DOCUMENT RESUME

ED 319 599 SE 051 409

AUTHOR BouJaoude, Saouma B.

TITLE The Relationship between Students' Learning Strategies and the Change in their Chemical Misunderstandings during a High School Chemistry Course.

PUB DATE 90

NOTE 25p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (63rd, Atlanta, GA, April 8-11, 1990).

PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.

DESCRIPTORS Abstract Reasoning; Attitudes; *Chemistry; *Concept Formation; High Schools; *Learning Strategies; *Misconceptions; Prior Learning; Science Instruction; *Science Tests; *Secondary School Science

ABSTRACT

The purpose of this study was to: (1) investigate the relationship between the learning approaches of high school students, their prior knowledge, and their attitudes toward chemistry, and their performance on a misconceptions test; and (2) describe and analyze the differences between the responses of students of different learning approaches on the same test. Forty-nine high school students enrolled in two sections of New York State Regents Chemistry classes at a suburban school participated in this study. The Misunderstandings Test about burning and chemical change, Students' Learning Strategies Questionnaire, Attitude toward Chemistry Questionnaire, and Differential Aptitude Tests were used to collect data. The Misunderstandings Test was used twice within an 8-month span; students' responses from the two are discussed. Results demonstrated that students' performance on a misunderstandings pretest and students' learning approaches accounted for a statistically significant proportion of the variance on students' performance on the misunderstandings posttest. The results showed that students who identified themselves as meaningful learners performed better than rote learners on the misunderstandings posttest. (Author/YP)

The Relationship Between Students' Learning Strategies and the Change in Their Chemical Misunderstandings During a High School Chemistry Course

Saouma B. BouJaoude
Department of Science Teaching
Syracuse University, Syracuse, NY 13244

Running Head: STUDENTS' LEARNING STRATEGIES

Paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta, Georgia April 8-11, 1990.

Abstract

The purposes of this study are as follows: 1) to investigate the relationship between the learning approaches of high school students, their prior knowledge, and their attitude toward chemistry, and their performance on a misconceptions test; and 2) to describe and analyze the differences between the responses of students of different learning approaches on the same test. Forty nine high school students enrolled in two sections of New York State Regents Chemistry classes at a suburban school in New York State participated in the study. The results of the study demonstrated that students' performance on a misunderstandings pretest and students learning approach accounted for a statistically significant proportion of the variance on students performance on the misunderstandings post-test. Additionally, the results showed that students who identify themselves as meaningful learners performed significantly better than rote learners on the misunderstandings post-test.

The Relationship Between Students' Learning Strategies and the Change in Their Chemical Misunderstandings During a High School Chemistry Course

Introduction

Interest in students' intuitive theories and topic-related understandings of scientific concepts has increased significantly in the past decade. Presently, it is rare to find an issue of a science education journal which does not include at least one article on the topic. Research in this area has focused on identifying, classifying, and characterizing students' understandings about a large number of science topics. For example, Larkin, McDermoth, Simon, and Simon (1980) investigated students' understandings about mechanics, Clough and Driver (1985) examined the nature of students' understandings of heat and temperature, Carey (1985) analyzed students' understandings about the concept of life, and more recently Treagust and Smith (1989) investigated students' understandings of gravity and the motion of planets. Research conducted to identify the sources of students' incorrect scientific understandings and to evaluate instructional strategies to change these incorrect understandings has been less prevalent in the science education research literature (Hashweh, 1988). Another important yet little understood area of research is the relationships between students' learning strategies, their chemical misunderstandings, and their ability to correct these misunderstandings.

The purposes of the present study are as follows: 1) to investigate the relationship between the learning approacnes of high school students, their prior knowledge, and their attitude toward chemistry and their performance on a misconceptions test; and 2) to describe and analyze the differences between the responses of students with different learning approaches on the same test.

Background

Meaningful learners who "choose to relate new knowledge to relevant concepts and propositions they already know" (Novak & Gowin, 1984, p.7) may be able to use the information they acquire in science classes to correct their misunderstandings. By consciously creating meaningful links between the concepts acquired in a chemistry course, meaningful learners may reduce memory overload and increase their processing capacity (Linn, 1986), and consequently improve their ability to correct misconceptions and solve problems. Conversely, rote learners--those who acquire new knowledge by verbatim memorization and arbitrarily integrate this knowledge into existing knowledge structures--(Novak et al., 1984), may not be as successful as meaningful learners in correcting their misunderstandings. In other words, rote learners do not produce coherent understandings of scientific topics and elaborate cognitive structures to reason through science problems (Eylon & Linn, 1988). In addition, traditional science instruction which emphasizes breadth of coverage rather than depth of understanding, may contribute to memory overload, decreased processing capacity, and consequently a diminished ability to correct misunderstandings.

Method

Subjects

Subjects for this study were 49 students (22 males and 27 females, range= 16.0 years to 18.0 years, mean age=16.8 years, SD=0.6) enrolled in two sections of a New York Regents Chemistry course taught by the same teacher at a suburban school in New York State. The New York Regents Chemistry course is a survey course which emphasizes breadth rather than depth of coverage. All these students have passed the New York Regents Biology examination and have successfully completed a prerequisite mathematics course before enrolling in the New York Regents Chemistry course.

Instruments

The following instruments were used in this study:

(a) The Misunderstandings Test. This test was developed as a result of previous research conducted by this author (BouJaoude, in press). During 1988, 20 junior high school students were interviewed to identify their misunderstandings about the concepts of burning and chemical change. The identified misunderstandings were utilized to develop the Misunderstandings Test. This test was used to collect more information about students' misunderstandings about burning and chemical change at the high school and university levels and in different cultural settings. The content validity of the Misunderstandings Test was verified by a panel of experts including two junior high and high school teachers, three university professors, and two science education graduate students.

This test consists of 13 items and employs a two-tier question format to identify students' understandings as well as collect information about students' rationales for their answers. The scores on the test are computed as percentages. The following is an example of the questions used in the test--this question was obtained from Welford's (1988) report on English children's performance in chemistry:

I. Equal quantities of steel wool are suspended from the arms of a scale so that they are balanced. The steel wool on side A is heated. What happens to the scale?
   a. It tilts toward A
   b. It tilts toward B
   c. It stays balanced

II. Explain you answer

(b) The Students' Learning Strategies Questionnaire. This questionnaire is an adaptation of the Learning Approach Questionnaire developed by Donn (1988, personal communication; Novak, Kerr, Donn, & Cobern, 1989). The questionnaire design was based on the work of Biggs and Collis (1982), Entwistle (1981), and Entwistle and Ramsden (1983) in Great Britain.

The Students' Learning Strategies Questionnaire used in this study consists of 39 items and is scored out of a maximum of 195. Students were asked to respond to each item using a five-point Likert scale ranging from A (Always True) to E (Never True). A Cronbach alpha internal consistency coefficient of 0.77 was obtained for the present sample.

(c) The Attitude Toward Chemistry Questionnaire. This instrument consists of 10 items and utilizes a semantic differential to measure students' attitude toward chemistry. The maximum score on the test is 70. The directions of the adjective continua in the items were randomly altered to decrease the possibility of response set. The semantic differential was used because "it is easy to construct, it is short and thus quick to administer, and it is usually very highly reliable[1]" (Mueller, 1986, P. 55). A Cronbach alpha internal consistency coefficient of 0.87 was obtained for the present sample.

(d) Differential Aptitude tests (DAT). Students' scores on the verbal reasoning, numerical ability, and abstract reasoning subgroups of the DAT were obtained from the students' files (Maximum score of 50). All the students took these tests at the ninth-grade level. The Differential Aptitude Tests has reported reliability coefficients ranging from 0.91 to 0.94 for the three subgroups used in this study.

---

[1] According to Mueller (1986) test-retest reliability coefficients and internal consistency coefficients of around 0.90 are not uncommon for instruments utilizing semantic differentials.

Procedures

The Misunderstandings Test, used as a pretest, and the Studen.s' Learning Strategies Questionnaire were administered at the beginning of October 1988, while the Attitude Toward Chemistry Questionnaire was administered at the end of the same month. The Misunderstandings Test, used as a post-test, was re-administered in June 1989 one week before the students were expected to take the New York Chemistry Regents Examination and following scheduled review sessions for the same examination. In addition, the investigator attended classes for a total of 16 weeks (eight weeks in September and October 1988 and eight weeks in May and June 1989) to ascertain the nature of teaching that took place in both classes.

For the purposes of this study, students who scored at or above the mean score on the Students' Learning Strategies Questionnaire were labeled as meaningful learners (Group 1, 24 students) while those who scored below the mean were labeled as rote learners (Group 2, 25 students).

Results

Table 1 presents the Pearson correlation coefficients between the scores on the Misunderstandings Test administered in October 1988 (PRE), the students scores on the Students' Learning Strategies Questionnaire (STRAT), the attitude scores (ATT), the scores on the Differential Aptitude tests (DAT), and the scores on the Misunderstandings Test administered during June 1989

(POST). This table shows that the highest correlation coefficient is between PRE and POST ($r=.60$, $p<.0001$), followed by the correlation between STRAT and ATT ($r=.56$, $p<.0001$).

Insert Table 1 about Here

Since the predictor variables were correlated with one another, a stepwise multiple regression analysis was applied to the data to determine which variable(s) proved to be the best predictors of performance on the Misunderstandings Test (POST). Scores on the following served as predictors: a) The Misunderstandings Test, used as a pre-test (PRE); b) The Students' Learning Strategies Questionnaire (STRAT); c) The Attitude Toward Chemistry Questionnaire (ATT); and d) The Differential Aptitude Test (DAT). The results of the multiple regression (Table 2) show that PRE and STRAT accounted for a statistically significant proportion of the variance on POST.

Insert Table 2 about Here

Table 3 shows the means and standard deviations of the meaningful (Group 1, N=24) and the rote learners (Group 2, N=25) on the different variables used in the study.

Insert Table 3 about Here

An analysis of covariance[2] was used to compare the performance of meaningful and rote learners on the post-test scores (POST). The scores on the pretest (PRE), the attitude scores (ATT), and the scores on the Differential Aptitude Tests (DAT) were used as covariates. The results of the ANCOVA show that there is a statistically significant difference between the meaningful and rote learners ($F=24.98$, $p<.0001$). The adjusted means were $X_{meaningful}=54.79$, $X_{rote}=44.27$.

A qualitative analysis of the responses of students on the individual items of the multiple choice part of the Misunderstandings Test (Table 4) shows that the percentage of meaningful learners choosing the correct answer increased or did not change on 9 of the 13 questions while the percentages of rote learners choosing the correct responses decreased on 9 of the 13 questions. This is reflected in the very slight change between the means of the pretest and the post-test for the rote learners (Pretest mean=41.56, post-test mean=42.20). Additionally, the

---

2 The assumptions for ANCOVA were tested as follows:

a. The assumption of homogeneity of variance did not need an empirical test since ANCOVA is robust to this assumption when groups have approximately equal (larger number < or=1.5 smaller number)--meaningful learners=24, rote learners=25 (Huck, Cormier, & Bounds, 1974).

b. ATT, DAT, and PRE were significantly correlated with POST (Table 1). Additionally, There were significant correlations between the PRE and ATT of subgroups (meaningful and rote learners) with the post-test scores. In addition the correlation between attitude and pretest scores was not statistically significant.

c There was no interaction between the covariates and the grouping variables at the .05 level of significance.

percentage of rote learners responding correctly to questions 5, 6, and 7 (melting ice, dissolving sugar, and condensing water) decreased appreciably between the beginning and the end of the year.

Insert Table 4 about here

Finally, analysis of the differences between the responses of the students on the justification part of each question shows that meaningful learners, for the most part, developed more coherent understandings of some of the concepts underlying the questions. Tables 5 and 6 provide examples of the responses of meaningful and rote learners respectively to a number of the questions on the Misunderstandings Test.

Insert Tables 5 and 6 about here

Discussion

The results of the study demonstrate that the misunderstandings pretest (PRE) and students learning approach (STRAT) accounted for a statistically significant proportion of the variance on students' performance on the misunderstandings post-test. Additionally, the results show that students who identify themselves as meaningful learners performed significantly better on the Misunderstandings Test administered in June 1989 (POST). These findings suggest that in a class which emphasized breadth rather than depth of coverage, meaningful learners were better able to utilize the information they acquired to correct their misunderstandings about chemical change. Furthermore, the analyses of students' individual responses (Tables 4, 5, and 6) show that more meaningful learners than rote learners gave correct answers on the multiple choice part as well as on the explanation part of each question. The meaningful learners seem to have developed coherent understandings--as evident from the analysis of their written responses on the second part of each question on the Misconceptions Test-- that were useful in their attempts to answer questions that required more than rote learning (Eylon et al., 1988).

It is possible that students who identify themselves as meaningful learners, are able to organize the information they acquired in the classroom into bigger chunks, thus reducing their memory overload, increasing their processing capacities, and decreasing the possibility of acquiring new misunderstandings during instruction (Linn, 1986). Meaningful learners might be different from rote learners in that while rote learners store their information in smaller chunks (Clement, 1987), meaningful learners might have larger chunks of meaningful information and thus are better able to utilize information acquired in the classroom to correct misunderstandings. Moreover, the large amount of information that learners have to acquire in a course that emphasizes breadth of coverage can overwhelm rote learners and lead to a decrease in their performance.

Implications for Teaching

The results of this study highlight the importance of meaningful learning and teaching at the high school level. While survey courses might be necessary because of the influx of new information and the need to cover increasing amounts of basic materials in the sciences, meaningful learning and teaching might be one way to help students cope with the increasing memory and processing demands of these survey courses. Additionally, teaching students explicit strategies and training them to use these strategies might be necessary, since some students are able to develop effective strategies on their own while others need explicit instruction in the development and use of these strategies (Daehler & Bukatko, 1985). Training should help students to relate new information to prior knowledge, to integrate information for one subject area into another, and to relate classroom information to everyday experiences to help those students become meaningful learners who are better able to retain and use information in novel situations (Prawat, 1989).

Finally, because of its potential to help students understand, retain, and effectively use large amounts of information, meaningful learning might help students to develop learning or mastery goals, goals in which importance is attached to developing new skills through which learning itself is valued and long time student involvement in science is fostered (Ames &

Archer, 1988; Dweck, 1986).

Limitations of the Study

The fact that this study took place in intact classes, that the students came from a suburban school district, and that there was no experimental manipulation to determine cause-effect relationships between learning approach and students' abilities to correct their chemical misunderstandings limit the generalizability of the findings of this study. However, the emerging patterns from this study might provide a rationale for conducting more research on the relationship between students' learning approach, and their ability to correct misunderstandings (Novak, Kerr, Donn & Cobern, 1989). Additionally, the results of this study highlight the need to investigate the possibilities of training students to become meaningful learners and training teachers to become meaningful teachers.

References

Ames, C., & Archer, J. (1988). Achievement goals in the classroom: Students' Learning strategies and motivational processes. Journal of Educational Psychology, 80, 260-267.

Biggs, J., & Collis, K.(1982). Evaluating the quality of learning: The SOLO Taxonomy. New York: Academic Press.

BouJaoude, S. (in press). A study of the nature of students' understandings about the concept of burning. Journal of Research in Science Teaching.

Carey, S. (1985). Conceptual change in childhood. Cambridge, MA: Harvard University Press.

Clement, J. (1987). Overcoming students' misconceptions in Physics: The role of anchoring intuitions and analogical validity. Proceedings of the second International Seminar on Misconceptions and Teaching Strategies. (178-204). Ithaca, New York, July 26-27.

Clough, E., & Driver, R. (1985). Secondary students' conceptions of the conduction of heat: bringing together scientific and personal views. The Physics Educator, 20, 176-182.

Daehler, M. & Bukatko, D. (1985). Cognitive development. New York: Alfred A, Knopf.

Dweck, C. (1986). Motivational Processes affecting learning. American Psychologist. 41, 1040-1048.

Entwistle, N. (1981). Styles of learning and teaching. New York: John Wiley & Sons.

Entwistle, N. & Ramsden, P. (1983). Understanding student learning. London: Croom Helm.

Eylon, B., & Linn, M. (1988). Learning and instruction: An examination of four research perspectives in science education. Review of Educational Research, 58, 251-301.

Hashweh, M. (1988). Descriptive studies of students conceptions in science. Journal of Research in Science Teaching, 25, 121-134.

Huck, S., Cormier, W., & Bounds, W. (1974). Reading statistics and research. New York: Harper and Row.

Linn, M. (1986). Science. In R. F. Dillon, & R.J. Sternberg (Eds.), Cognition and Instruction (pp. 155-204). New York: Academic Press, Inc.

Larkin, J., McDermoth, J., Simon, D., & Simon, H. (1980). Expert and Novice performance in solving physics problems. Science, 208, 1335-1342.

Mueller, D. (1986). Measuring social attitudes. New York: Teachers College Press.

Novak, J., & Gowin, D., (1984) Learning how to learn. New York: Cambridge University Press.

Novak, J., Kerr, P., Donn, S., & Cobern, W. (April, 1989). Epistemological issues in science education. Symposium presented at the Annual Conference of the National Association for Research in Science Teaching, San Francisco, CA.

Prawat, R. (1989). Promoting access to knowledge, Strategy, and disposition of students: A research synthesis. Review of Educational Research. 59, 1-41.

Treagust, D., & Smith, C. (1989). Secondary Students' understandings of gravity and the motion of planets. School Science and Mathematics, 89, 380-391.

Welford, A. (1988). Children's performance in chemistry. Education in Chemistry, 25(1), 7-10.

Table 1.
Pearson Correlation Coefficients Between the Different Variables Used in the Study.

	PRE	STRAT	ATT	DAT
PRE	1.00			
STRAT	0.21	1.00		
ATT	0.14	0.56*	1.00	
DAT	0.49*	0.42*	0.22	1.00
POST	0.60*	0.49*	0.32*	0.44*

*P<.01

Table 2.
Stepwise Multiple Regression Summary for the Prediction of Performance on the Misunderstandings Tests (POST)

Step	Entered	Partial R^2	Model R^2	F
1	PRE	0.36	.36	26.56*
2	STRAT	0.14	.50	12.54**

* P<.0001
** P<.0009

Table 3.
Means and Standard Deviations (SD) of the Meaningful and Rote Learners on the Different Variables Used in the Study.

Variable	Group 1 (N=24) Mean	SD	Group 2 (N=25) Mean	SD
PRE	45.04	11.93	41.56	7.84
STRAT	124.62	7.80	105.12	8.00
ATT	39.67	14.49	26.40	12.66
DAT	40.91	6.52	37.44	5.71
POST	56.62	15.07	42.20	9.11

Table 4.
<u>Percentages of Meaningful and Rote Learners Responding to the Multiple Choice Part of the Misunderstandings Test.</u>

	Meaningful learners (N=24)		Rote learners (N=25)	
	Oct. 88	June 89	Oct. 88	June 89
1. When a candle burns there is a:				
chemical or chemical & physical change	70.83	58.33	48.00	44.00
Physical change	29.16	41.67	52.00	56.00
2. When a candle burns air is needed to help the flame but none of it is used up.	25.00	0.00	28.00	16.00
When a candle burns part of the air changes into something else.	75.00	100.00	72.00	84.00
3. When a candle burns wax:				
evaporates	20.83	20.83	0.00	0.00
melts	41.66	50.00	72.00	64.00
melts and evaporates	25.00	20.83	20.00	24.00
Melts and burns	12.50	8.33	0.00	0.00
burns	0.00	0.00	8.00	12.00
4. When a paper burns there is a:				
chemical change	66.66	70.83	80.00	72.00
Physical change	33.33	29.16	20.00	28.00
5. When ice melts there is a:				
chemical change	12.50	12.50	4.00	20.00
physical change	87.50	87.50	96.00	80.00
6. When sugar dissolves there is a:				
chemical change	25.00	25.00	16.00	60.00
physical change	75.00	75.00	84.00	40.00
7. When water condenses there is a:				
chemical change	4.16	8.33	4.00	32.00
physical change	95.80	91.66	96.00	68.00
8. When a nail rusts there is a:				
chemical change	83.33	91.66	92.00	88.00
physical change	16.66	8.33	8.00	12.00
9. When an empty bottle breaks there is a:				
chemical change	0.00	0.00	0.00	8.00
physical change	100.00	100.00	100.00	92.00
10. A candle is put on the pan of a scale and lit. After one hour the reading on the scale would be:				
less	87.50	91.66	92.00	72.00
the same	12.50	8.33	8.00	28.00
11. When matches suspended inside a tightly closed flask are lit, the weight of the flask:				
Increases	29.16	8.33	16.00	36.00
decreases	20.83	20.83	40.00	36.00
stays the same	50.00	70.83	44.00	28.00

Table 4 (cont.)

12. When a nail rusts its weight:				
increases	45.83	70.83	60.00	56.00
decreases	20.83	12.50	24.00	12.50
stays the same	33.33	16.66	16.00	32.00
13. When steel wool burns its weight:				
Increases	12.50	20.83	12.00	16.00
decreases	70.83	75.00	64.00	80.00
stays the same	16.67	4.17	24.00	4.00

Table 5.

Typical Responses of Meaningful Learners on the Second Part of a Number of Questions on the Misunderstandings Test.

Pretest response	Post-test responses
Question 1: What happens to the wax when a candle burns? Explain your answer.	
Student 1	
When a candle burns, it is a physical change because the wax changes phase	When a candle burns, It is both a chemical and physical change. It is a physical change in that the wax melts. It is a chemical change in that the wax burns and is changed into different gases.
Student 2	
The wax melts to a liquid and runs down the candle and solidifies again.	Heat from the flame melts the wax down. Some of the wax evaporates and makes the flame still burn.
Question 11: When matches suspended inside a tightly closed flask are lit, will the weight of the flask increase, decrease, or stay the same.	
Student 38	
It would be less because the burning matches loose their weight.	The mass will be the same because none of the particles were allowed to escape.
Student 30	
The mass will be more because the atoms are moving faster and there is different air	The same because the flask wasn't open to gain or lose anything
Student 49	
The mass after cooling will be more because a chemical change occurred so there was something new	(The mass would be) the same, everything that was in didn't get out and nothing was added.
Question 12: When a nail rusts, does the rusty nail increase in weight, decrease in weight, or stay the same and why?	
Student 6	
The rusty nail decreases in weight because it gives off something. If it didn't give off something then it wouldn't change	The nail gets heavier because of the oxygen reacting with the nail.
Student 13	
Stays the same because it takes iron to make the rust so the weight would even out	the rusty nail weighs more because some iron from the shiny nail combines with oxygen to form the rust so something was added.
Student 14	
It will decrease because water eats away at the nail to cause rust.	(It weighs) more some of the iron combines with water and the air to give a slight (not noticeable) increase in weight.

Table 6. Typical Responses of Rote learners on the Second Part of a Number of Questions on the Misunderstandings Test.

Pretest responses	Post-test responses
Question 1: What happens to the wax when a candle burns? Explain your answer.	
Student 12	
It melts and evaporates	It disintegrates into the air and it melts dow and drips
Student 15	
It melts and evaporates some of the wax has a low melting point so the flame can easily melt the wax when the candle is burning you can smell the wax in the air	The wax melts. the wax and the wick just turn to different materials or different forms of the same material.
Question 11: When matches suspended inside a tightly closed flask are lit, will the weight of the flask increase, decrease, or stay the same.	
Student 16	
The mass will be less because all the oxygen inside the tightly closed flask would be used up.	The weight will more because of the gas given off by the matches.
Student 19	
The mass will be the same because the flask was closed tightly and no air could get mixed with the air inside the flask to cause the mass to be different	less because all the oxygen in the flask would be used up
Student 32	
It would be more because the gas would be stuck inside of the flask	More, because carbon dioxide is given off from the matches and trapped in the closed flask.
Question 12: When a nail rusts, does the rusty nail increase in weight, decrease in weight, or stay the same and why?	
Student 19	
I think the nail will decrease in weight because the reaction will cause the nail to be lighter	A rusty nail decreases in weight because the rust weighs less than the previous outer layer of the nail.
Student 31	
The nail will decrease in weight because rust eats away the material it is on.	Decrease in weight because the rust has eaten away at the metal.