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Module 8: Learning Activities for Self-Regulation

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Introduction

It is quite clear from the earlier modules in this workshop that a teacher's awareness of students' patterns of reasoning will influence his choice of subject matter, level of presentation, selection of text, and assignment of homework problems. We shall now describe some ways in which the learning activities can be planned so as to enhance the opportunities for self-regulation after a student is introduced to a new idea.

On the basis of Piaget's developmental theory, concrete learning activities play a central role in the improvement of a student's reasoning. The physics laboratory, therefore, is an especially important part of instruction. Does it make any difference what kind of laboratory exercise we ask a student to perform? We believe that the answer is yes, and we shall describe what we have learned from Piaget's work that is applicable to labs and other aspects of teaching. We have called the resulting pattern of instruction a "learning cycle," since it may be used repeatedly for each successive topic or lab session in a course.

Objectives

To enable you to describe the "learning cycle" approach to teaching.

To assist you in designing laboratory activities that encourage self-regulation.

Procedure

This module provides for a laboratory investigation of physical pendula and two essays: on the learning cycle and on the physics laboratory. Please carry out the activities in the order described in the attached instructional materials. We recommend that you find a partner with whom you can compare notes and exchange ideas during this module.
Module 8 Instructional Materials

1. Exploration

To help you and your partner approach this module in an inventive frame of mind, we ask you to begin with the laboratory investigation introduced on this page. In the module area you will find the following equipment: support stands, timers, meter sticks, string, spring scales, and various objects that may be suspended. Suspend one of the objects, set it swinging, and observe its motion. Then think of some properties of the system that you can vary, look for some other properties that might be affected by the variations, and make measurements to determine quantitative relationships that seem to interest you. You may use objects in your possession in addition to the ones provided.

Please record your observations and data here. State any conclusions you reach.

After about ten to twenty minutes, join with a group of other workshop participants to discuss some ways in which the above "exploration" might be followed up in a student laboratory exercise.

Please turn to the next page for the first essay.
2. Essay. The Learning Cycle

Suppose you are planning to begin your course's section on geometrical optics. Would you begin it by:

(a) Listing the assumption of the ray model for light, from which the results of geometrical optics can be derived?

(b) Arranging for a laboratory period in which your students could assemble light sources, lenses, mirrors, plastic blocks, and glasses of water into optical systems to observe image formation under various conditions?

(c) Reminding your students of their everyday experiences with light and invite them to describe some of the properties of light that are revealed by their observations?

(d) Describing the transfer of energy by means of electromagnetic radiation of various frequencies, and then specializing to the visible part of the spectrum?

(e) Providing a laboratory as in (b), but making certain that your students could work with "pencils" of light, as emitted by a laser or a source with a good collimator?

(f) Providing a laboratory where your students are assigned to measure accurately the focal lengths of convergent and divergent mirrors and thin lenses on a carefully aligned optical bench?

Certainly, the resources available to you and the level of students will influence your choice. Compare your reactions with our comments on the alternatives:

(a) This procedure is frequently used because of its conciseness but it is likely to be difficult for your students, especially those using concrete reasoning patterns, to assimilate. They do not know the basis of the assumptions and therefore cannot evaluate when and how these are to be used.

(b) We would recommend an approach of this kind, where the student has a great deal of freedom to use his own judgment and try out his own ideas as he gains practical experience with the objects he will study theoretically later. See also (e).

(c) In the absence of laboratory materials, we would recommend this approach to connect the new ideas about light propagation with the student's previous experience; demonstrations with student participation would help

(d) This rather theoretical approach would be inappropriate at the beginning of the topic, because it highlights the wave nature of light which is disregarded in geometrical optics except insofar as it limits the applications.

(e) Since light "rays" play an important part in geometrical optics, we would consider this a very helpful addition to the lab. An ordinary comb with coarse teeth can be used very effectively to make a bundle of light "rays" whose behavior can be followed.
(f) This type of laboratory prevents the student from asking his own questions and satisfying his own curiosity. The concept of focal length needs to be defined and understood before this lab can be worthwhile. At a later time in the course it might be quite appropriate, though we favor a more open approach.

The preferred approach in (b) or (e) is an example of the "exploration" phase in the learning cycle which we recommend for the planning of teaching activities. The entire learning cycle consists of three phases that we call exploration, invention, and discovery. During exploration the students learn through their own more or less spontaneous reactions to a new situation. In this phase, they explore new materials or ideas with minimal guidance or expectation of specific achievements. Their patterns of reasoning may be inadequate to cope with the new data, and they may begin self-regulation. The laboratory exercise opening this module gave you an "exploration" experience.

During the "invention" phase, you define a new concept, introduce a new principle, or explain a new kind of application to expand the students' knowledge, skills, or reasoning. This step should always follow exploration and relate to the exploration activities. It will thereby assist in your students' self-regulation. In the example of geometrical optics above, for instance, alternative (a) represents a possible "invention" phase, perhaps introduced via (c) as an intermediate step to relate exploration and invention. Do encourage individual students to "invent" part or all of a new idea for themselves, before you present it to the class.

During the last phase of the learning cycle, "discovery," a student finds new applications for the concepts or skills he has learned earlier. The measurement of focal lengths of a variety of optical systems (single and multiple lenses, glasses of water) would be an appropriate discovery activity to follow the introduction of geometrical optics. Other discovery activities could involve the theoretical analysis of various optical elements and systems for object-image relationships. The discovery phase provides additional time and experiences for self-regulation to take place. It also gives you the opportunity to introduce the new concept repeatedly to help students whose conceptual re-organization proceeds more slowly than average, or who did not adequately relate your original explanation to their experiences. Individual conferences with these students to identify their difficulties are especially helpful.

As another example of the learning cycle, we direct your attention to this essay. We did not begin it with a definition of the learning cycle, but rather tried to place you in a situation of considering alternative teaching strategies according to your own experience and preferences, to be compared with our thoughts. That served as "exploration," the best we could think of in the context of this module. Next we described the three-phase learning cycle, the "invention" in this essay, with references to your exploratory experience with the optics example. Finally, we should like you to examine, after the conclusion of this workshop, our entire workshop plan, which is also formulated according to a learning cycle. That examination will form a "discovery" activity for you, we hope!
After concluding the essay, please discuss the following items with your partner and/or other workshop participants and staff.

1. Suppose you are teaching an introductory course in Newtonian Mechanics. What "exploration" activity might be suitable at the very beginning of the course? What "exploration" activity might be suitable to introduce the topic of rigid body rotation? Use this space to write down some good ideas that emerge from the discussion.

2. Suppose you are teaching an introductory course on electricity and magnetism. What might be the focus of some "invention" activities?

3. What might be some "discovery" activities to follow the items you listed for #2? What might be some "exploration" activities to precede the items in #2? Make notes of the ideas that are expressed.

4. Most advanced physics courses are strictly "blackboard and chalk." Pick a particular course with which you have worked recently and suggest "exploration" activities that might be introduced. Keep in mind the fact that many of the students may not have assimilated all the material that was covered by the prerequisites. Make notes about ideas that are brought up.

5. Do you see a relation between the learning cycle and self-regulation? How do you and your partner view the relationship?
3. Essay. The Laboratory and Self-Regulation

Suppose you are asked to develop a laboratory exercise on the pendulum for beginning general physics students. Rank the following procedures in terms of how you perceive their usefulness in encouraging self-regulation for the students; use 1 for the most useful and 4 for the least useful.

A. Provide the students with a mass on a string. Indicate the relevant variables of the system and suggest that they verify the square root relationship between the length of the string and the period of oscillation.

B. Provide the students with a mass on a string. Supply a list of possible variables of the system, i.e., angle of swing, mass, length of string, acceleration of gravity, the period of oscillation, etc. Supply a list of possible relationships between variables, e.g., the period oscillation is directly proportional to the mass; the length of string is directly proportional to the period, etc. Ask the students to identify the relevant variables and the most appropriate relationships between them.

C. Provide the students with a variety of periodic systems, e.g., a cork floating on water, a baseball bat swinging by a hole in its handle, a clock pendulum, a mass on a string, a uniform metal rod with pivot holes in it. Ask the students to identify common variables of these systems and to search for quantitative relationships between the variables.

D. Provide the students with a mass on a string. Indicate that for small angles of oscillation there is a relationship between the length of the string and the period of oscillation. Challenge them to discover it based upon their data and then compute the length of string required for a 10 second period.

According to our learning cycle model to induce self-regulation, an introductory period of exploration or openness in a laboratory exercise is to be recommended. Hence, procedures B and C are superior to A and D. Furthermore, C is a more open and exploratory procedure than B and may encourage the student to examine a number of aspects of a swinging object that you may not think are important or interesting, but that appear important to him. Procedure C enables the students to begin where they are in their understanding of periodic motion and enlarge their concrete experiences with such systems without having the instructor impose his own reasoning on their activities. Hence, we believe that C is the preferred procedure to use.

Procedure B also provides a good deal of openness while directing the students toward variables determined by the instructor. A variant of this procedure would be a good discovery activity. It tends to focus the activities of the students and make their efforts more efficient if content
goals are important. Predictions and expectations in advance of the experiments can be exploited to produce some contradictions in the thinking of the students and start them on self-regulation. Extreme cases not tested directly or concretely can also encourage self-regulation. Hence, we favor procedure D over procedure A. In fact, procedure A has little to recommend it as far as we are concerned.

The social interactions that occur in the laboratory setting are important for starting self-regulation. Testing one's ideas against the ideas of one's peers is a profitable way to spend some time during the laboratory period. Individual contact between the instructor and the student is possible in the laboratory. Such instructor-student dialogues can be very valuable when the instructor asks the student to justify his results. Helping students to become aware of their own thinking is a major function of the instructor if he wishes to encourage his students along the path of self-regulation. Such common thinking tools of physicists as checking the dimensions or units of an answer, making an order of magnitude estimate, and seeing if the answer makes sense at the extreme values of the variables are all aspects of the self-regulation process that can be learned as a part of laboratory activities.
4. Laboratory on Objects that Swing

In this exercise, we present a laboratory activity arranged according to the learning cycle into exploration, invention, and discovery. The students were given four pages, one with the title and instruction for exploration (see below), a second page organized as data sheet, an "invention" page, and an "application" (i.e., discovery) page. Since the last three pages required student recording of data or answering of questions, we are presenting them in reduced format with the data, answers, and work of one pair of students. Please examine these pages and look for evidence of concrete and formal reasoning patterns, self-regulation, and failures to respond to inconsistencies. Then look at our comments on page 8-12.

SWINGING OBJECTS

Purpose: Examine the properties of objects that swing to and fro when suspended on a string.

Equipment: Objects, string, timer, meter stick, and supports.

EXPLORATION

Explore the properties of a swing that consists of an object suspended on a string. What are the properties of that system that you can vary? Measure quantitatively these properties and the period of time required for the object to make ten complete swings to and fro.

When you are satisfied that you have examined all aspects of your system, ask the instructor for the invention page.

Please record all the activities you pursue, even ones that may lead to a dead end. You will be evaluated on the completeness of your records as well as the reasonableness of your conclusions.
### Quantitative Values of the Variables of the System

<table>
<thead>
<tr>
<th>Mass</th>
<th>Length</th>
<th>Time Required for Ten to and Five Swingings of the Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>200g</td>
<td>0.1m</td>
<td>0.2</td>
</tr>
<tr>
<td>500g</td>
<td>0.1m</td>
<td>0.3</td>
</tr>
<tr>
<td>720g</td>
<td>0.15m</td>
<td>0.1</td>
</tr>
<tr>
<td>200g</td>
<td>0.05m</td>
<td>0.4</td>
</tr>
<tr>
<td>500g</td>
<td>0.05m</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### Notes:

1. In the first test, we are varying the weight, while keeping the pull-back and string length constant. The length of time between the pull-back is recorded. The string length is constant to the extent that only the size of the weight causes an increase in the distance to the center of mass.

2. For the second test, the mass and object of the string length are held constant, while the pull-back is varied. Pull-back is made in 10 cm intervals and time is recorded for 10 swing intervals.

3. Not under these involves changing the length of the stringing string while holding the mass and pull-back constant. The problem is allowed to swing for 10 swings at the times recorded.

If you need additional data space, record your data on the back. If you have finished with your data collection activities, please ask for the next page.
INVENTION PAGE

The time required for a swinging object to make one complete
trip, to and fro, is called a period.

Which of the properties of your system seemed to have the
least effect upon the period of oscillation? It would appear that our
test 1 is closest to having the least effect upon the period of oscillation. By
using the mass and keeping a constant pull-back distance of 36.6cm our periods
of time were only from 19.19 to 19.3 sec. So it appears that using a constant
pull-back distance and swinging mass has little effect on period of oscillation.

Which of the properties of your system seemed to have the
most effect upon the period of oscillation? Test 2 and 3 have a slight
effect upon the period of oscillation. In test 2 we varied the pullback distance keeping
the mass constant. In test 3 we varied the length of the string keeping the pullback distance constant. In this test our periods of time varied
more and so it would seem that varying the length of the string had
the most effect upon the period of test.

What relationships between the period of oscillation and
the quantitative values of a property of the system can you
identify? In order to express these relationships in a
quantitative way you may wish to draw a graph of your data.

Test 1 on graph paper appears to be a constant
while tests 2 and 3 appear to be more like proportions.

What conclusions can you reach? State these here:
For test one it appears that little effect upon the period
of oscillation is reached by varying mass with constant pull
back but apparent constant length, while in the other two tests a
proportion seems to result between periods, pullback in z) and
length of string in 3). Quantitative analysis could be calculated
by means what you have written on this page with another
group of experiments. List the similarities and differences
between your results and theirs here:
Comparing your graph to the bell to the same conclusion:
(1) Keeping constant pull-back with varying mass leads to a constant
oscillation.
(2) Keeping constant mass and varying the pullback or angle causes
a slight difference, but the difference was minimal and would be due
to mechanical error.
(3) Keeping constant mass and C and varying length of string causes
Ask the instructor for the application page. An increase in oscillation
per sec.
Application Page

Now, based upon your previous results either construct or explain in detail how you can construct a system of a swinging object on the string which:

(a) has a period of oscillation of 1.0 second.

- length of string
  - 2.00 g constant
  - pullback (weight) x 50 cm

21 cm = \[a\]

Using test-time data and graph we established the graph (see graph 4) to include the one sec. oscillation

- 1 sec. interval. The same as a 21 cm.

(b) has a period of oscillation of 10.0 seconds.

Redraw graph in opposite direction and go through same steps as above answer comes out 122 cm

Common sense indicates this isn't right, but that is our value.

Graph 5
Comments on Student Work:

You will have noticed that these students set out systematically to examine the various properties of the system of a swinging object. They carefully isolated variables (mass, amplitude, length), a formal reasoning pattern.

The students' graphical analysis at the end of the experiment, however, does not show the self-regulation one might have expected. Graph 4 shows that a string of zero length would have a 0.70 second period, while Graph 5 leads to the prediction of a 0.0 second period for a string of 10.0 cm length. The inconsistency of these two inferences does not concern the students, though they do assert that their result for the 10 second period contradicts common sense. The use of an analytical tool (plotting points) and applying it to data (drawing a straight line) without self-regulation are characteristic of the step-by-step following of instructions characteristic of the concrete stage. Apparently this laboratory activity was not successful in leading these students to self-regulation with respect to data analysis.

Discuss the following items with your partner if they did not come up during your earlier conversation:

1. What other instances of concrete or formal reasoning can you identify in the students' work?

2. What aspects of their work could you use to guide them into self-regulation? Point out the discrepancies or other starting points you noticed.

3. Think about some laboratory activities of your students. Do they reflect the learning cycle approach? Do they require the students to follow a "recipe?" How might they help to initiate self-regulation?
Module 8 Review Questions

Please discuss these questions with your partner after marking your answers.

1. Suppose you are asked to design a laboratory exercise on the topic of Ohm's Law for beginning physics students. Rank the following procedures in terms of how you perceive their usefulness for encouraging self-regulation on the part of the students. Use 1 for the most useful, 2 for the next, etc. (For our answers, see the bottom of the page.)

<table>
<thead>
<tr>
<th>Rank</th>
<th>self-reg.</th>
<th>content</th>
</tr>
</thead>
</table>

A. Provide the students with a 1.5 volt battery, some known resistors, and an ammeter. Ask them to verify the V=IR relationship.

B. Provide the students with some 1.5 volt batteries, some known resistors, and an ammeter. Supply them with a list of the possible variables of the system: the number of batteries, the number of resistors, the current, the length of connecting lines, etc. Supply a list of possible relationships between the variables, e.g., the voltage is directly proportional to the number of resistors in the circuit, the current is proportional to the square root of the resistance, etc. Ask the students to identify the relevant variables and the most appropriate quantitative relationships between them.

C. Provide the students with a variety of batteries, a variety of resistors including some slide wire type, and a multimeter. Ask them to identify the variables of a circuit and find quantitative relationships between the variables.

D. Supply the students with a battery, two known resistors, a galvanometer of unknown calibration and several unknown resistors. Ask the students to compute the resistances of the unknown resistors.

E. Supply the students some lengths of unlabeled metal wires and a resistivity table. Ask them to identify the metals by using Ohm's Law and the definition of resistivity. Provide the necessary apparatus.

2. Now reread the list and rank the items according to their usefulness in transmitting content about Ohm's Law. Does this ranking agree with your self-regulation ranking? If not, why do you think that there is a difference?