THE HYPOTHESIS-EXPERIMENT-INSTRUCTION METHOD OF LEARNING

Its Implementation with Two Classwork Books, "Springs and Force" and "Magnets"

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In 1963, the author presented a paper entitled "Hypothesis-Experiment-Instruction" on an approach to content organization and teaching for science education, and since then a wide variety of materials have been developed and used for its implementation. Here, an outline of the theory and a brief report of the results of implementation with two "classwork books" will be given.

The Hypothesis-Experiment-Instruction Method refers to a theory of science teaching which has as its goal the teaching of the basic, general concepts and principles of science and the provision of experiences through which students can learn about the nature and purpose of science. The theoretical basis of this approach rests on the following two principles:

(1) Scientific understanding is developed during the process of purposive experimental inquiry into the nature of things, and it makes it possible to acquire, or systematically increase, knowledge which permits the correct prediction of unknown phenomena.

(2) Science is a social institution which provides for the increasing attainment of knowledge which all people can and do recognize as valid, and as such it provides knowledge which everyone can use without worrying about whether it is correct or not.

On the basis of the first proposition, it can be claimed that, before performing an experiment, each student should make his own prediction concerning the results of the experiment and create a hypothesis to support or generate his prediction. In addition, both propositions provide a basis for the importance of discussion and argument among students, in that such activities provide opportunities for students to share and use good ideas, to criticize unsound thinking, and to present evidence and reasoning to support their position and convince others, even in cases in which all the other students disagree with th correctnss or relevance of it.

Consequently, instruction based on the teaching method described in this paper is centered on a process which begins with the posing of a problem and continues through student prediction, discussion of their predictions and the related reasons or hypotheses, and finally the performance of an experiment. More explicitly, classroom activities involve carrying out the following process:

(1) First, before giving any instruction, the teacher gives the students a problem the outcome of which can be determined by carrying out a specific experiment.

(2) Then each student writes down his prediction of the outcome.

(3) The teacher has each student give his prediction (which is tabulated according to some classication) and the thinking or reasons on which it is based.

(4) Although some students make predictions which are only guesses or merely intuitive reactions, most students have some reason or hypothesis underlying their predication. In such cases, the teacher has the students explain and discuss their thinking, reasons, and hypotheses concerning the outcome.

(5) The results of this discussion are summarized, after allowing the students to change their predictions on the basis of what was said during the discussion.

(6) Finally, an experiment is carried out and the correct prediction is clarified on the basis of the results.

However, going through this process only once and obtaining the results from only one experiment is usually not sufficient to determine which hypothesis is correct. It is therefore necessary to prepare a series of problems for each scientific concept and/or principle and have the students go through the process in each case. In this way, the students will be able to confirm for themselves which ideas and thinking are valid and which hypotheses are acceptable as general principles or laws.

In order to carry out such classroom activities effectively, it is especially important to provide a series of appropriate problems in a suitable order of presentation. Accordingly, it was decided to develop "classwork books", i.e., a sort of textbook which provides notes and teaching programe for use in implementing such classroom activities. "Springs and Force" and "Magnets" are examples of these classwork books.

The author has provided these classwork books for a large number of teachers, who have used them with a large number of classes. As a result, it has been found that, given suitable problem content and ordering, any teacher can provide effective instruction for any class with these materials. That is, they make possible lively instruction activities which almost all students welcome enthusiastically and through which they thoroughly learn the concepts and principles that are the objectives of the instruction.

Since it is essential that students do not have prior knowledge of the problems and the content to be dealt with during instruction, the classwork books are not formally published and the necessary materials are prepared and distributed in the classroom each time they are used. These classwork books contain not only a series of of problems for inguiry, but also short readings concerning the history of science and results of the research of scientists. Such materials are included in accordance with the second proposition stated above, which justifies the provision of scientific knowledge and background information to the extent that students are able to understand and appreciate it.

By the end of 1973, the author completed about go classwork books—including "Pendulums and Oscillation," "Springs and Force," "Objects and Their Weight," "Magnets," "Solutions," "Crystallization," and "Air and Water"—and with the cooperation of many teachers, who have used these materials in the classroom, satisfactory results have been obtained in each cases. To date, more than 200 teachers have cooperated in using these materials with more than 1,000 classes. In the following, two of these classwork books will be presented and discussed.

"Springs and Force" Classwork Book

The classwork book "Springs and Force" has been produced for instruction in which the objective is to give the students an understanding of the concept of static force by the use of images of springs which are used to measure force. "Springs and Force," which has been used mainly with 5th and 6th grade students, contains 65 pages divided into four parts:

(1) Gravity and Springs (pp. 1—23)

(2) Springs and Other Objects (pp. 24.—33)

(3) Forces Acting on Springs and Objects (pp. 34—50)

(4) Equilibrium of Three or More Forces (pp. 51—65)

In these materials four points are given special emphasis. First, the concept of force is introduced in terms of the opposition of magnetic attraction to graivity. In the past, education concerning dynamics has often involved the introduction of the concept of force in terms of the human sense, or felt perception, of forces. This has been done under the assumption that in so doing science can be related to the everyday life and experinc of the students, thus raising their level of interest and increasing educational effectiveness. However, the author's research into the history of the study of dynamics recealed that difficulties encountered in the study and understanding of dynamics during the ancient and middle ages were due to the fact that the concept of force was based on the human sense or perception of forces. Furthermore, it has also become clear that education concerning dynamics has for the same reason suffered from a variety of serious difficulties and produced generally unsatisfactory results. Consequently, the author developed a new method of introducing the concept of force, as mentioned above.

Second, units of weight such as *g* and *kg* are distinguished from units of force by the use of *gf* and *kgf* units for forces.

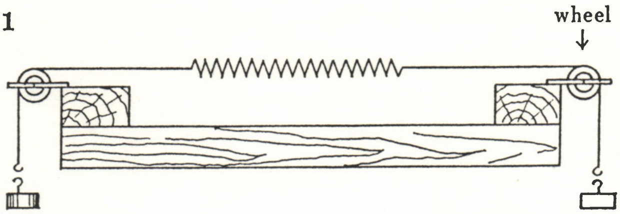
Third, the concept of resistance is introduced through the use of a spring model. Although most students understand that a spring exerts force on other objects, they often find it difficult to accept the fact that other ordinary objects such as string or a desk can and do exert a force on objects. The class work book were therefore designed so that the resistance exerted on things by ordinary objects can be readily undrstood and accptd by students as a result of their realizing the fact that the molecular construction of ordinary objects is such that they act as a kind of (rather "tight") spring.

Fourth, although statics theory has not been developed merely for the purpose of quantitively explaining already known forces, and can only be validated as a scientific theory through the successful prediction of unknown phenomena which can not be realized through common sense or intuition, examples of such predictions have yet to be included among the experiments that are carried out in the course of education concerning stitic mechanics. As a result, many students have felt that it is uninteresting, trivial, and useless to study it. The author therefore designed a series of experimental problems to demonstrate the value and validity of statics theory by requiring predictions which bring out and emphasize the difference between what is expected on the basis of the theory of forces and on the basis of a common sense or intuitive way of thinking. These materials turned out to be very effective, and the students have been deeply impressed by the beauty and usefulness of the theory of forces in physics.

Of the experimental problems in "Springs and Force," three of those in Part 3 have proved to be especially effective in the above sense: Problms 1, 4, and 5. In the following, these materials are presented as they appear in the classwork book so that the reader can get an idea of the nature of this approach and of the classwork book itself.

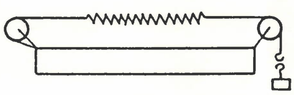
Part 3. Forces Acting on Springs and Objects

PROBLEM 1



Some string is attached to a spring, as in the figure, and weights weighing ____________ are hanging from each end. As a result, the spring, which was originally __________ cm long, stretched ___________ cm and became __________ cm long.

Then one of the weights was removed and the end of the string was fastened as in the next figure. How much longer do you think the spring became?



Prediction

A) About half as much as before.

B) About as much as before.

C) About twice as much as before.

Discussion

Why do you think it stretched that much? Read the hint below and discuss your prediction and reasons with your classmates.

Hint

When weights pull on both ends of a spring, the external force exerted on the spring can be shown graphically as in Figure A.

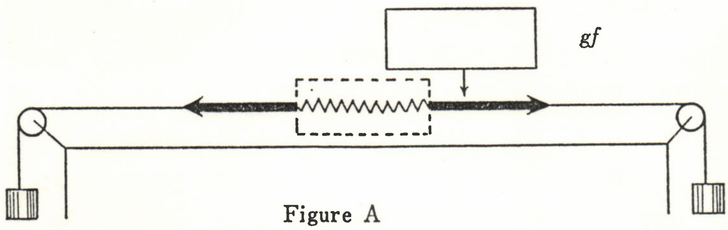


Figure A

But if a weight is attached to only one end of the spring, what will be the effect of the external force on both ends of the spring? On Figure B, draw a thick arrow to indicate the force on each end, making the length of the arrow proportional to the amount of force.

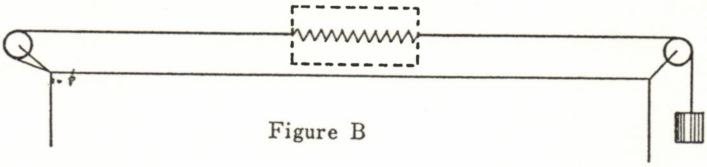


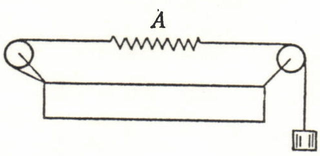
Figure B

Experimental Results

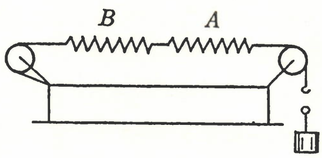
From the experiment, did you find out which prediction and reasons were correct?

PROBLEM 4

As in the figure, some string is attached to a spring *(A)*, with one end tied down and the other end attached to a weight. The spring, which was originally ________ cm long, stretched ________ cm and became ________ cm long.



Next, another spring *(B)* exactly like spring *(A)* was attached as in the next figure and the same weight was hung from the end of the string.



Now how much will the springs stretch?

Prediction

Spring *A*
- A) About the same as before.
- B) About half as much as before.
- C) About twice as much as before.
- D) About ________ cm.

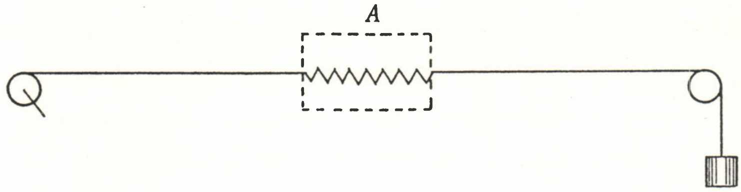
Spring *B*
- A) About the same as spring A.
- B) More than spring A.
- C) Less than spring A.

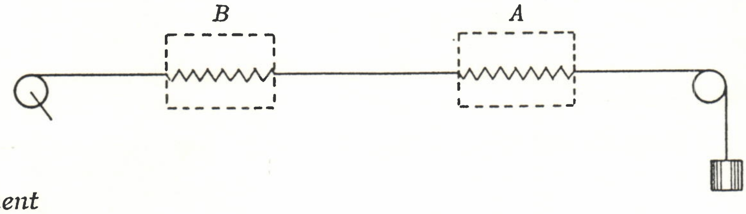
Discussion

Why did you choose those predictions? Give your reasons and discuss them your classmates.

Hint

Using arrows, indicate the force exerted on the springs in the diagrams here in order to clarify your thinking.





Experiment

Carry out an experiment to find out which predictions were correct. Write in the results below.

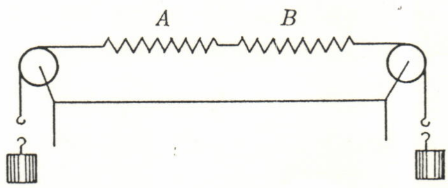
Spring *A* expansion: __________ cm

Spring *B* expansion: __________ cm

(If your prediction was correct, write in "As predicted.")

PROBLEM 5

The fastened string in Problem 4 was untied and another weight of the same size was hung from it. Now how much will each of the two springs stretch?



Expansion with one weight attached:

Spring *A*: __________ cm. Spring *B*: __________ cm.

Prediction

Expansion with two weights attached:

Spring *A*: __________ cm. Spring *B*: __________ cm.

Discussion

Why do you think they will stretch that much? Give your predictions and reasons, and discuss them with your classmates.

Experimental Results

Spring *A*, which was originally__________cm long, became__________cm long.

Spring *B*, which was originally__________cm long, became__________cm long.

Are these results about the same as you predicted?

"Magnets" Classwork Book

The classwork book "Magnets" was developed mainly for use as instructional materials in the 3rd and 4th grades. It contains 56 pages divided among the following three parts:

(1) Nature of magnets (pp. 1—14)

(2) North and South and magnetic needles (pp. 15—40)

(3) The magnet's secret (pp. 41—56)

Part 1 deals with three of the most basic facts about the characteristics of a magnet: (1) that all magnets attract only certain types of metal such as iron, nickel, etc.; (2) that all magnets have two different poles such that like poles repel each other and opposite poles attract each other; and (3) that a needle can be made into a magnet by rubbing it with a magnet.

Part 2 is designed to teach five things: (1) that a magnet has both a North and a South pole, (2) that a needle floating on water always indicates the direction of north and south, (3) that magnets and compass needles are the same in that they indicate the direction of north and south and they attract iron, (4) that magnets are originally a kind of mineral taken from rock, and (5) that a magnetic needle points north and south because the earth itself is a magnet.

Part 3 deals with the parts of a magnet, clarifying the fact that if a magnet is broken into pieces each piece becames a magnet with a North and a South pole, and introducing molecular magnets.

The content of these materials leads up to and includes a rather advanced level of content compared to that which has normally been taught to grade school students in Japan up to the present. However, the results of experimental instruction have shown that students from the first grade through the eighth grade are very interested in such things and are able to adequately understand all of the content.

In addition, this classwork book also contains reading material concerning related aspects of the history of science. These materials have also proved to be effective in arousing the interest of the students in magnetism and in science itself.

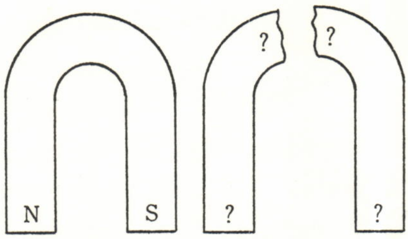
In the following, Problems 1, 2, 3, and 4 in Part 3 of the classwork book are presented for illustration. The results of classroom use show that student predictions in Problems 1 and 2 are wrong in more than half of the cases, but that in Problems 3 and, especially, 4 almost all students make the correct prediction, indicating that they are already aware of the fact that magnets have a

North and a South pole.

Part 3 The Magnet's Secret

PROBLEM 1

In order to understand magnets better, we are going to break one in two and see what happens to it. What do you think such a broken magnet will be like?



Prediction

A) Both parts will no longer be magnets and will not attract iron.

B) Both parts will become magnets and the broken end will also attract iron.

C) The original North and South poles will attract iron, but the broken ends will not.

D) Only the biggest part will be a magnet.

E) Something else will happen.

Tell your prediction to your classmates and then carry out the following experiment.

Experiment

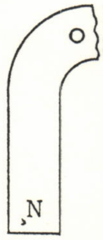
If you put a cast iron magnet in a vice and hit it with a hammer, it will break easily.

Experimental Results ____

____

PROBLEM 2

We found that part of a broken magnet attracts iron, even at the broken end. But what pole is the broken end of each part? First, let's find out about the broken end of the part that has the original North pole on it.



Prediction

A) It has become a North pole.

B) It has become a South pole.

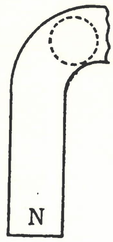
C) It is neither a North pole nor a South pole.

After everyone has chosen a prediction, do the following experiment.

Experiment

Put the broken end near a magnetized needle (or compass needle). Because the North pole was attracted/repelled, and the South pole was repelled/attracted, the broken end is a ________ pole.

(Write the letter N or S in the circle in the diagram here.)

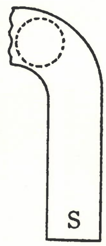


PROBLEM 3

Now we will investigate the broken end of the part with the original South pole on it.

Prediction

In the circle in the diagram here, write what pole you think the broken end is.



Discussion

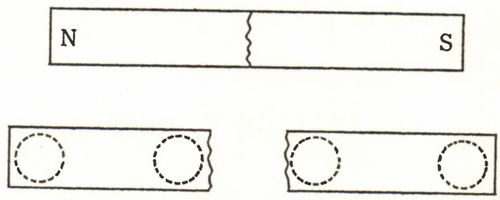
Discuss your prediction and reasons for it with your classmates.

Experimental Results

________ pole

***PRACTICE PROBLEM 1**

Next, let's break a bar magnet. What do you think will happen when we break a bar magnet in two? Write in your predictions for each circle in the diagram here. If you can not find a bar magnet that you can easily break, ask your teacher to tell you about the results of experiments performed by scientists with bar magnets.



PROBLEM 4

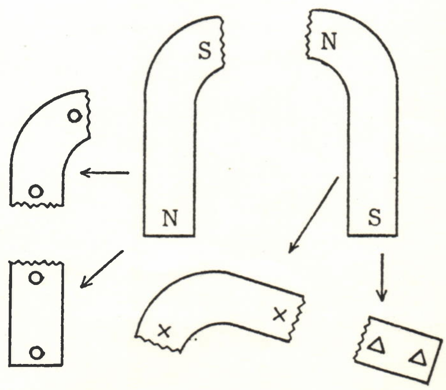
Now we will break each of the parts in two again and see what happens.

Prediction

A) of the pieces will become agnets.

B) All of the pieces will cease to magnets.

C) Some of the pieces will become magnets, and some will not

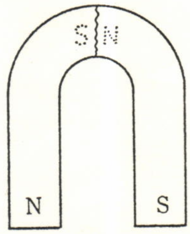


Give your prediction and then carry out an experiment to find out which one is correct.

Experimental Results ____

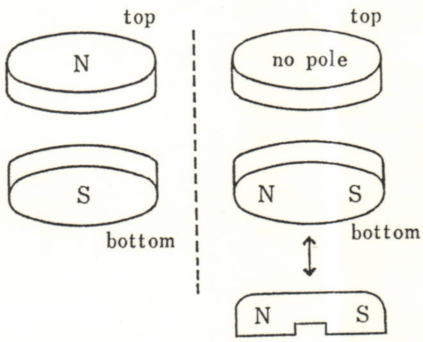
____

***RESEARCH PROBLEM 1**



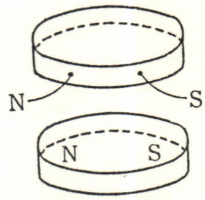
Get a magnet and stury its characteristics by breaking it, putting it together again, etc. When you put a broken magnet back together again, does it attract iron at the broken place?

***RESEARCH PROBLEM 2**



Where are the poles of a coin-shaped ferrite magnet located? There are two common types of coin-shaped ferrite magnets, as shown in the diagram here.

In magnets like the one on the right, in which both the North and South poles are on the bottom, the top is painted or has some decoration on it. When you put two of these magnets together, as in the next diagram, one magnet spins around so that the North and South poles are opposite each other and the two magnets attract each other.



If you can find such a magnet, find out where the North and South poles are located and think up vorious ways of playing with such magnets.

If you drop a ferrite magnet on a hard surface, it will break easily and you can investigate what happens to the pole when it breaks.