Learning Theory

Classroom Instruction that Works, Research-Based Strategies for Increasing Student Achievement by Robert Marzano, Debra Pickering, and Jane Pollock, 2001

In this book the authors summarize numerous studies conducted to evaluate[1] effective instructional strategies in the kindergarten through twelfth grade (student ages 5 - 18) classroom. The following strategies are the ones from the list of the top nine categories that apply directly to the use of system dynamics modeling in the high school curriculum.

Subset of the nine top categories of instructional strategies in Marzano's book that affect student achievement.[2]

1. Identifying Similarities and Differences (percentile gain = 45)

- Graphic and symbolic representations of similarities and differences enhance students' understanding of content.

An icon-based representation of a model is compared to the traditional closed form equation representation of a model in algebra classes for various functions, reinforcing the connection between the structure and behavior of different functions. Once a model is created, multiple graphs are easily produced in which the student is asked to alter a parameter value. Comparisons between the graphs aid students in determining the effect parameter values have on the overall behavior produced by the model.

2. Homework and Practice (percentile gain = 28)

- Students must adapt or shape skills as they are learning them. It is during this shaping phase that learners attend to their conceptual understanding of a skill.
- Focused practice is particularly important when students are practicing a complex, multi-step skill or process, such as a research process, scientific inquiry, or the writing process.

The process of building even very small models requires students to translate the information given in an instruction packet to the symbols and connections that must be made to create a working model. After a basic model is built students are given the task of modifying the model to simulate an altered scenario. Students usually know in advance what the graphs should look like. This knowledge helps guide the students as they assess their model-building success.

When students are required to build more open-ended models that are a little larger than a small core model, they are given suggestions and a sequence of steps through which they should progress to achieve their goal. The process becomes easier with practice and marks a significant step in student's ability to internalize model building as a useful method for analysis

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[1] For each of the categories, and some of the sub-categories, Marzano, et.al, list the Average Effect Size, ES(a meta-analysis standard deviation measurement of the increase or decrease in achievement of the experimental groups compared to the control groups), the percentile gain associated with the ES, the number of studies from which the data were calculated, and the size of one standard deviation for the category under study.

[2] The discussion given is limited to the use of system dynamics modeling as it is and can be used to apply the specific instructional strategy.

of a complex system. The initial model creation procedure is demonstrated by the teacher. The students are then required to apply the process to multiple assignments.

3. Nonlinguistic Representations (percentile gain = 27)
   - Knowledge is stored in two forms, linguistic (statements) and imagery (a mental picture, physical sensations, or kinesthetic associations). The more we use both linguistic and non-linguistic representations, the better we are able to think about and recall knowledge.
   - Explicitly engaging students in the creation of nonlinguistic representations stimulates and increases activity in the brain.
     - Nonlinguistic representations include 1. creating graphic representations, 2. making physical models, 3. generating mental pictures, 4. drawing pictures or symbolic pictures to represent information, and 5. kinesthetic activity.
     - Nonlinguistic representations should elaborate on knowledge. The power of elaboration can be enhanced by asking students to explain and justify their elaborations.

The creation of behavior over time graphs (BOTGs), which are often used to anticipate the behavior of a model that will be created, and the sketching of and explanation of circular feedback processes that are active in the models created both directly address nonlinguistic pattern identification. The use/creation of simulations would be an electronic variation of the creation of physical models. Since models created with the STELLA software use icons to represent each component building such models would address drawing symbolic pictures to represent information. In fact by building a model we have a more powerful representation than merely a drawing, as the 'symbolic pictures' can be activated. The models have an animation feature to show the stocks filling or draining, visually, and the output of the 'symbolic picture' can be graphed, when numbers are placed in each icon.

4. Generating and Testing Hypotheses (percentile gain = 23)
   - By definition, the process of generating and testing hypotheses involves the application of knowledge.
     - Hypotheses generation and testing can be approached in an inductive or deductive manner. Teachers should ask students to clearly explain their hypotheses and conclusions. The process of explaining their thinking helps students deepen their understanding of the principles they are applying.

In a math class some assignments require students to anticipate the behavior of a model they will create by drawing behavior over time graphs. This is a form of generating a hypothesis. The process of model building and the execution of the model require the student to test his/her understanding of what structures are necessary to produce the behavior they anticipated. Executing the model then tests their hypothesis. Due to the visual nature of the model diagram it is easy for students to modify the model to delve into more sophisticated behavior patters/hypotheses, which they can test. This model modification process allows students much more flexibility. Modifying closed form equation representations, except for changing parameter values, is much more difficult for students. Having students explain why the model produces the behavior displayed, using feedback analysis, is core to the appropriate use of system dynamics modeling in the classroom.

   - A subset of six types of tasks that employ hypotheses generation and testing are listed below:
     - Systems Analysis: students are asked to explain what would happen if a system were changed, explain the purpose of the system, the parts of the system, the function of each part, how each part affects the other parts.

- Problem Solving: students generate and test various solutions to problems, identify goals, barriers or constraints, select the best solution among various solutions, explain whether they were correct in their analysis.
- Experimental Inquiry: students apply scientific theories to explain an observation, set up an experiment to test their theory, and explain the results of the experiment.
- Decision Making: students choose the best solution to a problem or the solution that has the best chance of working and reflect upon their knowledge related to the given problem.
- Cues, Questions, and Advanced Organizers:
  - Questions that require students to analyze information produce more learning. All higher-level questions require students to restructure information or apply knowledge in some way. Even asking questions before a learning experience establish a 'mental set' with which students process the learning experience.

Systems analysis is what system dynamics modeling was designed to do. Every part of the model building process is designed to help students analyze the reason a system behaves as it does. Additionally, during the process of model building students are problem solving, actively engaged in experimental inquiry and are making decisions. Students can also test potential policies designed to mitigate some undesirable behavior of a system.

Students build (and test) their model in stages. Throughout the process students are asked to reflect upon the current state of the model and what behavior it should produce. They are asked upon what evidence they can draw their conclusions. Here the use of circular feedback analysis plays the pivotal role. They then run their simulations to test if they were correct in their analysis.

Real world problems are stimulating for students. They want to understand how the world works and are not shy about giving their opinions. Being able to test their hypotheses and conclusions helps focus and substantiate their claims. It is a way to help students enhance and hone their ability to think through difficult problems.