DOCUMENT RESUME

ED 362 383 SE 053 652

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TITLE Problem Solving Strategies for Pharmaceutical/Chemical Technology College Students.
PUB DATE [93]
NOTE 20p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Chemistry; Classroom Research; College Freshmen; *College Science; Foreign Countries; Higher Education; Medical Education; *Problem Solving; *Science Instruction; Teaching Methods; Technology Education

ABSTRACT

Teaching problem solving strategies and steps to first year college students enrolled in the pharmaceutical/chemical technology program as a part of their first year chemistry course focused on teaching the students the basic steps in problem solving and encouraging them to plan carefully and focus on the problem solving process rather than to feel a sense of helplessness and panic. The paper attempted to understand students' problem solving patterns, and to provide them with some strategies to enhance their problem solving skills. It was found that after showing the students basic problem solving strategies/steps, their mean test scores, as compared to a control group was significantly higher at 0.95 probability level. Contains 23 references. (Author)

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Problem Solving Strategies For Pharmaceutical/Chemical Technology College Students

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Teaching problem solving strategies & steps to first year college students enrolled in the pharmaceutical/chemical technology program as a part of their first year chemistry course focused on teaching the students the basic steps in problem solving and encouraging them to plan carefully and focus on the problem solving process rather than to feel a sense of helplessness and panic. The paper attempted to understand students' problem

solving patern, and to provide them with some strategies to enhance their problem solving skills. It was found that after showing the students basic problem solving strategies/steps, their mean test scores, as compared to a control group was significantly higher at 0.95 probability level.

INTRODUCTION

Problem solving is the mental process used to arrive at an appropriate solution to an unknown situation subject to a set of constraints (1). Problem solving skills include a knowledge base pertinent to the content of the problem; the ability to locate, identify, obtain and evaluate missing information; cognitive skills to analyze, reason, classify, and establish relationships; attitudinal skills to cope with ambiguity, fear, anxiety, procrastination; and the ability to use creativity and intuition along with analytical reasoning to reach the optimal solution to a given problem.

Instead of encouraging the students to memorize facts or ideas by rote memorization (called the expository method) , educators would focus on teaching problem solving skills as early as possible. Helping students to develop and organize, hierarchical knowledge based on understanding (called the discovery method) will undoubtedly help develop students' cognitive domain not only to cope with course work, but to thrive later in their chosen careers.

Educators of every philosophical persuasion, and from diverse background all agree about the importance of teaching problem solving skills to their students, although they may differ about the way in which this goal is to be accomplished. Educators can help students recognize that problem solving does not progress in a simple straight forward fashion from problem to solution. They can show that it is possible to use more than one method to solve a given problem. They should teach students to break a problem down into manageable components. They can help students develop a plan for solution, including the skill to use approximation in Math &Science problems. Problem solving skills can be taught in any subject curriculum and not as a separate course.

REVIEW OF LITERATURE

Piaget is frequently cited as the foremost authority on problem solving (2). He took the position that the baby experience the world through his own activities and perceptions as sensory motor operation. At grade 2, the student can perform concrete operation, at which ,/she can think logically and develop and test hypotheses. Piaget's theories are of special interest to science and mathematics educators.

Whimbey and Lockhead (3) have collaborated for a number of years in research on the skills related to problem solving and in applications to teach this knowledge to others. They published several books on problem solving that direct the learner in developing these skills, and they provide a large number of clever problems of gradually increasing difficulty upon which to practice. Cognitive scientists who have studied the differences between the thinking of novices and the thinking of experts have indicated four main characteristics according to Larkin (4):

1. The expert assembles information from the problem. When they read the original statement of the problem, they make a sketch of the situation, visualize the situation, figure out the meanings of the problem.

2. The expert plans the problem solution by constructing qualitative relations between major factors in the problems.

3. The expert solves the problem by applying principles to generate quantitative equations to yield the optimal solution.

4. The expert checks and validates the solution.

Unfortunately, classroom teachers who try to apply such habits have generally been disappointed with the results. In a study by Whites (5) in cognitive thinking and problem solving they suggested that expert reasoning patterns that are required in problem solving takes a long time to acquire. Hays (1) also supported their findings. Gregory (6) reported that problem solving confidence was important moderating variable which suggest that perception of long term experience seemed to moderate subsequent negative experiences that influenced current depressing levels which suggest a correlation between the emotional state and the ability to perform problem solving. Since Numeracy, literacy and lack of student's problem solving skills was one of the most common stressors facing college educators in Ontario, Canada as reported by Grant (7), teaching problem solving skills as part of every curriculum is essential particularly in Science and Mathematics. This supports the findings of Kadel (8).

Proctor (9) described two experiments conducted with a computer-aided problem solving tool called BRAIN. The program encourages students to formulate insights through iterative generation of word lists and meaningful statements. Eighty percent of participants found implementable insights into problems. Wong and Willoughby (10) also described a method of understanding student problem solving behavior during computer-assisted instruction using trigonometry as the example domain. They found that teaching problem solving was a rewarding experience.

Niedelma (11) reviewed the research on components of problem solving including two mechanisms for fostering transfer of problem solving strategies, low road and high road transfer, and two types of content (domain specific and higher order thinking). Lowenthal (12) pointed out that faculty has an opportunity to help students mature and become socially conscious critical thinkers. The problem solving process, dealing with alternative solutions, ambiguity, and flexible curriculum construction are emphasized.

Friedel (13) discusses the effectiveness of using analogies in chemistry instruction. Students' mathematical anxiety, spatial visualization skill, and proportional reasoning ability were found to be important aptitudes for determining chemistry achievement. Woods (14) described some strategies for the development of problem solving skills in solving stoichiometric chemistry problems; Rayner-Canham (15) examined teaching chemistry problem solving techniques by microcomputer; Bogner (16) presented an approach to solve oxidation-reduction reactions problems; Pickering (17) analyzed the performance of students on numerical versus conceptual chemistry problems in their freshman general chemistry course and their sophomore organic chemistry course. Data indicated that the ability to solve a problem did not necessarily imply an understanding of the concepts involved; Sawrey (18) and Lythcott (19) indicated the importance of teaching problem solving skills for their chemistry students. It would appear that teaching problem solving in science courses is of vital importance . Blakeslee (20) outlined the importance of both right and left brain junctions in problem solving; Carkhuff (21) offered a simplified, approach to learning skills in helping oneself and others through problem solving. He described a step by step approach, starting with understanding the problem and ending with implementing courses of actions. Olson (22) equated creative thinking with problem solving ability. After a preamble in which obstacles to creativity and common characteristics of creative people were discussed, he presented a creative problem solving system called DO IT (define the problem, open yourself to many ideas, identify the best solution and transform into action). Ross (23) examined the factors which blocks creative problem solving such as fear of risk taking and preference for the predictable and orderly; cultural barriers the tendency to proscribe playfulness and fantasy behaviors for adults; environmental barriers, failure of teachers to reward innovative thinking; the tendency to use common items in a conventional manner only; and habitual ways of visualizing, e.g. difficulty in visualizing things in new and different way. It can be seen from this brief literature review that teaching problem solving skills to college and university students in the science and mathematics curriculums, is of utmost importance and should be incorporated as a part of every subject to help students not only cope with course work but thrive later in their careers in an increasingly competitive world.

METHODOLOGY

The freshman chemistry class was divided equally into two groups at random, where one group (test) of 22 students was given strategies and specific steps to enhance their problem solving skill and the other group of 22 students (control) was not instructed and used for comparison.

During a one hour lecture, the test group was given the strategies for problem solving using the following key steps:

I) **Problem**

P lan for the problem solving process by drawing pictures.
R elax when faced with the problem to allow for clear thinking.
O vercome any fear when dealing with the problem.
B reakdown the problem into small manageable components.
L ook back for any missing information in the problem statement.
E valuate ways (forward/backward) to solve the problem.
M easure all possible logical ways to solve the problem.

II) **Solving**

S elect the most apparent logical solution to the problem.

O rganize your thought to reach an optimal solution.

L ocate another possible solutions to the problem, if any.

V alidate and verify the reached solutions.

I nspect all possible solutions and choose the optimal one.

N ever give up Persist until you reach solution.

GO celebrate you have reached a solution to the problem.

It was emphasized to the students the importance of the planning stage since the majority of the students try to avoid initiating the process and they simply panic not knowing from where and how to start the process. The second step (relaxing) was crucial for clear and creative thinking as reported by Ross (23). The next step was to help students overcome fear when faced with ambiguity which are inhibiting factors in the process of problem solving. Breaking down the problem into small manageable components was an important step particularly in solving mathematics or chemical calculations problems. The students were instructed to look back for any missing information in the problem statement without which the process of problem solving would be difficult if not impossible. The next step was the evaluation step where the student can look at the problem and decide whether to solve it forward or backward using analytical reasoning. The students were told that every problem should be evaluated differently and not to expect an identical solution path for all problems. The following step was to help the students measure all possible logical ways to reach an optimal solution for the problem. The students were instructed to be patient going through the previous steps and not to expect an instant solution rather than going step by step through the process until they are fully familiar with the problem and ready to reach an appropriate solution.

The next step in the process of the problem solving is to focus on the solution and select the most logical solution after carefully assessing the problem. At this point the students were asked to organize their thoughts to reach an optimal solution through creative and logical thinking as well as using techniques such as brainstorming to search for that idea which may not be obvious through traditional way of thinking. To locate other possible solutions was an important steps in reaching an optimal solution since many problems may have multiple solutions from which only one is considered an ideal. The students were shown how to validate the solution in order to verify the fit between the solution and the problem. This is a vital step in science and mathematics types of problem solving. The next step was simply to inspect all possible solutions and decide on the optimal one. During the lecture one key aspect of the process of problem solving which was emphasized the most was persistence particularly for first year students. The last step after reaching the optimal solution was to go and celebrate and all students did not have any difficulty with this step.

Both test and control groups were given five basic mathematical problems to test the difference in their abilities to perform the problem solving strategies. (appendix 1)More complicated chemical problems related to stoichiometery were then given to students to evaluate their progress. The student's t test was used to determine the validity of the null hypothesis (H^0 : $\bar{X}1 - \bar{X}2 = 0$) (no difference in test score after learning problem solving strategies) or the alternate hypothesis (H^1 : $\bar{X}1 - \bar{X}2 = 0$) (there was significant in test score between the two population) using tow tailed test at 95% probability level. The degree of freedom (df)= n1 + n2 - 2 = 42

$$t = \frac{X1 - X2}{\sqrt{\frac{sd1}{n1} + \frac{sd2}{n2}}}$$

RESULTS

The ability of the students to solve the given five basic mathematical problems from the test (trained) and control groups can be summarized in table 1.

Table 1: % of students who successfully completed the solution of basic mathematical problems.

	Test Group	Control Group
Problem 1	72	67
Problem 2	56	41
Problem 3	65	57
Problem 4	74	63
Problem 5	61	50
Average (X)	65.6	55.6
Standard deviation (sd)	7.5	9.2
n	22	22

$$t = \frac{65.6 - 55.6}{\sqrt{\frac{(7.5)}{5} + \frac{(9.2)}{5}}}$$

t = 1.89 which is less than 2.02 (Df=42), therefore there was a significant difference at 0.95 probability level. As a result, the null hypothesis was rejected and the alternate hypothesis was accepted, which suggests that teaching problem solving strategies improved the student's abilities to solve problems.

Although the first problem was answered successfully by more than two thirds of the students in both test and control groups, it was surprising to see that most students had difficulty with the second problem. In the third problem only a few students were able to reach both possible solutions, but the majority were able to reach the first obvious solution. (13 x 1=13)perhaps because they did not follow step L (locate other possible solutions).

Since basic mathematical skills are essential in the learning of chemical calculations (19),all diagnostic tests (appenix 1) were of mathematical types. The test was also used as an assessment tool for the students' knowledge in mathematics and the results were shared with their mathematics professor for a remedial action. The five problems were used as a problem solving tool to evaluate the degree to which the students were able to apply the basic problem solving steps learned by the test group.

The students indicated that they needed to practice the steps of problem solving and asked for more problems in mathematics and chemistry to try which was an encouraging sign. Most students from the test group found that the planning stage was the most valuable step.

Examination scores for the chemistry midterm was 7.5% higher than in the control group and the failure rate (lower than 56%) was lower in the test group by 5% when compared to the control group. These results were also found to be significant at a 0.95 probability level.This suggests that learning and practicing problem solving strategies influenced the students' success, assuming that no other variables had any influence on both the test and control groups.

Therefore we can conclude that problem solving strategies embedded into a science and mathematical curriculum can make a significant contribution towards a students' success.

CONCLUSION

A class of freshman college students were divided into two groups; one group was taught problem solving strategies in a step by step format and the other group was used as a control. The test group outperformed the control group at a statistically significant level(0.95). Also their midterm test results was 7.5% higher than control group which was also significant at 0.95 level. It can be concluded that teaching problem solving strategies help students improve their performance and increase their confidence level to cope with problems at the college during their studies and hopefully after graduation when they join the real world.

RECOMMENDATIONS

Further research to elucidate the need to include problem-solving in college curriculum is required.Pre-Math classes for students who are weak in Mathematics and problem-solving abilities is recommended .Educators should emphasize the importance of acquiring problem-solving skills to their students particularly when outome based education is emphasized .

APPENDIX 1

1. Determine the pattern. Find the missing number in fig. (1)

9	8	20	3
16	4	32	12
15	9	29	5
23	13	50	14
9	12	?	16

Fig. (1) Problem #1 (Answer 37)

2. Determine the pattern. Find the missing number in fig. (2)

25	52	31	26
9	4	7	5
38	28	18	19
7	20	7	?

Fig. (2) Problem #2 (Answer 9)

3. When a single digit number multiplied by a double digit number a double digit number results. The sum of the three numbers is 27? What are the three numbers? Two answers(13 x 1= 13 or -3 x -15= +45).

4. The sum of two consecutive number is 225, find the two numbers? answer (113 and 114)

5. Fill each square (fig. 3) with a number, one through nine
Horizontal squares should add to totals on right
Vertical squares should add to totals on bottom
Diagonal squares through center should add to total in upper
and lower right.

				24
			6	32
7				17
		3		22
	8			19
32	34	13	11	22

Fig. (3) Problem #5

				24
9	9	8	6	32
7	8	1	1	17
8	9	3	2	22
8	8	1	2	19
32	34	13	11	22

fig.(4) Solution to problem #5

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Acknowledgement: We wish to thank Maureen Georgy for preparing the manuscript.