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Scenario

In Carbondale, Illinois, Ms. Walters' 31 seventh graders enter the science classroom to find an array of materials and equipment on the tables. At each table are a balance, metric scale, graduated cylinder, and six cubical solids and six spherical solids; two of each solid type are made of aluminum, two of plastic, and two of steel; one of each pair of solids is larger than the other. After taking roll, Ms. Walters begins class:

> It's obvious you have noticed the materials and equipment I placed on the tables. Many of you have already started on the activity for today — I saw James examining the materials and Sue weighing them.
>
> For today's activity each group is to explore the physical properties of the 12 regular solids that are on your table using the balance, metric scale and graduated cylinder. I have put together a worksheet that will help guide you as you collect and organize your data. Once you have completed the task, examine your data for anything common to the types of solids or to the types of materials the solids are made of. Don't be afraid to reorganize your data as you search for any relationship.
>
> We'll spend about 30 minutes on this activity and then we will discuss what you found.

As the students work on the task, Ms. Walters walks from group to group using supportive comments and posing questions to stimulate thought, to keep the students on task and to collect feedback on their progress. She notices that on their own Brad and Sue have found the unique mass-to-volume ratio which is a property of each material; and with a little prompting via questions she asks, Trudi also finds the relationship. As she anticipated, however, most of the students have not recognized this relationship in their data.

After about 30 minutes, Ms. Walters begins a class discussion of the data the students collected. She uses probing questions to focus the students' attention on the constant mass-to-volume ratio which is unique to each of the three materials, irrespective of the solid's shape or size. The term "density" is introduced and operationally defined as the discussion and class period draws toward a conclusion.

At the end of the session summary, Ms. Walters tells the class, "Tomorrow we will have an activity in which you will apply the understanding of density you developed today." In that activity Ms. Walters will ask the students to determine if any of five unknown objects, all painted the same color, are made of a different material than the other four.

A Piagetian Perspective

When Ms. Walters' 31 students approached the activity she had designed for them, they did so using their prior notions/knowledge of the properties they were to examine and the mental structures they had developed through previous interactions with solid objects (Piaget refers to these mental structures as schema/schemata; Karplus uses the term reasoning pattern). The two students who independently found the unique mass-to-volume ratios, Brad and Sue, may have done so via one of two routes. First, they already may have possessed mental structures which could be used to assimilate the information from the activity. In that case both students would have had their mental structures broadened by the experiences provided by the activity, unless those experiences were congruent with ones the two students had previously. Or, the activity may have provided Brad and Sue with sufficient impetus to reorganize their mental structures, and so, enable them to discover the mass-to-volume ratios. This is what occurred in Trudi's case. Ms. Walters' interactions with Trudi as she worked on the activity provided her with the direction she needed to discover the concept of density from her data.

The 29 students who did not discover the unique mass-to-volume ratios in their data were not able to do so because they did not possess the mental structures into which information from the activity could be assimilated. Most probably this is because the students had few prior experiences which were germane to the concept of density. The realization that their mental structures were not adequate sent these students into a state of mental disequilibrium. The disequilibrium manifested itself as an intrinsic need to move back into equilibrium; the students became more receptive to learning. The discussion Ms. Walters led on the data provided a way for these students to order their observations, and so come back into mental equilibrium. In essence, Ms. Walters helped these students create (accommodate) a mental structure associated with the concept of density as it was dealt with in the lesson.

Because the breadth of the newly created mental structure was limited to the experiences which led to its creation, these students could not immediately apply it to a wide range of experiences. The activity Ms. Walters planned for the second day was designed to encourage use of the new mental structure and to provide further observations the students would assimilate into the new structure, thus broadening or strengthening it.

The internal mental process used by the students to try to adjust and reorganize their mental structures is called self-regulation. To encourage self-regulation students must be placed in situations where they are challenged by a problem, asked to consider tentative solutions, be able to assess and evaluate the effectiveness of those solutions, and reflect upon their reasoning.

Whatever students' specific method of coping with the challenge, if the required modifications in or additions to existing mental structures are NOT too great, students are likely to complete these reorganizations (self-regulate) themselves, i.e., Brad and Sue, or with a slight amount of assistance, Trudi.

If the required changes in mental structures are great, as they were for the majority of Ms. Walters' students, the student will need and probably seek overt help from peers, teachers, or others who they believe can suggest more appropriate reasoning. The discussion Ms. Walters held on the activity, in which the concept of density was introduced, was a direct attempt by her to encourage self-regulation among those students who needed greater degrees of help, and to continue the self-regulation process among those students for whom it had begun in the preceding activity. Such direct teaching, however, usually is not effective unless the student has had previous experiences related to the ideas (e.g., the preceding activity), or already possesses relevant mental structures and can subsequently test them against his/her present observations. Still, the student must continue to get encouraging feedback from the environment to make sure that the interplay of mental structure and action, an essential part of the self-regulation, continues until the new mental structures are firmly established, thus the need and purpose of the activity Ms. Walters designed for the second day.

The Learning Cycle

The teaching strategy Ms. Walters was using encourages self-regulation tendencies in students and discourages unquestioning acceptance of poorly understood principles and procedures. It is known as the Learning Cycle.

The Learning Cycle is the inquiry strategy which was originally designed and implemented by Robert Karplus in the Science Curriculum Improvement Study (SCIS), an elementary school science curriculum project. Since 1976 Karplus has also encouraged use of the Learning Cycle strategy by secondary level school science teachers through the *Science Teaching and the Development of Reasoning* science teacher workshop materials.

A Learning Cycle lesson has three phases: an exploration phase, a concept introduction phase and a concept application phase. During exploration, the students learn through their own actions and reactions in a new situation which has been designed for that purpose by the teacher. In this phase students explore new materials and new ideas with minimal guidance or expectation of specific accomplishments. The new experience should raise questions that the students cannot answer with their existing mental structures. Having made an effort that was not completely successful, the student will be ready for self-regulation and the second phase of the Learning Cycle lesson.

The second phase, concept introduction, starts with the introduction of a new concept or principle, e.g. density, that allows students to apply new mental structures to the exploration's experiences. The concept may be introduced by the teacher, the textbook, a film, and/or another medium. This step, which aids in self-regulation, should always follow the exploration phase and be **directly** related to the exploration activity.

In the last phase of the new learning cycle, concept application, students apply the new concept (mental structure/schema/reasoning pattern) to additional examples. A concept introduction often may be followed by more than one application activity. In some cases where the instruction is strictly sequential, the exploration for the next related concept can become a second concept application activity for the previous concept (thus, the source of the name Learning Cycle).

The application phase is necessary to extend the range of applicability of the new concept. It provides additional time and experiences to further encourage self-regulation and to stabilize new mental structures. Without a number and variety of applications, the concept's meaning will remain restricted to the examples used during concept introduction. Concept application also helps those students whose conceptual reorganization takes place more slowly.

Please note how the Learning Cycle, though based primarily on Piaget's Learning Theory, takes advantage of other learning theories also. The exploration phase permits learning by "discovery"; the concept introduction phase allows learning by repetition and practice. However, it must be noted that a preliminary report on research soon to be released by John Renner, Michael Abraham and Howard Birnie shows that the elimination of any one of the three phases decreases the effectiveness of the Learning Cycle. (The dependent variables in their study were science content achievement and retention, and student attitudes toward science). Teachers also must not expect all students to demonstrate specific uniform accomplishments after each phase.

Epilogue

All too frequently educators imply or teachers infer that a particular instructional innovation, whether material or procedural, is a cure-all for the ills of education. While the effectiveness of the Learning Cycle is substantiated in the literature, it is not, by any means, a panacea for the problems of science education. It is, however, an instructional strategy which science teachers will want to have in their repertoire and use to its best advantage.

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