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ABSTRACT

The purpose of this study was to determine the effect of a preservice science methods course emphasizing the mastery of selected science process skills on the level of development of logical thinking of students majoring in elementary school education. The problem was investigated for one semester with experimental subjects in their junior year, enrolled in elementary science methods classes. Non-equivalent control subjects were an intact class of seniors who had previously taken the same class, but with different emphases. Phase one consisted of pretesting 81 experimental subjects and testing the non-equivalent control subjects. A group test was used to assess the initial level of logical reasoning development. Phase two consisted of coursework whereby the experimental subjects systematically performed tasks designed to teach them skills in basic and integrated science processes. In the final phase, the test was administered again to the experimental subjects. Also, a group test of science processes was given to the experimental subjects to assess their mastery of the science processes. The findings provided evidence that preservice elementary teachers did grow in their development of logical reasoning when exposed to a one-semester course in elementary school science methods which emphasized mastery of science processes. (Author/CW)

THE EFFECT OF A PRESERVICE ELEMENTARY SCIENCE METHODS COURSE EMPHASIZING THE MASTERY OF SCIENCE PROCESS SKILLS ON THE DEVELOPMENT OF INTEGRATED PROCESS SKILLS AND LOGICAL THINKING

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ABSTRACT

The purpose of this study was to determine the effect of a preservice science methods course emphasizing the mastery of selected science process skills on the level of development of logical thinking of students majoring in elementary school education.

The problem was researched for one semester with experimental subjects in their junior year, enrolled in elementary science methods classes. Non-equivalent control subjects were an intact class of seniors who had previously taken the same class, but with different emphases. Phase One consisted of pretesting eighty-one experimental subjects and testing the non-equivalent control subjects. A group test, developed by Lawson (1978) was used to assess the initial level of logical reasoning development. Phase Two consisted of coursework whereby the experimental subjects systematically performed tasks designed to teach them skills in basic and integrated science processes. The final phase, Lawson's test, was administered again to the experimental subjects. Also, a group test of science processes developed by Dillashaw and Okey (1980) was given to the experimental subjects to assess their mastery of the science processes.

Comparison of the means of the pretest and posttest scores using a correlated t-test indicated statistically significant growth in the thinking development of the: entire experimental group of subjects; formal level subjects; transitional subjects; and concrete level subjects.

A Pearson correlation revealed a strong statistically significant correlation between the final logical thinking classification and the science processes test scores of the experimental subjects.

An analysis of variance between the experimental subjects' posttest scores and the non-equivalent control subjects' scores indicated a statistically significant difference favoring the experimental subjects.

In conclusion, these findings provided evidence that preservice elementary teachers did grow in their development of logical reasoning when exposed to a one-semester course in elementary school science methods which emphasized mastery of science processes.

Introduction

One of the primary goals of education is to develop logical thinking ability. Much of Jean Piaget's research dealt with the development of modes of thought based upon the individual's neurological development from birth to adulthood. (Piaget, 1964)

Piaget's theory of cognitive growth relies heavily upon a genetically determined pattern of neurological development. However, in recent years many investigators have found that many students in high school and college do not do well on the tasks designed to identify the highest level of reasoning described by Piaget, even after having completed the development of their neurological systems. (Lawson & Renner, 1974; Texley & Norman, 1984; Norman, 1989)

Purpose

The finding that logical development may not always keep pace with physiological and neurological development led to the formulation of the purpose of this research. The purpose was to determine the effect of a preservice elementary school science methods course which emphasized mastery of selected science processes on the level of development of formal reasoning of students majoring in elementary school education.

Questions from this research problem were:

1. Does the entire class advance in logical reasoning during a preservice science methods course which emphasizes mastery of science process skills?

2. Do students who test at the early-formal level advance in the level of their logical reasoning during a preservice science methods course which emphasizes mastery of science process skills?

3. Do students who test at the concrete operational level advance in the level of their logical reasoning during a preservice science methods course which emphasizes mastery of science process skills?

4. Do students who test at the transitional level advance in the level of their logical reasoning during a preservice science methods course which emphasizes mastery of science process skills?

5. Is there a relationship between the reasoning level of students who have completed an elementary school science methods course which emphasized mastery of selected science processes and the reasoning level of students who took an elementary school science methods course with less emphasis on mastery of science processes?

6. Is there a relationship between the logical reasoning classification and the score on the process skills test of students who have completed an elementary school science methods course which emphasizes mastery of selected science process skills?

Background

Several of the federally funded science programs are structured upon the Piagetian theory of cognitive and mental growth. The ability to think logically, to consider alternatives, to control variables, to develop hypotheses and to design and analyze experiments are processes that have been cited among goals of elementary school science education. Roger Webb (1974) reports that these processes require formal level reasoning. Yet, persons who have not acquired formal reasoning patterns are severely limited in their ability to comprehend any science concepts when the concepts are introduced at a formal level as described by Piaget's theory of mental development. (Lawson and Renner, 1974)

Process skills have been described by Funk, et al. (1975) as "what scientists do when they study and investigate problems." Padilla and Dillashaw (1981) found that the development of science process skills requires thinking strategies and reasoning patterns that begin at the concrete level and evolve into the formal operational level. Based upon this analysis by Padilla and Dillashaw, mastery of selected science process skills was the procedure used to stimulate and provoke further development of reasoning levels of students enrolled in the science methods course.

According to Piaget's theory of logical reasoning development, at about age seven the thinking processes of children are such that they think about and learn through concrete experiences. Piaget calls this period the concrete operational stage. (Inhelder & Piaget, 1958)

Beginning about age eleven, a child develops what Piaget calls formal operational thought. For Piaget this stage constitutes the highest level in the development of mental structures. Piaget initially believed that individuals reached the upper levels of formal operational thinking about age fourteen (Piaget, 1966).

Since some youngsters in elementary school may have attained the neurological and physiological development required for higher levels of cognitive development (as theorized by Piaget), then it is assumed that elementary school teachers would be more effective teachers and better prepared for the challenge of teaching youngsters if their level of reasoning development is higher or at least as high as their students.

Method

Design

A pretest-posttest quasi-experimental design with a non-equivalent control group was used. The first phase of the study was the pretest of the elementary school science methods students. This group was the experimental subjects. The purpose of the pretest was to classify the subjects into their respective logical thinking category. The instrument used to identify the logical thinking level of the subjects was Lawson's test of Logical Thinking. (Lawson, 1978) Subjects were categorized in a non-equivalent control group. These students were tested on the same instrument as the experimental group. The purpose was to determine the reasoning level of students who had already completed an elementary school science methods course which was structured more on science content such as magnetism and electricity, plants and animals, rocks and minerals, rather than science processes.

The second phase of the study consisted of course work whereby the subjects systematically performed tasks and activities that were designed to teach basic and integrated science process skills. (See Table 1.) One of the main objectives of the science methods course was mastery of the science process skills, whereas this achievement alone counted for 35 percent of the final grade.

The third phase of the study was the posttest of the experimental subjects to measure any gain in the level of logical thinking. The measuring instrument for the posttest was the same instrument used for the pretest, namely, Lawson's Test of Logical Thinking. (Lawson, 1978)

The final stage of the study was a test for mastery of the science process skills. The instrument used to evaluate the subjects was the group Test of Integrated Science Processes. (Tobin & Okey, 1982)

Subjects

The experimental subjects were the students (N=81) enrolled in the elementary science methods classes. The students from a Senior Seminar (N=20) were designated the non-equivalent control group since they had completed a more traditional elementary methods course a year or more before the study began.

Procedures

Instruments

The instruments used in this study were the Test of Logical Thinking (TOLT), which was reported to have a Kuder Richardson 20 estimate of reliability of 0.78. (Lawson, 1978) Also, a Test of Integrated Process Skills (TIPS) developed by Tobin and Okey (1982) was administered.

Treatment

The treatment for the experimental subjects was an elementary science methods course which focused on learning selected science processes. The text used was Learning Science Process Skills, by Funk, et al. In addition, for the students who tested on the concrete level of thinking, there were take-home modules from the textbook, Science Teaching and the Development of Reasoning, by Karplus.

Results

The experimental group of science methods subjects demonstrated statistically significant growth in logical thinking. The posttest scores at the end of the semester on the measuring instrument were higher for (1) the entire experimental group, (2) early-formal subjects, (3) transitional level subjects, and

(4) concrete level subjects. (See Tables 2, 3, 4, and 5.)

Using the Test of Logical Thinking scores, those twenty subjects comprising the non-equivalent control group were classified as seven (35%) concrete; ten (50%) transitional; and three (15%) formal. Comparatively, using the same instrument, the experimental group had a final classification of four (5%) concrete; twenty-eight (35%) transitional; and forty-nine (60%) formal.

Moreover, when the mean of the score of the experimental subjects on the posttest and the mean of the scores of the non-equivalent control subjects were compared, the mean of the scores of the experimental subjects were significantly higher. (See Table 6.)

A strong correlation was found between the posttest of logical thinking and the process skills posttest scores of the experimental group. (See Table 7.)

Conclusions

1. An entire elementary school science methods class did improve their developmental level of logical thinking as a result of taking a one semester course in elementary school science methods which emphasized mastery of science process skills. This finding was evidenced by the use of a correlated t-test, which indicated that there were statistically significant differences between the means of pretest and posttest scores of the preservice experimental subjects.

2. Those subjects who were classified as reasoning on the concrete operational level did improve their developmental level of logical thinking after participating in a one semester course in elementary school science methods which emphasized mastery of science process skills. This finding was established by using a correlated t-test, which indicated that there were statistically significant differences between the means of pretest and posttest scores of experimental subjects who tested on the concrete operational level of logical thinking.
3. Those subjects who were classified as transitional in their logical thinking development improved their developmental level when exposed to a one semester course in elementary school science methods which emphasized mastery of science process skills. This finding was evidenced by the use of a correlated t-test which indicated that there were statistically significant differences between the means of the pretest and posttest scores of experimental subjects whose level of logical development was classified as transitional.
4. Those subjects who were identified as reasoning on the formal operational level (some were early-formal) improved their developmental level after exposure to a one semester course in elementary school science methods which emphasized mastery of science process

skills. This finding was evidenced by using a correlated t-test, which indicated that there were statistically significant differences between the means of pretest and posttest scores of experimental subjects who tested on the formal level of logical thinking.

5. Those experimental subjects who were exposed to a one semester elementary school science methods course which emphasized mastery of science process skills demonstrated overall higher levels of logical thinking development than a non-equivalent control group of subjects who had already taken an elementary science methods course during the previous year with less emphasis on mastery of science process skills. This conclusion was established by the analysis of variance of the scores from the testing instrument of the experimental subjects and the non-equivalent control subjects which indicated a statistically significant difference between the means of the two groups.

6. Those experimental subjects who were exposed to a one semester course in elementary school science methods which emphasized mastery of science process skills were administered a test to assess achievement in learning the process skills at the end of the semester. It was established that there was a statistically significant relationship between the

final logical thinking classification of the experimental subjects and their science process skills test score.

Discussion of Results

The attempt of this study was to determine the effect of a preservice science methods course emphasizing the mastery of selected science process skills on the level of development of formal reasoning of students majoring in elementary school education.

The pretest scores of the entire experimental science methods subjects were used to identify the developmental levels of logical thinking of the subjects. The levels of logical reasoning development were found to be considerably lower than was theorized by Piaget, but similar to more recent findings on reasoning development by Texley and Norman (1984), and Norman (1989). The findings of this study indicated that the entire experimental group demonstrated growth in logical thinking by testing higher on the posttest measure than on the pretest. Secondly, those subjects classified as concrete, transitional, and formal tested higher in their specific categories on the posttest than the pretest, thereby demonstrating statistically significant growth in logical thinking. Those results were interpreted as indications that many individuals were indeed "locked-in" at a level of logical thinking which was below the level of their capabilities.

Moreover, further indications were that those subjects could significantly advance in their level of logical thinking when exposed to a one semester science methods course which totally emphasized mastery of selected science processes.

The experimental group scores from the posttest and the science process skills test showed a high correlation. Those results were seen to be indicative of a strong relationship between higher levels of logical thinking and the ability to "do what scientists do when they investigate and solve problems." (Funk, et al., 1975) Further, those data were interpreted to support a basic premise of this study that mastery of the science processes is an effective procedure to stimulate the development of logical thinking in science methods subjects.

Another strong indication of the effectiveness of mastery of the science processes skills as a reasonable and prudent procedure to stimulate development of logical thinking was demonstrated by the scores of the experimental science methods subjects on the posttest measures compared to the scores from the same measure of the non-equivalent control subjects. When the means of the scores of the two groups were compared, the mean of the scores of the experimental subjects was considerably higher. The control group was composed of students who had taken an elementary school science methods course the previous year. However, the science methods courses taken by the control subjects were structured mainly around the science content.

Implications for Future Research

Questions generated from this study which are recommendations for further research are as follows:

1. Would an interdisciplinary approach of mathematical processes and science processes improve the procedure for development of logical reasoning patterns in students?
2. Would an analysis of the performance of subjects on each test item of the pretest measure better streamline the planning, and increase the effects of a preservice elementary school science methods course designed to develop logical reasoning skills?
3. What would be the effect of an "all subject area" approach to the development of logical thinking development of preservice teachers majoring in elementary school education?
4. Does the level of logical thinking attained by subjects during a one semester course remain at the existing state or does the attained level require a maintenance of periodic stimulation?
5. What would be the effect of an inservice education project aimed at the development of logical reasoning skills of elementary school teachers?
6. What would be the nature of a "Science Ed." course that maximized content mastery, logical reasoning skills and methods?

TABLE 1

ELEMENTARY SCHOOL SCIENCE METHODS CLASS SCHEDULE--
WINTER SEMESTER 1982

Date	Meeting Number	Process Skills #; Activity; Assignment
	1	Orientation; ½ Reasoning Inventory
		½ Reasoning Inventory; Observation #1; Classification #2
	3	Communication #3; Measurement #4; New Program: SCIS
	4	Prediction #5; Inference #6; New Program: SAPA
	5	Identifying Variables #7; New Program: ESS (Homework assignment: Constructing a Table of Data #8)
	6	Constructing a Graph #9; Teaching Science Lessons (Homework assignment: Describing Relationships between Variables #10)
	7	Acquiring and Processing Your Own Data #11; Teaching Science Lessons
	8	Analyzing Investigations #12; Teaching Science Lessons
	9	Constructing Hypotheses #13; Teaching Science Lessons
	10	Defining Variables Operationally #14; Teaching Science Lessons
	11	Designing Investigations #15; Teaching Science Lessons
	12	Experimenting #16; Teaching Science Lessons
	13	Experimenting #16; Teaching Science Lessons
	14	Reasoning Inventory

TABLE 2

CORRELATED t-TEST COMPARISON BETWEEN PRETEST AND POSTTEST SCORES OF EXPERIMENTAL PRESERVICE ELEMENTARY SCHOOL TEACHERS ON THE TEST OF LOGICAL THINKING

Group	N	Mean	S.D.	S.E.	df	t
Pretest	81	8.135[a]	4.029	.450	80	-13.265*
Posttest	81	11.691	3.172	.345		

$^{*}p < .001$

TABLE 3

CORRELATED t-TEST COMPARISON BETWEEN PRETEST AND POSTTEST SCORES OF FORMAL LEVEL EXPERIMENTAL SUBJECTS

Group	N	Mean	S.D.	S.E.	df	t
Pretest	20	13.5	1.284	.294	80	-4.589*
Posttest	20	14.6	.735	.168		

$^{*}p < .001$

TABLE 4

CORRELATED t-TEST COMPARISON BETWEEN TOLT PRETEST AND POSTTEST SCORES OF EXPERIMENTAL CONCRETE SUBJECTS

Group	N	Mean	S.D.	S.E.	df	t
Pretest	27	3.629	1.337	.262	26	-11.107*
Posttest	27	8.296	2.224	.436		

$^{*}p < .001$

TABLE 5

CORRELATED t-TEST COMPARISON BETWEEN PRETEST AND POSTTEST TOLT SCORES OF EXPERIMENTAL TRANSITIONAL SUBJECTS

Group	N	Mean	S.D.	S.E.	df	t
Pretest	34	8.558	1.752	.305	33	-11.063*
Posttest	34	12.676	2.151	.374		

*p < .001

TABLE 6

ANALYSIS OF VARIANCE OF TEST OF LOGICAL THINKING (TOLT) SCORES OF EXPERIMENTAL SCIENCE METHODS AND NON-EQUIVALENT CONTROL SENIOR SEMINAR SUBJECTS

Group	N	Mean	S.D.	df	F-ratio
Post TOLT SM	81	12.925	11.59	1+99	13.376*
TOLT SS	20	7.910	3.16		

*p < .001

TABLE 7

CORRELATION OF LOGICAL THINKING SCORES AND PROCESS SKILLS SCORES OF EXPERIMENTAL GROUP

Test	N	Mean	S.D.	S.E.	df	r
Logical Thinking	80	11.662	3.173	.357	78	.783*
Process Skills	80	83.337	18.051	2.031		

*p < 0.001

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