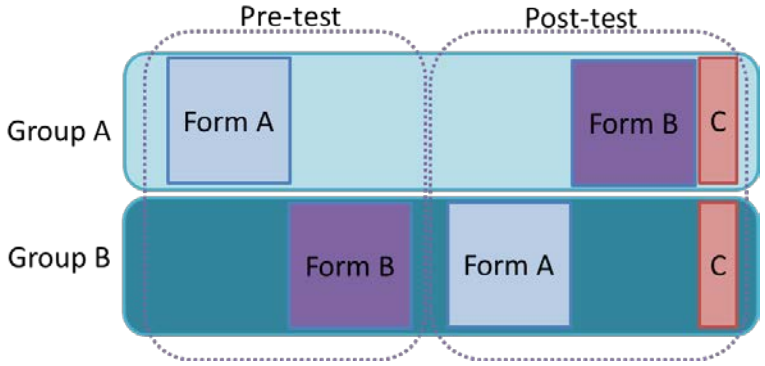

Figure 1. Data structure

The proportions of each attribute mastery profile based on the final LCDM are indicated in Figure 2. There are eight attribute mastery profiles because three different attributes were measured. The first attribute is Osmosis, the second attribute is Diffusion, and the third attribute is Filtration. For the attribute mastery profile, mastery is coded as one and non-mastery is coded as zero. For example, the attribute mastery profile for a student who has mastered only the first attribute (i.e., Osmosis) is

[1, 0, 0].

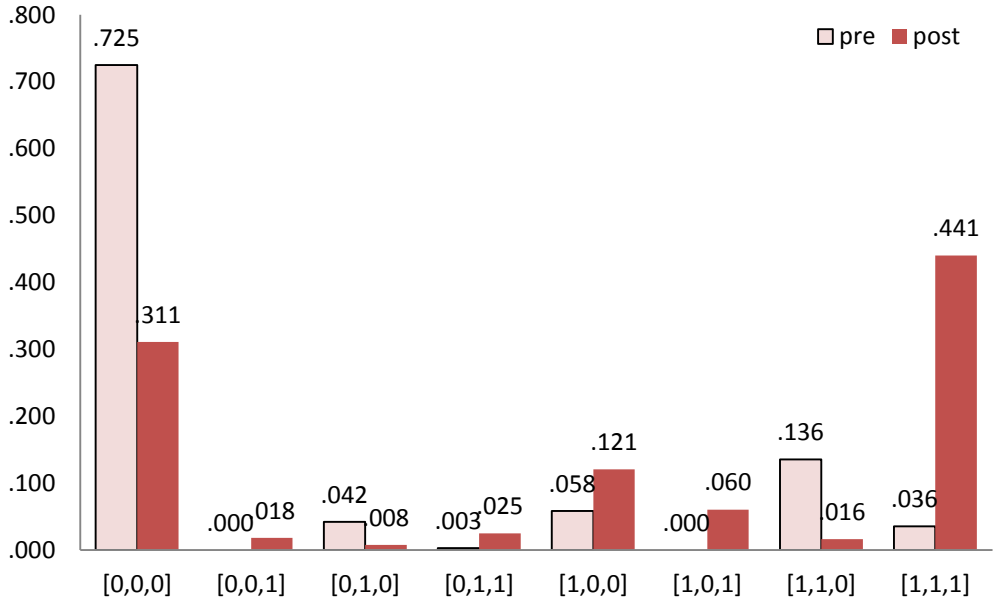

Figure 2.The estimated proportions of each attribute mastery profile for the pre-test and post-test.

Figure 3 shows students' mastery at the pre- and post-test, indicating for each concept that a large portion of students transitioned from non-mastery to mastery. For example, 22.9% of students were masters of Osmosis before instruction and 63.8% of students were masters of Osmosis after instruction.

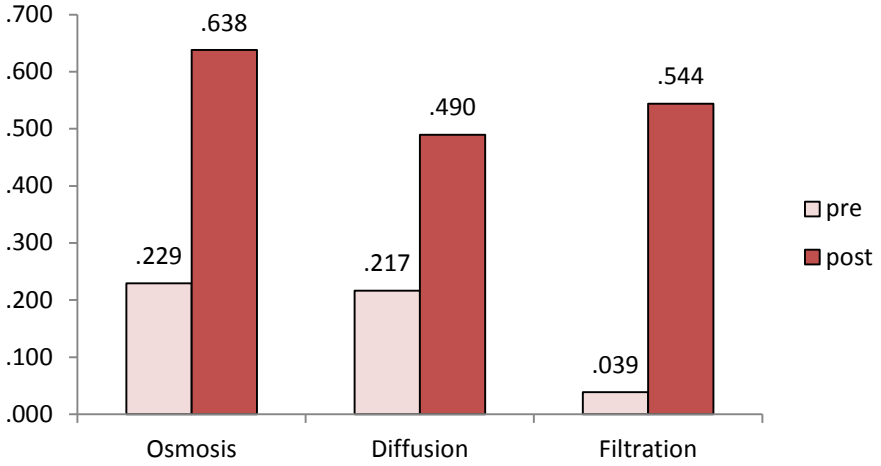

Figure 3. *Proportion of mastery for each of three concepts (osmosis, diffusion, filtration) on the pre-test and post-test*

Based on the results of the attribute mastery profiles, the proportion of students who had mastered three attributes (i.e., attribute mastery profile [1, 1, 1]) significantly increased from pre-test to post-test. Moreover, the proportion of students who had not mastered all attributes (i.e., attribute mastery profile [0, 0, 0]) noticeably decreased from pre-test to post-test. In addition, the estimated marginal probabilities of mastery for all attributes increased from pre-test to post-test. Filtration, above all, shows dramatic improvement by 3-D animations. This means that 3-D animations have a significantly positive influence on students' learning for three biological attributes, especially Filtration.