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Abstract Approved: ______________________
Fred W. Fox

This study was designed with two major aims. The first was to examine certain characteristics of both Departmental and Non-Departmental teachers who were teaching matriculation chemistry in South Australian secondary schools during 1967. The numbers of teachers who participated were: Departmental 40, and Non-Departmental 23. The second was to ascertain certain learning outcomes of matriculation chemistry students. The learning outcomes investigated were: critical thinking, understanding of science, and achievement in chemistry. The students were divided into four groups for comparison, viz. City Departmental, Country Departmental, Independent and Roman Catholic. There were approximately 200 students in each of the school groups.

In order to secure the required information, the participating

chemistry teachers were asked to complete a Questionnaire for Chemistry Teachers while the students were asked to complete a Questionnaire for Students. A measure of two of the learning outcomes was obtained by administering the following tests:

1. Watson-Glaser Critical Thinking Appraisal, Form Ym.
2. Test on Understanding Science, Form W.

The measure of achievement in chemistry was taken from the results of the public examination in leaving chemistry.

The responses to the student questionnaire were not treated by any specific statistical test. However, the responses revealed that nearly three quarters of the students desired a tertiary education while only six percent expressed any intention of becoming science teachers. A little more than half the students were doing chemistry because they had an interest in it. The average age of the students was 16.10 years.

The conclusions from the teacher questionnaire as well as the two tests are that the following null hypotheses should be accepted:

1. There is no difference in the teaching methods used by teachers in Departmental and Non-Departmental systems.
2. There is no difference in the objectives of science teaching held by the teachers in the two systems.
3. There is no difference in the teacher factors of the teachers in the two systems.

4. There is no difference in the critical thinking abilities of the graduates from the four school groups, viz. City Departmental, Country Departmental, Independent and Roman Catholic.

5. There is no difference in the understanding of science between the graduates from the four school groups.

The following null hypotheses should be rejected:

6. There is no difference in the achievement in chemistry between the graduates from the four school groups.

7. There is no correlation between critical thinking ability and understanding of science of the graduates from the four school groups.

8. There is no correlation between the learning outcomes and the achievement in the public examination in chemistry of the graduates from the four school groups.

A Study of Selected Teacher Factors and
Learning Outcomes in Chemistry in
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by

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Redacted for privacy

Chairman of Department of Science Education

Redacted for privacy

Dean of Graduate School

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Each state in Australia has essentially two systems of education. The larger of these two systems is operated from federal funds by the state governments in the individual states. The administration of an educational program is the responsibility of the Department of Education within the state which is, in turn, responsible to the government of that state. The schools which come under the jurisdiction of the Department of Education are referred to as Departmental schools, and these educate approximately 70 percent of the secondary school enrollment.

The other system of education is administered by the various churches or private agencies and functions independently of the Department of Education. Because of this, these schools are referred to as Non-Departmental schools. This group is divided further into two sub-groups. One sub-group is known as the Independent schools and it includes schools operated by private agencies as well as various Protestant denominations. The Independent schools educate about 10 percent of the secondary school enrollment.

The other sub-group of Non-Departmental schools comprises those which are administrated by the Roman Catholic Church, since it is the policy of this denomination to educate its own children in its own schools. These are simply referred to as Roman Catholic schools and educate 20 percent of the secondary school enrollment.

The above percentages are the average for Australia, but there are variations from state to state. Students attending the Non-Departmental schools pay tuition fees, whereas those attending Departmental schools pay no tuition fees.

Present Status of the Secondary School System in South Australia

The secondary school educational program is arranged to provide five years of continuous instruction for those pupils who wish to enroll. The average student enters high school at the age of 12 years and must stay there until he reaches the age of 15 years, which is the minimum age for leaving. Because students may leave after three years, the five year period is divided into three sections. The first section covers the first three years of the secondary education, at the end of which the student receives an Intermediate Certificate if his work over this period of time has been satisfactory. The student may choose either to leave high school at this stage, in which case he will very likely become apprenticed or will seek some other kind of employment, or to continue for a further period of one or two years, the latter of which will equip him for a tertiary education.

The number of subjects taken in the first three years is usually eight. English, mathematics and science are taken each year. For those students terminating their secondary education at the end of three years, the science course consists of a two unit integrated course covering topics in physics, chemistry, biology, geology and astronomy. Students continuing toward matriculation may specialize in the individual fields of science.

In the fourth year the student takes six or seven subjects and at the end of this year sits for an external examination, an examination not administered by the school, known as the Leaving Examination. This examination is generally accepted as a basic requirement to enter the various government departments, police forces, banks and clerical work.

At the completion of the fifth year, during which the student takes six subjects, he sits for the matriculation examination. A "B" pass in five subjects, one of which must be English, is required for University entrance.

The examinations mentioned are state-wide and are administered by the Public Examination Board. The subject matter to be examined in each subject is contained in a syllabus for that subject.

Table 1 contains some information concerning secondary school enrollments in South Australia during 1966.

Some General Considerations

Teacher preparation, objectives and methods are, to varying degrees, constantly changing. Periodically the requirements for teacher certification undergo changes which result in increasingly higher standards. As our society progresses the objectives of science teaching undergo modification. Similarly, methods change as research into the various facets of science education reveals more effective ways of attaining the desired objectives.

Teacher education, therefore, should be thought of as a continuous process throughout the lifetime of the teacher. Since this present day is considered to be the "age-of-science", the science teacher has added responsibilities. The 46th Yearbook of the National Society for the Study of Education (N. S. S. E.) (59) says:

> . . . the education of a prospective science teacher should qualify him to assist to the maximal degree in stimulating, aiding and bringing about growth in functional understanding of facts, concepts and principles in both instrumental and problem solving skills; and in the attitudes, appreciations and interests of science. To be able to do this, the science teacher must be competent in the subject matter and skills of science and must himself possess the desired attitudes, appreciations and interests. (p. 282)

Table 1. Secondary school enrollments in South Australia in 1966. (4, p. 16)

	Departmental		Independent		Roman Catholic		
	Number	Percentage	Number	Percentage	Number	Percentage	Total
Enrollments for all grades	58,940	82	6,630	9	6,379	9	71,949
Matriculation enrollment	1,881	65	739	26	273	9	2,893

Scientific literacy is one aspect of science teaching which is consistently being stressed by various committees. Of chemistry teachers the 46th Yearbook (59) says:

> Chemistry teachers, like all other teachers are no doubt justly accused of failing to develop adequately a pupil awareness of the extent to which facts, principles and generalizations of chemistry relate to everyday living. (p. 201)

It has been suggested in this yearbook that, to assist in the development of understanding science with its social ramifications, "the prospective science teachers should have a good foundation in social science and its application in the study of issues of today". (p. 282)

Reports in the 59th Yearbook of the N. S. S. E. (58) suggest that the professional curriculum most useful to the beginning science teacher should include:

a) a study of basic aims of education in our society and the contribution that science can make to the realization of these aims,

b) a study of human growth and development and the learning process,

c) a study of the methods and techniques of duties and responsibilities of the science teacher,

d) an extensive, imaginative, and well-planned program of student teaching,

e) activities designed to develop an understanding of the role of the science teacher in the guidance program. (p. 262)

This statement was not intended to be exhaustive as is evident by its lack of depth. However, it does give an outline of the breadth desirable in teacher preparation.

In Australia the trainee science teacher who will be teaching the last two years of high school completes the three year baccalaureate in science. He then proceeds to a teachers' college for one year to study professional courses leading to a Diploma in Education. Doherty (23) suggested that, instead of taking professional science courses, trainee science teachers should take a complete baccalaureate course specially designed to meet the needs of the science teacher.

Tisher (77) has outlined the objectives of Australian science education:

> The objectives in the distilled essence are that science be taught as a procedure of inquiry, the student be given the opportunity to try his hand at scientific enquiry to develop the attitude of intelligent caution and restraint of committment, the student's ability to state problems, observe, compare, classify, measure, evaluate and draw conclusions as well as his ability to communicate in science be fostered. A teacher capable of this must have his own understanding of science highly developed as well as being student oriented. (p. 25)

While such objectives are desirable, are they in fact those which the teachers are presently trying to achieve? Do the teachers have the academic preparation which will enable them to do this?

While teacher preparation and methods may vary from country to country, a study of the literature reveals three major objectives of science education, viz:

a) to develop a knowledge of scientific facts and principles,

b) to develop critical thinking,

c) to help students to acquire an understanding of science and the scientific method.

The literature appears deficient concerning the objectives to which Australian science teachers aspire, as well as the procedures they use to attain these objectives. Again, there is little information on whether science students develop some desirable understanding of science regardless of the teachers' objectives. Fortunately, other countries have been active in this area. Dewey has said "education consists in the formation of wide-awake, careful, thorough habits of thinking" (21, p. 78). Many other educators have endorsed this judgement and some have added to or enlarged upon Dewey's work. For example, the Harvard Committee (37) reports that:

> . . . education is not merely the imparting of knowledge but the cultivation of certain aptitudes and attitudes of the mind. . . abilities (which) should be sought above all others---these are in our opinion to think effectively, to communicate thought, to make relevant judgements, to discriminate among values. (p. 64-65)

It is the hope of teachers that those constructing the new programs will not rely on past experiences but will bear in mind what the future citizens require in their training today as preparation for tomorrow. The statement of Hurd (42), addressed to educators in the

United States, is very pertinent at this point:

> A curriculum is needed that is oriented toward a period not yet lived, influenced by discoveries not yet made and beset with social problems not yet predicted. (p. 8)

Australian science education stands in need of evaluation of its teachers' objectives, methods and factors as well as the learning outcomes of the pupils.

The Problem

This study was an investigation of:

a) the preparation, methods and objectives of teachers who teach the graduating students in chemistry in secondary schools in South Australia,

b) three areas of learning outcomes of the graduating students, viz. critical thinking, understanding of science and achievement in chemistry,

c) the correlation between the students' achievement in chemistry and the other two learning outcomes, viz. critical thinking and understanding of science.

In addition the teachers were asked to indicate their thoughts on the present status of chemistry teaching and examining in the state. Information was also be sought concerning the students' intentions after graduation as well as their reasons for electing chemistry at the matriculation level.

The small number of teachers teaching matriculation chemistry in Roman Catholic schools made the division of the teachers into three groups statistically untenable. The teachers therefore will be grouped as Departmental and Non-Departmental.

There being no Non-Departmental matriculation students outside the Adelaide metropolitan area it was possible to divide the students into four groups for statistical analyses, viz. City Departmental, Country Departmental, Independent and Roman Catholic.

The following null hypotheses were treated statistically.

1) There is no difference in the teaching methods used by teachers in Departmental and Non-Departmental systems.

2) There is no difference in the objectives of science teaching held by the teachers in the two systems.

3) There is no difference in the teacher factors of the teachers in the two systems.

4) There is no difference in the critical thinking abilities of graduates from the four school groups, viz. City Departmental, Country Departmental, Independent and Roman Catholic.

5) There is no difference in the understanding of science between the graduates from the four school groups.

6) There is no difference in the achievement in chemistry between the graduates from the four school groups.

7) There is no correlation between the critical thinking ability and the understanding of science of the graduates from the four school groups.

8) There is no correlation between the learning outcomes and the achievement in the chemistry examination of the graduates from the four school groups.

Importance of the Study

Tertiary education in Australia was subject to intensive investigation in the years 1961-1964. This investigation resulted in the publication of the report on Tertiary Education in Australia (3). Concerning teacher education in Australia the report recommended:

> 4. viii) The Committee is convinced that both the increase in the supply of teachers and the improvement in the quality of the professional preparations are matters of urgency in the interest not only of the schools concerned but of the whole of the nation's educational structure.
>
> 4. xiv) The Committee believes that the academic preparation of graduate teachers should be improved if the question of the nature of university courses they are expected to complete were critically examined.
>
> 4. xv) The Committee is aware of what is being done in some states to provide courses of in-service training for teachers and considers that all authorities which employ teachers should make adequate

> provision for such in-service training. With the continuous expansion of knowledge in all fields it is essential that all teachers should attend refresher courses at regular intervals. (pp. 103-4)

In the light of the above recommendations it is important to have a record of teacher preparation, objectives and methods. It is especially necessary to have such a record of those teachers preparing students for tertiary education. It is also important that teachers not only be well qualified but willing to up-date their knowledge of the subject matter, as well as learn new methods of presenting their subject.

Last year, 1966, was the first year of the new matriculation syllabi in all subjects with the emphasis on a broad liberal education. As 1966 progressed it became increasingly evident that the "broad liberal education" was not being realized. Pertinent comments on this situation appeared in the main Adelaide newspaper, The Advertiser (15).

> Experience in most secondary schools seems to be that 1966 matriculation subject syllabuses have generally proved to be loaded beyond the capacity of all but the ablest student.
>
> The schools fear that the new matriculation examination is thus certain to produce more cramming and narrow academic specialisation in the last year at school--the very opposite of what recent reforms were said to be aimed at. (p. 2)

With regard to chemistry in particular, there were many letters to the editor of the South Australian Science Teachers Journal complaining about the unreasonableness of the examination.

The students' "papers in the matriculation examination were poor and they passed. What encouragement is there for a student to work hard when mediocre work gets a high grade? " (50, p. 41).

An editorial in the same journal said ". . . syllabuses are so vaguely worded that almost anything an examiner wishes may be read into them" (50, p. 2).

It is hoped that a questionnaire for chemistry teachers and a measure of the learning outcomes will be helpful in producing a constructive evaluation of the new chemistry syllabus. Those who formulated the new syllabus intended emphasis to be placed on the understanding and application of certain principles and concepts considered appropriate to students at this stage of their development in understanding chemistry.

The Questionnaire for Chemistry Teachers will further be able to give an indication of:

1) the extent to which the voluntary in-service courses have reached science teachers, (Since 1960 the South Australian Education Department has greatly increased the number of voluntary in-service courses.)
2) an evaluation of teaching objectives and methods which will provide evidence for the effectiveness of the recently increased teacher-recruitment drive in South Australia.

Delimitation of the Problem

The problem was delimited as follows:

1. The study is limited to teachers in the secondary schools of South Australia who teach chemistry at matriculation level.
2. The above delimitation is applied to students in secondary schools in South Australia enrolled in matriculation chemistry.

Procedures

In order to secure the necessary information a teacher's questionnaire was given to all those teaching matriculation chemistry in South Australia. This was done late in 1966 or early 1967 depending upon the time which was best suited to the teachers.

Early in the year, preferably within the first three weeks of the commencement of the term, the students were given the Questionnaire for Students, the Test on Understanding Science (TOUS) and the Watson-Glaser Critical Thinking Appraisal (WGCTA). Where possible the investigator administered the tests. Once the data were collected, they were analysed statistically. The information from the Questionnaire for Chemistry Teachers was divided into Departmental and Non-Departmental since the small number of Roman

Catholic teachers made statistical analyses invalid for a three group analysis.

The students' achievement in the Leaving Examination together with scores in TOUS and WGCTA were put on data cards for processing. Four groups of students were used, viz. City Departmental, Country Departmental, Independent and Roman Catholic. Each group contained approximately 200 students. This meant that students for the four groups were randomly chosen from all who participated. As well as the four horizontal groups indicated in Table 4 (p. 53) there were two vertical groups--boys and girls.

Since the TOUS and WGCTA are divided into sections it was possible to have an estimate of the over all responses for each section from each of the four groups of schools.

The statistical tests carried out were:

a) Chi-square: for analyses of data from the Questionnaire for Chemistry Teachers.

b) Chi-square for goodness of fit: to assure that the students' scores on the WGCTA and the TOUS are normally distributed.

c) Correlation co-efficients: to find the relation between student's scores on the WGCTA, TOUS and chemistry achievement examination (administered by the Public Examination Board of South Australia).

d) Analysis of variance: to determine the variation of scores on the WGCTA, TOUS and chemistry achievement examination of the students from each of the four groups as well as by sex.

e) t-test: to determine which cell or cells of the analysis of variance vary significantly.

Definitions and Explanations

Teacher Factors. The term as used in this survey refers to the following factors: academic preparation, years of teaching experience and membership in professional and scientific organizations.

Teaching Methods. Good (33) has defined a teaching method as "a rational ordering and balancing in the light of knowledge and purpose of the several elements that enter into the educative process, nature of the pupil, materials, and total learning situation" (p. 253).

The following methods were investigated in this survey:

1. Notes taken down by the pupils in class, i.e., notes dictated by the teacher.
2. Discussion based on topical assignments.
3. Lecture-demonstration combination.
4. Demonstration-discussion combination.
5. Laboratory with no discussion.
6. Laboratory-discussion combination.

7. No or little use of the laboratory.

Learning Outcome. The Dictionary of Education (33) defines "outcome" as a "change in behavior resulting from learning" (p. 381). The term learning outcome is used throughout the study to clarify the fact that the outcome mentioned resulted from learning.

Critical Thinking. This term has been defined in the Dictionary of Education (33) as "thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions as objectively as possible through consideration of all pertinent factors and the use of valid procedures from logic" (p. 570).

A list proposed by the Cooperative Study of Evaluation in General Education (25) sets forth the following abilities that appear to be related to the concept of critical thinking:

1) The ability to define a problem.
2) The ability to recognize stated and unstated assumptions.
3) The ability to select pertinent information for the solution of a problem.
4) The ability to formulate and select relevant and promising hypotheses.
5) The ability to draw conclusions validly and to judge the validity of inferences.

Understanding of Science. It is very difficult to formulate an adequate definition for this term and in the absence of such a definition Cooley and Klopfer (17) have analysed "understanding of science" into three components:

Area I. Understanding about the scientific enterprise.

Area II. Understanding about scientists.

Area III. Understanding about the methods and aims of science.

This analysis will be used in this study.

Basic Assumptions

In this survey it is assumed that:

1. the Watson-Glaser Critical Thinking Appraisal, Form Ym (WGCTA) indicates the student's ability to use critical thinking skills,
2. the Test on Understanding Science, Form W (TOUS) indicates the student's opinions and attitudes toward the scientific enterprise, the scientist and the methods and aims of science,
3. the teacher's responses to the Questionnaire for Chemistry Teachers reveal the objectives which the teacher planned to achieve,
4. the student's responses to the Questionnaire for Students reveal certain background information about the student,
5. it is possible for other factors not measured to influence the outcomes which will be investigated,

6. the WGCTA and TOUS, although prepared for American conditions, are equally valid in Australia.

The Instruments

Questionnaire for Chemistry Teachers. This questionnaire is basically that designed by Howe (40) to gain background information about the teachers in general as well as to ascertain objectives and methods used in teaching. Howe's questionnaire was adapted for use in this study and where possible statistical analyses have been made between the two groups of teachers, viz. those from Departmental and Non-Departmental schools.

Questionnaire for Students. This questionnaire was designed by the investigator to gather some background information about the students, e.g. age, subjects, future intentions and a reason for doing chemistry.

Test on Understanding Science (TOUS). This test was developed by Cooley and Klopfer from the Harvard University Graduate School of Education. The test used in this study, Form W, has been the result of extensive testing. In 1960 Form X was administered to 2,950 students in high schools throughout the United States. On the basis of item analysis, most of the weak alternatives were eliminated and Form W became the final form.

The TOUS consists of 60 multiple choice items and is in three sections:

Area I (18 items)	Understanding about the scientific enterprise, e. g. human element in science, communication among scientific societies, instruments, money, international character of science and society.
Area II (18 items)	Understanding about scientists, e. g. generalizations about scientists as people, institutional pressures on scientists and abilities needed by scientists.
Area III (24 items)	Understanding about the methods and aims of science, e. g. generalities about scientific methods, tactics and strategy in science, theories and models, aims of science, accumulation and falsification, controversies in science, science and technology as well as unity and interdependence of the sciences. (17, p. 3-4)

Watson-Glaser Critical Thinking Appraisal (WGCTA). This appraisal was developed in the late 'thirties and has undergone many changes. These changes have resulted from repeated experiments on various groups, item analyses, intercorrelation studies and analysis studies which were related to the concept and measurement of critical thinking.

The form of the test to be used in this study is Form Ym and consists of 100 items which cover areas of critical thinking.

Test 1 Inference (20 items). Samples ability to discriminate among degrees of truth or falsity of inferences drawn from given data.

Test 2 Recognition of assumptions (15 items). Samples ability to recognize unstated assumptions or presuppositions which are taken for granted in given statements or assertions.

Test 3 Deduction (25 items). Samples ability to reason deductively from given statements or premises; to recognize the relation of implication between propositions; to determine whether what may seem to be an implication or a necessary inference from given premises is indeed such.

Test 4 Interpretation (24 items). Samples ability to weigh evidence and to distinguish between (a) generalization from given data that are not warranted beyond a reasonable doubt, and (b) generalization which, although not absolutely certain or necessary, do seem to be warranted beyond a reasonable doubt.

Test 5 Evaluation of Arguments (15 items). Samples ability to distinguish between arguments which are strong and relevant and those which are weak or irrelevant to a particular question at issue. (81, p. 2)

Watson and Glaser (81) consider the ability to think critically to involve three things:

1) An attitude of wanting to have supporting evidence for opinions or conclusions before assuming them to be true.

2) Knowledge of the methods of logical inquiry which help determine the weight of different kinds of evidence and which help one to reach warranted conclusions.

3) Skill in employing the above attitude and knowledge.

Briefly, a critical thinker effectively examines beliefs or proposals in the light of supporting evidence, of the relevant facts in the case, instead of jumping prematurely to a conclusion. In general, critical thinking requires that one be able to comprehend and use language for accurate and discriminating communication of thought. It should recognize the existence (or non-existence) of logical relationships between propositions, interpret data and draw warranted conclusions or generalizations, appraise the adequacy and worth of alleged evidence, weigh such evidence and judge the different degrees of probability of certain conclusions, recognize unstated assumptions, and evaluate arguments.

II. REVIEW OF LITERATURE

Objectives and Methods for Science Teaching

The last three decades have seen a considerable amount of literature published about the process and product of science teaching. Many summaries of the literature have been made by workers in the United States of America and the United Kingdom. In the former country a comprehensive volume of work has been published through such agencies as the National Science Foundation and the Office of Education. In the United Kingdom the Nuffield Foundation has been prominent in science educational research.

For the field of science education, objectives can be found in Educational Policies Commission (57); National Society for the Study of Education, 46th (59) and 59th (58) Yearbook; and Progressive Education Association (66). Some individuals writing on the subject are Obourn (61), Curtis (20), Hurd (41), Saunders (69), Olsen (63), Barnard (6), Lewis (51), Meyer (55) to name but a few.

The most important contribution to the study of objectives in education in recent years has been Bloom's (10) Taxonomy of Educational Objectives. This major work divides objectives into six categories: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. It has been widely used in evaluations concerning curriculum as well as examinations.

With the present emphasis on science teaching it is of interest to know that the modern objectives do not differ radically from those of several decades ago.

Noll (60) in 1933 stressed the importance of the acquisition of sound thinking habits, and after making a survey he concluded that the students should develop good habits in accuracy in operations, intellectual honesty, open-mindedness, suspension of judgements in light of insufficient facts, looking for cause and effect relationships as well as good habits in criticism.

Following closely behind the work of Noll the Science Master's Association (S. M. A.) of Great Britain in 1938 (27) listed "specific features with which the teaching and examining of science should be concerned" (51, p. 187). The list was in two parts; the first dealt with acquisition of scientific information and knowledge while the other was concerned with the development of scientific modes of thought. The latter bore a very close relationship to those listed by Noll.

Lewis (51) in his review says that the work of Frutchley and Tyler in 1937 added little to the work of Noll and the S. M. A. Lewis (51) also said that the work of Kesslar in 1945, which was conducted with only university students in mind was "unduly ambitious" (p. 189).

Burmester (11), in a survey describing the behavior patterns of students with and without a considerable scientific ability, produced the following as characteristic of able students:

1. Ability to recognize problems.
2. Ability to delimit a problem.
3. Ability to recognize and accumulate facts related to the solution of problems.
4. Ability to recognize a hypothesis.
5. Ability to plan experiments to test a hypothesis.
6. Ability to carry out experiments.
7. Ability to interpret data.
8. Ability to apply generalizations to new situations. (11, p. 260)

This list was constructed with university science courses in mind and parallels the list by Kesslar (47).

Wrigley and Kerr (86) found that there was a contrast between the objectives of science teaching as visualized by practicing science teachers and those in administrative or advisory capacity. It is the teachers' task to start from the students' insight and actively widen the students' experience. The objectives were divided as shown.

Mental Discipline	a) To form habits for accurate observation.
	b) To promote habits of clear thinking.
Utilitarian	c) To pass an examination.
	d) To help pupils to decide future career.
	e) To give basic training for future career.
	f) To teach factual information of value in everyday life.
Cultural	g) To satisfy child's natural curiosity.
	h) To develop an inquiring interest in common things and experiences.
	i) To experience the intellectual

enjoyment of seeing the pattern of nature revealed by scientific study.

j) To ensure that modern society appreciates the significance of scientific development. (p. 60)

Wrigley and Kerr (86) found that the teachers in the schools rate the above aims differently from one type of school to another. Those teachers from grammar schools considered objective "b" to be the most important while the teachers from technical and modern schools had as their main aim "e" and "h" respectively.

Although the present objectives of science teaching can be seen to be basically similar to those of Noll (60) a trend can be seen in a broadening of such aims, e. g.

1) greater recognition of levels of development, cf. Piaget, Kerr and Neal (46),

2) science as an essential part of our culture,

3) emphasis on principles rather than memorization.

The objectives of science teaching in Australia do not vary from those overseas as is evidenced by the statement of Stanhope (74) on the objectives for chemistry teaching. In particular they were:

a) the acquisition of a functional understanding of important chemical facts, concepts, laws and principles,

b) the ability to use the methods of chemistry in the solution of problems of concern to the individual, the community, the nation and the world, and

c) the development of desirable attitudes, appreciations and interests. (p. 7)

Meyer (54), following up a study which he did in London, made a study of the relationships between attitude and general scientific knowledge of high school students in Sydney. Some assessment was also made of the influence parents' attitudes had on their children. The findings were:

1) Boys and girls in Sydney were interested in and had good attitudes towards science.
2) Sydney students showed less inclination to lose interest in science as they approached the minimum leaving age (15 years) than their counterparts in London.
3) There should be a broadening of the variety of scientific experience at all ages.
4) Favorable attitudes toward science were closely linked to the attitudes held by the parents.
5) The type of school attended had little or no bearing on the levels of scientific attitude or interest.
6) Students liking science liked chemistry most, while students disliking science disliked chemistry least.

In an extensive study on objectives and examinations in chemistry in all states in Australia, Morris (56) found that examiners stressed a grounding in facts, a sound understanding of principles, an ability to use these principles and the ability to use the method of scientific enquiry. Despite this laudable list the examinations, when classified according to Bloom, revealed that 64% of the questions were at Knowledge level, 11% at Understanding level, 24% at Application level, leaving only 1% at the more advanced levels. To make matters worse the examiners prepared examinations which were apparently aimed at future university undergraduates with a consequent neglect of broader demands of everyday living. In the Australian examination-dominated secondary schools it is little wonder that students would tend to acquire objectives in proportion to the stress which the examination places on them.

Sound educational objectives are known, and indeed adopted wherever and whenever possible. However, teachers in Australia are continually faced with issues, inherent in the educational system, which limit the opportunities necessary for constant pursuit of desirable objectives. Three of the more obvious issues are:

1) Syllabi invariably have no aim listed.
2) Teachers are bound by the limits of the syllabus.
3) Threat of the public examination inhibits a widening of the scope of the subject matter.

It is not surprising that the "educational system" is subjected to adverse criticism. At a recent science teachers' conference in Brisbane, Professor Bassett (7) of the University of Queensland said:

> Educational aims in Australia seem to be in the realm of the taken-for-granted. They are something that one just knows, that one just accepts. It sounds almost an impertinence to ask what they are. If you press people for statements about what they are trying to do in education in Australia, they may come to some such idea as giving people opportunity to get on in the world, or to pass examinations. (p. 9)

Sir Marcus Oliphant (62) has voiced a similar opinion.

> It is difficult to escape the conclusion that Australian education falls far short of our real needs in both quality and content. One of the gravest dangers we face is that of the dull uniformity imposed on education in this country by centralized control. (p. 16)

It is of interest to note the impression which the Australian "educational system" had upon a visiting American Professor, R. F. Butts (13).

> On all sides I felt that the Departments of Education do not really trust teachers to teach well, to keep students up to standard, or to develop the curriculum without constant supervision and inspection from above. The assumptions of a centralized system that a uniform policy must be achieved and that the basic decisions should be made by a relatively few persons in head offices reflect this lack of confidence in teachers. (p. 75)

Of the teachers, Butts (13) said:

> I found relatively little concern among teachers or inspectors to re-examine fundamentally their practices or assumptions. I did not find a widespread eagerness to think hard and long about the theory of education. (p. 90)

Fortunately the last few years have seen a big improvement in the status of science education in all states. The influence of overseas curricula has been evidenced by the adoption of P. S. S. C., Chem. Study., C. B. A., and B. S. C. S. (Blue Version) in some states. See Table 2.

At the same time several states have increased the period of secondary school study required for matriculation. This has resulted in the formulation of new syllabi at all levels with greater flexibility. This in turn has put enthusiasm into teachers as is seen by the large increase of in-service courses.

Table 2. A distribution of the use of overseas science courses in Australian high schools.

State	Course	Grade taught
Queensland	Chem. Study	11, 12
New South Wales	C. B. A., Chem. Study	11, 12
Victoria	B. S. C. S. (modified)	11, 12
	C. B. A., Chem. Study	12
	P. S. S. C.	11, 12
South Australia	B. S. C. S. (modified)	12
Western Australia	Chem. Study (modified)	11, 12
Tasmania	B. S. C. S. (modified)	11

Pennington and Doherty (64) have stated the aims of the new science syllabus in New South Wales as follows:

> Firstly there are cognitive aims:
> To give the pupils a knowledge of the broad and related principles of science and the ability to use these principles to interpret the material world for themselves.

> To have the pupils understand, practice and evaluate the method and habit of mind adopted by scientists in solving problems in the field of science.
>
> To have the pupils understand and evaluate the changes that modern science, by its applications and attitude, has brought to society and may bring in the future.
>
> Secondly, there are two affective aims:
>
> To maintain and promote pupils' wonder and curiosity concerning their material environment.
>
> To develop the pupils' appreciation of the value of science. (p. 12)

Even examiners are becoming cognizant of the "new" objectives. Whereas examiners "have traditionally demanded copious floods of detailed factual knowledge" (55, p. 146), they are at present considering "current ideas on educational objectives; on the impact of examinations on the teaching system; on testing procedures and on present trends in the sciences themselves" (55, p. 152). It is pleasing to know that examiners are being made more aware of the implications of the new syllabi. However, the problem of setting examinations to examine learning as influenced by the objectives is quite a different problem. Fensham (29) found there was difficulty in setting questions which adequately tested those objectives which underlay the teaching. The results suggested "that a single paper of the type given gave results which did not reflect the aims of the examiner" (p. 103).

The consistent fervor in science education will undoubtedly result in continuous evaluation of existing programs. Each evaluation will probably produce changes in content and possibly methods. Perkins and Conover (65) frequently met resistance to change in science curriculum and this resistance was not limited to professional spheres. Australian curriculum designers likewise will experience resistance, but hopefully this will be minimal.

Teacher Preparation

The Tertiary Education in Australia report (3) mentioned that the rapid advance in scientific knowledge posed great problems in keeping abreast of current events. In chemistry alone the number of scientific publications doubled during the eight years from 1953 to 1961. The present rate of accumulation of chemical knowledge is such that every three years as much chemical information is produced as during the entire nineteenth century. It becomes obvious that the teaching of scientific principles at all levels of education must become increasingly more important. Studies done by Johnson (43), Tyler (78) and Wert (83) indicate that facts are forgotten rapidly, whereas principles are retained over a long period of time.

Some aspects of teacher preparation have already been mentioned (23, 77), but it is certain that much thought has yet to be given to sound teacher-preparation programs.

Doherty (22) made a survey on what characteristics successful teachers possessed. He found by observation that such teachers were enthusiastic about their teaching and their subject. They also had a clear concept of their objectives, as well as the ability to organize themselves and their pupils.

Teacher preparation programs must be formulated in the light of the objectives for science teaching. Hence, trainee science teachers should have courses in subject fields, history and philosophy of science, social relations of science, relationship of science to other disciplines and professional subjects.

Doherty (22) suggests that the future teacher have:

> - a broader and deeper understanding of the general characteristics of science and its relation to other aspects of society - a clear and precise understanding of his changed educational objectives - a clearer and more functional understanding of modern educational principles and methods - an acceptance of the reality of change in science and education and his responsibility to keep abreast of it. (p. 52)

Science teachers should not only have the above preparation but should be well qualified academically. Too often the highly qualified science graduates are lost to teaching. Wilkinson (84) attributes this partly to the fact that the teaching profession is unattractive to the good honors graduate. Some of the facts about science teaching which Wilkinson said made it unattractive are:

1) There is loss in prestige to be a teacher.

2) Teaching is repetitive and leads to unhealthy mental habits.

3) There is no availability to do research in his subject field.

4) There are infrequent opportunities to make contributions in the teaching of his own subject.

A closer liaison between high school teachers, teachers' college and university lectures in subject matter and teaching methods would be helpful. The availability of research equipment in universities at night and holidays would also be helpful in bridging the gap between the research scientist and the science teacher.

Much experimentation has yet to be done with respect to teacher preparation to bring it into the same light of understanding as exists in other areas of science education.

The June, 1965, issue of the Journal of Research in Science Teaching was devoted to a comprehensive coverage of secondary school science teacher preparation programs at 15 campuses throughout the United States. The programs had many points in common but all attempted to deal with the current issues in science education.

Appreciation and Understanding of Science

Studies by Mead and Metraux (52) and Baker *et al.* (5) revealed that high school pupils did not have a positive attitude toward the image of a scientist and his work. Allen (1) was motivated to design an inventory to determine the attitudes of high school pupils toward science and scientific careers. He was especially interested in those attitudes which might act as deterrents to an occupational choice in some branch of science.

From interviews with scientists and a survey of current periodicals as well as the noting of degrading statements appearing in the literature, Allen developed a 95-item inventory. The statements contained in this inventory were classified into five categories: 1) The Impact of Science on Society, 2) The Impact of Society on Science, 3) The Scientist, 4) Scientific Work, 5) The Nature of Science.

The inventory was submitted to a panel of scientists to determine the most desirable responses of the students. For the most part Allen (1) found that the high school pupils had some positive and constructive attitudes toward science.

In a follow-up study two years later using the same test items, Allen (2) found that there was more agreement with the scientists' responses on ten items pertaining to the scientist and his work as well as the nature of the scientific enterprise than on the same items previously. Concerning students' attitudes toward science and scientific careers Allen (1) made the following statement:

> 1. Perhaps the most important area of need disclosed from this study was the evident misunderstanding and ignorance of the nature of science. . . Systematic attempts at every grade level should be made to help young people comprehend the meaning of facts, concepts, theories and principles used in scientific endeavor.
>
> 2. The image of a scientist held by young people at any given time is a consequence of previous experiences in school and out.

> 3. There is considerable misunderstanding and ignorance among young people as to the actual impact of science on society and the impact of society on science. (p. 38)

When Howe (40) used Allen's inventory (1), but modified slightly, he found that the attitudes of the students changed in the direction of the attitudes possessed by their teachers. Some of the students possessed attitudes which lacked information concerning the scientific endeavor and the status of science.

Allen has not been alone in an attempt to assess high school pupils' attitudes to science. Belt (8) found from Likert-type statements and the Purdue Opinion Panel, that relatively high ability pupils have more favorable attitudes toward science and scientists than do a representative cross section of high school pupils.

Gatewood (30) found that the Oklahoma State University Traveling Science Program was ineffective in producing favorable attitudes toward science; however, he used the Purdue Opinion Poll in his study and remarked that, although the poll had been validated in 1957, it could be that opinions have changed sufficiently to invalidate the poll.

Of the public's lack of understanding of science much has been said over a long period of time. Sherburne (71) epitomizes this situation in a recent editorial in Science.

> Budgets can suggest very interesting questions about program needs. The National Science Foundation,

> in its current budget, allots $400,000 to furthering public understanding of science. Examination shows that this item has increased only slightly since its first appearance in the budget in 1959. Meanwhile, the total budget for the Foundation, which includes funds for basic research, for graduate fellowships and for improving science curricula, amounts to about $430 million, an increase of some 600 percent over 1959.
>
> Individual laymen have no one, except perhaps the more responsible representatives of the mass media, to whom to turn for the holistic point of view that the citizen needs.
>
> There is remarkably little formal assumption of responsibility by government agencies for informing and educating the public about problems, and solutions, to which scientific research gives rise. (p. 381)

Schwab (70, p. 44) has said that the "need for an informed public is a crucial one. Only the secondary school is in a position to assume fulfillment of the needs for an informed public." Too often the school or the teacher is blamed for this lack of an adequately informed laiety. This blame must be shared by the textbook writer and publisher as well (36, 75).

Conant (16) in discussing the necessity for an understanding of science by all citizens said:

> . . . the remedy does not lie in a greater dissemination of scientific information among non-scientists. Being well informed about science is not the same as understanding science though the two propositions are not antithetical. What is needed is methods for imparting some knowledge of the tactics and strategy of science to those who are not scientific. (p. 4)

Before methods can be developed it is necessary to find areas in which the difficulties lie. To this end Klopfer and Cooley (48) designed a study which demonstrated that understanding of science can be significantly increased with little or no loss of attainment in usual subject matter. These researchers used 2, 535 students to investigate the gain in the understanding of science by pupils taught by case study materials as compared with those pupils who had no case study materials. The special criterion instrument designed for the analysis was Form X of the Test on Understanding Science (TOUS). The authors found no significant difference in the understanding of science in the chemistry and physics groups of pupils but did find a significant difference in the groups of pupils doing biology.

Cooley and Klopfer (18) in the summer of 1960 found that a group of 78 talented high school students, having been in active contact with working scientists, changed significantly in the direction of correct responses.

Smith (72) and Craven (19) found that at the high school and college levels respectively, the boys had significantly better TOUS scores than did the girls.

Renner (67) in a study involving more than a thousand pupils concluded that the pupils in junior high schools regressed in the understanding of scientists' work while they gained in the understanding of the work of an engineer.

In a study involving high school seniors, Hamilton (35) found that scientific literacy was dependent on mental ability and was affected by environment. However, there was no difference in the scientific literacy of boys and girls, whether resident in urban, sub-urban or rural areas.

In a study involving critical thinking abilities and understanding of science, Smith (72) found that the boys had better scores from tests measuring critical thinking ability and understanding of science than did the girls. The correlation coefficient between the two tests for the boys was 0.62 while that for the girls was 0.11.

Critical Thinking Ability

Since the beginning of the 20th century educators have been emphasizing the necessity for pupils, in science especially, to think scientifically. Today the term "scientific thinking" has been re-placed by the term "critical thinking". As early as the 1930's Downing (24) had constructed tests to measure students' ability to think scientifically. Since this time several tests have been designed to measure critical thinking abilities. Perhaps three of the better recognized tests are:

1. American Council on Education Test of Critical Thinking.
2. Induction, Deduction, Semantics Critical Thinking Test.
3. Watson-Glaser Critical Thinking Appraisal.

Each of these tests has been subjected to varying degrees of testing for validity, and each has undergone changes over a period of years.

Concerning the importance of critical thinking Edwards (26) has stated:

> Development of the ability to do critical thinking is generally regarded as one of the most important aims of education at all levels and in all areas; . . . understanding must be present before there can be critical thinking and that critical thinking is essential for both the scientific method and to correct the solution of problems. (p. 263)

Although critical thinking is an accepted objective of education, the meaning of it is frequently unclear. Wallen, Haulick and Reid (80) have said that it encompasses the following features:

1. The use of scientific methods including emphasis on evidence and the nature of hypotheses.
2. The tendency to be inquisitive, critical and analytical with respect to issues, personal behavior, susceptibility to propaganda.
3. Use of correct principles of logic. (p. 529)

Wellington and Wellington (82) consider that a talented teacher is able to bring about critical thinking by successfully combining subject matter with the needs of the pupils.

Dressel and Mayhew (25) in reviewing the status of research in critical thinking made the following observations:

> Much of the research accomplished has been divorced from teaching practice. . . . Perhaps the first step in the development of major research in this area is for teachers to become concerned about the development of thinking on the part of their students. (p. 180)

Glaser (32) who is a respected worker in this area has stated:

> Such evidence as there is points to the development of critical thinking as a long term task in which but small gains will be shown for any particular course. It is, therefore, of utmost importance that fostering the ability to think critically become the aim of all teachers for the entire period of the student's schooling. (p. 419)

Burton, Kimball and Wing (12, p. 243) concluded from a variety of studies that "knowledge of the principles in a particular field of knowledge in no way assures that these principles will be properly applied in problem solving situations". This conclusion is somewhat supported by Ennis (28) who stated that "people who are good critical thinkers in one area are not so in another" (p. 18).

Dressel, et al. (58, p. 39) reviewed several studies and discovered that success in science showed high correlations with verbal reasoning, numerical ability and certain aspects of language usage.

Several studies have been made to discover methods by which critical thinking could be taught. Graham (34) found that students at the college level, when taught by student centered methods, showed significant gains in critical thinking, (as measured by the WGCTA) over students taught by teacher centered methods. There were also more favorable attitudes between instructors and students in the student-centered groups.

In a study by Charen (14), open-ended experiments of the Manufacturing Chemists Association were used in an experimental group as opposed to traditional experiments in a control group. He found no significant difference in gains of critical thinking ability in either group. He also found that it had been difficult to test for the crucial attributes of critical thinking. In elaborating further he said:

> Identification of these attributes is important in any effort to compare the effectiveness of different teaching procedures in achieving this ability. More sensitive measuring instruments in this area are a prerequisite for conclusive research. (p. 189)

The study of Lee (49) supports that of Charen. Lee used problem solving methods to teach critical thinking. He also found that low achievers benefitted most from this method of teaching.

Herber (39) concluded from his survey that the ability to think critically can be improved and that the variables of sex, grade level and course do affect development of critical thinking. He also found that instruction in critical thinking strengthens vocabulary and comprehension as well as accuracy in reading.

Dewey (21, p. 78) has said "education consists in the formation of wide-awake, careful, thorough habits of thinking". However, while there is almost unanimous agreement that the major aim of education should be teaching pupils to think, many authorities have been more than sceptical about the realization of this aim. Burton, Wing and Kimball (12) have said that despite the stress placed on teaching to think, results have been negligible.

Kastrinos (45), using a critical thinking approach to the teaching of high school biology, found significant changes for the better in the critical thinking ability of his pupils.

Sorenson (73) also has shown that critical thinking ability can be significantly improved when this is the criterion for which the teacher specifically taught.

Craven (19) has shown that there is a negative correlation between critical thinking abilities and grade points earned in science at college. This infers that the mere taking of science courses does not insure an ability to think critically.

In another study involving college students George (31) found that science-education and mathematics majors were significantly better on a list of critical thinking than all other academic majors.

Dressel and Mayhew (25) reported that when teachers tried to modify their technique to achieve better critical thinking ability, there were only slight gains. They stated that minor changes in techniques imposed upon a course where the major emphasis remains on coverage of content are inadequate to the problem.

Teaching Methods

There are many texts available which deal with the methodology of science teaching. Of those texts available Richardson's (68) Science Teaching in Secondary Schools is very widely used, with two more up-to-date texts becoming well accepted, viz. Thurber and

Collett's (76) Teaching in Today's Schools and Woodburn and Oburn's (85) Teaching the Pursuit of Science.

The above mentioned texts are suited to science in general while the two texts of Brandwein *et al*. (44) (55) deal with methods in physical and biological sciences separately. The teacher's manuals published in conjunction with many new courses are more specialized again.

While the afore-mentioned texts deal with a variety of methods and experiments in the many disciplines there are at least two dominant themes, viz. student activity and student discussion. It is possible in the methods literature to find a trend over the last half-century from experiment-pupil centered methods to teacher-demonstration methods to experiment-pupil-discussion methods.

Audio-visual aids have become popular, especially the use of films and closed circuit television; however, the consensus is that pupils perform equally well when taught by conventional methods. Films and television have a limited use, being dependent upon the availability of finance and the teachers' ability to use these aids effectively.

In order to gain specific learning outcomes one must solve the question of which methods and patterns of pupil behavior are related, not which method is best for the teaching of science. This is supported in a study by Bibergall (9) who found that the discovery techniques have severe limitations when high motivation is desired or when transfer or recall is the objective.

There is no scarcity in the field of chemistry of the number of texts available for high schools throughout the English speaking countries and possibly elsewhere. Both the new texts and modified established texts have adopted, to varying degrees, the approach to teaching advocated in the publication of the C. B. A. and CHEMS programs. The aim of both these programs is broadly one of applying principles rather than submitting students to a great deal of memorization. These principles are those induced or deduced by the students from observations made in the laboratory via the method of questioning, experimentation and hypothesizing. Both allow the student to formulate and weave isolated facts into a meaningful pattern or structure whereby he is, ideally, better able to comprehend chemistry.

Such objectives are very important. However, it has been noted in the United States that in both these new programs the reading level is beyond that of the average student and the principles to be grasped from the various experiments are in many ways too cryptic. In short, they are catering mainly for the more able students. On the other hand, one must bear in mind that the new courses were never designed to be followed religiously or that all the material contained in them had to be covered in class; a great deal of the success is a matter of individual teaching (79).

Before the C. B. A. and CHEMS era, Harriman (36) and Summers (75) conducted extensive studies in the area of "textbook content". Harriman found that current chemistry texts contained topics more nearly similar to those in 1924 standard courses than those in the standard course developed in 1959. Summers reported that such basic concepts as nomenclature and theories were badly outmoded. A glance at texts printed since 1965 reveals a marked trend toward overcoming the above inadequacies.

Whether a text is well planned or poorly planned the success of the lesson or course depends largely upon the enthusiasm of the teacher and the method/s used in presentation of the subject matter.

It is a tremendous task to produce material which will adequately cater for the needs of all high school students. The new programs and texts in Australia, as well as the United States, are encompassing the modern trends in science education to meet the needs of an increasing number of students.

Conclusion

Since the quantity of literature relating to the topics of this review is very extensive, only a representative sample has been reported. From this sample it would appear that the objectives of science education are basically to teach facts, thinking and understanding. These fundamental objectives remain constant; what varies is the human element wherein different emphases and extensions become manifest as they are translated to varying circumstances.

It is evident that the teaching methods reflect the current objectives. Although the teaching methods used today (with the exception of certain audio-visual aids) vary little from those used several decades ago, the emphasis is on student participation. This is a reflection of the emphasis placed on creative thinking and understanding of science.

Considerable attention has been given to the problem of defining and clarifying the thinking process. Critical thinking can be taught but the mechanism by which people think remains a problem.

Appreciation for and understanding in science can also be taught and must assume a more important role in educating children for a technological age.

III. THE STUDY

This is the first study of this kind and extent to be conducted in an Australian state. The study involved approximately 85% of the students doing matriculation chemistry in South Australia and the same percentage of chemistry teachers. It is hoped that this study will be profitable in evaluation of present syllabi and that information obtained will be valuable in the construction of future syllabi.

The Instruments

Questionnaires. The Questionnaire for Chemistry Teachers was basically that designed by Howe (40) to gain background information about the teachers in general as well as to ascertain objectives and methods used in teaching. Howe's questionnaire was adapted for use in this study and where possible statistical analyses have been made between the two groups, viz. the Departmental and Non-Departmental schools. The Questionnaire for Students was a simple list of questions designed by the investigator which gave some background information about the pupils and their future intentions.

The validity of the responses to the student questionnaire was spot-checked by discussing some of the student responses with the teachers, who considered that they were a true reflection of the students concerned.

Because the teacher questionnaire was anonymous the validity of the responses was not as readily verified; however, since some of the teachers returned the questionnaire personally, it was possible to discuss replies with them to ensure that the questions were not ambiguous.

Watson-Glaser Critical Thinking Appraisal (WGCTA). The WGCTA Form Ym was used to evaluate the critical thinking ability of of the students.

Helmstadter (38, p. 256) in reviewing forms Ym and Zm said that the former was superior and that it "represents a highly professional attempt to measure an important characteristic".

The split half reliability coefficients ranged from 0.85-0.87 in a survey (81) involving 10,114 high school students. In this survey there was a positive correlation with the Otis Mental Ability Tests: Gamma (0.75). In another study (81) involving 378 Freshmen at a liberal arts college there was a positive correlation with the College Entrance Examination Board, Verbal (0.54) and Mathematics (0.43).

The WGCTA Form Ym represents 25 years of study, research and experimentation on the measurement of critical thinking abilities. This form consists of a series of test exercises which require the application of some of the important abilities involved in critical thinking. There are five subtests designed to measure different, though interdependent, aspects of critical thinking. The five subtests are:

Test 1. Inference

Test 2. Recognition of Assumptions

Test 3. Deduction

Test 4. Interpretation

Test 5. Evaluation of Arguments

Test on Understanding Science (TOUS). This test was developed by Cooley and Klopfer from the Harvard University Graduate School of Education. The test used in this study, Form W, has been the result of extensive testing. In 1960 Form X was administered to 3,000 students in high schools throughout the United States. On the basis of item analysis, most of the weak alternatives were eliminated and Form W became the final form.

The TOUS consists of 60 multiple choice items and is in three sections: Area I. Scientific enterprise. Area II. The scientist. Area III. Methods and aims of science.

Standardization data from 2,535 high school students gave by means of the Kuder-Richardson formula an over all reliability of 0.76.

During the month of October, 1960, both the TOUS and the Otis Mental Ability Test, Form Am, were administered to 2,950 high school students in grades nine through twelve. The product moment correlation ranged from 0.64 to 0.69, indicating a moderate positive correlation.

Population and Procedure

The teachers and pupils who participated in this study came from the Departmental, Independent and Roman Catholic schools in South Australia. The teachers and pupils represented approximately 85% of the school population.

In order to obtain permission to enter the Departmental schools the Superintendent for High Schools was approached. The study was explained in detail to the Superintendent who willingly consented. He then sent a letter to all Principals briefly outling the project and informing them that official permission had been given to conduct the survey.

Because of the limited number of testing materials, the country schools received the tests after they had been administered to the city schools.

Permission to conduct the survey in the Independent and Roman Catholic schools was obtained by contacting the Principal of each school. All the Roman Catholic schools teaching matriculation chemistry were contacted and all agreed to participate. In the case of the Independent schools all agreed to participate but some schools had less than ten students doing matriculation chemistry. These schools were deleted from the survey because of administrative difficulties.

The number of teachers responding to the questionnaire was as follows: Departmental 40, Independent 17, Roman Catholic 6. The number of students participating is found in Table 3.

Whenever possible the investigator administered the WGCTA and the TOUS personally but on several occasions this was not possible because there was more than one school doing the tests at one time. In circumstances where the class teachers had to administer the tests, duplicated instructions were provided for the teacher to follow. No problems arose due to lack of interpretation of instructions. The whole testing program was executed very smoothly.

Table 3. Distribution of all participating students by school group.

Sex	Departmental City	Departmental Country	Independent	Roman Catholic	Totals
Boys	899	131	280	209	1,519
Girls	296	63	45	20	424
Total	1,195	194	325	229	1,943

Because the number of students in each of the four groups of schools differed greatly (see Table 3), it was decided to limit, for statistical purposes, the number of students in each group to approximately 200.

In order to have a true assessment of the learning outcomes as listed, it was decided to eliminate those students who were repeating the year as well as those who had not presented themselves for recent South Australian public examinations, i.e. those students from inter-state or overseas.

Very few of the Departmental students were eliminated according to the above criteria. This meant that the sample of city students was obtained by selecting in alphabetical order every sixth student, resulting in a group of 198 students. The country schools suffered no loss due to elimination and this sample comprised 194 students. The elimination process reduced the Roman Catholic students to 200, so that no further selection was necessary. The Independent students, after eliminations, were reduced to a total of 186. Table 4 shows the final figures.

Table 4. Distribution of the student sample used in the survey, by school group.

Sex	Departmental City	Departmental Country	Independent	Roman Catholic	Totals
Boys	150	131	162	180	632
Girls	48	63	24	20	159
Total	198	194	186	200	791

Data Analysis

As mentioned previously (p. 10) the small number of Roman Catholic teachers necessitated that they be grouped with the Independent teachers. Hence, the responses to the teacher questionnaire were treated as Departmental and Non-Departmental. The chi-square test was used to determine any significant difference in the responses to the teacher questionnaire.

The responses to the student questionnaire were simply tabulated both numerically and as percentages. No statistical tests were applied.

The large number of students in the study warranted the use of a computer to process their scores. Each student had a data card on which was punched the code number of the school group, the number for male or female, a student number, followed by his or her WGCTA, TOUS and achievement scores. An analysis of variance (2x4) was applied to each of the three scores. If the F-values were significant then t-tests were applied to establish which cells were significantly different. Correlation coefficients between the scores were also computed.

IV. RESULTS AND DISCUSSION

The results of the study have been assembled under the heading of the questionnaire or test concerned. A discussion accompanies the presentation of the results in each case.

Questionnaire for Chemistry Teachers

Because of the nature of the questionnaire it was convenient, for discussion, to divide it into four sections as follows: a) Items 1-6, b) Item 7, c) Item 8 and d) Items 9-18. Each of these sections fulfills a different function. The results are summarized in Tables 5 through 11.

Items 1-6: The responses to these items are to be found in Table 5, and from this table it can be seen that two of the seven chi-square values are significant.

Basically there is no significant difference in the amount of teaching experience of the teachers in the two systems. However, the table does reveal a large proportion of Departmental teachers with up to ten years teaching experience compared with a more even distribution of teaching experience for the Non-Departmental teachers. This variation is attributable to the fact that competent young Departmental teachers are promoted to administrative positions, whereas in Non-Departmental schools promotion is very limited.

Table 5. A Summary of Items 1-6 of the Questionnaire for Chemistry Teachers.

Item		Department Number Replying	Department %	Non-Departmental Number Replying	Non-Departmental %	Total Response Number Replying	Total Response %	Chi-square value
1. School system		40	64	23	27	63	100	
2. Years Teaching	a) less than 5	16	40	5	22	21	33	6.94
	b) 5-9	16	40	6	26	22	35	
	c) 10-14	3	8	4	17	7	11	
	d) 15-19	3	8	4	17	7	11	
	e) over 19	2	5	4	17	6	9	
3. a Degree	a) Yes	39	98	21	91	60	95	0.26
	b) No	1	3	2	9	3	5	
b Chemistry Major	a) Yes	39	98	22	96	61	97	0.11
	b) No	1	3	1	4	2	3	
4. a Professional Courses	a) Yes	38	95	12	52	50	79	13.9*
	b) No	2	5	11	48	13	21	
b Method Courses	a) Yes	37	93	12	52	49	78	11.5*
	b) No	3	8	11	48	14	22	
5. In-Service Course	a) Yes	33	83	22	96	55	87	3.59
	b) No	7	18	1	4	8	13	
6. Professional Organizations	a) Yes	34	85	21	91	55	87	1.23
	b) No	6	15	2	9	8	13	

*Significant at the one percent level.

Only three of the total of 63 teachers did not possess a university degree. Of these, one had begun but not completed a degree course, one had a pharmacy diploma while the other had some training in a Roman Catholic college. The teacher with the pharmacy diploma was considered for the purpose of the study to possess a chemistry major, hence it was that only two teachers, one from each system, did not have a chemistry major. These two teachers had completed some chemistry at the tertiary level.

Concerning the amount of professional training which these matriculation teachers have had, it is noted that there is a significant difference between the two systems. The Departmental teachers are required to do both professional and method courses before becoming certificated. In contrast the Non-Departmental schools place no rigid requirement in this area although they consider some professional preparation desirable.

Item five reveals that a higher percentage of Non-Departmental teachers attend in-service courses. This could be, to some degree, explained by the fact that about ten of the Departmental teachers were resident in country areas and hence would find it difficult to attend such courses.

Professional organizations are well supported by the teachers, with 85 percent Departmental and 91 percent Non-Departmental teachers being members.

On the basis of the information contained in Table 5 it is safe to accept the null hypothesis, viz:

There is no difference in the teacher factors of the teachers in the two systems.

Item 7: The responses to this item were not as consistent as were those of the other items because all teachers did not answer all parts. The item deals with materials and aids used by teachers and is summarized in Table 6. This table reveals that, with one exception, the use of materials and aids by Non-Departmental schools was very similar to that of Departmental schools.

The Non-Departmental teachers make significantly greater use of duplicated notes than do Departmental teachers. In Non-Departmental schools much of the factual material is given to the students in the form of duplicated notes thus probably shortening the time students spend reading text books. This practice could tend to diminish student initiative and resourcefulness.

The fact that the other responses vary is probably due to personal preferences on the part of teachers, but this variation is not significant. The smaller number of Departmental teachers taking students on field trips is possibly due to the larger class sizes in Departmental schools as well as the fact that many country schools would not be able to take students on such trips.

Item 8: This item dealt with the teaching objectives and teaching

Table 6. A Summary of Item 7 of the Questionnaire for Chemistry Teachers.

Item		Departmental Number Replying	Departmental %	Non-Departmental Number Replying	Non-Departmental %	Total Response Number Replying	Total Response %	Chi-square value
a) One text	a) Always	18	53	7	33	25	46	5.60
	b) Sometimes	14	41	8	38	22	40	
	c) Never	2	6	6	29	8	15	
b) Several texts	a) Always	5	14	8	40	13	23	5.77
	b) Sometimes	27	73	10	50	37	65	
	c) Never	5	14	2	10	7	12	
c) Duplicated Notes	a) Always	5	13	8	38	13	22	7.23*
	b) Sometimes	23	61	12	57	35	59	
	c) Never	10	26	1	5	11	19	
d) Text for Problems	a) Always	5	13	5	20	10	16	4.94
	b) Sometimes	27	69	18	78	45	73	
	c) Never	7	18	0	0	7	11	
e) Make up own Problems	a) Always	0	0	0	0	0	0	2.64
	b) Sometimes	36	92	17	74	53	85	
	c) Never	3	8	6	26	9	15	
f) Field Trips	a) Always	0	0	0	0	0	0	3.24
	b) Sometimes	13	33	12	52	25	40	
	c) Never	27	68	11	48	38	60	
g) Audio-Visuals	a) Frequently	19	49	11	48	30	48	0.39
	b) Occasionally	20	51	12	52	32	52	
	c) Never	0	0	0	0	0	0	

*Significant at the five percent level.

methods used by the teachers. The results are found in Tables 7 through 10.

From the information contained in Table 7 it can be seen that 95 percent of all the teachers taught so that students could demonstrate a knowledge of basic scientific facts, principles and concepts. Because of the fundamental nature of this objective in education it is perhaps rather surprising to find that some teachers did not pursue it. It is possible that those teachers who indicated that they did not teach to attain this objective possessed no conscious teaching objectives or interpreted the objective in a different way.

Although there was no significant difference in the methods used by the teachers to attain this objective, a preference for certain methods was revealed. In the case of the Departmental teachers the three most frequently used methods were:

a) Laboratory-discussion

b) Lecture-demonstration

c) Discussion on assignments

The three most frequently used methods for the Non-Departmental teachers were:

a) Laboratory-discussion

b) Lecture-demonstration

c) Demonstration-discussion

The results indicate that the teachers favor discussion as an important part of the teaching process.

Three-quarters of the teachers from each system aimed at equipping the students to apply the methods of science. This is revealed in Table 8, and shows no significant differences in the objective and methods used by the teachers. In teaching for this objective the teachers in both systems favored discussion methods; however, the two most frequently used methods were not the same for the teachers from both systems. The Departmental teachers favored:

a) Laboratory-discussion

b) Discussion on assignments,

while those teachers from the Non-Departmental schools had a preference for:

a) Laboratory-discussion

b) Lecture-demonstration.

According to the information contained in Table 9 more Departmental teachers teach to improve the students' ability to think critically than do Non-Departmental teachers. This difference was not statistically significant.

Methods which involved discussion by students were again highly favored. However, in this case there was a significant difference in the methods used by the teachers from the two systems.

Table 7. A summary of Item 8a* of the Questionnaire for Chemistry Teachers.

		Departmental No.	Departmental %	Non-Departmental No.	Non-Departmental %	Total No.	Total %	Chi-square Value
Did you teach to accomplish this objective?	a) Yes	39	98	21	91	60	95	0.30
	b) No	1	3	2	9	3	5	
Methods used to attain this objective.								
1. Notes dictated in class		9		10		19		6.26
2. Discussion on assignments		21		9		30		
3. Lecture-demonstration		24		16		40		
4. Demonstration-discussion		13		13		26		
5. Laboratory with no discussion		3		0		3		
6. Laboratory-discussion		33		17		50		

*The student can demonstrate increased knowledge of basic scientific facts, principles and concepts.

Table 8. A summary of Item 8b* of the <u>Questionnaire for Chemistry Teachers</u>.

		Departmental		Non-Departmental		Total		Chi-square Value
		No.	%	No.	%	No.	%	
Did you teach to accomplish this objective?	a) Yes	30	75	17	74	47	75	0.04
	b) No	10	25	6	26	16	25	
Methods used to attain this objective.								
1. Notes dictated in class		4		7		11		11.33
2. Discussion on assignments		14		8		22		
3. Lecture-demonstration		6		11		17		
4. Demonstration-discussion		6		9		15		
5. Laboratory with no discussion		4		0		4		
6. Laboratory-discussion		28		15		43		

* The student is able to apply the methods of science.

Table 9. A summary of Item 8c* of the Questionnaire for Chemistry Teachers.

		Departmental No.	Departmental %	Non-Departmental No.	Non-Departmental %	Total No.	Total %	Chi-square Value
Did you teach to accomplish this objective?	a) Yes	36	90	17	74	53	84	1.77
	b) No	4	10	6	26	10	16	
Methods used to attain this objective.								
1. Notes dictated in class		4		5		9		13.72+
2. Discussion on assignments		28		9		37		
3. Lecture-demonstration		4		11		15		
4. Demonstration-discussion		8		12		20		
5. Laboratory with no discussion		2		2		4		
6. Laboratory-discussion		21		15		36		

*The student can show evidence of improving his ability to think critically.

+Significant at the five percent level.

The Departmental teachers who taught to achieve this objective most frequently used the following methods:

a) Discussion on topical assignments

b) Laboratory-discussion

The Non-Departmental teachers had

a) Laboratory-discussion

b) Demonstration-discussion

as their most frequently used methods.

The responses to the fourth objective, Item 8d (Table 10), showed a significant difference between the teachers of the two systems. Sixty-five percent of Departmental teachers did not teach to inculcate in the students an understanding of science, the scientist and scientific careers. In the case of Non-Departmental teachers it was revealed that 65 percent did teach for this objective.

The teachers of both systems showed similar preferences for methods used, viz.

a) Laboratory-discussion

b) Discussion on topical assignments

By far the most popular method of teaching to attain the objective was the laboratory-discussion method, while methods involving discussion by students were conspicuously prominent.

An inspection of the chi-square values for the four objectives and the methods used to attain these objectives (Tables 7 through 10) reveals that only once did the Departmental teachers significantly differ in their objectives and only once in their methods. On the basis of this it is safe to say that the two null hypotheses should be accepted, viz.

a) There is no difference in the teaching methods used by teachers in Departmental and Non-Departmental systems.

b) There is no difference in the objectives of science teaching held by the teachers in the two systems.

Items 9-18: The only item to show a significant difference between the two school groups in Table 11 dealt with the employment of a laboratory assistant. Most Departmental schools employed a laboratory assistant while approximately half of the Non-Departmental did likewise.

In those items relating to the content and compilation of the syllabus a surprising number of teachers were undecided in their responses. This could mean that the teachers have not given such matters much thought and/or that there is poor communication, leaving teachers uninformed of the means whereby syllabus alterations may be effected.

Suggestions of topics for selection and inclusion in the syllabus were too fragmentary to be treated statistically; therefore, the suggestions were treated as those of the teachers as a whole.

Those deletions most frequently favored were: aromatic

Table 10. A summary of Item 8d* of the Questionnaire for Chemistry Teachers.

		Departmental No.	Departmental %	Non-Departmental No.	Non-Departmental %	Total No.	Total %	Chi-square Value
Did you teach to accomplish this objective?	a) Yes	14	35	15	65	29	46	6.60+
	b) No	26	65	8	35	34	54	
Methods used to attain this objective.								
1. Notes dictated in class		2		5		7		1.87
2. Discussion on assignments		9		11		20		
3. Lecture-demonstration		3		7		10		
4. Demonstration-discussion		6		9		15		
5. Laboratory with no discussion		1		1		2		
6. Laboratory-discussion		12		12		24		

*The student can demonstrate attitudes which indicate an understanding of science, the scientist and scientific careers.

+Significant at the one percent level.

Table 11. A Summary of Items 9-18 of the Questionnaire for Chemistry Teachers.

Item		Departmental Number Replying	Departmental %	Non-Departmental Number Replying	Non-Departmental %	Total Response Number Replying	Total Response %	Chi-square value
9. Syllabus adequate	a) Yes	37	93	23	100	60	95	1.83
	b) Undecided	3	8	0	0	3	5	
10. Enough time to cover course	a) Yes	11	28	4	17	15	24	1.77
	b) No	21	53	16	70	37	59	
	c) Undecided	8	20	3	13	11	17	
11. Delete content	a) Yes	20	50	13	57	33	52	0.35
	b) No	7	18	4	17	11	17	
	c) Undecided	13	33	6	26	19	30	
13. Add content	a) Yes	12	30	5	22	17	27	3.87
	b) No	11	28	12	52	23	37	
	c) Undecided	17	43	6	26	23	37	
15. Teacher influence	a) Yes	8	20	9	39	17	27	4.22
	b) No	18	45	5	22	23	37	
	c) Undecided	14	35	9	39	23	37	
16. University influence	a) Yes	20	50	6	26	26	41	3.51
	b) No	11	28	10	44	21	33	
	c) Undecided	9	23	7	30	16	25	
17. Students unsupervised in laboratory	a) Sometimes	9	23	9	39	18	29	1.26
	b) Never	31	78	14	61	45	71	
18. Laboratory assistant	a) Yes	38	95	12	52	50	79	13.9*
	b) No	2	5	11	48	13	21	

*Significant at the one percent level.

chemistry, heterogeneous equilibria and parts of the inorganic chemistry involving plain recall. The most frequently favored additions were: aromatic chemistry and organic reaction mechanisms.

The presence of aromatic chemistry at the top of both lists is explained by the fact that several teachers considered the very small amount in the present chemistry syllabus was useless and should be eliminated. Those teachers advocating inclusion of aromatic chemistry were desirous of having the quantity increased to provide a meaningful section for study.

The information in Tables 5 through 11 reveals that, of the 26 items on the questionnaire, for which chi-square values were calculated, the responses to four showed a significant difference between the teachers from the two systems. Hence it is safe, over all, to say that teacher factors, objectives and methods are similar for both Departmental and Non-Departmental teachers.

Questionnaire for Students

A summary of the student questionnaire is to be found in Table 12.

The average age for all the students was 16 years and eight months while the eldest were the Roman Catholic students with an average age of 17 years.

It is interesting to note that approximately 70 percent of the students in each group expressed a desire for a tertiary education. An average of only 14 percent had not made up their minds as to what vocation they would pursue. The final examination results will probably have a marked effect on the course of action taken and may see a wide divergence from the data in Table 12.

The larger number of students from Departmental schools contemplating being science teachers is mainly a reflection of social values. A greater number than 130 science teacher-trainees is required to meet current needs, and if this number is a reflection of next year's intake of student teachers then a rigorous recruiting program is advisable.

Fifty-six percent of the students indicated that the main reason for doing chemistry was an interest in the subject, as opposed to 32 percent who indicated that their main reason for doing chemistry was that it would be needed for future study. The assumption is made that the students are sure of their motives for doing chemistry.

Watson-Glaser Critical Thinking Appraisal

The number of students who took both this test and the TOUS was a little below the number who completed the student questionnaire. The reason for this was that a few students did not attempt both tests.

The mean for the WGCTA for all students was found to be 68.0 with all four groups falling within 1.4 points of the mean (Table 13).

Table 12. A Summary of the Questionnaire for Students.

Item on Questionnaire	Departmental City		Departmental Country		Non-Departmental Independent		Non-Departmental Roman Catholic		Total	
1. Average Age (yr. mth.)	16.10		16.10		16.8		17.0		16.10	
2. Activity after Graduating?	No.	%	No.	%	No.	%	No.	%	No.	%
a) Tertiary education	888	74	131	68	227	70	164	72	1410	73
b) Job & Study part-time	76	6	12	6	6	2	11	5	105	5
c) Repeat	8	1	3	2	14	4	8	3	33	2
d) Undecided	153	13	39	20	47	14	30	13	269	14
e) Other	70	6	9	5	31	10	16	7	126	6
3. To be Science Teacher										
Yes	105	9	16	8	1	0	9	4	131	6
No	1090	91	178	92	324	100	220	96	1812	94
4. Why do Chemistry?										
a) No other choice	108	9	24	12	24	7	6	3	162	8
b) Interest	703	59	102	53	163	50	113	49	1081	56
c) Necessary for future	338	28	63	33	128	39	99	43	628	32
d) Other	46	4	5	3	10	3	11	5	72	4

Table 13. Averages for WGCTA and TOUS scores for all students.

Test	City n=1193	Country n=194	Independent n=322	Roman Catholic n=228	Total
WGCTA	68.0	69.2	68.4	66.6	68.0
TOUS	33.2	34.4	32.5	31.5	32.9

The rank order for the means was found to be Country, Independent, City and Roman Catholic schools. The low score for the Roman Catholic schools is possibly explained by the fact that some of their final year students were from Southeast Asian countries and were spending the year in the last year of high school as part of their preparation for university entrance.

The WGCTA is divided into five areas: Inference, Recognition of Assumptions, Deduction, Interpretation and Evaluation. Table 14 reveals the percentage of correct answers for each of the five areas by the four school groups. There was very little difference between the school groups for the first four areas of the appraisal. However, the Roman Catholic responses to the last two areas were several points below the mean for all the schools. One possible explanation has been given above. Another possible explanation is the fact that the Roman Catholic schools were the first tested in the survey and this testing was conducted on the first two days back at school after the summer vacation. The temperature during these days was in excess of 100 degrees F.

On the basis of the WGCTA the areas of critical thinking which were well managed by the students were: Recognition of Assumptions, Deduction and Interpretation. These three areas were managed especially well by all four groups. The two areas least successfully handled by the students were: Inference and Evaluation of Arguments.

Table 14. Percentage of correct answers to each section of the WGCTA for all schools.

Section of WGCTA	Number of Items	City n=1193	Country n=194	Independent n=322	Roman Catholic n=228	All schools n=1937
Inference	20	54	55	55	54	54
Recognition of Assumptions	15	73	77	77	78	75
Deduction	25	73	74	74	73	73
Interpretation	24	77	79	77	73	77
Evaluation of Arguments	16	61	59	56	53	59

Table 15. Mean and Standard Deviation of WGCTA, TOUS and Chemistry Achievement scores for the random samples used in the study.

Test	City Mean	City S. D.	Country Mean	Country S. D.	Independent Mean	Independent S. D.	Roman Catholic Mean	Roman Catholic S. D.	Total Mean	Total S. D.
WGCTA	67.3	9.8	69.5	8.9	67.6	9.6	68.3	10.3	68.2	10.2
TOUS	32.7	6.4	34.2	6.4	32.5	6.9	31.9	6.8	32.8	6.3
Chemistry Achievement	55.8	14.6	56.5	13.0	50.5	16.1	51.1	14.3	53.5	14.3

It would be a rather subjective assessment if reasons were advanced for the poor responses to these two areas of the WGCTA. However, it could be conjectured that the same thought processes are involved when students draw inferences as when they evaluate arguments. Whether teachers teach these two aspects of critical thinking is difficult to answer. Perhaps the first and last sections of the WGCTA are not as reliable in what they measure as are the other three sections. It is not beyond the realm of possibility that the first and last sections of the appraisal are not as valid in Australia as they are in the United States. A discrepancy does exist between the correct responses to the various subtests, but its explanation is beyond the scope of this survey. However, such information could be useful in the preparation of teachers as well as for in-service courses.

The elimination of students by random selection and those new to the state, as well as those who had not presented themselves for public examination in 1966, resulted in approximately 200 from each group being used in the survey. The mean and standard deviations of the scores for the students in the sample are found in Table 15.

From page 16 it will be remembered that an analysis of variance was to be computed for each of the three tests taken by the students. The F ratios were computed for the four groups for critical thinking and these ratios are shown in Table 16.

Table 16. F ratios for WGCTA.

Source	d.f.	F ratio
F between columns	3	2.11
F between rows	1	7.54*
F interaction	3	1.35

* Significant at 1% level.

The non-significant F for interaction indicates that whatever the F value is for columns it is also true of both rows and that the relative rows effect holds over all columns. The F ratio for columns is not significant which means that the ability to think critically does not differ significantly from group to group. However, the F ratio for rows is significant at the one percent level. The mean value for the girls was 69.6 with n=156, while the mean value for the boys was 67.8 with n=622. This information indicates that the girls are significantly more able to think critically than are the boys. This may well be expected since it is the norm for most girls to leave school before matriculation to go to business colleges or to seek employment of some kind. This would leave the more able girls in the schools and the more able still would be doing the sciences.

If the F ratio is found to be non-significant then the usual practice is to omit the compilation of t values. However, the possibility exists that significant differences in the student scores may be evident between various cell combinations as well as between column combinations. It was therefore decided to compute t-tests for the six combinations of columns as well as for the 28 combinations of cells. A list of the significant t values is found in Table 17. This information indicates a marked superiority by the Country students in critical thinking ability. The two of the six column combinations which were significant involved the Country students.

The combinations of cells gave rise to seven significant t values of which five involved Country girls. These five t values can be assumed to possess a reasonable degree of validity since the largest ratio of student numbers between any two groups is 1:3. However, the validity of the significance of the t values for the Roman Catholic girls must be viewed with a degree of suspicion because of the large ratio of student numbers (1:9).

On the basis of the F test for columns the over all null hypothesis is accepted that:

There is no difference in the critical thinking abilities of the graduates from the four school groups.

Test on Understanding Science

The mean for the TOUS for all students was found to be 32.9 (Table 13), with all four groups falling within 1.5 points of the mean. The rank order by school group was found to be Country, City, Independent and Roman Catholic. This differed slightly from the rank order for the WGCTA, viz. Departmental Country, Independent,

Table 17. All cells from the 2x4 analysis of variance which gave significant t-ratios for scores on WGCTA.

Cell		Mean		n		
a	b	a	b	a	b	t-ratio
Co.[1] total	Ci.[2] total	69.5	67.3	194	198	2.45
Co. total	Ind.[3] total	69.5	67.6	194	186	2.02
Co. girls	Ci. girls	71.3	67.5	64	48	2.21
Co. girls	Ci. boys	71.3	67.1	64	150	2.89*
Co. girls	Co. boys	71.3	68.6	64	130	2.02
Co. girls	Ind. boys	71.3	67.3	64	162	2.89*
Co. girls	R. C.[4] boys	71.3	67.9	64	180	2.30
R. C. girls	Ind. boys	72.4	67.3	20	162	2.20
R. C. girls	Ci. boys	72.4	67.1	20	150	2.20

*Significant at 1% level. All others significant at 5% level.

[1]Departmental Country

[2]Departmental City

[3]Independent

[4]Roman Catholic

Table 18. Percentage of correct answers to each section of the _TOUS_ for all schools.

Section of _TOUS_	Number of Items	City n=1193	Country n=194	Independent n=322	Roman Catholic n=228	All schools n=1937
Scientific Enterprise	18	57	58	57	53	56
The Scientist	18	61	62	58	57	59
Methods and Aims of Science	24	51	53	50	49	50

Departmental City and Roman Catholic.

The TOUS is divided into three areas: Scientific Enterprise, the Scientist and Methods and Aims of Science. Table 18 reveals the percentage of correct responses by the four groups in each of the three areas. This table also reveals relatively equal responses to each area of the test by all the school groups. No school group varied by more than three percentage points from the mean and in each case the Roman Catholic students were below the mean. Some possible reasons as to why the Roman Catholic students' scores were the lowest of the four school groups have already been suggested in connection with the WGCTA (see page 73). These reasons may well be applied to this situation also.

The students' understanding of the Scientist, as measured by the TOUS was better than their understanding of the Scientific Enterprise, which in turn was better than their understanding of the Methods and Aims of Science. It is to be noted that the percentage of correct responses to all areas of the TOUS was below that for the WGCTA. This is probably explained by the fact that the students have opportunities, very early in their lives, to think critically, whereas opportunities to develop an understanding of science would not be present until high school.

The poor response to the third area of the TOUS could be explained by the fact that a syllabus does impose limitations on teachers;

even to the extent that sometimes laboratory periods are sacrificed to cover the subject matter of the syllabus.

The means and standard deviations of the scores for the students in the sample have been given previously (Table 15). The rank order of groups is the same as that for the total population.

The F ratios for the four groups for understanding of science are shown in Table 19.

Table 19. F ratios for TOUS.

Source	d. f.	F ratio
F between columns	3	3.60
F between rows	1	4.39*
F interaction	3	2.61

*Significant at 5% level

The F for interaction is again not significant, nor is the F for columns, whereas the F for rows is significant at the five percent level. The numbers of boys and girls are the same as for the WGCTA while the means for the TOUS are 32.6 for boys and 33.6 for girls. For the same reasons as in the WGCTA (see page 77) t-tests were computed for six combinations of columns. The Country schools were again significantly better than the other schools (Table 20). It is also shown in the table that three groups of girls scored significantly higher than five groups of boys while one group of boys scored significantly higher than one group of girls. This allows for some

Table 20. All cells from the 2x4 analysis of variance which gave significant t-ratios for scores on TOUS.

Cell		Mean		n		
a	b	a	b	a	b	t-ratio
Co.[1] total	Ci.[2] total	34.5	32 7	194	198	2.05
Co total	Ind.[3] total	34.5	32.5	194	186	2.36
Co. total	R.C.[4] total	34.5	31.9	194	200	3.16*
Co. boys	Ind. boys	34.1	32.0	130	162	2.65*
Co. boys	R.C. boys	34.1	31.6	130	180	3.33*
Co. boys	Ci. girls	34.1	32.1	130	48	1.96
Ind. girls	Ci. girls	35.4	32.1	24	48	2.14
Ind. girls	Ind. boys	35.4	32.0	24	162	2.23
Ind. girls	R.C. boys	35.4	31.6	24	180	2.60*
Co. girls	R.C. boys	34.0	31.6	64	180	2.41
R.C. girls	R.C. boys	35.4	31.6	20	180	2.36
R.C. girls	Ind. boys	35.4	32.0	20	162	2.03

* Significant at 1% level. All other significant at 5% level.

[1] Departmental Country

[2] Departmental City

[3] Independent

[4] Roman Catholic

conjectures as to why the girls in the sample are better at understanding science than are the boys. Suggested reasons would be the same as those for critical thinking (see page 77). The same degree of caution with regard to the sample size must be considered as with the WGCTA.

The F value for columns necessitates an acceptance of the over all null hypothesis that:

There is no significant difference in the understanding of science between the graduates from the four school groups.

Chemistry Achievement

The chemistry achievement scores were obtained from the Public Examination Board for all the students in the representative sample only. The means and standard deviations for each group have been given previously (Table 15).

The F ratios for the four groups for chemistry achievement are shown in Table 21.

Table 21. F ratios for chemistry achievement.

Source	d. f.	F ratio
F between columns	3	9.42*
F between rows	1	.33
F interaction	3	1.35

*Significant at 1% level

The F value for interaction is again insignificant indicating that the significant differences among columns (F columns significant at 1% level) holds for both rows. Table 22 reveals those *t* values which were significant for the combinations of columns and cells. It is interesting to note that 12 of the 13 significant values were significant at the one percent level.

Both City and Country students were significantly better in their chemistry achievement than the Independent and Roman Catholic students. Likewise both City and Country boys were significantly better achievers than the Independent boys and Roman Catholic boys and girls. The Country girls were also significantly better achievers than the Independent boys and Roman Catholic boys and girls. The obvious question to arise from this information is - why are Departmental students better achievers in chemistry than the Non-Departmental students? Is this due to:

a) Professional training which is mandatory for Departmental teachers?

b) Poor laboratory facilities in the Non-Departmental schools?

c) Less choice of subjects in Non-Departmental schools?

More searching is undoubtedly necessary before reasons can be further elucidated.

The F value for columns necessitates a rejection of the null hypothesis that:

Table 22. All cells from the 2x4 analysis of variance which gave significant t-ratios for Chemistry Achievement scores.

Cell		Mean		n		t-ratio
a	b	a	b	a	b	
Ci.[2] total	Ind.[3] total	55.8	50.5	198	186	3.35
Ci. total	R. C.[4] total	55.8	51.1	198	200	3.45
Co.[1] total	Ind. total	56.5	50.5	194	186	4.00
Co. total	R. C. total	56.5	51.1	194	200	4.25
Ci. boys	Ind. boys	56.7	50.2	150	162	3.64
Ci. boys	R. C. boys	56.7	51.4	150	180	3.53
Ci. boys	R. C. girls	56.7	48.5	150	20	2.46*
Co. boys	Ind. boys	56.2	50.2	130	162	3.38
Co. boys	R. C. boys	56.2	51.4	130	180	3.29
Co. boys	R. C. girls	56.2	48.5	130	20	2.63
Co. girls	Ind. boys	57.0	50.2	64	162	2.93
Co. girls	R. C. boys	57.0	51.4	64	180	3.04
Co. girls	R. C. girls	57.0	48.5	64	20	2.77

*Significant at 5% level. All other ratios significant at 1% level.

[1] Departmental Country

[2] Departmental City

[3] Independent

[4] Roman Catholic

There is no difference in the achievement in chemistry between the graduates from the four school groups.

Correlation coefficients were computed for a measure of the correlation between the scores on three tests: TOUS, WGCTA and Chemistry Achievement. All but one correlation were significant at the one percent level (Table 23).

The correlation between critical thinking and understanding of science is higher than between chemistry achievement and these two learning outcomes.

This information leads to a rejection of the two null hypotheses that:

There is no correlation between critical thinking and understanding of science of the graduates from the four school groups.

There is no correlation between learning outcomes and the achievement in the chemistry examination of the graduates from the four school groups.

Summary

The information obtained from the teacher questionnaire indicates that teachers from the Departmental and Non-Departmental schools differ slightly in their qualifications and objectives. Only half of the Non-Departmental teachers had had professional training, whereas 95 percent of Departmental teachers had. The number of

Table 23. Correlation coefficients on the test scores for students in the random samples.

School	Test	Correlation	Level of Significance
City	WGCTA vs. TOUS	0.41	0.01
	WGCTA vs. Chemistry	0.30	0.01
	TOUS vs. Chemistry	0.28	0.01
Country	WGCTA vs. TOUS	0.42	0.01
	WGCTA vs. Chemistry	0.33	0.01
	TOUS vs. Chemistry	0.19	0.01
Independent	WGCTA vs. TOUS	0.43	0.01
	WGCTA vs. Chemistry	0.32	0.01
	TOUS vs. Chemistry	0.38	0.01
Roman Catholic	WGCTA vs. TOUS	0.58	0.01
	WGCTA vs. Chemistry	0.06	0.01
	TOUS vs. Chemistry	0.21	0.01
All Schools	WGCTA vs. TOUS	0.47	0.01
	WGCTA vs. Chemistry	0.25	0.01
	TOUS vs. Chemistry	0.28	0.01

Non-Departmental teachers teaching for the objective that "students can demonstrate attitudes which indicate an understanding of science, the scientist and the scientific enterprise", was significantly more than the number of Departmental teachers. Duplicated notes were more widely used by Non-Departmental teachers than by Departmental teachers.

The teachers who taught to achieve the objectives listed favored methods which involved the students in discussion, with the laboratory-discussion combination method being the one most frequently used.

The student questionnaire revealed that 73 percent of the students were interested in proceeding to tertiary education, but only six percent expressed a desire to become science teachers. It was interesting to note that 56 percent of the students were doing chemistry because of an interest in the subject.

It has been thought by many educators in Australia that Country students are placed at a disadvantage compared with those students from metropolitan schools. The success of the Country students in the three tests employed in this study should dispel ideas that these students are below standard in certain facets of the educational process.

Several questions may be raised as to why the Country students were so successful. Such questions could be:

a) Is the smaller class size of Country schools as compared to all City schools responsible?

b) Are Country schools better equipped?

c) Do students in the country have less outside distractions?

d) How much emphasis can be placed on the fact that most teachers in Country schools are recent graduates?

Obviously much work has to be done to clarify the situation.

The superiority of the girls at critical thinking and understanding science has been discussed and suggested explanations have been given.

It is of interest to note that there was no significant difference in the student scores for two of the three tests (see Tables 16, 19 and 21), although the scores were somewhat lower in the case of the Non-Departmental students. This leads one to ponder the necessity and effectiveness of professional training on the one hand and the dampening effect of the examination-dominated educational system on teacher-initiative on the other. Some questions which must arise are:

a) Is the present professional preparation program inadequate?

b) Are the present methods of teacher preparation outmoded?

c) Does the presence of public examinations negate sound lesson preparation by the teachers?

These are challenging questions and as such need thorough investigation.

Some possible postulates from the findings of the survey are:

a) Assuming the <u>WGCTA</u> and the <u>TOUS</u> to be valid instruments, critical thinking ability in graduating high school students in South Australia is more highly developed than is their understanding of science.

b) The students learn to think critically while simultaneously gaining an understanding of science.

c) The students learn to think critically in subjects other than science.

d) The chemistry achievement examination makes some provision for students to think critically and to exhibit an understanding of science.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study was designed with two major aims. The first was to examine certain characteristics of both Departmental and Non-Departmental teachers who were teaching matriculation chemistry in South Australian secondary schools in 1967. The numbers of teachers who participated were: Departmental 40, and Non-Departmental 23. The second was to ascertain certain learning outcomes of matriculation chemistry students. The learning outcomes investigated were: critical thinking, understanding of science and achievement in chemistry. The students were divided into four groups for comparison, viz. City Departmental, Country Departmental, Independent and Roman Catholic. There were approximately 200 students in each of the school groups.

An analysis of the information supplied in the teacher questionnaires revealed that:

1. No significant differences existed between the teachers from the two groups in relation to the teacher factors investigated. However, there were minor areas in which significant differences were observed. The differences were:

   a) Most Departmental teachers had professional qualifications, whereas only half of the Non-Departmental teachers had completed professional courses.

b) More Non-Departmental teachers made use of duplicated notes, as teaching aids, than did Departmental teachers.

c) More Departmental teachers had the services of laboratory assistants than did the Non-Departmental teachers.

2. The teaching objectives of the participating teachers from both groups were generally in fair agreement. However, the number of Non-Departmental teachers teaching for the objective that "the students can demonstrate attitudes which indicate an understanding of science, the scientist and the scientific enterprise" was significantly greater than the number of Departmental teachers.

3. The methods used to attain the objectives were similar, with both groups of teachers making extensive use of discussion techniques. The laboratory-discussion combination was the method most frequently used.

The responses to the student questionnaire were not treated by any specific statistical test. However, the responses revealed that nearly three quarters of the students desired a tertiary education while only six percent expressed any intention of becoming science teachers. A little more than half the students were doing chemistry because they had an interest in it.

From the scores obtained on the WGCTA it was noted that the girls were significantly better at critical thinking than were the boys. Suggested reasons for this have been given (p. 77). It was also noted that the Country Departmental students had significantly higher scores than both City Departmental and Independent students.

The TOUS scores indicate that the girls scored significantly higher than did the boys. Reasons for this have been suggested (p. 77). The Country students had significantly higher scores on the TOUS than did the students from the other three school groups.

There was no significant difference in the achievement scores in chemistry between the two groups of Departmental students. However, both groups of Departmental students had significantly higher achievement scores than either the Independent or Roman Catholic students.

The test scores obtained by the Country students in the three tests indicated that these students were capable of higher results in critical thinking, understanding of science and achievement in chemistry.

The correlation between scores in the WGCTA and the TOUS was highly significant as were the correlations between the scores in the WGCTA and chemistry as well as the scores in the TOUS and chemistry.

The conclusions, in the terms of the null hypotheses previously formulated, are that the following should be accepted:

1. There is no difference in the teaching methods used by teachers in Departmental and Non-Departmental systems.
2. There is no difference in the objectives of science teaching held by the teachers in the two systems.
3. There is no difference in the teacher factors of the teachers in the two systems.
4. There is no difference in the critical thinking abilities of the graduates from the four school groups, viz. City Departmental, Country Departmental, Independent and Roman Catholic.
5. There is no difference in the understanding of science between the graduates from the four school groups.

The following null hypotheses have been rejected:

6. There is no difference in the achievement in chemistry between the graduates from the four school groups.
7. There is no correlation between critical thinking ability and the understanding of science of the graduates from the four school groups.
8. There is no correlation between the learning outcomes and the achievement in the public examination in chemistry of the graduates from the four school groups.

Recommendations

On the basis of the results from this study it is possible to make some specific recommendations which would be helpful to science education in South Australia. Recommended studies would be to determine:

a) Why the Country students, on an over all basis, gained significantly higher scores on the WGCTA, TOUS and the public examination in chemistry than the other school groups. Areas to be studied would include:

   i) teaching methods employed

   ii) professional training of the teachers

   iii) class size

   iv) physical environment

   v) socio-economic background of the students

b) Why the Roman Catholic students had significantly lower scores on the three tests as in a above.

c) If item analyses of WGCTA and TOUS reveal any weakness in these tests for Australian students.

d) If it is possible to construct a test which will adequately measure both critical thinking and understanding of science in the one test.

BIBLIOGRAPHY

1. Allen, Hugh, Jr. Attitudes of certain high school seniors toward science and scientific careers. New York, Columbia University, 1959. 53 p.

2. _______________ The high school seniors: two years later. New York, Columbia University, 1961. 58 p.

3. Australia. Committee on the future of tertiary education in Australia. Tertiary education in Australia: Report to the Australian Universities Commission. Vol. 1. Melbourne, 1964. 244 p.

4. Australia. Commonwealth Bureau of Census and Statistics. Schools 1966. Social Statistics: Australia. Canberra, 1967. 50 p.

5. Baker, P C. *et al*. Physical science aptitude and attitudes toward occupations. Lafayette, Purdue University, 1956. (The Purdue Opinion Panel Poll. No. 45.)

6. Barnard, J. Darrell. Science teaching objectives and methods. Science Teacher 26:110-111. 1959.

7. Bassett, G W. Towards a national system of Australian education. Australian Science Teachers' Journal 11:9-15. Aug. 1965.

8. Belt, Sidney Leon. Measuring attitudes of high school pupils toward science and scientists. Ed. D. thesis. New Brunswick, N. J., Rutgers University, 1959. 180 numb. leaves. (Abstracted in Dissertation Abstracts 20:3625. 1960.)

9. Bibergall, Jo Anne. Learning by discovery: It's relation to science teaching. Educational Review 18:222-231. 1966.

10. Bloom, Benjamin S. (ed.). Taxonomy of educational objectives; the classification of educational goals. New York, Longmans, 1956 207 p. (Handbook I)

11. Burmester, M. A. Behavior involved in the critical aspects of scientific thinking. Science Education 36:259-263. 1952.

12. Burton, William H., Roland B. Kimball and Richard L. Wing. Education for effective thinking. New York, Appleton-Century-Crofts, 1960. 508 p.

13. Butts, R. Freeman. Assumptions underlying Australian education. Melbourne, Brown, Prior, Anderson, 1964. 95 p.

14. Charen, George. The effect of open-ended experiments in chemistry on the achievement of certain objectives of science teaching. Journal of Research in Science Teaching 1:184-190. 1963.

15. Cockburn, Stewart. Misgivings over new matric. The Advertiser (Adelaide, South Australia), p. 2. Nov. 26, 1966.

16. Conant, James B. Science and common sense. New Haven, Yale University, 1951. 371 p.

17. Cooley, William W. and Leopold E. Klopfer. TOUS test on understanding science manual for administering, scoring and interpreting scores. Princeton, N. J., Educational Testing Service, 1961. 20 p.

18. ________________ The evaluation of specific education innovations. Journal of Research in Science Teaching 1:73-80. 1963.

19. Craven, Gene F. Critical thinking ability and understanding of science by science teacher candidates at Oregon State University. Ph.D. thesis Corvallis, Oregon State University, 1966. 148 numb. leaves.

20. Curtis, Francis D. Teaching scientific methods. School Science and Mathematics 34:816-819. 1934.

21. Dewey, John. How we think. New York, Heath, 1933. 301 p.

22. Doherty, J. P. The kinds of science teachers we need. Australian Science Teachers' Journal 12:49-52. Nov. 1966.

23. ________________ The science teacher. Australian Science Teachers' Journal 10:41-45. Aug. 1964.

24. Downing, Elliott R. Does science teach scientific thinking? Science Education 17:86-89. 1933.

25. Dressell, Paul L. and Lewis B. Mayhew. General education; explorations in evaluation. Washington, D. C., American Council of Education, 1954. 302 p.

26. Edwards, T. Bentley. Measurement of some aspects of critical thinking. The Journal of Experimental Education 18:261-278. 1950.

27. England. Public Schools' Science Masters Association. The teaching of general science. Part II. London, 1938. 79 p.

28. Ennis, Robert H. Needed: Research in critical thinking. Educational Leadership 21:17-20. Oct. 1963.

29. Fensham, P. J. Educational objectives in the examining of science subjects. Australian Journal of Education 6:102-112. 1962.

30. Gatewood, C. W. The effect of Oklahoma State University travelling science teachers' program on the attitudes of high school students toward science and scientists. Journal of Research in Science Teaching 1:191-194. 1963.

31. George, Kenneth D. A comparison of the critical thinking abilities of science and non-science majors. Science Education 51:11-18. 1967.

32. Glaser, E. Critical thinking. National Education Association, Journal 44:418-420. 1955.

33. Good, Carter V. Dictionary of education. New York, McGraw-Hill, 1959. 676 p.

34. Graham, Daniel Woodrow. An experimental study of critical thinking in student-centered teaching. Ed. D. thesis. Denton, North Texas State College, 1961. 103 numb. leaves. (Abstracted in Dissertation Abstracts 22:801-802. 1961)

35. Hamilton, Nancy B. The scientific literacy of seniors in urban, suburban and rural high schools in Kentucy. Ph. D. thesis. Columbus, Ohio State University, 1965. 144 numb. leaves. (Abstracted in Dissertation Abstracts 26:3701. 1966)

36. Harriman, V. J. The inclusion of modern chemistry in current secondary school chemistry texts. Ed. D. thesis. Columbia,

University of Missouri, 1960. 130 numb. leaves. (Abstracted in Dissertation Abstracts 21:1423. 1960)

37. Harvard University. General education in a free society; report of the Harvard Committee. Cambridge, 1945. 267 p.

38. Helmstadter, G. C. Watson-Glaser critical thinking appraisal. Journal of Educational Measurement 2:254-256. 1965.

39. Herber, Harold L. An inquiry into the effect of instruction in critical thinking upon students in grades ten, eleven and twelve. Ed. D. thesis. Boston, Boston University, 1959. 221 numb. leaves. (Abstracted in Dissertation Abstracts 20:2174. 1959)

40. Howe, Robert H. The relationship of learning outcomes to selected teacher factors and teaching methods in tenth grade biology classes in Oregon. Ed. D. thesis. Corvallis, Oregon State University, 1963. 263 numb. leaves.

41. Hurd, Paul Dehart. The educational concepts of secondary school science teachers. School Science and Mathematics 54: 89-96. 1954.

42. ________________ Theory into action. Washington, D. C., National Science Teachers' Association, 1964. 48 p.

43. Johnson, P. O. Curriculum problems in science at the college level. Minneapolis, University of Minnesota, 1930. 188 p.

44. Joseph, Alexander _et al_. A sourcebook for the physical sciences. New York, Harcourt, Brace and World, 1961. 674 p.

45. Kastrinos, William, Jr. Teaching for critical thinking in high school biology. Journal of Research in Science Teaching 1: 345-354. 1963.

46. Kerr, J. K. and G. Neal. Understanding junior science. Education Review 11:57-67. 1958.

47. Kesslar, O. The elements of scientific method. Science Education 29:273-278. 1945.

48. Klopfer, Leopold E. and William W. Cooley. The history of science cases for high schools in the development of student understanding of science and scientists. Journal of Research

in Science Teaching 1:33-47. 1963.

49. Lee, Earnest Wilton. A study of the effects of two methods of teaching high school chemistry upon critical thinking ability. Ph.D. thesis. Chapel Hill, University of North Carolina, 1963. 253 numb. leaves. (Abstracted in Dissertation Abstracts 25: 4578. 1965)

50. Letters to the editor. South Australian Science Teachers' Journal, Mar. 1967, p. 39-41.

51. Lewis, D. G. Objectives in the teaching of science. Educational Research 7:186-190. 1965.

52. Mead, Margaret and Rhonda Metraux. Image of the scientist among high school students; a pilot study. In: Sociology of science, ed. by Bernard Barker and Walter Hirsch. New York, Free Press of Glenco, 1962. p. 230-246.

53. Merholt, Evelyn, Paul F. Brandwein and Alexander Joseph. A sourcebook for the biological sciences. New York, Harcourt, Brace and World, 1958. 506 p.

54. Meyer, G. R. Factors related to scientific attitudes within the secondary schools of an Australian city. Australian Journal of Education 7:21-40. 1963.

55. ________________ New concepts in science education in secondary schools. Australian Journal of Education 9:137-154. 1965.

56. Morris, Graham C. Educational objectives of higher secondary school science. Masters thesis. Sydney, University of Sydney, 1961. 273 numb. leaves.

57. National Educational Association. Educational Policies Commission. Education for all American youth. Washington, D. C., 1944. 421 p.

58. National Society for the Study of Education. Rethinking science education. Chicago, University of Chicago, 1960. 344 p. (Yearbook. Vol. 59, pt. 1)

59. National Society for the Study of Education. Science education in American schools. Chicago, University of Chicago, 1947. 306 p. (Yearbook. Vol. 46, pt. 1)

60. Noll, V. H. The habit of scientific thinking. Teachers College Record 35:1-9. 1933.

61. Obourn, Ellsworth S. Fifth annual review of research in science teaching. Science Education 41:375-411. 1957.

62. Oliphant, Mark. Science as a part of education. Australian Science Teachers' Journal 10:15-27. Aug. 1964.

63. Olsen, F. J. Educational requirements of a scientific world and our teaching response. Australian Science Teachers' Journal 1:23-26. Aug. 1955.

64. Pennington, L. W. J. and J. P. Doherty. Science teaching, examinations and objectives. Science Education News 12:11-24. Nov. 1963.

65. Perkins, William D. and John T. Conover. Patterns of resistance to change in science teaching. Science Education 49: 339-348. 1965.

66. Progressive Education Association. Science and general education. Report of the Committee on the Function of Science in General Education. New York, D. Appleton-Century, 1938. 591 p.

67. Renner, John W. Science, engineering and technology as the junior high school student understands them. Journal of Research in Science Teaching 1:89-94. 1963.

68. Richardson, John S. Science teaching in secondary schools. Englewood Cliffs, New Jersey, Prentice-Hall, 1957. 385 p.

69. Saunders, H. N. The teaching of general science in tropical secondary schools. London, Oxford University, 1955. 248 p.

70. Schwab, Joseph Jackson. The teaching of science as enquiry. Cambridge, Harvard University, 1962. 152 p.

71. Sherburne, E. G., Jr. Public understanding of science. Science 149:381. 1965.

72. Smith, P. M. Critical thinking and the science intangibles. Science Education 47:405-408. 1963.

73. Sorenson, Levar Leonard. Change in critical thinking between students in laboratory centered and lecture-centered patterns of instruction in high school biology. Ed. D. thesis. Corvallis, Oregon State University, 1966. 132 numb. leaves.

74. Stanhope, Ray E. Some characteristics of good science teaching. Australian Science Teachers' Journal 4:7-18. May 1958.

75. Summers, Donald B. Are high school chemistry texts up-to-date? Journal of Chemical Education 37:263-264. 1960.

76. Thurber, Walter A. and Alfred T. Collette. Teaching science in today's secondary schools. Boston, Allyn and Bacon, 1964. 693 p.

77. Tisher, R. P. The training of science teachers. Australian Science Teachers' Journal 11:25-32. Aug. 1965.

78. Tyler, R. W. Constructing achievement tests. Columbus, Ohio State University, 1934. 110 p.

79. Uricheck, Michael J. Research proposal: An attempt to evaluate the success of the CBA and CHEMS chemistry courses. Science Education 51:5-11. 1967.

80. Wallen, Norman E., Vernon F. Haulrick and Ian E. Reid. The outcomes of curriculum modifications designed to foster critical thinking. Journal of Educational Research 56:529-531. 1963.

81. Watson, Goodwin and Edward M. Glaser. Manual for forms YM and 2M. Watson-Glaser critical thinking appraisal. New York, Harcourt, Brace and World, 1964. 16 p.

82. Wellington, C. Burleigh and Jean Wellington. Teaching for critical thinking. New York, McGraw-Hill, 1960. 364 p.

83. Wert, James E. Twin examination assumptions. Journal of Higher Education 8:136-140. 1937.

84. Wilkinson, W. J. The role of universities in improving science teaching. Education for Teaching 68:300-304. 1965.

85. Woodburn, John H. and Ellsworth S. Obourn. Teaching the pursuit of science. New York, MacMillan, 1965. 470 p.

86. Wrigley, Jack and J. F. Kerr. Attitudes and aims in science teaching. Educational Review 11:57-67. 1958.

QUESTIONNAIRE FOR CHEMISTRY TEACHERS

Please put a tick ( ) in the appropriate place.

1. In what school system are you at present teaching?
   Departmental ____ Independent ____ Roman Catholic ____

2. Total years teaching experience, less than 5 ____ 5-9 ____
   10-14 ____ 15-19 ____ 20 and over ____

3. Undergraduate education
   (a) What degree(s) do you possess? ________________________
   (b) List the units of University Chemistry you have taken

   ____

4. (a) Professional courses. (Teachers College and Dip. Ed.)

   ____

   (b) Method courses.

   ____

5. Have you attended any In-service Courses for chemistry teachers?

   Yes ____ No ____

6. Indicate any Professional and/or Scientific organizations of which you are a member.

   ______ S. A. Science Teachers' Association

   ______ Australian and New Zealand Association for the Advancement of Science.

   ______ Royal Australian Chemical Institute.

   Please specify any others ______________________________

   ____

7. Lesson Plan (in the following please tick where applicable)

   In following the course of study as set out in the syllabus, do you use any of the materials listed?

   a) One basic text. Always ____ Sometimes ____ Never ____

b) Several basic texts. Always ____ Sometimes ____ Never ___

c) Your own or duplicated notes. Always ____ Sometimes ____

Never ____

d) Do you use a text for chemical problems? e.g., normality, equiv. wt., etc.

Always ____ Sometimes ____ Never ____

e) Do you ever make up your own chemical problems?

Always ____ Sometimes ____ Never ____

f) Do you ever take your classes on field trips to see how chemistry is used in industry?

Frequently ____ Occasionally ____ Never ____

g) Do you make use of models, films and other audio-visual aids?

Frequently ____ Occasionally ____ Never ____

h) Do you follow any other lesson plan or use other methods to make chemistry meaningful to the student?

Please specify ____

____

8. Methods and Aims of Teaching

Select the methods of teaching which best describe the practice you use to teach for specific objectives.

a) Objective
The student can demonstrate increased knowledge of basic scientific facts, principles and concepts.

1. Did you plan to accomplish this objective?

Yes ____ No ____

2. If you answered yes, tick the method(s) used to teach for this objective.

____ Notes taken down by the student in class.

____ Discussion based on topical assignments.

____ Lecture-demonstration combination.

____ Demonstration-discussion combination.

_____ Laboratory with no discussion.

_____ Laboratory-discussion combination.

_____ No or little use of the laboratory.

Other, please specify ______________________________

b) Objective

The student is able to apply the methods of science.

1. Did you plan to accomplish this objective?

   Yes _____ No _____

2. If you answered yes, tick the method(s) used to teach for this objective.

   _____ Notes taken down by the student in class.

   _____ Discussion based on topical assignments.

   _____ Lecture-demonstration combination.

   _____ Demonstration-discussion combination.

   _____ Laboratory with no discussion.

   _____ Laboratory-discussion combination.

   _____ No or little use of the laboratory.

   Other, please specify ______________________________

c) Objective

The student can show evidence of improving his ability to think critically.

1. Did you plan to accomplish this objective?

   Yes _____ No _____

2. If you answered yes, tick the method(s) used to teach for this objective.

   _____ Notes taken down by the student in class.

   _____ Discussion based on the topical assignments.

   _____ Lecture-demonstration combination.

   _____ Demonstration-discussion combination.

   _____ Laboratory with no discussion.

   _____ Laboratory-discussion combination.

_____ No or little use of the laboratory.

Other, please specify ______________________________

d) Objective.

The student can demonstrate attitudes which indicate an understanding of science, the scientist and scientific careers.

1. Did you plan to accomplish this objective?

   Yes _____ No _____

2. If you answered yes, tick the method(s) used to teach for this objective.

   _____ Notes taken down by the student in class.

   _____ Discussion based on topical assignments.

   _____ Lecture-demonstration combination.

   _____ Demonstration-discussion combination.

   _____ Laboratory with no discussion.

   _____ Laboratory-discussion combination.

   _____ No or little use of the laboratory.

   Other, please specify ______________________________

9. Do you consider that the present Matriculation Chemistry Syllabus has enough subject matter in it?

   Yes _____ No _____ Undecided _____

10. Do you consider that you have enough time to cover the subject matter of the above syllabus?

   Yes _____ No _____ Undecided _____

11. Would you like to see certain parts of the above syllabus deleted?

   Yes _____ No _____ Undecided _____

12. If answer is yes, what parts? ______________________________

   ____

13. Would you like to see certain other subject matter added to the above syllabus? Yes _____ No _____ Undecided _____

14. If the answer is yes, what would you include? ________________

____

15. Do you think that teachers have enough influence in determining what will be taught at the matriculation level?

Yes ____ No ____ Undecided ____

16. Do you think the Universities have too much influence as to what will be taught, in chemistry, at the matriculation level?

Yes ____ No ____ Undecided ____

17. Do you allow any of your matriculation chemistry students to plan their own experiments and to carry them out without constant supervision?

Often ____ Sometimes ____ Never ____

18. Does the school in which you are now teaching employ a laboratory assistant to make up standard solutions, check supplies, etc.?

Yes ____ No ____

QUESTIONNAIRE FOR STUDENTS

To be completed by all students participating in the survey.

Surname ____________________ Christian Name ____________________

School ______________________ Sex _____________

1. Age in years and months ____

2. What do you expect to do next year? Mark only your first choice with a tick.

   a) _____ Continue study at tertiary level.

   b) _____ Get a job and study part time.

   c) _____ Repeat the matriculation examination.

   d) _____ Undecided

   e) _____ Other ____

3. Do you intend being a Science Teacher?

   Yes _____

   No _____

4. Why are you doing Chemistry as a matriculation subject?

   a) _____ No other choice.

   b) _____ Interest in Chemistry.

   c) _____ Needed for Matriculation.

   d) _____ Any other, please indicate ______________________________
   ____

5. List the subjects you are doing for matriculation.

   1. __________________________ 4. ____________________________

   2. __________________________ 5. ____________________________

   3. __________________________ 6. ____________________________