THE RELATIONSHIP BETWEEN CRITICAL THINKING AND EXPOSURE OF HIGH SCHOOL STUDENTS TO SCIENCE COURSES

A Thesis

Presented to

the Faculty of Graduate Studies

The University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Education

Ralph H. Berry

May, 1978

THE RELATIONSHIP BETWEEN CRITICAL THINKING AND EXPOSURE OF HIGH SCHOOL STUDENTS TO SCIENCE COURSES

BY

RALPH H. BERRY

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF EDUCATION

ABSTRACT

The problem of this study was to examine the growth of critical thinking of senior high school students as a function of the number and kind of science courses that they completed in grades eleven and twelve.

A sample of two hundred twenty students was tested with the Watson-Glaser Critical Thinking Appraisal Form YM at the end of grade ten. By the end of grade twelve, the sample size had been reduced, for reasons beyond the control of the experimenter, to sixty two students. These students were tested using the Watson-Glaser Critical Thinking Appraisal Form ZM.

After data collection, the gain in critical thinking was expressed in terms of gain between pretest and posttest z-scores. Then, correlational and anlysis of variance techniques were applied. In this analysis, the subjects were classified on the bases of age, sex, class (science major, science minor and non-science) and type (university entrance, mixed and general). The effects of specific subjects such as physics, biology, chemistry, and mathematics were examined. Within the limitations of the small sample in the study, the importance of science courses as a factor in the growth of critical thinking in grades eleven and twelve was established.

The results of the study point to several conclusions which merit discussion and from which implications for future educational practice may be drawn.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. H. D. Williams for his patient and constructive guidance in the completion of this thesis, Dr. H. Grunau for his helpful suggestions and encouragement and also Dr. G. Hoare for many constructive criticisms.

Among others to whom he owes a debt of gratitude are Superintendent L. Milne and Principal G. Sefton for permission to carry out the study in the schools; to Messrs. John Fotheringhame and Terry Robertson for computer processing of data and to Dr. W. Clifford Carbno for his suggestions about the statistical analysis.

Winnipeg, Manitoba.
May, 1978.

R. H. B.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Importance of the Problem

Some thirty-five years ago, Dressel (1955) underscored the importance of the development of critical thinking as an educational goal:

> Critical thinking then is evidently the desired integrating principle or goal of education, the achievement of which promises that there will be a life-long interest in learning.

This stated importance of critical thinking has been emphasized in the development of science courses. Such courses are designed to foster in students the ability to think critically and to help students evaluate data gained scientifically while remaining open-minded and tolerant of the opinion of others. For example,

> A course in Physics should serve a more valuable purpose than simply the acquiring of basic information in the form of facts, principles and formulae. It should primarily:
>
> 1. Provide an understanding of scientific principles...
>
> 2. Be designed to develop the student's ability to visualize relationships...
>
> 3. Provide the student with an opportunity to do some individual experimentation, to develop his powers of observation and increase his ability to gather, interpret and analyze data independently. Such experience should enable him to acquire some facility in handling scientific apparatus, providing opportunity to test the accuracy of his measurements, to draw generalizations from his results, and become acquainted to some small degree with the experimental technique of scientific investigation, (Manitoba High School Program of Studies, 1967, p.42).

The question arose then of the effectiveness of the new science courses, as currently taught, in reaching this objective. Hence, there was a need for a study to evaluate the effectiveness of science courses *per se* and of science courses as opposed to non-science courses. The approach selected was to compare the performance in terms of gain scores of each of these classes of students.

The Problem of the Study

The problem of this study was to examine the growth in critical thinking of senior high school students as a function of the number and kind of science courses that they completed in grades eleven and twelve.

The Delineation of the Study

Since 1960, a number of science courses have been adopted in the secondary education programs in Manitoba Schools. These courses, including I.P.S., CHEM Study, PSSC Physics and BSCS Biology, were designed to emphasize the structure and process of science through scientific enquiry. Indeed, the Program of Studies for Science Grades 7-9, as authorized by the Minister of Education for the Province of Manitoba in 1967, emphasized this objective as follows:

> A major goal of the discovery approach is the development of intellectual independence. It seeks to raise thinking above mere memorization and recall. Pupils are expected to formulate their own observations, evaluate their own data and reach their own conclusions. This discovery approach encourages curiosity and observation, inquisitiveness and speculation. Careful thinking habits and the ability to search for cause and effect and to make cautious conclusions are developed. Pupils must critically evaluate evidence and be critical of unsupported statements, while remaining open-minded and tolerant of the opinions of others (1967, page 1.).

Implicit in this statement is the assumption that there are various levels of thinking and that students exposed to the content and method of the "new" science courses would develop their critical thinking abilities to levels beyond that of "mere memorization and recall." The expectation seems to be that with increased exposure to science programs of a specific nature, habits of critical thinking would be fostered. Implicit also in this statement is the assumption that critical thinking ability among students is identifiable and measurable.

According to Watson and Glaser (1964), critical thinking is a composite of attitudes, knowledge and skills. Consequently, for them, in educational and psychological terms, the student who is high in critical thinking ability is characterized by:

1. Attitudes of enquiry that involve the ability to recognize the existence of problems and the acceptance of the general need for evidence in support of what is asserted to be true.

2. Knowledge of the nature of valid inferences, abstractions and generalizations in which the weight of accuracy of different kinds of evidence are logically determined.

3. Skills in employing the above attitudes and knowledge.

For the purposes of this study, the operational definition of critical thinking, proposed by Watson and Glaser, was adopted and critical thinking was measured by the Watson-Glaser Critical Thinking Appraisal. In this test, critical thinking is defined operationally in terms of the combined score from five sub-tests, namely: inference, recognition of

assumptions, deduction, interpretation and evaluation of arguments. Implicit in the use of this test is the assumption that there exists within this list of abilities designated as critical thinking sufficient overlap to warrant the expectation that the subtest scores will have a very high correlation with the total score. A more complete description of critical thinking, as a valid educational outcome, and of the Watson-Glaser Critical Thinking Appraisal, as a measure of critical thinking, is to be found in Chapters II and III respectively.

On the basis of the literature reviewed, it would appear that students in the upper grades could be expected to achieve higher scores in critical thinking than those in the lower grades. For the purposes of the study then, it was necessary to ask what independent variables might be important in any gain observed in critical thinking over the time span of the study. Could such gain be attributable to age or sex? Would older students gain more or less than younger ones? Would sex at this stage of development have any effect? Would students of initially higher levels of critical thinking ability tend to make greater gains? Would the number of science courses completed affect the size of the gain? Would there be any effect on the gain that could be attributed to the type of course taken, either university entrance or general science? And finally, within the science types, would there be any differences in gain that could be attributable to specific subject matter content?

It follows that the study should be limited to seeking answers to the following questions:

1. Is there an increase in critical thinking ability of senior high school students between grades ten and twelve?

2. Is there a difference in the mean gain in critical thinking of the sexes?

3. Do students high in critical thinking ability tend to select a greater number of specific science courses?

4. Is there a difference in the mean gain in critical thinking ability of science and non-science students?

5. Among the science students, is there a difference in the mean gain in critical thinking of university entrance and general course students?

6. Among university entrance and general course students, is there a difference in the mean gain in critical thinking of students who take and complete more science courses than of those who do not?

It should be noted that this study did not seek to compare the critical thinking ability of students pre-matched on the bases of age, sex and grade who subsequently were enrolled in specific science or non-science programs. Nor did the study seek to compare the pre- and post-performances of students, in terms of course grades, who had been exposed to a methodology that was designed to foster critical thinking as opposed to those who had not. Instead, the study sought to identify differences, if any, in the critical thinking abilities of students who, by reason of parental or other guidance or by reason of individual choice, have pre-selected themselves into the categories labelled science/non-science.

Definition of Terms

For the purposes of this study, students at the time of post-

testing were classified as (1) a science major if they had successfully completed four or more science courses, (2) a science minor if they had completed successfully not more than three science courses, and (3) a non-science student if they had completed fewer than two science courses. Within these categories, a further distinction was made between university entrance course students and general course students. A general course student did not take any university entrance courses.

In making these distinctions, it is to be noted that (1) a general science course is a course designated as an "01" course, e.g., biology 201, 301; physical science 201, 301; and (2) a university entrance science course is a course designated as a "00" course, e.g., biology 200, 300; chemistry 200, 300. Further, the numbers 200 and 201 refer to courses normally taken in the grade eleven program and the numbers 300 and 301 refer to courses normally taken in grade twelve.

Justification of the Study

A review of the literature suggested that there was room for a study, the findings of which could prove useful in future curriculum planning. Such a study could answer to some degree the question of the relationship between the selection of science courses as opposed to non-science courses and critical thinking ability. It could also seek to discover whether the ability to think critically is a factor in determining which science courses, if any, are selected. And further, it could help to determine the relationship between growth in critical thinking and exposure to science courses.

Plan of the Thesis

In this chapter, a statement of the problem of this study has been made. Chapter II contains a summary of the literature relevant to this problem. Chapter III contains an outline of the study conducted. The results of the study are presented in Chapter IV. The summary and conclusions to be drawn from the results follow in Chapter V.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

When one examines the available literature, one is struck by the fact that, although critical thinking is often cited as a desirable goal of education, exactly what is meant by the term or how one can judge (i.e., measure) critical thinking is rarely discussed. There are, then, two purposes to which a review of the literature might be addressed: (1) to attempt to delineate more clearly what is meant by the term critical thinking per se and (2) to examine the results of the research into the achievement of critical thinking as a valid goal of science education. Both of these objectives are pursued in this review.

The Literature Pertaining to the Concept of Critical Thinking

A review of the available literature reveals that psychologists and educators do not always agree on the precise nature of critical thinking. Consequently, the definition given for critical thinking is found to vary from writer to writer. In this section, an attempt is made to identify the common elements among the various definitions and so to arrive, for the purposes of this study, at a satisfactory operational definition of the term critical thinking.

Critical thinking has been defined by Burmester (1952) as encompassing most if not all of the following abilities: (1) to recognize a problem, (2) to delimit a problem, (3) to recognize and accumulate facts related to a problem, (4) to recognize and formulate an hypothesis, (5) to

plan an experiment to test an hypothesis, (6) to carry out an experiment to test an hypothesis, (7) to interpret data collected, and (8) to generalize the conclusion to a new situation.

The similarity of this list of abilities to those that are required for the successful application of the scientific method is obvious. But, if critical thinking is the ability (or abilities) required to define a problem, to recognize assumptions, to formulate relevant hypotheses, to select pertinent information, and to draw conclusions validly (Dressel and Mayhew, 1954), how is this ability to be distinguished from general intelligence?

Utilizing tasks that are not commonly used in the construction of intelligence tests, Watson and Glaser (1964) reported substantial correlations between the scores on their critical thinking appraisal and the scores on various verbal intelligence test scores (for complete details, see Chapter III). Their findings were, later, substantiated by Haas (Skinner, 1971).

Coefficients ranging from .55 to .75 with a median $\underline{r}$ of .68, are evidence of a substantial relationship between critical thinking and mental ability scores as measured by conventional intelligence tests. Further light on the relationship between critical thinking and general intelligence may be shed by the results of factor analytic studies and, in particular, by those undertaken by J. P. Guilford.

In his Structure of Intellect, Guilford (1963) recognizes at least one hundred and twenty factors which he classifies according to three dimensions: cognitive, productive and evaluative. According to him, whenever a process or problem is to be solved and the constructs of the

situation are required, the cognitive factors are at play. Then, the production factors are brought into action until a solution is achieved by either a divergent or a convergent thinking process. And finally, the evaluative factors are utilized to determine the suitability or the effectiveness of the thinking process.

In terms of Guilford's model, Ennis (1969) believes that critical thinking corresponds closely to convergent thinking and evaluation. But, others support the concept of critical thinking as problem solving which is a multi-factor process (Johnson, 1962). Allan and Rott (Madison, 1964) conclude that critical thinking should be regarded as a "pluralistic act" including an evaluative process.

It appears, then, that a high level of general intelligence may be prerequisite to a high level of critical thinking but it is not clear in any of these definitions whether critical thinking is to be identified with reflective thought in the Dewey sense (Dewey, 1923), with formal reasoning in the Piagetian sense (Inhelder and Piaget, 1964) or with problem solving in the Gestalt sense (Wertheimer, 1945).

Burton, Kimball and Wing (1971) define critical thinking as "the critical reflective search for valid conclusions which solve our problems, resolve our doubts, and enable us to choose between conflicting statements of doctrine or policy." Their concept of critical thinking, as delineated by a critical thinking scale (1971, pp. 450-451) is supported by Usery (Madison, 1964) who considers critical thinking to be "an act of searching for the clearest ideas about a subject derived from the facts, points of view, observations, and other elements."

Smith (Madison, 1964), on the other hand, argues that critical thinking is characterized by "good unemotional judgement that results from an analysis of the situation or of the materials." He is supported in this view by Lien (1967) who concludes that, in the weighing of evidence and in the answering of the question: What are the logical results?, the underlying elements in critical thinking involve the distinguishing of facts from opinion, the drawing of inferences, and the drawing of valid conclusions.

Ennis (Troost, 1971) also supports the idea that critical thinking involves reasoning. Ennis emphasizes that critical thinking is characterized by "the correct assessment of statements" and lists the following situational aspects:

1. Grasping the meaning of a statement;
2. Judging whether or not there is ambiguity in a line of reasoning;
3. Judging whether or not certain statements contradict each other;
4. Judging whether or not a situation is actually the application of a specified principle;
5. Judging whether or not a statement is actually specific enough;
6. Judging whether or not an observation is reliable;
7. Judging whether or not a conclusion necessarily follows;
8. Judging whether or not an inductive conclusion is warranted;
9. Judging whether or not the problem has been identified;
10. Judging whether or not a statement is an assumption;
11. Judging whether or not a definition is adequate;
12. Judging whether or not a statement made by an alleged authority is acceptable.

It appears then that critical thinking can be regarded as "a psychological or mental process in which a pupil draws from his knowledge background plus an ability to use logical reasoning in an effort to avoid common errors in judgement" (Brown and Brown 1971). But, there remains a problem still. If critical thinking is to be measured, it must be defined operationally in terms of a number of sub-steps through which an investigator must carry his search in order to bring it to fruition.

Typical of this approach is that of Burton, Kimbal and Wing (1964) who provide in classical form, the following summary of this process:

1. Recognition and definition of a problem.
2. Hypothesis formulation of possible solutions.
3. Inquiry or search which involves procedures of (a) experimentation, (b) collection of data, and (c) reasoning by induction, deduction and analogy.
4. Decision and acceptance of an hypothesis.
5. Testing and the use of the accepted conclusion.

Ennis (1969), on the other hand, provides a more detailed and more useful description of the application of a subject's critical thinking ability in terms of specific problem situations. According to him, a subject having a high level of critical thinking ability can:

1. Give illustrations of his own (Can you give another example of this?)
2. Relate facts to past experiences (What do you already know about this?)
3. Apply facts which relate to his own life (How does this relate to you now?)