DOCUMENT RESUME

ED 141 079 SE 022 530

AUTHOR Smith, Patricia J.; Van Egeren, Thomas
TITLE Piagetian Principles Used in a High School Chemistry Class.
PUB DATE Mar 77
NOTE 12p.; Paper presented at the national meeting of the American Chemical Society (New Orleans, Louisiana, March 1977)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS *Achievement; *Chemistry; *Cognitive Development; Course Descriptions; Course Evaluation; Educational Research; *Instruction; Science Courses; Science Education; Secondary Education; *Secondary School Science
IDENTIFIERS *Piaget (Jean); Research Reports

ABSTRACT

This document describes and evaluates a high school chemistry course developed to promote formal reasoning in students by increasing opportunities for self-regulation and to increase student understanding of chemical concepts by making instruction relevant to their developmental level. General results indicate that students enrolled in the course did realize an increase in their Piagetian level of formal thinking ability as measured with a modification of the Longect test. (SL)

PIAGETIAN PRINCIPLES USED IN A HIGH SCHOOL CHEMISTRY CLASS

Patricia J. Smith and Thomas Van Egeren
Air Academy High School
United States Air Force Academy, Colorado 80840

Most of the content of nationally available high school chemistry curriculum materials, such as CHEM study, assume the ability to use formal operational thought processes. For example, one of the CHEM study versions (1) devotes approximately one page to observable properties of acids and bases and eighteen pages to acid base theory. At the end of the chapter there are 39 problems, all of which require the use of abstract concepts or memorized algorithms to obtain the answer. Three experiments for this chapter are calculation of an equilibrium constant, calculation of a heat of hydration, and determination of the molecular weight of an unknown acid by titration. All of these topics appear in the CAN'T DO portion of Herron's (2) list of competencies of concrete operational students. Another widely used high school chemistry text (3) has an entire chapter on the theory of chemical bonding including hybridization of orbitals. Two tables summarize the properties of ionic and covalent compounds in the next chapter.

However, many investigators (4) have shown that approximately 50% of high school students are unable to use formal thought processes. Others have shown that students who are classified formal frequently do not operate at this level. Sheehan (5) showed that when formal students were taught using both concrete and formal methods, those who had concrete instruction did significantly better on a subject matter test. Lawson and Renner (6) found that students who were classified fully formal (III-B) were able to answer only 40-50% of the formal questions on biology, chemistry, and physics tests validated by their classroom teachers and a panel of judges.

This paper was presented at the Piaget Symposium at the National Meeting of the ACS at New Orleans in March, 1977.

The purpose of this paper is to describe a high school chemistry course developed to promote formal reasoning by increasing opportunities for self-regulation and to increase students' understanding of chemical concepts by making the instruction relevant to their developmental level. Gain scores on a paper-pencil nonscience content measure of concrete and formal thinking ability of students in this course will be compared to those of students enrolled in a traditional chemistry course of the same level of difficulty. It was hypothesized that there would be a significant difference in the gain scores after an 18-week semester of instruction.

DESIGN OF THE EXPERIMENT

The participants in the study were students at Air Academy Senior High school located on the United States Air Force Academy, Colorado. The 1200 students were approximately 40% military dependents with the remainder being primarily children of business and professional people. Approximately 70% of the students in the high school planned to go to college. This fall there were 300 students (one-fourth of the student body) enrolled in two types of chemistry courses, College Preparatory Chemistry and Practical Chemistry. The students in the Practical Chemistry course have been identified by themselves, their parents, teachers, or counselors as lacking interest in science or as being unprepared to succeed in the more rigorous college preparatory course. The participants in the portion of the study reported here were in the Practical Chemistry classes.

Intact classes were used because enrollment policies in the school did not permit random selection. Different teachers taught the two groups although the students were not aware of this at the time of enrollment. A pretest-posttest design was used.

A modification of the Longeot (7) test was used to measure formal thinking ability. This test consisted of 15 items in three parts: Part I - Propositional Logic, Part II - Proportionality Problems, and Part III - Combinatorial Analysis. Validity of the examination was originally established by Longeot using scalogram analysis techniques. The KR-20 reliability co-efficient determined by Lawson and Blake was 0.85. They also compared this examination with three Piagetian tasks: pendulum, bending rods, and balance. Chi square analysis of their data yielded a significant relationship between the classification instruments ($X^2 = 17.9$; df = 9; $p < .02$). Classification of the students in the sample using the same criteria as Lawson and Blake is shown in Figure 1. Nearly two-thirds of the students are classified concrete operational.

THE EXPERIMENT

Four traditional chemistry topics were chosen for the first semester's study: Properties and Changes, States of Matter, Structure and Periodicity, Acids and Bases. The learning cycle - - exploration, invention, and discovery - - as described by the developers of the SCIS elementary science program was used.

The exploration phase of the learning cycle consisted of a series of experiments each on a single green card with a point value in the lower right corner. The students working in pairs chose enough experiments to accumulate a total of 50 points for each unit. A wide variety of experiments was available to allow for individual differences in interest and developmental level. Table 1 shows a sample of experiments from each of the four units. The laboratory work differed from that in most traditional courses in several important ways. The student was an active participant in the entire experience. While laboratory manuals nearly always give a specific procedure to be followed, our experiments provided only minimal instructions. It was necessary for the students to design their own procedures. To guard against accidents and excessive waste of time the procedures were read and initialled by the instructor before work was allowed to begin.

Many commercially available laboratory manuals provide blanks or data tables in which the student places his measurements or observations. (Table 2 and Table 3). In tables such as those shown the student need not make decisions; he does not even have to decide which mathematical operation is appropriate. With such a prepared format he is not likely to note any unusual or interesting happenings not required for the data table. Each of the students in the experimental program had a notebook with crosshatched paper in which a record of his laboratory activities was kept. When appropriate and necessary the student designed a data table. The only requirement for the notebook was that all observations and some kind of data interpretation for each experiment was to be recorded there.

Because of the open-ended nature, often the experiments did not yield the expected results. Students were encouraged to analyze their results, discuss possible sources of error, and recognize the part that random fluctuation plays in data collection. Frequently the source of the error was failure to control variables. In such cases appropriate questioning techniques and suggestions for further experimentation often resulted in the student's improving his design and repeating the experiment. A questionnaire indicated that the students were not disturbed by experimental failures as long as they were not penalized for the need to repeat a portion of their work.

Many of the experiments such as SM-2 (Table 1) presented situations which contradicted the student's expectations. Rather than be faced with a situation which required accommodation, students often unconsciously distorted or ignored parts of their data. In other experiments the students predicted outcomes and tested their predictions (PC-11), identified and controlled variables (SP-2), and used combinatorial analysis (SP-6).

The students were encouraged to quantify their results and search for mathematical relationships at whatever competency level they were comfortable. In experiment SM-7 students were told to investigate the relationship between pressure and volume of a gas (air) trapped in a hypodermic syringe sealed at the bottom by placing books on the top of the syringe. Graphical analysis of data was suggested. All students were able to understand that the variables were inversely related. Those who were more sophisticated mathematically observed that the difference in volume grows smaller with increasing mass and some were able to formulate the mathematical relationship, $PV = k$.

In experiment PC-11 students obtained pieces of several different types of cloth and looked at them under the microscope. From what they observed they predicted properties such as tensile strength, elasticity, and water absorption. Finally, they devised means of testing these characteristics and comparing the results to their predictions. In addition to predicting the students found it necessary to control variables in order to have "fair" tests for the different types of fabrics. An opportunity to use combinatorial analysis was presented by experiment SP-6.

The invention phase of the learning cycle actually took place continually as the student interacted with his partner, other students and the instructor. At the beginning of each unit students were given a study guide consisting of questions to ponder, problems, and a reading list to locate additional information on the unit. Discussion groups were convened on request of two or more students. Finally, a written test was given, whenever the student was prepared, which had to have a score of 75 or greater in order for the student to proceed to the next unit. This required several tests of equivalent difficulty.

The discovery phase of each unit consisted of one or more "yellow" card experiments which were much like the previously described exploration experiments except that they required some knowledge of the subject matter. Frequently, these discovery experiments required understanding at a formal level, but there were always some experiments available that were of a concrete nature. As often as possible the discovery experiments provided a link between one unit and the next.

RESULTS

The Longeot test results comparing the experimental group to the control group after 18 weeks of instruction are shown in Table 4. The percentage of students in the experimental group scoring in each of the Piagetian categories is shown in Figure 2. In 1975-76 no pretest was given, but scores on a posttest after one year of instruction are shown in Figure 3. Sixty percent of these students were early formal and 21% were late formal. Nearly one-half of the students who were not graduating seniors are successfully competing in College Preparatory Chemistry this year; ten percent of them expect to be chemistry majors in college, although they were not especially interested in science in the fall of 1975.

DISCUSSION

Some factor to which these students were exposed caused an increase in the scores on this particular test. Because of the lack of ran... selection we should not generalize beyond this group of students. Two possible confounding variables are the use of two different teachers and the Hawthorne effect. Replication of the study controlling some of these variables would be valuable.

At Air Academy High School two variations of this study are still in progress. Students who elected to take Practical Chemistry for one year will be tested in late April and compared to a similar group. There is also a group of college preparatory students using a parallel program but at a higher level of difficulty who will be compared to a traditional college preparatory class. In this portion of the study the same teachers will be involved with both groups.

Many parts of the course described in this paper need further development before they are consistent with Piagetian principles. It is especially difficult to find reading material that is suitable. Many problems and questions have been written but much more work is needed in this area.

Fuller, Karplus, and Lawson (10) define the process of self-regulation as ". . .. one in which a person actively searches for relationships and patterns to resolve contradictions and bring coherence to a new set of experiences. Implicit in this notion is the image of a relatively autonomous person, one who is neither under the constant guidance of a teacher nor strictly bound to a rigid set of precedents." We believe that this chemistry course is a first step in this direction.

TABLE I

Unit	No.	Experiment
PROPERTIES & CHANGES	9	On the reagent shelf in a jar marked PC-9 is a mixture of sand and salt. Separate the two solids and hand in a pure sample of each.
PROPERTIES & CHANGES	11	Obtain samples of cotton, linen, wool, silk, and at least two synthetic fabrics. Look at them under the microscope. Predict some of the properties such as tensile strength, elasticity, and water absorption. Test your predictions.
STATES OF MATTER	2	Measure (carefully) 10.0 ml methanol and an equal volume of water. Predict the volume if the two should be added. Add them. Account for your results.
STATES OF MATTER	7	Get a specially constructed 30 ml capacity hypodermic syringe from the teacher. Using several identical books for weights, determine the relationship between pressure and volume. A graph would be a good way to express your data.
STRUCTURE & PERIODICITY	2	Determine how much sodium chloride (NaCl), sodium bromide (NaBr), and sodium iodide (NaI) will dissolve in 1.0 ml water. Predict how much sodium fluoride (NaF) would dissolve in water.
STRUCTURE & PERIODICITY	6	Make all possible combinations of A solutions and B solutions. Add 1 ml of carbon tetrachloride to each combination. Explain what happened. A Solutions: chlorine water; bromine water; iodine water B Solutions: sodium chloride (1.0M); sodium bromide (1.0M); sodium iodide (1.0M)
ACIDS & BASES	3	How little NaOH (sodium hydroxide) still has enough basic character to turn red litmus paper blue? Do other indicators give the same results? Hint: Make a 10% solution and dilute it.
ACIDS & BASES	7	From the appropriate acids and bases make small quantities of the following salts: $CaCl_2$, $ZnSO_4$, and $NaNO_3$.

Table 2 (8)

Mole Relationships in Chemical Rxns

Mass of crucible + $NaHCO_3$	________
Mass of crucible	________
Mass of $NaHCO_3$	________
Mass of crucible + Na_2CO_3 (after heating)	________
Mass of crucible	________
Mass of Na_2CO_3	________

Table 3 (9)

Mass of dish and its contents after heating	________ g
Mass of dish and its contents before heating (Line 1 in data chart)	________ g
Difference in mass (subtract the masses)	________ g

Table 4

Test Results

	Experimental	Control
Pre test	$\overline{X} = 6.4$	$\overline{X} = 4.8$
Post text	$\overline{X} = 7.8$	$\overline{X} = 5.7$
	$t = 2.76$ $p < .01$	$t = 0.933$ NS

Figure 1

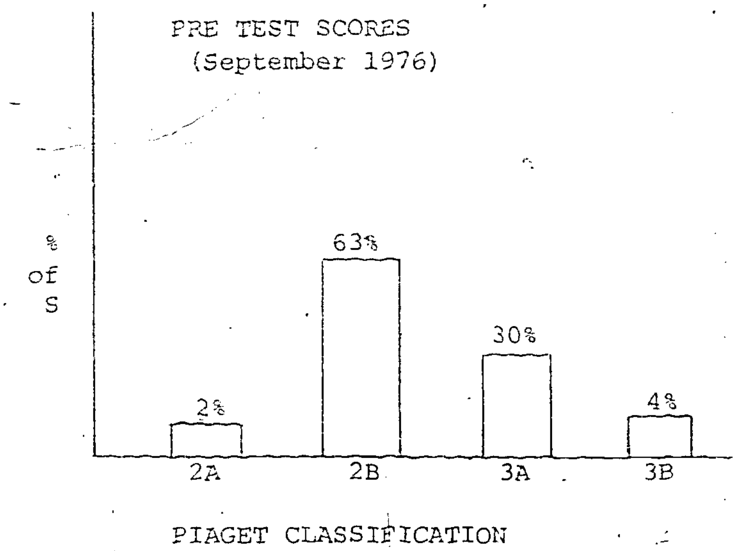


Figure 3

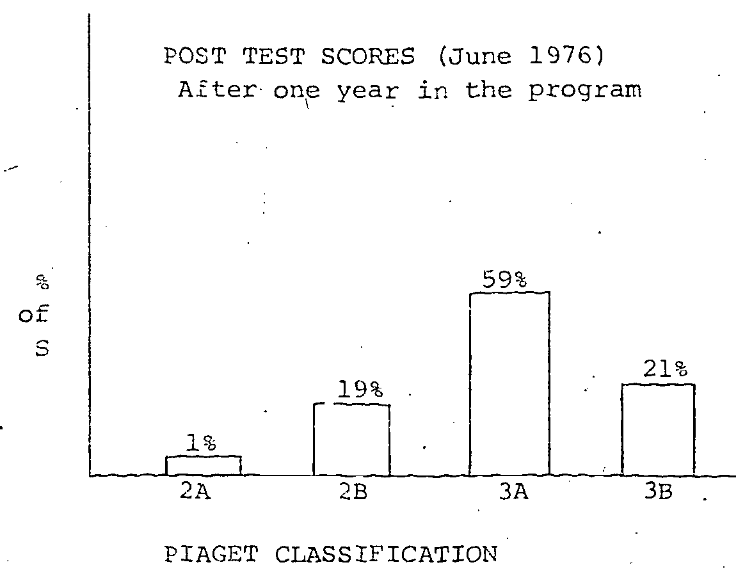
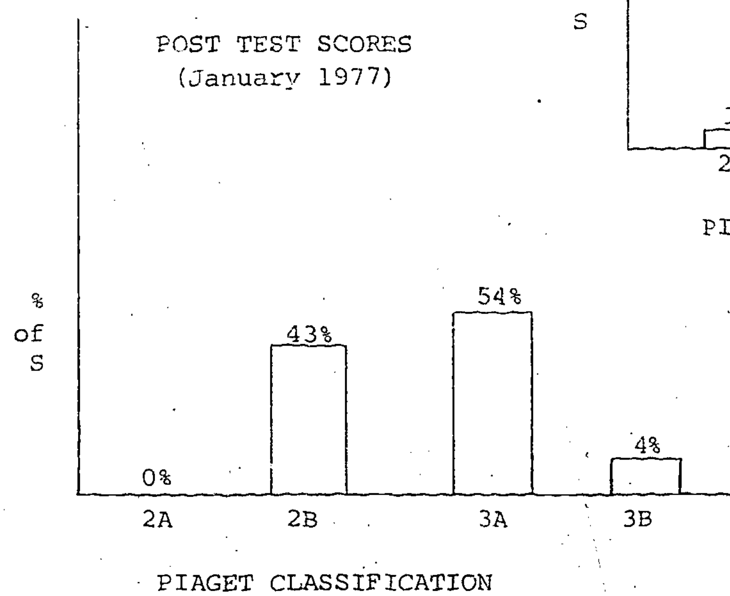


Figure 2



LITERATURE CITED

(1) Parry, R. W., Dietz, P. M., Steiner, L. E., and Tellefsen, R. L., "Chemistry: Experimental Foundations," 2nd ed., Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1975, p. 296.

(2) Herron, J. D., J. CHEM. EDUC., 52, 146 (1975).

(3) Toon, E. R., and Ellis, G. L., "Foundations of Chemistry," Holt, Rinehart and Winston, Inc., New York, 1973, p. 261.

(4) Chiappetta, E. L., SCI. EDUC., 60 (2), 253 (1976).

(5) Sheehan, D. J., "The Effectiveness of Concrete and Formal Instructional Procedures," unpublished doctoral dissertation, State University of New York, Albany (1970).

(6) Lawson, A. E., and Renner, J. W., J. RES. SCI. TEACH., 12 (4), 347 (1975).

(7) Lawson, A. E., and Blake, A. J. D., J. RES. SCI. TEACH., 13 (3), 227 (1976).

(8) Toon, E. R., and Ellis, G. L., "Laboratory Experiments for Foundations of Chemistry," Holt, Rinehart, and Winston, Inc., New York, 1973, p. 57.

(9) Bolton, R. P., Lamphere, E. V., Menesini, M., and Huang, P. C., "Laboratory Experiments in Action Chemistry," Holt, Rinehart, and Winston, Inc., New York, 1973, p. 1/55.

(10) Fuller, R. G. Karplus, R., and Lawson, A. E., PHYSICS TODAY, 30, (2), 23, (1977).