AN EVALUATION OF
SECONDARY SCHOOL CHEMISTRY COURSES

AN EVALUATION OF THE AIMS AND CONTENT OF SECONDARY SCHOOL CHEMISTRY COURSES

By

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ABSTRACT

A number of criticisms have been made regarding high school chemistry introductory courses in recent years. Many of these criticisms are based on claims that those secondary school courses are too theoretical. Some chemical educators claim in particular that current chemistry curricula do not possess enough material emphasizing the application of chemistry. In addition, some evidence exists that there is not enough time available in secondary school courses to balance theoretical material with appropriate, descriptive material.

This project is designed to obtain basic information about the nature of these introductory chemistry courses and to assess the amount of time available for chemistry in secondary schools.

In order to obtain these basic information mentioned above, a questionnaire seeking data from chemistry teachers in England, Canada and the United States would be used. It is hoped that the questionnaire analysis will provide basic data on the validity of the criticisms of the present curricula. The facts revealed about the time spent on chemistry teaching and the emphasis given to applications will facilitate a comparison of the Ontario structure with those of other industrialized areas.

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CHAPTER I

INTRODUCTION

The curriculum in chemistry at the introductory level in high schools and first-year university courses in Canada, Britain and the United States has a number of difficulties associated with it which still remain unresolved in the view of many chemical educators.[1]

Let us consider two relevant quotations:

1. The aim in present texts and in much instruction represents a compromise between the largely descriptive chemistry of a few decades ago and the ideas of physical chemistry which have been incorporated in elementary courses during the past 20-25 years. The result is an encyclopaedic hodge of the old and the new, too extensive for thorough treatment in the time usually alloted and so rich in multiplicity of related details as to bewilder the earnest student. Clearly a pruning process is desirable.[2]

2. The principle reason for this sad state of affairs is the continually increasing volume and sophistication of knowledge in the field of chemistry and the fact that we have not succeeded in coping with this deluge of material.[3]

The second quotation, from a publication by R.J. Gillespie (1976) appeared, a little over 50 years after the first, from an article by Cornog and Colbert in an early issue of the Journal of Chemical

Education (1924). The problem of imbalance in the curriculum then, is certainly not new; as is evident today, the balance of descriptive versus theoretical material in the high school chemistry curriculum, the sequential arrangement of this material and the most effective methods of treating this material remain an unsettled issue.

The lack of an acceptable solution for this "sad state of affairs" is reflected in the continued criticisms regarding introductory chemistry courses.[4] Many of these are based on claims that secondary school courses are too theoretical. In particular, it has been claimed that there is not enough material emphasizing the application of chemistry. In addition there is some evidence that the time available in North American secondary school chemistry courses to balance theoretical material with appropriate descriptive material is insufficient.[5]

This project is designed then to obtain basic information about the nature of introductory chemistry courses and to assess the time available for chemistry especially in North American secondary schools.

In highly industrialized societies, it is important that more science be included in the secondary schools' curricula and that curricular changes reflect real technological problems. These curricular modifications could assist chemistry students in applying their knowledge to current issues of importance, e.g.

1. The energy crisis.

2. The containment of nuclear waste.
3. Toxic and carcinogenic chemicals.
4. Pollution of lakes, rivers and streams, etc.

Such modifications which emphasize the application of chemical principles, it is hoped, would help produce a scientifically literate society in the future.

The data and information from this project are particularly important at this time, since several groups including the Ministry of Education in Ontario are about to develop new curricula in chemistry for high schools.[6]

The main objectives of this project are:

1. To identify the emphasis given to chemistry in secondary school courses (Canada in particular, with some data from the U. S. A., Europe and other countries).
2. To investigate the relationship between principles and applications in the various chemistry courses.
3. To identify the sources and origins of the curricula used in secondary schools.
4. To develop a base for the subsequent development of a new chemistry curriculum for secondary schools, especially in Ontario.

PAST SOLUTIONS AND PRESENT STATE OF AFFAIRS

Internationally, some important previous efforts have been made to solve this problem of balance, sequence and application. Consequently, there are a number of curricular guidelines of Ministries and Boards of Education[7] now discarded, that displaced the traditional syllabuses of earlier eras. They, in turn, have been replaced by a number of elaborate curricula developed in the early 1960's.[8]

One such major attempt to redesign chemistry courses emphasizing the principles of chemistry was made in 1960.[9] The resulting programme - CHEM-STUDY - has greatly influenced chemistry curriculum, as many North American high school programmes are based on it. In Ontario, the present grade 12 and 13 programme is a modified form of the Chem-Study programme.[10]

The Chem-Study programme in the U.S. was initiated after the Garrett Committee and a Steering Committee, funded and supported by the National Science Foundation, unanimously decided that the chemistry courses offered in high schools then, were seriously deficient.[11]

They alleged that courses tended to:

1. Encourage students to memorize a lot of descriptive detail, chemical history and technology that had very little or no pertinence to everyday life.

2. De-emphasize the major unifying concepts and principles of modern chemistry and

3. Avoid the use of meaningful laboratory exercises and materials.

Thus the Chem-Study group adopted as its primary objective the following:

a) To diminish the current separation between scientists and teachers in the understanding of science.

b) To encourage teachers to undertake further studies in chemistry that are geared to keep pace with advancing scientific frontiers, and thereby improve their teaching methods.

c) To prepare and stimulate those high school students whose purpose it is to continue the study of chemistry in college as a profession.

d) To further in the students who will not continue the study of chemistry after high school an understanding of the importance of science in current and future human activities[12] (Merrill and Ridgeway, 1969).

These were the broad aims of the programme which experienced some important modifications when an attempt was made to translate them into specific objectives for classroom execution by chemistry teachers. An overall idea of the aims of the Chem-Study programme was given by Lockart (1972) when he wrote:

> To develop a course based upon experiment where observations and measurements lead to the development of unifying principles -- Heavy reliance is placed upon the laboratory work, so that chemical principles can be drawn directly from students' experience. Not only does this give a correct and non-authoritarian view of the origin of chemical principles, but it gives a maximum opportunity for discovery -- the most exciting part of scientific activity.[13]

Through the efforts of this group of high school teachers, college and university professors and a few others, i.e. industrial and research chemists, a course of study embracing a text, a laboratory manual, a teachers' guide and numerous films materialized. These were successfully piloted and evaluated and have since been disseminated and translated into 15 different languages for use in different parts of the world.

Chem-Study has attained some of its objectives, others, however, have been partially met according to studies conducted by Herron (1964, 1966)[14] in which Chem-Study students scored significantly higher on the cognitive level of "Application" than many students in conventional courses irrespective of ability. Anderson (1964)[15] also reported that low ability students performed better on "Analysis" subtests than did their Chem-Study counterparts. Diderich (1969)[16], on the other hand, criticized Chem-Study and the Chemical Bond Approach in terms of their views on enquiry and the nature of science. He alleged that the various principles of enquiry were not well illustrated. Ramsey[17] (1970) was specific in pointing out areas of deficiency of the Chem-Study programme among which is the lack of suggestions for teachers experiencing difficulties with the programme.

He writes:

> The course was to be based on experimentation, ideas were to be developed inductively from evidence and the emphasis was to be on understanding principles rather than knowing facts. Yet a search of the literature has

> revealed no definite description of how these ideas were to be accomplished in the classroom. How does one teach inductively? How does a teacher integrate the laboratory into classroom experience? What techniques are needed to develop understanding? Little attention has been directed to these instructional questions and the newsletters or teachers' guides seem to leave them largely to the teachers' intuition.

Maybe in the final analysis the worthiness of the Chem-Study programme was simply expressed by Merrill and Ridgeway[18] in the Chem-Study Story when they wrote:

> It is probably safe to say that if anyone has time in the year 2000 to study the history of Chemical Education in the 20th century, he will conclude that the work of Chem-Study was competent, that it had a significant and salutary impact and that it was badly needed. Whether or not it sufficiently met the needs of the times will depend on what further efforts it stimulated.

Other notable curricular developments in addition to individual curricula based on local needs include:

a) the Chemical Bond Approach - whose control theme is the chemical Bond.

b) The Nuffield Scheme.

c) The Alchem Approach.

d) The Australian Approach.

a) THE CHEMICAL BOND APPROACH PROJECT

In 1957, a conference on the teaching of chemistry was held at

Reed College under the sponsorship of a grant from the Crown - Zellenbach Foundation. Fifteen high school teachers and eighteen college teachers participated in this conference, their prinary concern being the question of correlation between high school and college chemistry[19] (Kieffer, 1958). The following objectives were considered desirable for both high school and college, including both cultural or liberal arts and science major courses:

1. To present the basic principles of chemistry as an intellectual discipline and to achieve an appreciation of chemistry as a creative pursuit of human knowledge.
2. To develop facility in analytical, critical thinking - especially thinking which involves logical and quantitative relationships.
3. To develop scientifically literate citizens through an understanding of (a) the methods of science (b) the role of chemistry in society and everyday living.
4. To stimulate interest in chemistry, to identify promising students, and to provide adequate preparation for further scientific studies.

The outcomes of the conference were (1) to formulate a course in high school chemistry that would achieve the above objectives and (2) to utilize the concept of "chemical bonds" as the unifying theme of the course. The resulting C. B. A., or Chemical Bond Approach, consisting of an 18 chapter text, Chemical Systems, and 20 experiments, written by nine high school and nine college teachers during the summer of 1959, was tested in nine high schools during the 1959-1960 academic year[20] (Westmeyer, 1961).

b) THE NUFFIELD SCHEME

The emphasis in the Nuffield Syllabus is on learning instead of waiting to be taught; understanding processes, principles and concepts rather than amassing information, has also gained a central position in this programme. Thus learning, by finding out or discovery rather than being told is its main theme, and consequently, a very large proportion of the subject time is devoted to laboratory experience. As such, the Nuffield Scheme, Stage I, is mainly experimental in nature, using a guided discovery approach, first proposed by Gerome Bruner (1963).

In Stage II, topics such as the mole concept, molecular and crystalline structure, energetics, bonding, and atomic structure follow in this order. However, the main aims of the scheme are for students to be aware of:

1. The nature and limitations of scientific laws.
2. The inter-relationship between facts and theories; the

immutability of the former, and the mutability of the latter.

3. The intimate connection between fact and hypothesis.
4. The need to assume a particular structure for atoms in considering the reactions in which matter takes part.
5. Elementary notions of the ways in which atoms can interact to produce substances, with new properties, leading to molecular and ionic equations and the information which they convey.
6. Simple qualitative ideas of the factors which can affect a chemical reaction.

These latter two curricula, i.e. the Chemical Bond Approach and the Nuffield have not met with wide-spread acceptance in North America. Whichever one of these has formed the basis of a chemistry course, there still seems to be the widespread dissatisfaction and criticisms noted earlier on in this report.

This scheme has been in use mainly in Britain for over ten years, and during this period has been revised and reviewed, mainly in the direction of some psychological theories of learning, e.g. Piaget and Gagne.

In North America and in the United Kingdom in particular, the Universities complain that:

1. Students do not know enough basic facts about common

chemicals.[21]

2. A smaller fraction of good students attempt chemistry as a major in college than do other science subjects.[22]

3. Students lack laboratory skills and experience with chemicals.[23]

4. In covering a lot of theoretical material at too early a stage in their chemistry career, students are forced to rote learn and as such do not grasp the significance of the concepts taught.[24]

In Alberta,[25] Australia[26] and the Soviet Union[27] interesting new chemistry curricula have been developed in response to some of the problems elaborated above.

c) THE ALCHEM APPROACH

ALCHEM[28] (Alberta Chemistry Projection Materials) was initiated by the Edmonton Regional Chemistry Council and is centered around the following objectives:

1. Keeping a high level of chemistry (content).
2. Provision of easy-to-learn-from classroom materials, and
3. Integration of applied chemistry into classroom exercises.

The applied chemistry in turn is defined as:

a) environmental

b) consumer

c) industrial, and

d) historical chemistry

Throughout both the formative and summative evaluation stages of this programme, feedback has been positive and valuable; it has also been claimed that in a comparative study[29] Alchem students have significantly out-performed students utilizing other approaches and materials.

d) THE AUSTRALIAN APPROACH

The Australian Approach[30] is progressive, in that it attempts to deal with some of the problems discussed earlier. There are ten main objectives of this programme, one of which is singled out for particular comment:

> The course should present, at a level of sophistication appropriate to the stage of intellectual development of the school leaving age group (1 - 50 percentile), the theoretical background and important generalizations that have enabled a vast array of chemical facts to be systematically ordered and correlated. Conceptual and theoretical considerations that demand a level of intellectural maturity greater than one might reasonably expect of a 17-18 year old should be omitted.

Paul Hirst's (1970)[31] idea of a rational curriculum involves creating a course with a certain amount of content, to be taught using certain methods of activity in achieving certain prescribed objectives.

In the opinion of Lawrence Stenhouse[32] (1970-71) process is a more favourable theme; a curriculum should, according to him, possess the following qualities:

a) Definition of the course content,

b) Acceptable teaching procedures, and

c) Articulation of standards of evaluation of pupils.

Whatever the choice of a theme, be it content or process oriented, questions such as: What are the value-systems, unquestioned assumptions and learning theories embraced by curriculum makers arise. Other questions worthy of attention are:

a) What view is taken of the nature of knowledge? Usually in these curricula, chemistry is depicted as a body of knowledge of which there is a consensus of opinion. Is chemical knowledge then assumed unproblematic? Does chemistry subscribe to the Popperian view that science proceeds by the refuting of reputable hypotheses?[33] (Lakatos and Musgrave, 1970). To expand on these and other questions would require the neglect of more direct and pertinent questions viz.:

b) What assumptions are made about the nature of the pupil? Is their intellectual development at different age ranges catered to in the curriculum? (Herron, 1975)[34] (Beistel, 1975)[35]. Sometimes it is even unclear as to whether these various chemistry curricula are directed towards pupils in streams or towards mixed ability groups.

c) Add to this the almost complete reticence about the learning theory(ies) embraced, it is interesting then to observe that in this Australian programme the Piagentian Theory of Developmental Stages has gained some measure of acceptance.

Elsewhere, more recently, the use of programmed texts in the Nuffield A-level chemistry involves tacit acceptance of the ideas of B. F. Skinner and of the Stimulus-Response Theory of learning. This is a small but welcome change in the situation.

THE ONTARIO SCENE

Curriculum 17 was the main curriculum guideline available to chemistry teachers in Ontario, who as a rule followed what could be termed the "Traditional" course of teaching up to 1952[36]. Soon thereafter, a gradual dissatisfaction developed in the late 1950's and early 1960's. In 1962, a publication emerged entitled Design for Learning. This publication directed criticisms against science teaching in Ontario at nearly every school level as the following observation illustrates:

> In general, far too much unrelated information is given in the courses (preparation and properties of too many compounds, complex reactions treated

> superficially and crude details of industrial processes). The result is that an average student, faced with a widening mass of new factual material resorts to memorizing these facts and gains little or no insight into the nature of chemistry. These courses form a poor background, both for students who intend to continue their studies and for those who do not. The knowledge gained is superficial and unrelated and is consequently soon forgotten.[37] (Frye, 1962)

Following this and other criticisms several changes occurred in the teaching of chemistry in Ontario secondary schools, almost simultaneously with similar changes in the U.S.A. and Great Britain. These are some of the Ontario changes:

1. In 1966 a new grade 13 curriculum was announced and subsequently came into use in 1967. This curriculum was called S-17D.
2. In 1967, as a consequence of widespread dissatisfaction, the grade 13 province-wide, departmental examinations were phased out.[38]
3. Next in turn was the phasing out also of the inspectorate school system in 1968-69.
4. In 1970, when the "Credit System" was introduced into the school system, Ontario schools again were forced to allocate less time to the teaching of chemistry.[39]

The S-17D Chemistry Curriculum, though heavily influenced by Chem-Study, especially in its sequencing of topics, nonetheless maintains its own peculiar arrangement in order to accommodate the two-year span of grades 12 and 13.[40]

Presently, as a result of all these changes in the Ontario school system, curriculum and evaluation have now become a matter of local concern and responsibility.

CHAPTER II

PROCEDURE

In order to investigate present chemistry curricula, a questionnaire was constructed and circulated seeking the following information:

1. Time spent in the teaching of chemistry as a subject in the secondary schools of:
   a) The Canadian Provinces
   b) England
   c) The United States (30 states were selected for sampling).
2. Whether chemistry is compulsory at any stage in a student's secondary school career and whether the chemistry programmes available cater to:
   a) University-bound students
   b) Technical and Community College-bound students, or
   c) The terminal students
3. What type of chemistry curriculum is operative in a particular region in which a school is located and whether such

a curriculum is widely accepted?

4. The aims and contents of the curricula covered in these various regions, including the extent to which they incorporate industrial, environmental, and domestic applications.

5. To what extent, if any, the laboratory skills and experimental techniques of chemistry are developed in secondary school chemistry students.

In addition to the mailed questionnaire, comparison data were obtained from the literature wherever possible.

In December 1977, a pilot survey was conducted in the Canadian Provinces using a representative sample, extracted from 140 participants of the McMaster University Shell programme for science teachers. The pattern of distribution for the first batch of questionnaires was as follows:

Ontario	20
Alberta	20
Manitoba	20
Saskatchewan	20
Quebec	20
British Columbia	20
New Brunswick	20
Nova Scotia and Prince Edward Island	20

Newfoundland 20

In this pilot survey a response percentage range of 60-78 for the above Provinces was obtained.

A follow-up survey of selected schools in England, the U.S.A. and Canadian Provinces was conducted. In order to obtain reliable information, only the heads of the Chemistry departments were asked to respond to the questionnaire distributed.

The mailing list of the Chem-13 News Bulletin, printed and distributed by the University of Waterloo, Ontario, Canada was used to select schools for the U.S. survey. Finally, through the Interlibrary Loan System, a list of the major secondary schools in England was secured. This aided in determining a U.K. sample.

In order to eliminate subpopulations in these samples, no further discrimination was made between respondents as to age, sex, or years of teaching experience.

ANALYSIS PROCEDURE

The questionnaire (see appendix) items were treated as follows:

Question 1.

a) Amount of Time Spent on Chemistry: diagram I on page 28 shows a schematic illustrating the number of years during which chemistry is taught as a separate subject for the 10 provinces of Canada, England and six states in the United States, i.e. New York, New Jersey, Michigan, Oregon, Ohio and Pennsylvania. Evidence of the extend to which chemistry is taught as part of a General Science programme was also obtained from the additional information furnished by respondents. All data used were derived from questionnaires returned. The average number of hours shown in diagram I, was computed by averaging in the various samples, the hours spent in a programme which prepares students for University entrance only, as this will inevitably be the programme involving the highest number of teaching periods.

b) Table 1 was set up displaying the percentages for the various samples, including England and the six states in the U.S. Since chemistry could be a compulsory subject for one or more years in a particular school, the total percentage for all years in a given sample may or may not sum up to a hundred.

c) The data regarding the percentage of all students taking chemistry as a separate subject were analysed by computing limits within which these percentages varied in a sample. These percentage ranges were then arranged vertically to give a direct comparison among samples.

Question 2.

a) For each sample, the average of all hours spent teaching chemistry for the various programmes viz:

1. University entrance
2. Technical, Community or Post-Secondary programmes and
3. Terminal programmes

were computed.

These averages were then used to compute in turn a national average for these various programmes. This information is included in the schematic shown in diagram I.

b) Student Laboratory Work: In this section, the total number of respondents for each of the six ranges of percentages was computed as a percentage of the total number of respondents to that particular question in a sample. Tables 2 and 3 on pages 34 and 35 were set up, showing these final percentages for the various samples in Canada, England and six states in the U.S.

Question 3.

a), b) and c) Curriculum Section: Since the questions in this section are of the fixed-alternative type, the total sum of the individual responses for each alternative in any given sample was calculated as a percentage of the total number of respondents in a given sample. The result is Tables 4 and 5 on pages 45 and 46 which incorporates these percentages for all samples of the survey.

Question 5.

a) Aims and Content of Chemistry Courses: In coding the data from this portion of the questionnaire, nine categories were devised into which the aims and rationale for a variety of chemistry programmes in these high schools seem to fit.

This particular procedure was adopted, because in a vast majority of the questionnaires returned, students attempted the same courses for the different programmes mentioned in the questionnaire. Therefore, although the rationale for each programme might be different, yet they are all embodied in the one course. Furthermore, the content of these programmes remains the same. The only variation being that student participation might be for one, two or three years, depending on whether they enrolled in grades 10 only, grades 10 and 12, grades 10, 12 and 13 or just grades 12 and 13.

Most of these schools showed no separate programmes for pupils who are either technically or terminally bound. Only a small fraction of the total number of responses showed definite separate programmes for students in all three categories. Therefore, the analysis procedure was to score for each questionnaire, the items quoted as aims or rationale against the nine categories devised. The next step was to total the number of selections in each category and compute its percentage of respondents selecting each category in the various samples. It is important to note that since a given respondent might select one or more of these categories as aim or rationale, the total percentage points for each sample will of necessity exceed a hundred.

b) When a list of the different topics from the responses in these samples was compiled, they amounted fortuitously to a total of 16 items. To these items, two more were added, viz.: - Blanks and NONE to give a total of eighteen categories each. One such list was for Inclusions and the other for Deletions. The items so listed were next classified as Descriptive-Theoretical, or both Descriptive and Theoretical. Subsequently, the percentage of Descriptive and Theoretical components in both the Deletions and Inclusions was tabulated. The last operation involved the calculation of the percentage of individual items selected by respondents as a percentage of the total number of respondents in a particular sample. See Tables 7-10.

c) and d) What is of importance here is the degree to which practical applications are included in the chemistry introductory programmes. Thus, the range (in percentages) displayed by each province was tabled vertically to give a direct comparison of the extent to which industrial, biological and domestic applications were involved. -Table 11.

e) In Table 12 is a list of chemicals. It was compiled after consultation with some professors at McMaster University Chemistry Department (i.e. Professors R. Childs, R.J. Gillespie and D.A. Humphreys). This list was then compared with a list of the most common metals and chemicals currently being used in U.S. industry which appeared in a publication of a 1977 issue of Chemistry and Engineering News. Table 12 also shows the six categories into which these substances have been classified.

The coverage given these categories by respondents was defined as:

1. Very Substantial - 75% and over - (S)
2. Moderate - Substantial - 50-75% - (MS)
3. Slight - Moderate - 25-50% - (SM)
4. None - Slight - 0-25% - (NS)

In computing the percentage coverage for a category in each sample, firstly, a point each is awarded for preparation, properties, applications, and use in the laboratory. Hence, each substance in a category is worth a maximum of four points. The different categories will then carry sum totals of 36, 28, 24, 28, 20 and 28 points respectively. The actual coverage by respondents was then compared with these maxima. By extending this process over all questionnaires in a given sample, the percentage coverage was derived. This is shown in Tables 13 and 14 respectively. These tables further display the comparative coverage of the Canadian Provinces, England and six states of the U.S.

In the survey of the U.S., 900 questionnaires were distributed in thirty states, selected to represent all possible geographical areas. However, a) because responses were very low in some states, and b) because of badly worded and incompletely filled questionnaires, only questionnaires from six states with a significant percentage return (after eliminating incomplete questionnaires) were utilized.

The six selected states then offered results that were forty percent and above in response: - i.e.

New York	55%
Pennsylvania	50%

New Jersey	40%
Ohio	40%
Oregon	75%
Michigan	80%

Returns for the Canadian Provinces were as follows:

Ontario	65%
Quebec	55%
Newfoundland	45%
Nova Scotia and Prince Edward Island	45%
New Brunswick	50%
Manitoba	50%
Saskatchewan	55%
Alberta	95%
British Columbia	60%

Returns for England were:

England	42%

f) Other Chemicals: The list supplied by respondents, of other basic chemicals discussed and used in this course were badly done and, therefore, discarded.

CHAPTER III

ANALYSIS AND DISCUSSION

With the exception of the provinces of Ontario, Alberta, Quebec and New Brunswick which offer general science courses for the age range of 13-16 years, it will be observed in diagram I that the rest of the Canadian Provinces offer chemistry as a separate subject mainly in the last two years of a student's high school career. The number of hours devoted to chemistry teaching proper per year also varies widely within Canadian Provinces. There is a high of 154 hours per year for New Brunswick, closely followed by Alberta with 131 hours, Newfoundland with 131 hours, and Prince Edward Island with 130 hours. Ontario with 113 hours per year is amongst a small group of provinces that spend less time on chemistry.

In the six states surveyed in the U.S., more time is spent with an average of 156 hours per year than is spent in Canada. These data agree with published figures by J.A. Young (1972) who wrote:

> At the secondary level, and only for older students, one year is devoted to chemistry giving a total of some 150 hours. Occasionally there is an optional second year available giving a grand total of about 300-350 hours of chemistry instruction in the secondary schools, typically achieved near the end of the student's seventeenth year.[41]

DIAGRAM 1: Total Hours Spent Teaching Chemistry As A Subject In Relation To The Age Range Of Pupils

Ages (Years)	10	11	12	13	14	15	16	17	18	19	20	Total Hours
Ontario							113	114				227
Alberta							131	136				267
Saskatchewan							114	115				229
British Columbia							108	109				217
Manitoba							116	117				233
Quebec							100	100				299
Newfoundland							131	131				262
Nova Scotia & P.E.I.							130	130				262
New Brunswick							154	154				308
N.W. Territories							120	120				240
England & Wales				50	68	91	160	160				529
U.S.A.							156	156				312
	10	11	12	13	14	15	16	17	18	19	20	

KEY

- Evidence of General Science Being Taught
- First Year in Which Chemistry as a Separate Subject is Taught in a 3-Year Programme
- First Year of Chemistry in a 2-Year Programme

In England where chemistry instruction starts much earlier than 16 years (at the age of 13 years), the yearly hours devoted to chemistry taught as a separate subject increases from 50 hours at age 13 years to a maximum of 160 hours for each of the two sixth form years. It is obvious from diagram I that many of the Canadian Provinces (especially Ontario) do not make available a comparable number of hours for chemistry instruction.

In comparing national averages, the figures from this survey are:

Canada	- 254 hours	- total for 2 years
U.S.A.	- 302 hours	- total for 2 years
England	- 569 hours	- total for 5 years

A significant observation here concerns the fact that by age 14-15 years most European chemistry students, including both England and Wales, are already experiencing chemistry as a separate subject, whereas on the North American continent, students wait till their 16th year or later.

J.J. Thompson (1971) observed:

> Only in a few countries is the study of chemistry delayed until age 16 or over, and only in Iceland is the chemistry course non-continuous; no chemistry being taught there in the penultimate year.[42]

This difference in total number of hours devoted to chemistry teaching between Canada, the U.S. and England has been frequently cited by many Canadian teachers in this survey as being responsible for their inability to cover a chemistry curriculum, which in their opinion would be adequate for students in Canadian high schools. R.M. Kalra (1971) echoed this opinion in British Columbia in these comments:

> Instruction in chemistry starts too late in high schools and not enough courses are offered.[43]

On the other hand, it has been suggested that prolonging the student's period of general education, without specialization, is advantageous in a dual way:

a) The students are allowed the opportunity of acquiring a broad general education, which hopefully puts them in a position to make a more suitable professional choice.

b) They reach a stage of mental development appropriate to the learning of formal theories and concepts.[44]

COMPULSORY STATUS OF CHEMISTRY

Table I provides additional information as to whether chemistry courses are compulsory or optional. In the majority of schools, chemistry courses are optional, and no prerequisites are demanded for student participation. This appears to be a normal trend, except in New Brunswick, where a departure from this is observed. Other provinces with a slight deviation from this trend are British Columbia and Manitoba.

In England, however, the situation is completely reversed. In

TABLE 1: Years In Which Chemistry Is Taught As A Compulsory Subject; Displayed As A Percentage of Total Response

F.Y. = Final Year

Sample Location	F.Y.	F.Y.-1	F.Y.-2	F.Y.-3	F.Y.-4	F.Y.-5	None
Ontario	-	-	-	-	-	-	100
Alberta	-	-	5.3	-	-	-	94.7
Saskatchewan	-	-	9.1	-	-	-	90.0
British Columbia	-	-	-	14.3	-	-	85.7
Manitoba	10.0	10.0	-	-	-	-	90.0
Quebec	-	-	-	-	-	-	100.0
Newfoundland	-	-	-	-	-	-	100.0
Nova Scotia & P.E.I.	-	-	-	-	-	-	100.0
New Brunswick	10	30	-	-	-	-	70.0
England	-	-	14.3	57.1	100.0	42.8	-
New York	-	-	-	-	-	-	100
Pennsylvania	18.18	-	-	9.09	-	-	72.7
Michigan	12.5	-	-	-	-	-	77.5
Oregon	-	-	-	-	-	-	100.0
New Jersey	-	-	-	-	-	-	100.0
Ohio	-	-	-	-	-	-	100.0

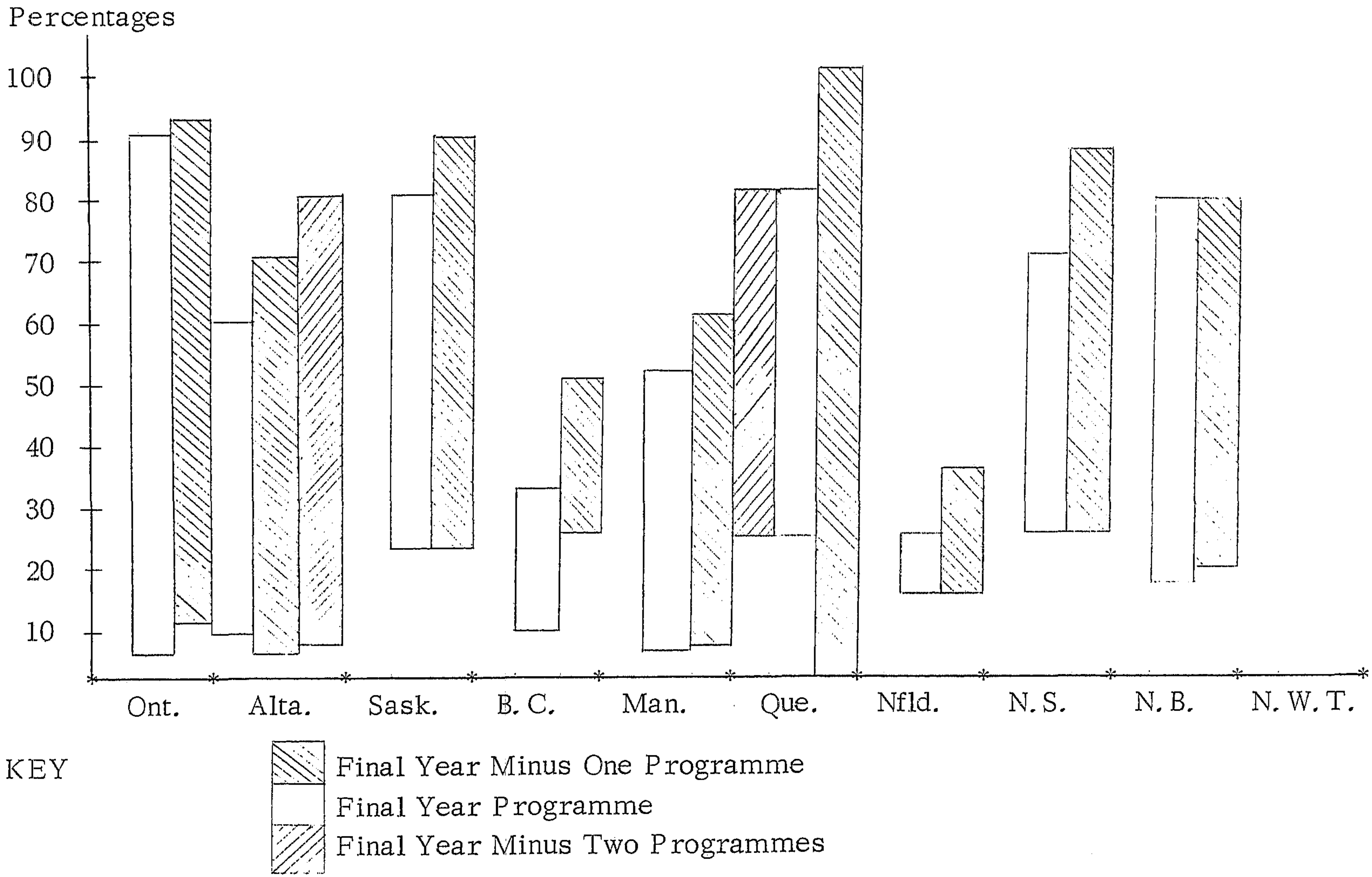
none of the years quoted in the questionnaire is chemistry an optional subject. In the final and penultimate years, chemistry seems to be optional mainly because at the sixth form level, there are certain combinations of subjects that are desirable for the pursuit of specific professions, and therefore, choice of subjects is kept as flexible as possible. However, in the remaining years, chemistry is a compulsory subject to a degree; the compulsory year or years depending on the individual institution. From our British samples, the second year of chemistry seems to be popular for making chemistry compulsory.

Of the six states in the U.S., only Pennsylvania and Michigan are similar to New Brunswick in Canada, in their degree of deviation from this non-compulsory norm shown in Table I. In this regard, Canada and the U.S. are similar, but clearly different from England.

Much has been offered by way of written opinions in support of the benefits to be derived from making chemistry compulsory in high schools.[45] However, some claim that such a move may not necessarily be beneficial to students, as it may create a further bias against the subject, through adverse information drifting down what has been referred to as the "Student Grapevine".[46]

The non-compulsory aspect of chemistry teaching on the North American continent greatly influences the number or percentage of students taking chemistry at any given time as a separate subject. The graphs in diagrams 2, 3 and 4 give a comparative view of this situation.

DIAGRAM 2: Percentage Range Of Students Offering Chemistry As A Separate Subject In The Last Three Years Of High School



In diagram 3, the percentage range of students in their final year taking chemistry as a separate subject is clearly below 20% for four of the six U. S. States. For Pennsylvania and New Jersey, the percentage ranges between 20 and 30%. In contrast, diagram 2 for the Canadian Provinces shows a consistent percentage of 30% and above, except for Newfoundland, where only about 10% of the students in their final year attempt chemistry as a separate subject.

In diagram 4, there is a consistent 35% range of students both in the upper and lower sixth forms in England attempting chemistry as a separate subject. This consistency is not surprising as students would normally maintain their subject combinations best suited for whatever professions they aspire to at the tertiary level.

In England, for the first and second year programmes in chemistry in which participation for students is invariably compulsory, the percentage range is a 100. Thereafter, this percentage decreases to 60, for students offering chemistry as a separate subject at "O" level and finally to 35 at "A" levels.

In the returned questionnaires from many institutions, it was clear that no separate programmes existed for the university bound, the technical or community college bound, or the terminally bound student. These three categories of students are provided with and exposed to a single programme in chemistry, but to varying degrees. The college or university entrants would normally complete the entire

DIAGRAM 3: Percentage Range Of Students Offering Chemistry As A Separate Subject In The Last Three Years Of High School

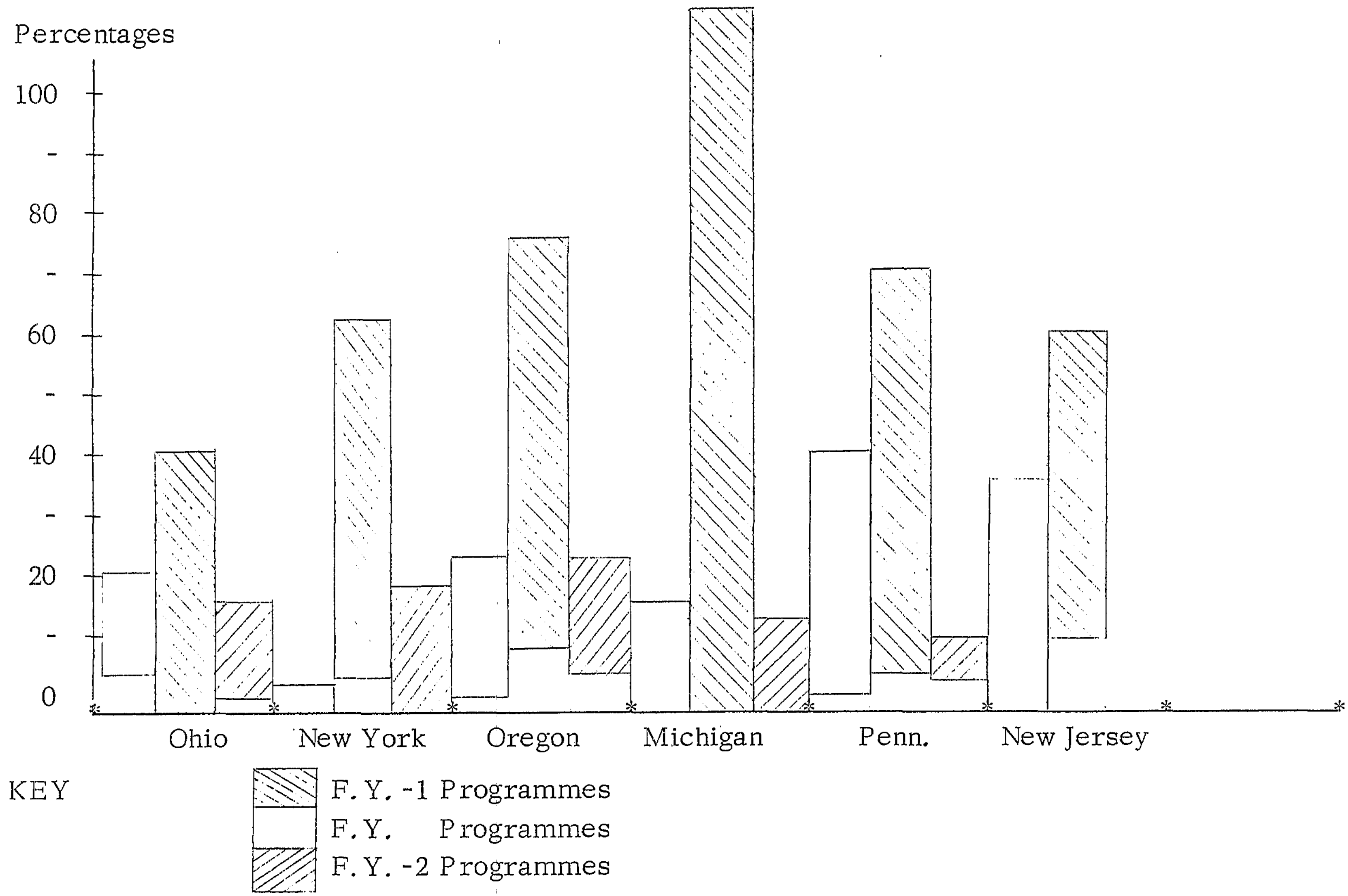
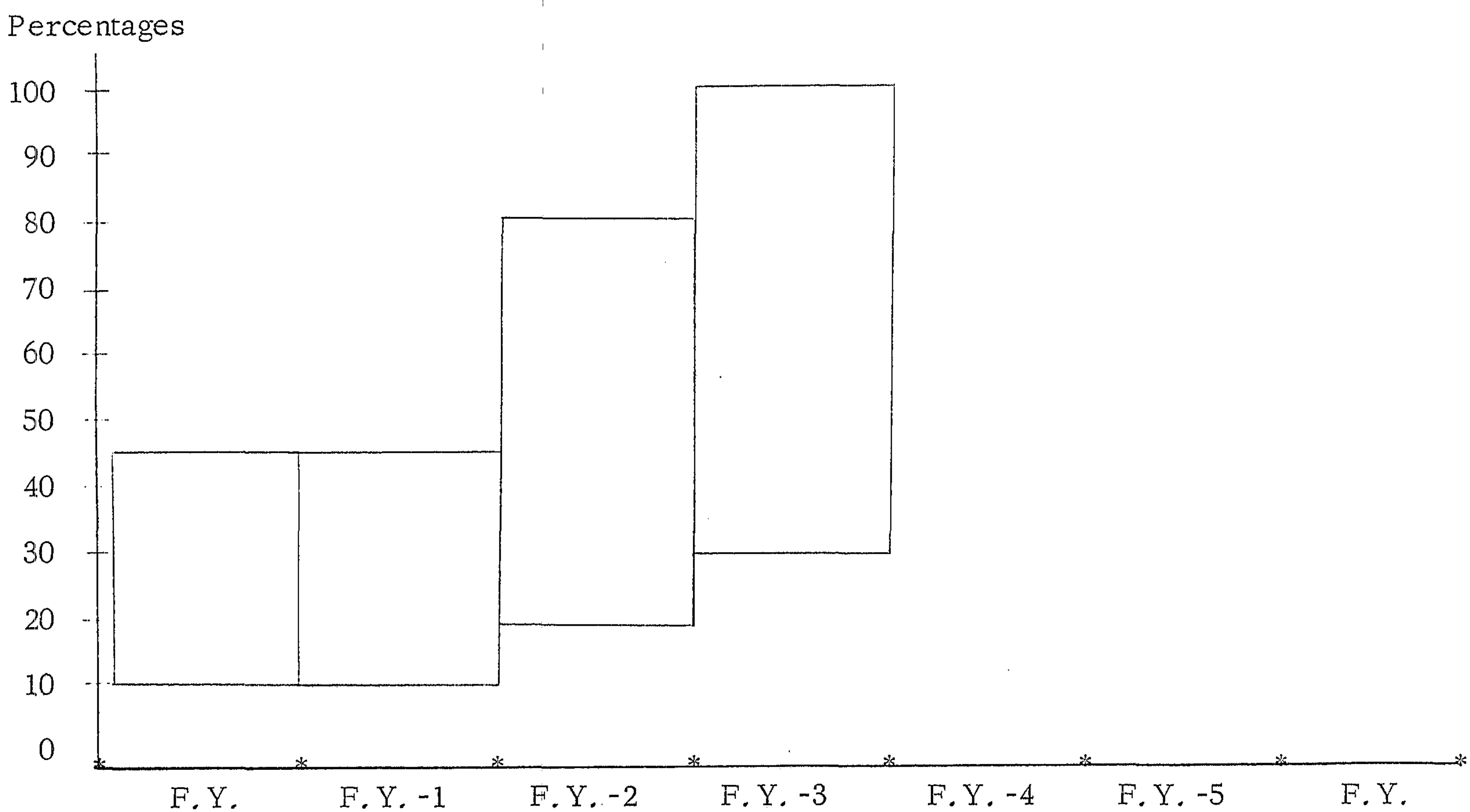


DIAGRAM 4: Percentage Range of Students Offering Chemistry As A Separate Subject in English Secondary Schools



programme; whereas the community college students - 75% of the programme, and the terminally bound - 50%. As such, a diagram similar to diagram I for community college bound and terminal students was impossible to construct. The figures shown in diagram I, therefore, are figures entirely for question 2. (a) (1) of the questionnaires: - i.e. (A programme which prepares for university entrance in pure and applied science).

LABORATORY ASPECT

In the diagrams showing the varying times allocated to laboratory work in the different samples, i.e. diagrams 5, 6 and 7, a major observation is that in five of the Canadian Provinces between 9 and 30 percent of the respondents spend from 0 - 10% of the time allocated to teaching chemistry in the laboratory. This is in direct contrast to the U.S., England and the remaining Canadian Provinces that spend more than 10% of the Chemistry timetable as laboratory sessions.

A remarkable 30% and over of the English schools in the sample allocate between 30 and 50 percent of the total time for chemistry as laboratory periods. This must reflect the emphasis on laboratory work to be found in the curricula employed in these schools. Of the six states in the U.S. sample, only in New Jersey is there a drop in the percentage of schools that utilize 20 - 30% of the subject time in the laboratory.

TABLE 2: The Fraction Of Time Spent On Chemistry Teaching In The Provincial High Schools, That Is Allocated To Student Laboratory Sessions. This Is Presented As A Percentage Of The Total Response For Each Province

Percentage Range	Ont.	Alta.	Sask.	B. C.	Man.	Que.	Nfld.	N. S.	N. B.	N. W. T.
< 10%	7. 69	-	18. 18	-	30. 0	12. 5	-	-	11. 1	-
10 - 20%	19. 2	42. 1	54. 54	14. 28	50. 0	25. 0	50. 0	11. 1	55. 55	-
20 - 30%	50. 00	42. 1	27. 27	42. 85	10. 0	25. 0	25. 0	33. 3	22. 22	33. 33
30 - 40%	19. 2	15. 75	-	28. 57	10. 0	37. 5	25. 0	33. 3	11. 1	66. 6
40 - 50%	3. 84	-	-	14. 28	-	-	-	22. 2	-	-
over 50%	-	-	-	-	-	-	-	-	-	-
	99. 3	99. 95	99. 99	99. 98	100. 00	100. 00	100. 00	99. 9	99. 97	99. 93

TABLE 3: The Fraction Of Time Spent On Chemistry Teaching Allocated To Student Laboratory Sessions

Percentage Range	Eng.	N.Y.	N.J.	Penn.	Ohio	Oregon	Mich.
10%	-	-	-	-	-	-	-
10 - 20%	-	36.4	25.0	27.3	12.5	40.0	25.0
20 - 30%	-	27.3	37.5	45.4	12.5	40.0	50.0
30 - 40%	37.5	27.3	37.5	27.3	37.5	-	25.0
40 - 50%	50.0	-	-	-	25.0	-	-
over 50%	-	-	-	-	12.5	20.0	-
Blanks	12.5	9.1	-	-	-	-	-

DIAGRAM 5: Time Allocated To Laboratory Sessions

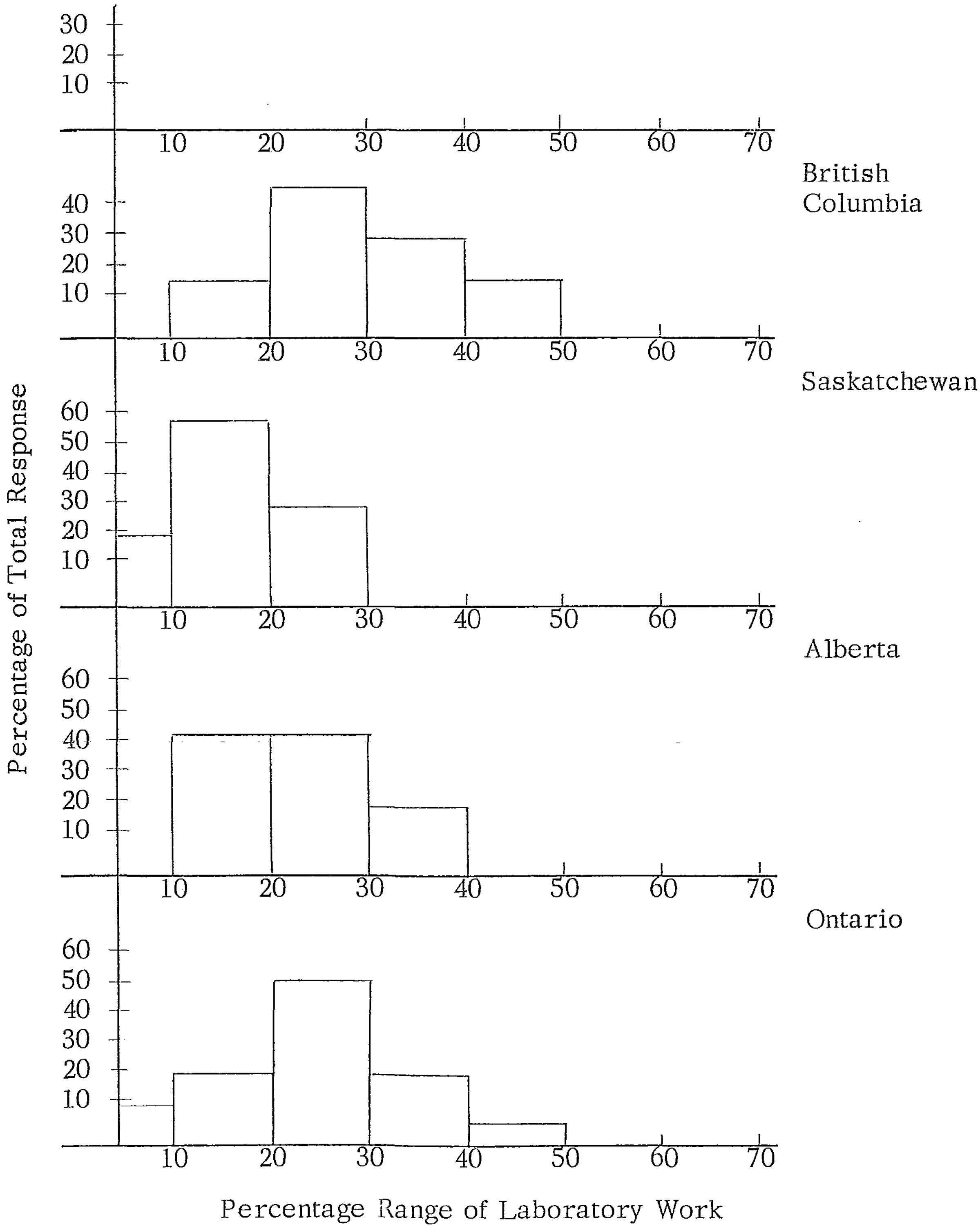


DIAGRAM 6: Time Allocated To Laboratory Sessions

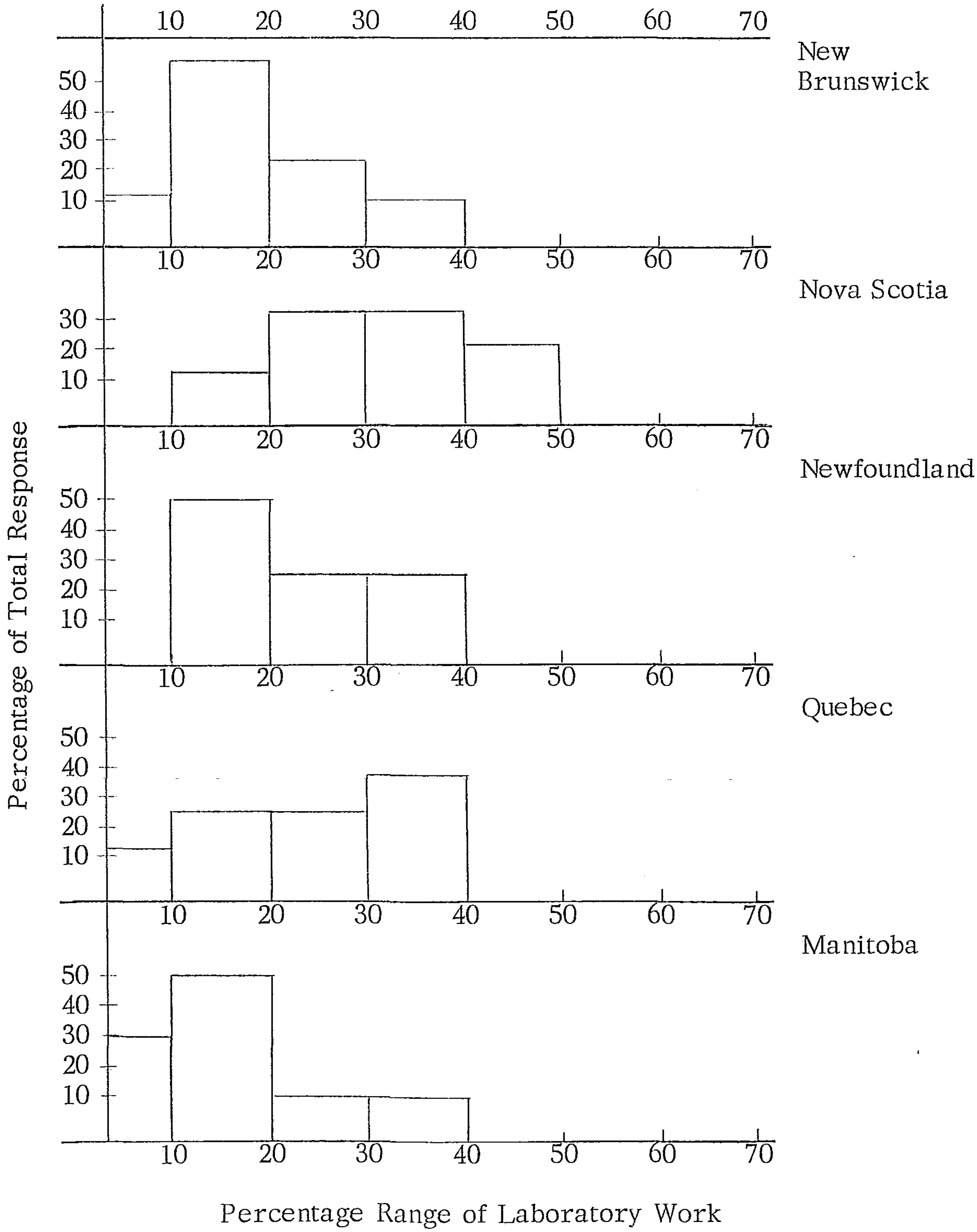
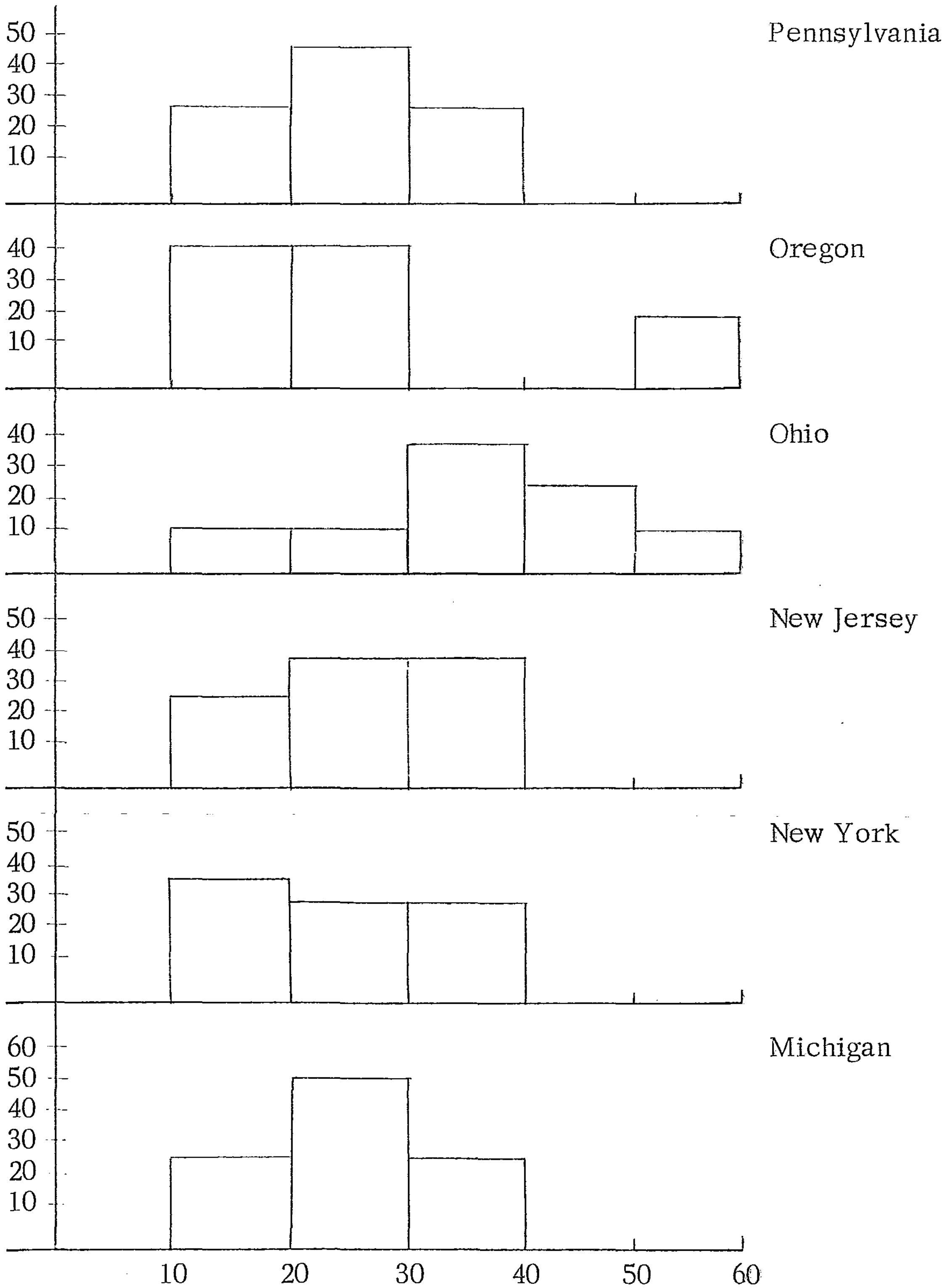
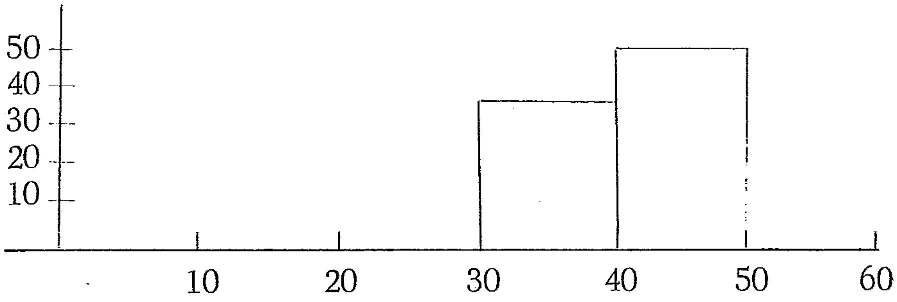


DIAGRAM 7: Time Allocated To Laboratory Sessions





England

New York, which has a state-wide syllabus, seems to stress the importance of practical activities according to survey results. Over 20 percent of the respondents allocate between 10 and 20 percent of the subject time to experimental exercises, whilst a further 40 percent of the respondents allocate 30 - 40 percent of the subject time to laboratory sessions.

Table II on page 38 further shows that the five Canadian Provinces that allocate less than 10 percent of the chemistry timetable to practical sessions (in 10 - 30 percent of their secondary schools) are: Saskatchewan, Ontario, New Brunswick, Quebec and Manitoba. Of these five provinces, only New Brunswick utilizes a chemistry curriculum not based on Chem-Study to any significant extent (11. 1 % Chem-Study Component). The other four provinces base their curricula on the Chem-Study approach to the extent of 90. 0, 88. 4, 97. 5 and 80. 0 percent respectively.

At this stage we encounter a paradox as Chem-Study classes demand that a high proportion of the subject time should be devoted to laboratory sessions, even if this paradox is rationalized on the grounds that:

a) Funding is insufficiently provided for the purchase of necessary equipment and apparatus.

b) In some of these schools teachers still follow the didactic method of instruction.

TABLE 4: Canadian Provinces Curriculum Data

		Ont.	Alta.	Sask.	B. C.	Man.	Que.	Nfld.	N. S.	N. B.	N. W. T.
Is The Curriculum In Your School Set By:	A Ministry of Education	80.76	89.47	90.9	100.0	70.0	100.0	100.0	77.77	88.8	-
	A University Entrance Board or Committee	-	-	-	-	-	-	-	-	-	-
	A Regional Board of Education or Committee of Education	-	-	-	-	-	-	-	-	-	-
	By the Individual Local School	19.3	5.26	-	-	10.0	-	-	11.1	-	66.6
	Others	-	5.26	9.1	-	10.0	-	-	11.1	-	33.3
Is Your Chemistry Course Typical of Those Found in Your Area	YES	88.46	89.7	100.0	100.0	90.0	100.0	100.0	100.0	100.0	66.6
	NO	11.53	10.52	-	-	10.0	-	-	-	-	33.3
Is Your Curriculum Based On:	The Nuffield Scheme	-	-	-	-	-	-	-	-	11.1	-
	The Chem-Study Programme	-	78.94	90.9	85.71	80.0	87.5	100.0	44.44	11.1	66.6
	The Chemical Bond Approach (CBA)	88.43	-	9.1	-	-	12.5	-	22.22	-	-
	Any Others	3.84	21.05	-	14.28	20.0	-	-	33.33	55.5	33.3
	Blank Responses	7.69	-	-	-	-	-	-	-	22.2	-

TABLE 5: England And The United States Curriculum Data

		Eng.	N.Y.	Penn.	Mich.	Ore.	N.J.	Ohio
Is The Curriculum In Your School Set By:	A Ministry of Education	-	90.9					12.5
	A University Entrance Board or Committee	63.6	-					-
	A Regional Board of Education or Committee of Education	-	9.1	9.0	12.5	40.0	12.5	25.0
	By the Individual Local School	100.0	-	100.0	87.5	80.0	87.5	75.0
	Others	-	-	-	-	-	-	-
Is Your Chemistry Course Typical of Those Found In Your Area	YES	100.0	100.0	72.7	100.0	60.0	100.0	50.0
	NO	-	-	36.3	-	60.0	-	25.0
Is Your Curriculum Based On:	The Nuffield Scheme	63.6	-	9.0	-	-	-	-
	The Chem-Study Programme	9.1	27.2	63.6	75.0	80.0	62.5	62.5
	The Chemical Bond Approach (CBA)	-	-	9.0	-	-	-	-
	Any Others	54.5	90.9	54.5	50.0	60.0	62.5	50.0
	Blank Responses	-	-	-	-	-	-	-

c) The Chem-Study programme itself has been modified to such an extent that experimentation is expendable; yet the percentage range of schools making use of less than 10% of the subject time as laboratory sessions seems unusual. This behaviour perhaps prompted G. F. Aitkinson (1975) to comment about Canadian secondary school students:

> Some secondary school chemistry students today will have seen numerous demonstrations probably including Chem-Study films but may have performed almost no experiments with their own hands. Others will have seldom completed a week without experimentation, doing as many as 400 experiments in their schools. Little emphasis is placed on technique and in general, students entering university cannot perform a simple volumetric analysis unless they have followed the industrial chemistry syllabus in a technical high school.[47]

The extent to which the Chem-Study programme was modified to produce the Ontario S-17E Curriculum is further evident, when the average time allocated to laboratory sessions is compared for Canada and the U.S. in the ranges of: 20 - 30 percent and 30 - 40 percent in which the highest allocations are observed. Thus:

Range	Canada	Average of Six U.S. States
20 - 30 percent	31.1	35.5
30 - 40 percent	27.4	32.2

In the English sample, hardly any schools allocate 20 - 30 percent of the chemistry timetable to laboratory sessions; whereas over 35% of these English schools allocate laboratory sessions in the 30 - 40 percent range and an additional 50% in the 40 - 50 percent range. In Table 5 is a further indication that the curricula in 63.7% of English schools are highly influenced by University Entrance Boards. However, since the individual local schools participate 100% in the formulation of these various curricula, the University requirements must be used as core, and expanded to cater to students of all categories.

The Nuffield syllabus also seems to be widely used in English schools. Since it is highly experimentally oriented, it is no surprise that quite a significant proportion of the subject time in English schools is apportioned to laboratory sessions.[48]

It has been recently suggested that to foster understanding of chemistry we need to make the curriculum process-oriented, i.e. a more heuristic approach is necessary.[49] In accordance with this proposition, more guided experimental methods have been recommended in the teaching of chemistry as opposed to the didactic method.

If this suggestion is accepted, the allocation of 30 - 40 percent of the subject time to laboratory sessions could be justified.

In the U.S. there is not the sort of centralization of curriculum activities comparable to that found in England and in Canada. The Ministries of Education in Canada play a role in this centralization of activities. Surprisingly, it is also noticed that the Universities in North America (sample areas only) contribute very little, if any, to these chemistry curricula. This lack of university input, no doubt, contributes to the complaints about the disappointing performance of many college freshmen, in first year university chemistry courses.

In the state of New York it is interesting that chemistry curriculum activities are highly centralized. In fact, the State Board of Education has developed the REGENTS CHEMISTRY SYLLABUS which, from information volunteered by respondents, was constructed by Department of Education officials in cooperation with both teachers and university chemistry professors. As a result, there is an additional course of study referred to as the Advanced Placement Chemistry Course, which college and university aspirants are urged to take. Whether such a course was compulsory or non-compulsory was, however, not revealed. The significant information here is that the universities do possess a channel through which they can express their requirements for the guidance of those students wishing to pursue some form of tertiary education in chemistry. The Canadian Provinces, looking at Table 4, are shown to lack such university input. In Ontario recently, the universities did attempt to bridge the gap by publishing what is referred to as the "Core Chemistry Topics".[50] This joint venture of high school chemistry teachers, Community College instructors and University Chemistry professors in Ontario produced a list of chemistry topics, suggesting the minimum assumed knowledge required for entrants to chemistry programmes in Ontario Universities. Contrary views, however, have been voiced about this document. One critical view by D. H. Webber (1978) stated that:

> This document served only to further complicate the issue for teachers. On reading the core document, it is evident to teachers that they were teaching everything that was required. The document appeared to be redundant.[51]

In fact, a survey of chemistry teachers in Ontario (D. A. Humphreys - Unpublished results 1976) showed that over 75% of the time in the last two years of high school chemistry was spent covering core topics. The danger of such core lists is that they become mistaken for curriculum. In addition, they encourage the needs of the Universities to dominate the high school courses. While preparing students for University entrance, many high school students of chemistry need to learn other aspects of chemistry not required by the Universities.

Finally, judging from the findings of this research, the Chemical Bond Approach programme has not been widely used as was originally expected.

AIMS AND RATIONALE

Klopfer (1971) established some objectives for the teaching of science (chemistry) which are outlined below:

Klopfer's Scheme[52]

a) Knowledge and Comprehension.

b) Processes of Scientific Enquiry I: In observing and measuring.

c) Processes of Scientific Enquiry II: Seeing a problem and seeking ways to solve it.

d) Processes of Scientific Enquiry III: Interpreting data and formulating generalizations.

e) Processes of Scientific Enquiry IV: Building, testing and revising a theoretical model.

f) Applications of scientific knowledge and methods.

g) Manual Skills.

h) Attitudes and Interest.

i) Orientation, Social and Moral Skills.

These general aims, if further refined, could yield specific objectives in chemistry which could be relevant to the short-term goals of the classroom activities.

It has become fashionable to specify objectives in teaching chemistry. These objectives give meaning to the overall aims and rationale for the teaching of a chemistry course. They provide an immediate application of these long-term aims to the day-to-day classroom activities. Another classification of objectives that has gained widespread recognition is Bloom's Taxonomy. However, Bloom's taxonomy dwells primarily on the cognitive domain, although some classifications both in the psychomotor and affective domains are available. In this work, the Aims and Rationale of Table 6 have been classified under four main findings as follows:

1. Discipline-Centred (subject matter only).

TABLE 6: The Aims And Rationale Of Chemistry Courses Offered In High Schools Expressed As A Percentage Of Total Response

Categories of Responses	Ont.	Alta.	N.S.	Sask.	B.C.	Man.	Que.	Nfld.	N.B.	NWT
Blank Responses	-	-	-	18.8	14.3	-	-	-	20.0	
1. Further Education: University entrance only	69.2	72.2	55.6	72.7	57.1	50.0	12.5	75.0	50.0	
2. To be able to engage in further studies in other sciences	23.0	22.2	33.3	63.6	42.9	30.0	12.5	50.0	50.0	
3. For the satisfaction of social needs	11.5	11.1	55.6	45.5	28.6	20.0	37.5	50.0	40.0	
4. For the understanding of the pervading influence of chemistry in society	11.5	11.1	66.7	45.5	28.6	20.0	37.5	50.0	40.0	
5. The appreciation of chemistry as a tool for the investigation of the environment	15.3	16.6	66.7	45.5	57.1	60.0	37.5	100.0	40.0	
6. Preparation for employment in a scientific or technological job	23.0	11.1	55.5	45.5	42.9	90.0	50.0	50.0	40.0	
7. To possess an informed and critical interest in scientific matters	15.0	11.1	66.7	54.5	14.3	20.0	37.5	50.0	20.0	
8. Acquaint students with the fundamentals of the subject only	61.5	11.1	55.6	54.5	57.1	80.0	62.5	75.0	30.0	

2. Student-Centred (student needs and interests).

3. Philosophical (nature of knowledge claims and uses).

4. Historical.

Under these headings the frequencies of the eight categories of responses are as follows:

a) Discipline-Centred, Aims: - 8 and 1 in Table 6.

b) Student-Centred, Aims: - 6, 2 and 7 in Table 6.

c) Philosophical, Aims: - 3, 4 and 5 in Table 6.

d) Historical, Aims: - None claimed.

The frequencies of the Student-Centred and Philosophical types of aims could be explained by the shift towards more process-oriented chemistry curricula in many areas of the world today. This, however, has been achieved at the expense of historical aims which were more widely used and accepted some 30 - 50 years ago. The apparent neglect of historical aims in teaching chemistry in today's secondary schools reflects an attitude in science teaching in general which Grant Smith (1960) observed so well when he wrote:

> Historical material is of importance and interest for the understanding of the development of science and as a part of one's education and culture, but it is rather an illogical and rather inefficient way to study modern chemistry.[53]

Does the development of an ahistorical bias among many science teachers indicate a gap in their repetoire of teaching methods? Or does it simply show that they lack an adequate grasp of the nature of science?

J. J. Thompson (1971) listed four broad aims of high school chemistry teaching which were characteristically common to the European Secondary Schools. They are:

1. To give the student such a knowledge of the framework of the subject as to enable him to understand the structure and changes of matter under chemical conditions.

2. To make clear to the student the possibilities and limitations of such knowledge and to create in him an awareness of the impact and influence this knowledge has on society, so preparing him for life in a technological age.

3. To inculcate in the student a critical attitude with theoretical speculations based on experimental facts and subject to change, together with the ability for precise formulation of thought.

4. To develop in the student those manipulative and experimental skills necessary to make him competent and confident in the investigation of the materials around him.[54]

In consideration of the aims listed under (2) and (3) above, it is difficult to perceive how a chemistry teacher embracing the ahistorical approach could efficiently achieve the goals involved in these aims, especially when teaching students aiming to acquire a general education. In current chemistry curricula being developed, careful attention should be paid to pedagogical means of fulfilling desired aims.

DELETIONS AND INCLUSIONS

Much has been written and said about the imbalance of

Descriptive vs. Theoretical material in the majority of the more widely known high school chemistry curricula used today.[55] An often quoted reason for the unpopularity of the Chemical Bond Approach programme is that it is too theoretical in outlook and that the chemical concepts expected to be understood by students have been introduced at a stage in their mental development in which they lack the necessary framework of descriptive chemistry.

Eric Hutchison (1971) shared this view when he observed:

> I am obliged to point out what I regard as an unfortunate trend in the teaching of science, particularly chemistry at the secondary level. This is the trend towards teaching material which is more intelligibly taught at the university level and the tendency to use it in high school texts, which were explicitly designed for university classes.....The laudable attempt to improve the teaching of science in high schools has taken the regrettable direction of focusing attention almost exclusively on the theoretical aspects of chemistry, (and, for all I know, the same bias may have infected other areas of science teaching).[56]

Certainly the data in tables 7 and 8 agree with Hutchison's observation of a trend towards the more "Theoretical aspects of Chemistry" in most of today's chemistry high school curricula. In tables 7 to 10, of the topics recommended for deletion from the various curricula operating in the Canadian provinces, sixty six percent were theoretical in character, whereas 16.6 percent were both descriptive and theoretical in nature and only 5.6 percent of descriptive material was recommended for deletion. Among the topics recommended for

TABLE 7: Deletions

Topics Recommended For Deletion From The Present Chemistry Courses Taught In The Canadian Provinces

Topics	Theoretical	Descriptive	Both
1. Biochemistry - as it is more appropriately covered in Biology	-	-	√
2. Quantum Mechanics	√	-	-
3. Solubility Products	√	-	-
4. Gas Laws	√	-	-
5. None	-	-	-
6. Less Emphasis on Atomic and Molecular Structure	√	-	-
7. Chemical Kinetics	√	-	-
8. Spectroscopy	√	-	-
9. Stochiometry	√	-	-
10. Less Stress on the Mole Concept in Grade 11	√	-	-
11. Nuclear Chemistry	-	-	√
12. Some Organic Topics	-	√	-
13. History of Discoveries which pertain to Atomic structure	-	-	√
14. Detailed Bonding Theory	√	-	-
15. Enthalpy and Entropy	√	-	-
16. Less Theory on Sizes and Ionization Potentials of Atoms and Molecules	-	-	-
17. Courses are too theoretical	√	-	-
18. Blanks	-	-	-
TOTALS	12	1	3
PERCENTAGES	66. 6	5. 6	16. 6

BLANKS: - 5. 6% NONE: - 5. 6%

TABLE 8: Inclusions

Topics Recommended For Inclusion In The Present Chemistry Courses Taught In The Canadian Provinces

	Theoretical	Descriptive	Both
1. The Chemistry of Common Metals	-	descriptive	-
2. Applications of Chemistry - Consumer, Environmental, Industrial and Historical	-	✓	-
3. Descriptive Chemistry - Important Industrial Processes	-	✓	-
4. Radiation or Nuclear Chemistry	-	-	both
5. Solubility Product	theoretical	-	-
6. Ionic Equilibria	✓	-	-
7. * Less Emphasis on Molecular and Atomic * Structure	-	-	-
8. Gas Laws PV = nRT	✓	-	-
9. History of Important Discoveries	-	-	✓
10. Qualitative Analysis Using Flow Charts	-	✓	-
11. None	-	-	-
12. Organic Chemistry	-	✓	-
13. Rates of Reaction	✓	-	-
14. Simple Equilibria	✓	-	-
15. Biochemistry	-	-	✓
16. Molecular Bonding Theory	✓	-	-
17. Spectroscopy	✓	-	-
18. Blanks	-	-	-
TOTALS	7	5	3
PERCENTAGES	38.8	27.7	16.6

OMISSION: - 5.6% NONE: - 5.6% BLANKS: - 5.6%

* Item Omitted

inclusion, 38.8 percent ranked as theoretical in nature, 27.7 percent as descriptive and 16.6 percent were part descriptive and part theoretical.

In tables 9 and 10, showing data for the six U.S. states, of the items recommended for inclusion 14.3 percent were theoretical, 57.4 percent were descriptive and 21.4 percent were both descriptive and theoretical. Here, there is a noticeable downward swing (from Canadian figures) in the amount of desired theoretical material in the various curricula under consideration, whereas there is simultaneously a marked increase in the descriptive material content observed in the curricula. Turning finally to the recommended items for deletion, an overwhelming 100 percent of the items recommended were theoretical in nature. This is of tremendous significance. These topics were extracted from all six U.S. samples and they represent the full spectrum of topics (in all six areas) recommended for deletion in all six areas. We noted then, that all these topics were theoretical. Clearly, these teachers agree that there are too many theoretical concepts in their curricula. The data also show that Canadian teachers felt the same way - but to a lesser extent.

APPLICATIONS

Hurd (1964)[57] defined Scientific Literacy in the following terms:

TABLE 9: Inclusions

Topics Recommended For Inclusion In The Present Chemistry Courses Taught In The Six States Of The U. S. A.

Topics	Theoretical	Descriptive	Both
1. More Descriptive Chemistry	-	D	-
2. Some Mathematical Prerequisites	T	-	-
3. Organic Chemistry	-	D	-
4. Pollution Control	-	D	-
5. More Thorough Understanding of Stochiometry	T	-	-
6. More Vocational Discussion*	-	-	-
7. Unit on Poisons - drugs, etc. the hazards of: -	-	D	-
8. More Nuclear Chemistry	-	D	-
9. Consumer Chemistry (including environmental)	-	D	-
10. More "personal" history of concepts and materials in relation to their discoveries	-	-	B
11. Biochemistry	-	-	B
12. More "wet" chemistry	-	D	-
13. Some aspects of Descriptive Chemistry: - a return to "sight" and "smell"	-	D	-
14. Thermochemistry and Nuclear Chemistry	-	-	B
TOTALS	2	8	3
PERCENTAGES	14. 3	57. 8	21. 4

* Omissions: - 7. 14%

TABLE 10: Deletions

Topics Recommended For Deletion From The Present Chemistry Courses Taught In The Six States Of The U. S. A.

Topics	Theoretical	Descriptive	Both
1. Much of advanced theoretical material especially Quantum Mechanics	T	-	-
2. Equilibrium K_{sp} Free Energy, Entropy	T	-	-
3. Electrochemistry and Redox-systems	T	-	-
4. Kinetics and Equilibrium	T	-	-
5. Bonding Theory	T	-	-
6. Heavy Physical Chemistry Topics, e. g. Kinetics	T	-	-
7. Quantum Mechanical Models of Atomic Structure	T	-	-
8. Some Theoretical Aspects of Organic Chemistry	T	-	-
9. Less Electronic Configuration and Molecular Theory	T	-	-
10. Modality, Formality, Normality, etc.	T	-	-
11. Faraday Unit, Coulomb	T	-	-
12. Gas Laws - Empirical and Molecular Formulas Calculations	T	-	-
TOTALS	12	-	-
PERCENTAGES	100	-	-

> A person literate in science knows something of the role of science in society and appreciates the cultural conditions under which science thrives. He also understands its conceptual inventions and its investigative procedures.

Although chemistry is not specifically singled out in this quotation, yet its role can be readily recognized in the moulding of an individual, to be literate in science. In order to achieve such an objective, adequate planning and execution are important as noted in Hurd (1964)[58] again:

> The development of a literate citizenry does not result from the teaching in a single grade, nor is it the product of any one course. It can be achieved with a carefully planned kindergarten through grade 12 (K-12) programme in which there is vertical as well as a grade-level coherence within the science curriculum (N.S.T.A. 1964).

These views would normally lead one to suspect that in a high school chemistry programme an adequate fraction of time should be devoted to

1. Industrial
2. Biological and Environmental
3. Domestic and other relevant applications.

Certainly no guidelines have to date been suggested as to what fraction of the high school chemistry programmes should be taken up by such applications. However, table 11 shows that an appreciable percentage of the respondents in each sample claim to spend less than 10 percent of their time on these applications. The notable exceptions to this observation are Ohio and Oregon in the U.S., Ontario, Alberta and

TABLE 11: The Fraction of Chemistry Programmes Allocated To:
a) Industrial
b) Biological and Environmental
c) Domestic
d) Any Other Such Applications
Collectively In Each Sample

	10%	10-20%	20-50%	50-75%	75%	Blanks
Pennsylvania	54.5	45.6	-	-	-	-
Michigan	62.5	25.0	-	-	-	12.5
New Jersey	62.5	12.5	12.5	-	-	12.5
Ohio	25.0	37.5	37.5	-	-	-
New York	70.0	30.0	-	-	-	-
Oregon	20.0	60.0	-	20.0	-	-
Ontario	42.8	50.0	3.6	-	-	3.6
Alberta	36.8	26.3	31.5	-	5.3	-
Nova Scotia	50.0	50.0	-	-	-	-
Quebec	62.5	12.5	12.5	-	-	12.5
New Brunswick	50.0	10.0	-	10.0	-	30.0
Saskatchewan	90.0	9.1	-	-	-	-
Manitoba	60.0	40.0	-	-	-	-
Newfoundland	100.0	-	-	-	-	-
British Columbia	71.4	28.6	-	-	-	-
England	37.5	37.5	12.5	-	-	12.5

Quebec (borderline case) among the Canadian provinces. They allot a significant part (20-50 percent) of their subject time to applications. If some of the philosophical aims of chemistry are to be advanced, certainly more attention ought to be centred on such applications. The tentative nature of scientific knowledge renders it difficult, at times, to adequate practical applications, expecially where ethical and moral considerations are involved. There are many current examples of such applications where scientific knowledge has been abused through misinterpretation. Unfortunately, little by way of legislation is available to direct this aspect of scientific knowledge. It has been proposed by some curriculum developers[59] that applications of chemistry could be utilized as descriptive materials in high school chemistry courses to project chemistry as relevant to life in general. Theoretical concepts can then be taught from these applications so employed.

A final remark on this topic of application could be directed at what C. B. Hunt (1977) discussed in his article "The Media and Chemical Education" in which he discussed the neglectful attitude of radio and television in promoting chemical education. He wrote:

> One only has to witness the frequent mispronounciation of elementary chemical terms on radio and television and the very low level of scientific knowledge (cultural and technical) anticipated in programmes such as Universal Challenge to appreciate how much remains to be done in improving the public's understanding and knowledge of chemistry.[60]

In closing the article he remarked further that:

> The substantial changes in school chemistry teaching which have taken place over the past few years may or may not pay dividends in the years to come, but we must try to induce in the public, the same feeling of shame at failing to answer an elementary question on chemistry as we are evidently expected to feel when we fail to recognize a famous painting or identify a literary quotation.[61]

COVERAGE OF THE FORTY COMMON CHEMICALS

In an attempt to define a central focus for the construction of a chemistry curriculum, Bond (1974) proposed that:

> Chemistry is (ought to be) fun; chemistry is about smells and colours, about precipitates coming and going, about getting nice crystals out and even about (supervised) bangs and flashes. It is not about ionic radii, rate constants or the change in Gibbs free energy; these are the concepts which rationalize observations and permit a deeper understanding of the facts, but they follow and cannot precede the experiments.[62]

Assuming that a slight-moderate coverage of the first three and fifth categories in table 12 signifies a desirable proportion of desirable material in any high school chemistry curriculum, then the percentages shown in tables 13 and 14 indicate an inadequate coverage of the descriptive aspect of Chemistry overall.

The data in tables 13 and 14 validate the claim that most current high school curricula embody more theoretical material than the framework of descriptive chemistry in them is able to support.

TABLE 12: Categories Of Substances

Acids	Metals & Non-Metals	Bases & Carbonates	Natural Gas Products	Common Gas	Other Common Lab. Reagents
H_2O	Al	H_2O	Benzene	H_2, O_2	$KClO_3$
H_2SO_4	Fe	NH_3	Methane	N_2	$KMnO_4$
HNO_3	Ni	NaOH	Ethane	F_2	H_2O_2
HCl	Cu	$NaHCO_3$	Ethylene	Cl_2	$CaCl_2$
H_3PO_4	Na	Na_2CO_3	Methanol	CO	NH_4NO_3
CH_3COOH	S	$Ca(OH)_2$	Ethanol	CO_2	
	C	$CaCO_3$	Petroleum	SO_2	
				SO_3	

Definition Of Coverage Ranges In Tables 13 and 14

1.	Substantial	75%	-	S
2.	Moderate - Substantial	50-75%	-	MS
3.	Slight - Moderate	25-50%	-	SM
4.	No Coverage - Slight Coverage	0-25%	-	NS

TABLE 13: Percentage Coverage Of Substances In The Six Categories (Canadian Provinces)

	Coverage Category	Common Gases	Metals & Non-Metals	Acids	Bases & Carbonates	Natural Gas Products	Other Common Lab. Reagents
Ont.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	48.4	36.6	53.0	53.4	41.3	41.9
Alta.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	48.4	36.6	53.0	53.4	41.3	41.9
Sask.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	43.1	49.8	63.4	60.9	53.8	50.8
B. C.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	43.7	48.0	61.3	48.5	43.4	33.6
Man.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	32.5	33.9	49.2	35.7	37.9	33.5
Que.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	56.9	40.2	51.6	55.4	11.6	47.5
Nfld.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	45.8	50.0	61.5	53.6	51.8	41.3
P. E. I. & N. S.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	48.1	41.9	54.2	56.1	53.2	58.1
N. B.	75 & over -S 50-75 -MS 25-50 -SM 0-25 -NS	56.4	43.2	62.4	56.8	31.1	41.0

TABLE 14: Percentage Coverage Of Substances In The Six Categories (United States and England)

	Coverage Category	Common Gases	Metals & Non-Metals	Acids	Bases & Carbonates	Natural Gas Products	Other Common Lab. Reagents
Ore.	75 & over -S						
	50-75 -MS			56.7	51.4		
	25-50 -SM	38.9	43.6			32.1	31.0
	0-25 -NS						
Penn.	75 & over -S						
	50-75 -MS			63.8	72.5	51.1	59.0
	25-50 -SM	42.2	42.5				
	0-25 -NS						
N. Y.	75 & over -S						
	50-75 -MS			53.8	55.2		
	25-50 -SM	41.2	43.2			46.1	41.4
	0-25 -NS						
N. J.	75 & over -S						
	50-75 -MS	54.2	58.3	68.8	69.2		51.4
	25-50 -SM					46.4	
	0-25 -NS						
Ohio	75 & over -S						
	50-75 -MS	64.2	55.8	74.5	70.5	58.4	56.9
	25-50 -SM						
	0-25 -NS						
Mich.	75 & over -S						
	50-75 -MS			57.8	54.5		
	25-50 -SM	35.1	37.5			26.8	37.5
	0-25 -NS						
U.K. (Eng.)	75 & over -S	81.9		88.2	91.7	88.1	76.7
	50-75 -MS		72.0				
	25-50 -SM						
	0-25 -NS						

In Saskatchewan for example, the coverage given to the six categories of substances described in table 12 is consistently slight to moderate. The least coverage is the 26.6 percent of the metals and non-metals category; if this is coupled with the 40.2 percent coverage of the common gases, it appears that descriptive chemistry plays a minimal role in the high school chemistry curricula in this region.

This slight-moderate coverage of both the common gases and metals and non-metals is typical of the coverage given the other categories in Saskatchewan. The highest category coverage in Saskatchewan is of Bases and Carbonates at 43.8 percent which ranks second worst in the same category to that of Manitoba at 35.7 percent.

The overall extent to which these six categories are covered is at its worst in both Saskatchewan and Manitoba.

A final observation is that in all but the U.K. sample the coverage given to the common gases, metal and non-metal categories is somewhat below the normal average of 50 percent coverage.

The undercoverage of descriptive chemistry is also evident in the U.S. states sampled. New Jersey and Ohio are seen to have allocated a significant proportion of their chemistry curricula to descriptive studies: apart from these two states, the others show the same slight-moderate coverage of both the common gases, metals and non-metals categories evident in the Canadian samples. Ohio shows a better overall balance in all categories. It would be interesting to investigate a curriculum sample showing this balance in more detail.

The U.K. analysis shows that all categories are quite substantially covered except for the metals and non-metals category which is moderately-substantially covered. These percentages were, however, computed for schools in some of which sixth form work is normal and would, therefore, entail extra coverage beyond the grade 12 level. If an allowance is made for both the Advanced Placement programmes[63] and grade 13 Chemistry courses in the U.S. and Canada respectively, the differences in coverage between the U.K. and North America are minimal.

Even if the degree of coverage in the English sample is not acceptable as a standard, the observation that no sample in Canada approximates the coverages of a state such as Ohio creates a cause for concern.

In Alberta, where the highest Canadian coverages occur, attention should be focused on the fact that this research survey was conducted at a time when the Alchem project was in progress, and could have influenced the resulting percentages.

CHAPTER IV

CONCLUSIONS AND SUGGESTIONS

1) Amount of Time Spent on Chemistry

The philosophy that high school students should be allowed to attempt a variety of subjects during their high school career has its merits.[64] One such merit is that it provides them with a broad background against which a choice of specialization could be made.

On the other hand, an overall high school curriculum embracing such a philosophy experiences difficulties in allotting adequate time to teachers of different subjects. If these subjects are simultaneously gaining in social importance, as chemistry is at present, this problem of insufficient time becomes pronounced.

In Ontario, as well as in the other Canadian provinces, this study has shown that when time allotted to the teaching of chemistry in high schools is compared with time in England and the U.S.A., the Canadian provinces allot far less time to this subject.

There is no doubt that an increasing volume of chemical knowledge is being relegated to the high schools. This has led to a situation where the high school curriculum overlaps considerably with the first year college or University curriculum.[65]

The alternatives open for action are:

1. That a rationale be found for making appropriate deletions from the high school chemistry curriculum.
2. That more time be allotted to cover the large amounts of material suggested for inclusion in the curriculum.
3. An attempt be made at curriculum construction, that balances all important aspects of the subject suitable to be taught at this level of students' intellectual development.

In addition, maybe if the teaching of chemistry in secondary schools is made sequential, i.e. in grades 10, 11 and 12, or grades 11, 12 and 13, enough chemical content could be taught that would be beneficial to students who are either leaving school at the end of grade 13, or proceeding to a tertiary stage of education.

In England, and some 13 other European countries,[66] chemistry is a compulsory subject in the earlier years of a high school student's career. This compulsory status of the subject must have an influence on the higher percentages of students found taking chemistry in their final years of high school. A secondary cause creating these higher percentages could also be attributed to the early exposure of these students to chemistry as a separate subject.

The findings in this survey that up to 30 percent of the respondents in five Canadian provinces spend less than 10 percent of the total time devoted to chemistry teaching in the laboratory seems to suggest a situation for concern. Maybe this finding is a direct ramification of the high theoretical content of the chemistry curricula to be found in these provinces. If the descriptive content of these curricula was appreciable, certainly it would have been reflected in a higher percentage of the total time spent on chemistry laboratory work. This lack of descriptive content is further manifested in the coverage given the following categories of chemical substances in schools of the Canadian provinces.

1.	Metals and Non-metals	SM
2.	Acids, Bases and Carbonates	SM
3.	Common Gases	SM

If table 13 is consulted, it will disclose that the slight-moderate (SM) coverage in the majority of cases, is the lowest when all samples are collectively considered.

Of the alternatives available, suggestion (3) above (i.e. that a balanced curriculum be constructed that matches the intellectual development of the students) is the most attractive. Such curriculum reform involves identifying the unifying ideas or rationale that set the direction for the change in the curriculum. If chemical reactions or sections of descriptive chemistry are chosen as the vehicles to carry any concepts introduced into the curriculum, many of the problems discussed earlier might be solved. Such a theme would first introduce students to the basic facts which theories and concepts are devised to explain. It would provide a suitable background for all schemes, since all students need to know basic chemical facts. Those students proceeding to the tertiary level will have a framework on which to hang more difficult concepts appropriate for the college level. The overlap with college courses would be minimized since less inappropriate theory could be done at high school if the time remained the same, but the properties and reactions of elements became the theme of the curriculum.

In the teaching of chemistry, historical aims and objectives might play a more important role if a chemistry teacher has a good command of a variety of pedagogical approaches. It is obvious that by using case studies (histories), certain techniques, such as the enquiry technique, a good number of chemical concepts could be easily and efficiently taught. The total lack of historical aims and objectives, as shown by this survey, could suggest a limitation in the instructional methodology of the teachers concerned. Certainly, if they were aware of Klopfer's objectives for science teaching and the meanings of the enquiry method of teaching chemistry - i.e. (a) enquiry as a mode of logic, (b) enquiry as a mode of learning, and (c) enquiry as an instructional methodology - some measure of historical aims and objectives would have been apparent.

The case has always been made that only about 15 percent of the total number of students taking chemistry in their final year of high school proceed further to college or university.[67] Therefore, the chemistry curricula in high schools should reflect items that are of considerable meaning and application to the 85 percent of school leavers.

In order to serve the needs of the 15 percent, strong rapport should exist between high school chemistry teachers and university chemistry professors. It is essential that an explicit understanding prevail between these two groups, as well as a reciprocal exchange of ideas and endeavours in high school curricular affairs. University professors are usually at the frontiers of the chemical field. They are usually aware of some of the social implications of current researches. If environmental applications of chemistry are to be included in a high school chemistry curriculum, it is vital that university professors are not denied participation in their construction.

Secondarily, with regard to the 15 percent of high school students who proceed to a first or higher degree in chemistry, since the superstructure of the subject is mainly the domain of university instructors, there is no logical reason why they should not stipulate what they consider relevant prerequisites for those students that are university bound. A significant question that seems to emerge here is whether the chemistry content material stipulated by university instructors as prerequisite for those entering college would normally serve also as suitable instructional material for those terminating their education at the end of grade 13.

If a curriculum were built which properly balanced facts, skills and attitudes, it would be possible to distinguish a core curriculum which had general educational value, from the optional sections which covered aspects applicable to those students proceeding further in chemistry. The jointly-produced core topics document discussed earlier isolated concepts and skills from the fact, history and applications which distinguish a topic list of a curriculum. If those chemicals, aspects and concepts which have a value in the general education of citizens are included in the core of the curriculum, it will serve the needs of the 15 percent going beyond high school in addition to the important 85 percent who join the work force straight after high school.

But to arrive at such a compromise, university instructors must possess an established channel through which their opinions and suggestions could be directed. Lack of such a facility contributes to a widely variable standard of achievement, as is presently being experienced in the Canadian provinces and the U.S. It is interesting to note that this variation in standard of achievement in chemistry teaching is an integral part of the problem this survey set out originally to investigate.

The current conscious efforts of many science educators in secondary schools, universities and industrial organizations, i.e. (convening conferences, seminars, etc.) that tend to focus attention on the construction of a desirable high school chemistry curriculum, are important. These attempts at new chemistry curriculum development are to some extent bypassing such established processes as provincial and state curriculum committees. As discussed earlier, new chemistry curricula have appeared in British Columbia and Alberta in Canada; Australia has also proposed a new chemistry curriculum. In Ontario, the Ministry of Education is presently formulating guidelines for the construction of new curricula in Mathematics and the sciences, if the courses designed, ultimately for high school chemistry, deal with the problem as Lippincott (1975)[68] describes it:

> Developing a truly exciting, principles-based, culturally-oriented first course in chemistry including the laboratory

many of the current curriculum problems in chemistry would be solved.

In order for teachers to change what they do in the classroom, we need, however, more than curriculum guidelines. The process of change involves not only suggestions and outlines - but specific teaching materials, tests, books and guides. The wide use of Chem-Study is partly attributable to the availability of excellent texts, laboratory manuals and teachers' guides. The ALCHEM materials were adopted in Alberta largely because teachers had all they needed to help them each day in the classroom. If new approaches, where concepts are taught from descriptive chemistry, are to become more widely adopted, detailed examples must be available for teachers. The process of producing such material with test questions and mechanisms for training teachers in their use will require an extraordinary degree of effort and cooperation between chemistry practitioners at all levels. In a technological society, where the citizen of tomorrow will live in a chemical world of new complexity, such effort and cooperation are vital.

That all students should know about the common materials that make up our world and about the use and limitations of scientific knowledge is an urgent task for all science educators.

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APPENDIX 1

INSTRUCTIONAL DEVELOPMENT CENTRE

McMaster University
Hamilton, Ontario,
L8S 4M1
525-9140, ext. 4408, 4540

November 1977

Dear Chemistry Teacher,

You are probably aware of some of the debate that has been going on in recent years about the problems of chemistry curricula at the introductory level. There are a number of plans to discuss this question in Canada via a Chemical Institute of Canada Committee, and an international conference to be held in 1978.

We are currently in the midst of an important international project to gather basic information about the content and aims of chemistry courses in various parts of the world. We would very much appreciate your cooperation in filling out the enclosed questionnaire and returning it to us by December 15th, 1977. We recognize that this is a fairly lengthy questionnaire, but we need to have your views stated carefully. If you cannot make the May deadline please return the questionnaire as soon as possible.

Thank you for taking the time to fill out this questionnaire. We will try to keep you informed when the report is completed but of course, you may send an anonymous response if you wish.

Yours sincerely,

DR. D. A. HUMPHREYS,
Associate Professor of Chemistry,
Director, Instructional Development Centre.

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APPENDIX 1

QUESTIONNAIRE: SECONDARY (HIGH) SCHOOL CHEMISTRY CURRICULUM

Amount of Time Spent on Chemistry

1. (a) In what years do you teach chemistry as a separate subject? (F.Y. = final year)

Final Year of High School	Final Year minus 1 (F.Y. -1)	Final Year minus 2 (F.Y. -2)	Final Year minus 3 (F.Y. -3)	Final Year minus 4 (F.Y. -4)	Final Year minus 5 (F.Y. -5)

(b) In which of these years is chemistry a compulsory subject?

(F.Y.)	(F.Y. -1)	(F.Y. -2)	(F.Y. -3)	(F.Y. -4)	(F.Y. -5)

(c) What percentage of all students in each year take chemistry as a separate subject?

(F.Y.)	(F.Y. -1)	(F.Y. -2)	(F.Y. -3)	(F.Y. -4)	(F.Y. -5)

2. (a) Estimate the total number of hours spent on chemistry in all years by students who complete: -

(i) A programme which prepares for university entrance in pure or applied science: -

[ ] Hours

(ii) A programme which prepares for technical, community or other post-secondary college courses in science: -

[ ] Hours

(iii) A terminal programme for students who are not considering further formal studies: -

[ ] Hours

(iv) Any other programme(s): - Specify ______________

____

[ ] Hours

(b) What fraction of the time spent on chemistry as a whole is allocated to student laboratory work?

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
10%	10-20%	20-30%	30-40%	40-50%	over 50%

Curriculum

3. (a) Is the curriculum in your school set by: - (check ( ) as appropriate)

A Ministry of Education [ ]

A University entrance board or committee [ ]

A regional board of education or committee of education ☐ Other (specify) ☐ ____________

By the individual local school ☐ ____________ ____________

(b) Is your chemistry course typical of those found in your region?

YES ☐ NO ☐

(c) Is your curriculum based on: -

The Nuffield Syllabus ☐

The Chem-Study Programme ☐

The Chemical Bond Approach ☐

Any Other (specify) ☐

____

4. State the Location of your school (e. g. Province, State, County) and Country:

____

Aims and Content of Chemistry Course

Please give your opinion on the following questions:

5. (a) What is the main aim or overall rationale of the chemistry course:

(i) For a programme which prepares for university entrance in pure or applied science: -

____

____

(ii) For a programme which prepares for technical, community or other post-secondary college courses in science: -

____

____

(iii) For a terminal programme for students who are not considering further formal studies: -

____

____

(iv) For any other programme(s): - Specify: -

____

____

(b) What topics would you like to see: -

(i) Left out of the chemistry course, which are currently taught: -

____

____

____

____

(ii) Included in the chemistry course, which are currently excluded: -

____

____

____

____

(c) Give examples of any applications of chemistry which are included in your course or courses: -

(i) Industrial

____

____

____

____

(ii) Biological and environmental

____

____

____

____

(iii) Domestic

____
____
____
____

(iv) Any other

____
____
____
____

(d) What fraction of the chemistry programme is taken up with such applications?

☐ 10% ☐ 10-20% ☐ 20-50% ☐ 50-70% ☐ 70%

(e) To what extent to you cover the chemistry of the following basic chemicals? (Check (✓) as appropriate)

Substance	Preparation	Properties	Uses	Students use in Lab.	Not Included in Course
H_2					
O_2					
S					
N					
C					
F_2					
Cl_2					
Al					
Ni					
Cu					

Substance	Preparation	Properties	Uses	Students use in Lab.	Not Included in Course
Fe					
Na					
CO					
CO_2					
SO_2					
SO_3					
H_2O					
H_2SO_4					
HNO_3					
HCl					
H_3PO_4					
CH_3COOH					
NH_3					
NaOH					
Na_2CO_3					
$NaHCO_3$					
NaCl					
$CaCO_3$					
NH_4NO_3					
$Ca(OH)_2$					
$KMnO_4$					

Please return questionnaire to: -

Dr. D. A. Humphreys,
Chemistry Department,
Room 101,
Senior Science Building,
McMaster University,
1280 Main Street West,
Hamilton, Ontario, Canada,
L8S 4M1.