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Mark Hackling
Western Australian College of Advanced Education

Patrick Garnett
Western Australian College of Advanced Education

Frank Dymond
Western Australian College of Advanced Education

IMPROVING THE SCIENTIFIC THINKING OF PRESERVICE SECONDARY SCIENCE TEACHERS

Mark Hackling, Patrick Garnett and Frank Dymond
Western Australian College of Advanced Education

ABSTRACT

Previous studies indicate that many preservice science teachers lack facility with those formal reasoning patterns that are critical for learning science. The purpose of this project was to develop, implement and evaluate a curriculum package directed at improving preservice secondary science teachers' scientific thinking. A matched treatment-control, quasi-experimental design revealed significant gains achieved through use of the curriculum materials.

INTRODUCTION

Formal reasoning ability has been found to be an important factor influencing student learning in high school science. Studies in the United States (Cantu & Herron, 1978; Lawson & Renner, 1975; Sayre & Ball, 1975) and Australia (Garnett, Tobin & Swingler, 1985) have indicated that science achievement and the understanding of science concepts are significantly related to students' ability to use formal reasoning patterns. Similarly, Padilla, Okey and Dillashaw (1983) found that facility with science process skills correlates strongly with formal reasoning ability. These findings provide substantial support for the view (De Carcer, Gabel & Staver, 1978; Lawson, 1985) that a major goal of science education must be to promote the development of students' formal reasoning abililty.

It has been shown that a significant number of preservice science teachers lack facility with those formal reasoning patterns that are necessary for working on scientific investigation tasks (Garnett & Tobin, 1984). Such cognitive limitations are likely to reduce their effectiveness in teaching high school students the scientific thinking skills associated with materials-centred science curricula (Tobin & Garnett, 1984).

Some researchers have investigated whether students' ability to use formal reasoning skills can be improved by instruction. This research has, for the most part, focused on attempts to teach specific reasoning patterns.

In a comprehensive review, Lawson (1985) concluded that such training procedures can be successful and that the degree of success depends on the age of students, the length and diversity of the training experiences and the extent to which students are confronted with thought-provoking situations and placed in control of their own actions.

The aim of this study was to implement and evaluate the effectiveness of an educational intervention designed to teach preservice secondary science teachers those formal reasoning patterns necessary for conducting scientific investigations.

PROCEDURE

General Design

The study involved a pretest-posttest design with treatment and control groups. The subjects were preservice secondary teachers enrolled in second year curriculum studies units. The treatment group comprised science majors and the control group comprised English majors. A total of 38 science students and 37 English students was pretested, and from these 19 science and 19 English students could be matched in pairs on identical pretest scores. These subjects formed the treatment and control groups which therefore had the same mean pretest score and standard deviation.

Intervention

The intervention consisted of four 90 minute sessions designed to teach students about the nature of scientific inquiry, hypothesis testing and experimental design, and provide activities directed specifically at five formal reasoning patterns: identification and control of variables, and proportional, probabilistic, correlational and combinatorial reasoning. A brief summary of each session is provided in Figure 1:

Session	Topic	Approach
1a	The nature of science; observation and interference ; tentative nature of theory.	Observation/inference exercises in small groups; modification of inferences.
1b	Types of variables, hypotheses, experimental design	Teacher/class discussion of experimental design; demonstration of ramp experiment
2a	Isolation and control of variables	Small group discussion of experimental designs; students in small groups plan and carry out an experiment.

2b	Probabilistic reasoning	Individual and small group exercises identifying the probability of events involving one or more variables.
3a	Proportional reasoning	Individual predictions based on Mr Short/ Mr Tall and gears problems; calculations involving proportions.
3b	Correlational reasoning	Individual/small group exercises based on perfect and imperfect relationships and involving the construction of contingency tables.
4a	Combinatorial reasoning	Individual and small group exercises determining permutations and arrangements using a 'tree diagram' strategy.
4b	Module revision	Revision worksheet

Figure 1: Summary of the Intervention

The educational intervention commenced with instruction designed to develop an understanding of the nature of science and the structure of controlled experiments. The purpose of this was to build up students' schema knowledge regarding experimentation and to provide a context for the specific training in those reasoning patterns used in scientific investigations. The training sessions employed near-transfer tasks, that is, tasks requiring the same reasoning patterns but in a different context from those included in the pre and posttest.

The sessions were designed to induce cognitive conflict within students and stimulate a metacognitive awareness of the reasoning patterns being applied to the tasks. Activities were thought-provoking and involved frequent use of small group discussion to enhance engagement with the tasks. Some of the lessons employed a learning cycle strategy (Karplus, 1980) with exploration of concrete materials, rule introduction and rule application. Students were provided with opportunities to practise rule application with feedback from the teacher.

While the treatment group was exposed to the intervention the control group continued with their normal instruction on the curriculum resources and instructional approaches to teaching English. Topics covered at this time included teaching spelling and grammar, and evaluation of English text books. It was assumed that this instruction on English curriculum would be quite neutral in relation to developing formal reasoning skills in science.

Instrumentation

The preservice teachers' formal reasoning ability was assessed in the pretest and posttest using the Test of Logical Thinking (TOLT) (Tobin & Capie, 1981). The TOLT consists of ten items which provide measures on five reasoning modes: controlling variables; proportional reasoning; probabilistic reasoning; correlational reasoning and combinatorial reasoning. Each of the ten items in the TOLT requires participants to select a correct response and justification from a number of alternatives. The test has been shown to have high reliability and validity with a wide range of students (Tobin & Capie, 1981).

RESULTS AND DISCUSSION

The performance of the control and treatment groups on the pretest and posttest are shown in Table 1:

Table 1
Mean Pretest and Posttest Scores, and Standard Deviations for Control and Treatment Groups

	Pretest		Posttest		
	Mean	Std dev	Mean	Std dev	t
Treatment 4.60** (n = 19)	6.74	2.10	8.84	1.21	
Control (n = 19)	6.74	2.10	7.68	2.08	2.61*
t			2.71*		

*p .01, one-tailed t test for paired data.
**p 0.0005, one-tailed t test for paired data.

A one-tailed t test for paired data was employed to test for a significant increase in TOLT scores for the control and treatment groups and to test for a significant treatment effect. The results in Table 1 indicate a significant increase in TOLT scores for both the control and treatment groups and a significant treatment effect.

The mean score of the control group on the TOLT increased from 6.74 to 7.68 (+ 0.94) while that of the treatment group increased from 6.74 to 8.84 (+ 2.10). The improved posttest performance of the control group may be due to prior exposure to the test in the pretest situation, maturation, or some interaction of these factors. In view of the short time interval between pre- and posttests it seems likely that prior exposure to the test may be the main factor responsible for this improvement. The pretest aroused considerable interest and discussion among students, which may have generated some cognitive changes.

In addition to this, the test has an unusual format, consisting of two-level multiple choice items. The pretest would have provided practice in answering questions of this type so that students would be more familiar with that style of test item in the posttest.

The treatment group had significantly higher scores than the control group on the posttest, indicating that the intervention was successful in improving students' ability to use formal reasoning patterns. The effect size $(X_e - X_c/S_c)$ of 0.56 SD was most encouraging given the limited time available for the intervention and the developmental nature of the curriculum provided.

Observation of the experimental group during the posttest indicated that the students applied strategies they had learned during the intervention: for example, tree diagrams and contingency tables. These strategies were not used by the experimental group during the pretest.

The success of the materials can be attributed to activities that created cognitive conflict, and employed a learning cycle approach that provided students with a rule and opportunity to practise the application of that rule with feedback. The results support Lawson's (1985) contention that students' reasoning ability can be improved, particularly if a variety of thought-provoking activities is provided and students are intellectually in control of their own actions. It is anticipated that these preservice science teachers will benefit from the intervention in several ways. First, the improved facility with formal reasoning patterns will enhance their learning of abstract science concepts and science process skills from the remaining science units in their teacher education programme. Second, they will be more effective classroom teachers as they will be able to model appropriate reasoning patterns for their students. Third, they have been made aware of the types of activities that they might use to enhance the scientific thinking of high school science students.

CONCLUSIONS

Previous studies have shown that many preservice science teachers lack facility with those formal reasoning patterns that are necessary for conducting scientific investigations. This study indicates that a limited educational intervention using carefully designed instructional materials can be successful in improving preservice science teachers' scientific thinking. It is anticipated that the students teachers' improved facility with formal reasoning will enhance both their learning of science concepts and process skills and make them more effective classroom teachers.

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LITERACY IN PERSPECTIVE

Ken Willis

ABSTRACT

One aim of this Joint National Conference of the Australian Reading Association and the Australian Association of Teachers of English is to develop a National Literacy Policy. An essential pre-requisite to developing a policy on literacy is a definition of the term "literacy".

This paper argues that if this definition is stated in general terms it will be of questionable value, as it will be open to multiple interpretations dependent on the context.

To assist the processes of defining literacy and of developing a national policy this paper will:

1. consider dictionary definitions and current usage of the term "literacy";
2. examine the claim that standards of literacy have declined;
3. propose that there are numerous of aspects of literacy and that these aspects are of concern to different groups in the community;
4. examine the process of language development, including:
    a. the role of the home, the school and wider community in this development; and
    b. the economic, technological and social changes which have been affecting both the out-of-school and school environment;
5. consider the nature of language; and examine the expectations various groups have of secondary schools in the development of language usage.

In discussing this area the following aspects will be considered:

a. why some young people don't come up to the standards expected of them;

b. what schools, and in particular English teachers, are doing about this problem; and

c. what other people (examiners, employers and academics) can learn from what the schools are doing.