NUMERACY IN SCHOOL GEOGRAPHY

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Russell James Stewart

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ABSTRACT

Geography is taught in New Zealand secondary schools at three separate levels; fifth form, sixth form and seventh form. There appears at present to be little continuity in the teaching content of the subject, and in the development of practical skills, from fifth form through to seventh form.

Research is currently being conducted into geography teaching in New Zealand secondary schools with the intention of providing information with which to formulate a programme of curriculum revision aimed at integrating the geography syllabi from forms five to seven, with an emphasis on the sequential development of practical geographical skills. Many of the practical skills which have been identified in this research involve number operations and therefore require the student to be numerate. A definition of numeracy is proposed, and basic problems confronting students in their learning of mathematics - and so in their development of numeracy skills - are reviewed.

A brief analysis of past School Certificate Examination Geography papers is made in order to identify the types of numeracy skills which have been tested in geographical education. The results of a survey of geography students in New Zealand secondary schools serve to provide information on the experience of these students in studying geography and mathematics. Information on the extent of continuity of geographical

study is used to show that an integrated geography syllabus could be successfully operated. Although the incidence of the geography/mathematics subject combination is found to be relatively high, it is suggested that provision in the new integrated geography syllabus be made for formal instruction in numeracy skills.

A systematic analysis of the numeracy skills used in secondary school geography concludes this thesis, which has sought to show that it is necessary to identify and examine the types of numeracy skills which have been used in past geography examination papers, and which are therefore implicit in the existing geography syllabi, before proceeding to the formulation of an integrated syllabus for forms five to seven and to the programming of the sequential development of skills within this syllabus.

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PREFACE

In presenting this thesis I am obliged to acknowledge the cooperation received from head teachers of geography departments in 92 New Zealand secondary schools.

During a protracted period of revision, my patience was matched by Mr Eric Archer of the Education Department at Massey University who provided helpful guidance.

R.J.S.
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1. INTRODUCTION

1.1 An Overview

In the New Zealand secondary school curriculum, geography is taught as a subject to students in the fifth, sixth and seventh forms. It is first offered at the fifth form level of study. Here its content, and to an extent the manner in which it is taught, is influenced by the requirements of a national external examination, School Certificate, which the student may sit at the end of his third year at secondary school.

At each of the sixth form and seventh form levels of study, the content of geography is again prescribed by the syllabi set down for separate external examinations; at the end of the fourth year (University Entrance Examination, in which internal accrediting may be exercised), and the fifth year (University Bursary and University Scholarship Examinations) of secondary school study.

The general picture, however, is not as clear-cut as this summary suggests. Fifth form geography is not a prerequisite for sixth form geography, and some students (see Appendix 16) may take geography for the first time in the seventh form. The introduction of single-subject passes in School Certificate has given rise to some students studying geography in the sixth form who have not gained a pass in School Certificate Geography, but who may have gained passes in three or four other subjects thereby entitling them to sixth form entry. And a so-called second-year fifth-form student may have passed School Certificate in geography only and so be taking geography again in the fifth form together with the subjects in which he failed to pass.

In terms of popularity, geography in the fifth form is currently ranked third after English (which is compulsory) and mathematics. In the sixth form and seventh form, geography usually vies with biology and mathematics for second ranking (after English) in terms of the number of students taking the subject.

1.2 Geography in the Secondary School Curriculum

In this decade of the nineteen-seventies when change has been described as "an elemental force"(1), the processes of formal education are coming in for increasing scrutiny in order that some assessment be made of their contribution in equipping young people for a future society that will be the product of present change. This examination of the relative worth of educational processes in some subjects has stimulated specialists within these subjects to seek to justify their inclusion in the school curricula, particularly when confronted with the possible replacement of these subjects by more practical studies on say consumer right or family relationships.

To this end, geographers have been prepared to provide support for the continuing inclusion of their subject in the secondary school curriculum. McCaskill (1967) has declared that "geography's special justification arises from man's own awareness of the earth-space and his curiosity about the arrangement and inter-

(1) Toffler, A., 1970, 11.

action of the objects and forces that occupy earth-space.[2] According to Shortle (1971), geography ought to be concerned with "developing in pupils an understanding of the way in which man has changed his spatial environment, and ... an awareness of the need to maintain and improve the quality of the human spatial environment."[3] To generalise on the function of geographical education in the secondary school, it may be thought of as developing 'environmental literacy' in young people.

But there is more to justifying a subject's position in the school curriculum than deciding on its function and content. In common with other subjects taught in New Zealand secondary schools, the teaching of geography must be seen to achieve certain basic educational objectives. The standard means of evaluating achievement is by administering revision tests and examinations, whose results are expected to provide a reliable measure of the acquisition of knowledge and understanding, and the development of skills and attitudes: the educational objectives.

The influence of the external examinations system in New Zealand secondary school education cannot be overlooked. Most pedagogical endeavours are ultimately directed each year towards an external examination, and it is often from the previous year's examination format and content that the teacher discovers what was expected to have been taught.

1.3 The Geography Syllabus

With the end of the formal external examination

(2) McCaskill, M., 1967, 85.

(3) Shortle, D., 1971, 52.

system perhaps in sight, the attention of geographical educators and curriculum planners is turning towards the reorganisation of the current three separate geography syllabi taught in the secondary schools. This move represents a serious undertaking for certainly the future direction of geographical education in New Zealand rests on the nature and structure of the integrated syllabus that evolves from this planning work, and on its acceptance by practising teachers. The part played by a particular syllabus in achieving educational objectives is an important one. It can be illustrated by means of a simple syllogism. Given a major premise that a prescribed syllabus forms the basis on which an examination is structured, and given the minor premise that the examination is so designed as to evaluate the relative achievement of educational objectives, then the conclusion to be drawn is that these objectives are implicit within the syllabus.

The most active agency in the field of revision of geography syllabi in New Zealand is the Board of Geography Teachers' Curriculum Group. Research has been carried out by this Curriculum Group in a number of fields to gather together background information on which to base syllabus revision. By the end of 1974, five major reports had been presented:

1) Present Skills Required in Geography Syllabi
2) The Origin and Destination of Geography Students
3) Summary and Research Findings on Skills in Senior Geography
4) The Qualifications of New Zealand Geography Teachers
5) Teachers' Perception of Geographic Skills

1.4 Skills Required in Geography

Of the three reports issued by the Board of Geography Teachers which have been concerned with the identification of skills in geography teaching, the first - Present Skills Required in the Geography Syllabi - sought to enumerate the types of skills found in geographical education. The aim here was to provide a frame of reference from which a sequential development of skills scheme could be formulated and then programmed into syllabus revision plans for secondary school geography.

Although this particular report did not define the term 'skill', it is apparent from the content of the report that it was interpreted in a comprehensive light, and that in fact all geography teaching involves the imparting of knowledge and understanding through the medium of skill development. When, for example, the skills required in University Entrance Geography are identified, as listed below, there remains little else taught in sixth form geography that is exclusive of these five groups:

Sixth Form Geography Skills[4]

i) academic skills
ii) practical skills
iii) intellectual or thinking skills
iv) social skills
v) evaluation or examination skills

Since the development of skills plays an integral part in geographical education, and because present research into curriculum revision is concerning itself with the evaluation of skills, it is pertinent to

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[4] from the Report on Skills Required for Univeristy Entrance Geography, BOGT Curriculum Group Report, July 1973.

examine in more detail the nature of the skills required in learning geography. For the purposes of this work, however, general attention will be directed towards 'practical' or 'mechanical' skills, and particular attention towards skills involving numeracy.

1.5 Practical Skills in Geography

The Board of Geography Teachers, in their Curriculum Group Report of July 1973, identified a set of practical skills at each of the three levels of geographical study in the secondary school.

For School Certificate Geography the skills were listed as:

sketch maps
graphs
topographical maps
photographs
setting out (of map work, and in following instructions)
cross sections
use of terminology
field work

The practical skills required for University Entrance Geography were identified as:

i) graphicacy
- maps
- photographs
- diagrams and cross sections
- landscape sections and sketches
- models

ii) literacy
- terminology
- paragraphs
- case studies
- quotations

iii) numeracy
- mathematical concepts
- graphs
- raw statistics

And the mechanical skills for seventh form geography were listed as:

sketch maps
Graphs
topographical maps
aerial photographs
field work
measurement
cartography
diagrams

The practical and mechanical skills identified by the Board of Geography Teachers in this report are derived in each instance from syllabus prescriptions and from the content of past external examination papers. But where the examination is set in an expository essay form, as for Bursary and Scholarship Examinations, neither the examination nor "the syllabus preamble sheds ... light on the specific skills required "[5], and the level of skill attainment is not prescribed. The problem here is that there is little prescribed guidance at present for geography teachers at any of the three levels of geography instruction as to the nature of the practical skills required, and the level of attainment expected in the performance of these skills.

The practical skills in secondary school geography, as they have been identified in the report of the Board of Geography Teachers, contain a relatively large quantitative element. Maps, in plotting properties of location and distribution, are essentially quantitative tools. The drawing of graphs and the interpretations made from graphs and from data matrices (or tables) require an appreciation of scale, quantity and number. Field work which commonly involves the collection of numerical data requires the subsequent measurement and analysis of these data. To this extent, therefore, it

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(5) Burridge, S.T., in BOGT Curriculum Group Report, July 1973.

is evident that practical skills in secondary school geography require a facility not only with words but also with numbers.

2. THE NATURE OF NUMERACY

2.1 Numeracy Defined

The term 'numeracy' appears to be of quite recent coinage because neither the Oxford English Dictionary nor the Webster's New Collegiate – to cite two recognised ambi-Atlantic authorities – acknowledges its existence. In general terms, however, numeracy can be taken to relate to numbers just as literacy refers to words. To work this analogy further; if literacy is accepted as the state of being literate, then numeracy is the state of being numerate.

Basically, then, numeracy is associated with the ability to 'handle' numbers. And just as there exists a marked and demonstrable range in individual ability to handle numbers, so there exist levels of numeracy. From this preliminary concept of numeracy as the ability to handle numbers, it is necessary to resolve the picture more sharply.

Numeracy has as its basis two elementary number concepts; the conservation of number, and number succession. The first refers to the transformations of a number (representing an amount or quantity) which leave it unchanged. On the idea of number succession, Dienes and Golding (1966) state that "it has been amply demonstrated that until children achieve a certain measure of synthesis of these two ideas [of 'one more' and 'next'] their work on number will have a hit and miss appearance, as they will not be able to reason in any effective way in arithmetical situations of the simplest kind." (6)

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(6) Dienes, Z.P., and Golding, E.W., 1966, 29.

For the purposes of this work, numeracy will be taken to have as its basis three groups of number operations:

(1) recognising relationships between numbers
(2) organising and distributing numbers
(3) performing arithmetic operations

2.1.1 Recognising Relationships between Numbers

Consider this first example:

Town A has a population of 7000 people and Town B has a population of 14,000 people.

It is possible to draw four simple number relationships from this example:

(i) Town B is larger than Town A
(ii) Town A is smaller than Town B
(iii) Town B has a population twice the size of Town A's population
(iv) Town A has a population half the size of Town B

The first two relationships have been drawn from the information given with an elementary knowledge of number succession. The third and fourth relationships extend this knowledge and substantiate it by employing the mathematical concept of direct proportion. A specific relationship between the two numbers has been recognised.

Consider this second example:

Area in Grain Crops (hectares)

	1964	1969	1974
wheat	80	96	120
barley	56	90	112

From the information provided here, several relationships between the elements in the data matrix can be identified. While general increases in area for both grains for each succeeding year is evident, for example, it is possible to recognise also that:

(i) the area under barley has doubled over the period, 1964 to 1974

(ii) the area under wheat has increased by half again during the period, 1964 to 1974

(iii) in the period, 1964 to 1969, the increase in the area under barley was greater than the increase in area under wheat

(iv) in the period 1969 to 1974, the increase in area under wheat was greater than the increase in area under barley

In this second example, more information is provided and more relationships between the numbers can be drawn than was possible in the first example. This suggests that the range of number relationships which can be identified increases as the data matrix is enlarged; from A to B:

$$A = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \qquad B = \begin{pmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \end{pmatrix}$$

The recognition of relationships between numbers is greatly enhanced with the learning of such basic mathematical concepts as proportion, percentage and ratio.

2.1.2 Organising and Distributing Numbers

There are a large number of activities which involve the organising and distributing of numbers. Common to all of them is the need to observe certain rules set down to govern specific activities. Success at organising and distributing numbers depends largely on the learning of these rules. For example, if a set of numerical data contains many elements (say, $n > 100$) it is often convenient to group the data into a more manageable number of sub-sets, or classes. The two basic rules associated with organising numbers in this manner are that the classes should be both mutually exclusive and of equal size or class interval. A further consideration is that the class interval chosen should be of an appropriate size so that the number of classes does not become unwieldy and thereby defeat the purpose of grouping the data in the first place.

Other forms of number organisation and distribution, such as plotting given values along a number line, are also rule-bound and therefore can be satisfactorily performed only when such rules have been adequately grasped.

One activity which makes use of number organisation and distribution, although it is concerned with more than manipulation of numbers, is the drawing of graphs. Consider this example:

> In a given country, the number of hydro-electric power stations increased from 14 in 1950, to 16 by 1960, and to 20 by 1970.
>
> Draw a line graph to show this increase in the number of power stations over the period, 1950 to 1970.

Before the numbers provided in this example can be organised and distributed, however, a pair of axes each with an appropriate linear scale must be drawn. Strictly speaking, it is necessary to decide which of the two variables - number of stations and years - is the independent variable. Then each pair of related variables is plotted along respective axes and the intersection of each pair of coordinates is located. These points of intersection are then by a series of line segments, joined.

In addition to the line graph, two other types of graph are commonly used to present numerical data in a pictorial form. These are the bar graph (or histogram) and the pie graph. The construction of all three graph types requires the student, however, to be more than numerate. The term 'graphicacy' has been adopted by some geographers to describe skills that are essentially visual and spatial in their representation. The construction of graphs and related diagrams like cross-sections involves non-verbal language skills in which the information communicated is done so in a visual and spatial context rather than in verbal form.

2.1.3 Performing Arithmetic Operations

Although natural numbers can be abstracted in the early stages of number learning, set theory which forms the basis of the 'new' mathematics teaches that numbers do not exist by themselves; they are properties of the sets of elements to which they refer. So, for example, six is a property of any set of six objects, whether they be oranges, theatre tickets, or brass monkeys. A number can undergo a change of state which causes it to assume a new property. This process which brings about a change in number property is called an operation. The most commonly encountered 'number problems' involve the performance of one or more of the four arithmetic operations; addition, subtraction, multiplication and division.

Consider Problem 1:

i) add together the numbers: 42,4,18,24,33,17

ii) divide their sum by six

In this problem the two arithmetic operations required - addition and division - are both explicit. And each number has been abstracted; it does not refer to any specific set of objects.

Consider Problem 2:

> Over a period of six successive months, the mean monthly temperatures from a given location were recorded as:
>
> 11°C, 14°C, 16°C, 18°C, 21°C, 16°C
>
> What is the mean (or average) temperature for this sixth-month period?

The numbers in this problem are not abstractions because each belongs to the set of Celsius degrees. Although the arithmetic operations to be performed are the same as in Problem 1, this time they are implicit within the mathematical concept of 'average', or arithmetic mean. Before these two operations of addition and division can be performed, the concept of arithmetic mean must be made 'workable'.

It is evident from this that although the student may be able to perform the arithmetic operations of addition and division in isolation, unless he understands and is able to apply the concept of arithmetic mean, he will be unable to solve the problem. But once a number problem has been resolved into explicit arithmetic operations, its solution is then readily derived.

But not all number problems present themselves initially in the form of explicit arithmetic operations. As is more often the case, the understanding of a mathematical concept, like percentage increase or arithmetic mean, is the key to the successful performance of implied arithmetic operations. On the basis of understanding, it is important that those mathematical concepts exist in an operational state in the mind of the student.

2.2 Numeracy and Mathematics

According to the definition briefly outlined in the section 2.1, numeracy can be regarded as involving basically three groups of number operations: recognising relationships between numbers, organising and distributing numbers, and performing arithmetic operations. It is perhaps apparent from this that numeracy should be allied more closely with mathematics than with any other discipline, since learning mathematics may be regarded as essentially learning to work with numbers.

2.2.1 Mathematics and the Language of Number

The relationship between number and mathematics is seen by some mathematicians as a linguistic function. Carmichael (1963), for example, believes that "the invention of number was the first step in the creation of a language of mathematics; and the choice of adequate and convenient symbols for the representation of integers is one of the chief triumphs of the intellect." [7]

If number is to play an elemental role in linguistic activities, in much the same way as words do in verbal language, then its ultimate function will be one of communication. Schaaf (1963) identifies this in his partisan statement: "Mathematics is a linguistic activity; its ultimate aim is preciseness

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(7) Carmichael, R.D., 1963, 217.

of communication. Second only to the mother-tongue, the language of number is without doubt the greatest symbolic creation of man. And in some ways it is an even more effective agency of communication than the vernacular." (8)

More specifically, the function of mathematics and its language of number is in the communication of qunatity. "In the long run, mathematics is about the world of things, but it describes some very superficial properties of these things, namely their quantitative aspects." (9)

2.2.2 Learning and Understanding Numbers

There are important differences in learning the language of number and in learning the language of verbal communication. In returning now to the analogy of literacy and numeracy, it is apparent that the child grows up hearing and seeing language because he grows up in a society which abounds in ready-made symbols that stand for a variety of objects, classes of objects, situations, activities, relationships, places, and so on. These language-learning experiences are reinforced by a great range of auditory, visual and tactile symbols, which appear ordered and generally consistent with those of the experience set common to his society or culture. According to Dienes (1963), the acquisition of verbal language is "a natural process in the sense that no formal teaching accompanies our learning the mother-tongue." (10)

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(8) Schaaf, W.L., 1963, 15-16.
(9) Dienes, Z.P., 1963, 125.
(10) Dienes, Z.P., 1963, 124.

But the same type of process does not operate in learning the language of number. "Mathematical experiences, in the sense of experiences whose actual content would be isomorphic to mathematical structures, are almost totally lacking from our lives." [11] There are exceptions to this though because in the early stages of number learning, natural numbers are often abstracted from the sets of objects they describe so that learning is concentrated on the number symbol itself. And the arithmetic operations of addition and subtraction are common enough informal experiences; even division can be employed when sharing or distribution activities are called for. But, as Dienes says, "Multiplication ... leading to higher powers of a base ,.. [is] ... practically non-existent in practice, let alone structures like quadratic and higher-order polynomials, complex numbers, definite integrals ... and even if they did occur they would not be likely to occur together with the relevant mathematical chatter that would make the situation analogous to learning the mother-tongue." [12]

The foregoing suggests that an individual becomes literate as a result of both formal and informal learning processes, with contingent experiences playing a continuous though not always conscious role in the development of literacy. In the situation of an individual becoming numerate, the role of contingent experiences in developing numeracy is relatively minimal. Outside the institutional confines of formal mathematical instruction, an individual is generally not called upon to perform other than at a level which relates to elementary number operations.

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[11] Dienes, Z.P., 1963, 125.
[12] Ibid., 125.

The content of mathematics is made up of structures which are essentially abstract, and the learning of these abstract structures presents real problems of understanding. Evidence of understanding in mathematics is itself not easily measured. An individual may perform a series of number operations successfully but not be able to verbalise his understanding of them. There appears to be no direct relationship between mathematical performance and the verbal explanation of the operations involved.

An individual can also perform an arithmetic operation without being aware of the operational relevance of the principle he may be applying. His failure to appreciate say the principle of commutation would not limit him from performing addition and multiplication operations, and if performance is the sole criterion then the activity may be presumed to have been understood. A further problem encountered in attempting to examine understanding in mathematics is that "too often it is assumed that those principles in terms of which the mathematician finds he can best analyse arithmetic are identical with those by means of which the learner can best manage to 'understand' it."[13]

An explanation of this apparent disparity is found in the fact that, in many informal number situations, the individual is able to select his own mode of symbolisation. Although these individual means of symbol construction produce structures which are generally not intended for communication or recording, they often take the form of explicit symbolism which greatly aids in rendering implicit operations operable. A simple example of this is where an

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[13] Williams, J.D., 1964, 18.

individual who is familiar with say the height of a twelve-foot stud in his house uses multiples of this image to estimate heights of say up to fifty feet or more. Likewise, it is common for a cricketer to use his image of either a twenty-two-yard cricket pitch or a seventy-five-yard boundary when estimating 'short-range' distance.

According to Williams (1964), these "imaginal sequences are easier to hold in the mind, and then to manipulate effectively, than are abstract numerical statements."(14) These 'private' images, or metaphor symbols, are more convincingly interrelated for many individuals than are the symbols of the arithmetical situation.

Some of the processes of learning and understanding numbers - the language of mathematics - have been briefly identified. While initially the analogy drawn between 'learning' words and 'learning' numbers seemed to be a convenient device for examining numeracy, it has since been shown, however, that the two learning situations are not analogous. The development of numeracy, taken in this work to involve three number operations, takes place within a mathematical context that is characterised by its allowing few contingent experiences to aid in this development.

The acquisition of skills involved in numeracy is closely related to the learning of mathematics. Since numeracy has been identified by the Board of Geography Teachers' Curriculum Group as a skill, or collection of skills, required in secondary school geographical education, there is implied an intersection of Set A, containing all school geographical skills, with Set B, containing all school mathematical

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(14) Williams, J.D., 1964, 25.

skills. This intersection contains the three number operations - recognising relationships between numbers, organising and distributing numbers, and performing arithmetic operations - with their foundations in mathematics but with their scope of operation extended into the domain of secondary school geography.

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3. MATHEMATICS AND NEW GEOGRAPHY

3.1 Introduction

By the end of the nineteen-sixties, it was becoming evident that geographical education in New Zealand secondary schools was acquiring a certain measure of mathematical content. It is true that numbers and quantities have always been employed in geography but it is in the last five or so years that geography students have been required to work regularly with information that is often presented in numerical form. In the past, the students' number experiences may have been limited to say constructing climate graphs from given sets of temperature and rainfall data, and to calculating numerical increases over given periods for say populations or crop productions, but now numbers (and mathematics) have begun increasingly to provide a 'shorthand' for gathering and analysing the content of our rapidly growing store of knowledge in the disciplines of the social sciences.

In order to endorse these developments - and certainly to propagate them - there is currently appearing a great proliferation of geography textbooks (and handbooks and monoliths and manuals) containing information and exercises that expect of the students some ability at understanding and using numbers.

It is this 'mathematical' geography that has come to be termed 'new' geography. The emergence of new geography was seen to coincide with a quantitative revolution in the discipline which, according to Burton (1963), "began in the late 1940s and early 1950s; it reached its culmination in the period from

1957 to 1960, and is now over."[15] He remarked further that the consequences of the revolution " are likely to involve the mathematisation of much of our discipline ..."[16] At the same time, Ackerman (1963) asked: " Is mathematisation of our discipline the way of our future? " – to which he concluded – " the year is not far off when a geographer will be unable to keep abreast of his field without training in mathematics."[17]

No doubt these two geographers, and the others who have commented along similar lines, has each a clear concept of what is meant by the mathematisation of geography, but there has been little offered that does in any way unify the direction of 'mathematised' geography, particularly in geographical education.

Along elementary lines, one may postulate that mathematics is about numbers; and numbers about measurement and quantity. Numbers have an advantage over words – which can also be about measurement and quantity – in that they can express precisely and unambiguously; but they have a disadvantage in that they form the 'alphabet' of a language in which facility is not usually developed or extended outside the formal learning situation. If the formal learning period is prematurely terminated then the acquisition of skills in this particular language is incomplete. There can be no assurance either that the limited range of skills so acquired can be performed from reliably and accurately.

Broadly speaking then, mathematics has enabled geography to establish a quantitative basis on which to set its philosophies and methodology. This development has been in essence the genesis of new geography. The effect on secondary school geography generally has been to introduce new approaches to its teaching, such as

(15) Burton, I., 1963, 152.
(16) Burton, I., 1963, 151.
(17) Ackerman, E.A., 1963, 432.

the use of problem-solving techniques; and to introduce a greater range of descriptive and explanatory activities which involve, for both student and teacher, a working knowledge of number operations.

3.2 New Geography in Secondary Schools

An abundance of literature has been published over the last four or five years on the application of quantitative techniques in geographical education. At first sight, this development has been seen to inject geography with potential vitality and to open up greater possibilities for active and involved study. It has also caused attention to be focused anew on the role of geography in the secondary school curriculum with, in some instances, embarrassing consequences, particularly when it leads one commentator to believe that "geography exists as part of the curriculum simply because it has been part of the curriculum, and because it has staff, equipment and facilities geared to the teaching of geography."[18]

The introduction of quantitative techniques into school geography is one aspect of a new approach which is tending to challenge the conventional geography which traditionally emphasised the learning of established factual content. The main thrusts of this challenge have come from:[19]

(1) recent advances in geographical research
(2) the precedent set by the American curricula developments

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[18] Blachford, K.R., 1971, 216.
[19] according to Crisp, J.A.A., 1969, 11.

(3) a growing understanding by geographers of the natureof scientific enquiry

(4) the belief that styles of learning are ultimately more important than facts.

The new geography in secondary schools is generally characterised by a more systematic and purposeful planning of field work exercises, an interest in operational games, and efforts to employ problem-solving methods in teaching based on the scientific mode of enquiry. But with the call to adopt quantitative techniques in the teaching of geography, teachers and students alike are finding that new geography has an implicit mathematical content which is now making its presence felt. Making observations of geographical phenomena, researching data sources, measuring objects and events in the field, organising and analysing geographical data; all are activities which require a certain level of ability in mathematics generally, and in performing basic number operations in particular.

From a questionnaire on attitudes towards models and quantitative techniques in teaching which was administered to geography teachers in British secondary schools, it was found that " the mathematical competence of both the teacher and the taught was frequently brought into question ... "[20] – and also that – " many voices ... expressed the fear that the need for numeracy would drive pupils away from geography in the sixth form ... "[21]

Strong opposition to " 'new geography' with its advanced mathematics ... "[22] has come from Wright (1972)

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[20] Gregory, S., 1969, 8.

[21] Gregory, S., 1969, 9.

[22] Wright, D., 1972, 30.

who claims that " ... new geography is not suited to geography teachers, for most are not qualified to teach new geography well. They will be less effective teachers, or even lost to the profession, if new geography is widely adopted. The few that are appropriately qualified in quantitative techniques would be better occupied in reducing the shortage of mathematics teachers ... "(23) He feels too that the pupils will suffer " from an inadequate mathematics background that most of them possess ... "(24)

In support of Wright's contention, Cross (1972) claimed that " ... he [Wright] is in good company among teachers in suspecting that for all its attempts to blind with 'science' and 'mathematics', its basic premises are of doubtful validity."(25) Of his own geography teaching experience, Cross wrote that " most of my students [Salisbury and South Wiltshire College of Technology] are not only sadly lacking in much basic geography, but they are generally incapable of dealing with any mathematics beyond square roots."(26)

Admittedly these comments relate to teaching the new geography in British schools where perhaps syllabus requirements and subject offerings do not permit students to readily combine science and mathematics with geography, or where perhaps the quantitative approach to geographical teaching was forced initially with more enthusiasm than understanding into the high school curriculum. Nevertheless, the need for both geography teacher and geography student to have some numerate ability is highlighted by these British reports.

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(23) Wright, D., 1972, 30.
(24) Ibid., 30
(25) Cross, D.A.E., 1972, 28.
(26) Ibid., 28.

In New Zealand secondary schools, the climate with respect to the new methodological developments in geography teaching is at present difficult to assess. Research groups are in the process of collecting information on the state of geography in New Zealand schools with the intention of planning more carefully the development and direction of geographical education. Geography teachers themselves are becoming aware of the changes occurring in their discipline but demands made of them at the 'chalk-face' prevent them from participating in developments to the extent most would desire. It has been reported, from observation, "that a tremendous amount of experimentation and innovation is currently being attempted in geography classes and in the field as teachers respond to new emphases in geography methodology. School geography departments are pooling their resources and sharing their successes and failures; ideas highlighted and developed at in-service and refresher courses, are being spread among growing numbers of teachers. All this is good but these developments are still not reaching the great masses of teachers of geography."[27]

In the research carried out so far under the auspices of the Board of Geography Teachers in New Zealand, the need for the development of particular skills in geography has been appreciated, and to this end a report on Teachers' Perception of Geographic Skills was published in February 1974. The categories of skills were broadly headed by statistics and diagrams, mapping skills, photographs, geographic concepts, and field studies.[28] This same report denounced the

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[27] Innes, G., 1974, 27.

[28] BCGT Curriculum Group Report, July 1973.

present situation as "highly unsatisfactory where the explicit need for a teaching skill is first indicated in the exam room and the subsequent Reports of Examiners."(29) Since most of the skills considered by teachers in this report to be necessary in geographical education contain some quantitative or 'mathematical' element, there is implied the need for geography students to be sufficiently numerate in order to perform these skills.

Numeracy is, however, a neglected field of study in geographical education and yet, because it involves the understanding of mathematical concepts and the performance of basic number operations, it is fundamental to instruction in the empirical sciences. Perhaps it is presumed that with mathematics a compulsory subject in the first two years of secondary schooling in New Zealand, an adequate basis is established in this time with which later confrontations with the mathematical aspects of other subjects can be dealt. But the teaching of two years of secondary school mathematics tends to produce at its end a very great range of mathematical abilities. Faced then with the prospect of taking five subjects in his fifth-form year, the student who is contending successfully with mathematics tends to pursue a science course, from which geography is often exempt. The student who has no aspirations to being a mathematician instead selects the less numerate subjects of history or geography or modern languages or commerce.

If formal mathematics instruction in secondary schools cannot be depended upon to evoke a uniform standard of performance in the three broad groups of number operations which have been identified in this

(29) BOGT Report No. 4, Teachers' Perception of Geographic Skills.

work as constituting numeracy, then perhaps the new integrated geography syllabus which is proposed should make provision for instruction in the number operations and mathematical concepts which the learning of its content will require.

4. NUMERACY SKILLS IN SECONDARY SCHOOL GEOGRAPHY

4.1 Introduction

Curriculum revision groups in New Zealand are currently gathering information before proceeding towards the development of an integrated syllabus for teaching geography from the fifth form through to the seventh form in secondary schools. As was commented earlier, the Board of Geography Teachers has published a number of reports on the findings of research it has carried out into geographical education in New Zealand. When the information from this research, and from research and discussion undertaken by other partisan groups, is seen to be adequate, then the terms of syllabus revision in geography will likely be formulated.

It has been argued in the foregoing text that:

(a) geographical education has over the past five or six years acquired an explicit quantitative element which has led to the subject becoming 'mathematised'; that is, more learning activities in secondary school geography now involve the performance of numeracy skills.

(b) these number skills can be divided into three groups of number operations:

(i) recognising relationships between numbers
(ii) organising and distributing numbers
(iii) performing arithmetic operations.

The intention of this work is to now identify the types of numeracy skills currently being used in secondary school geography, to comment critically on their use, and to propose then a set of numeracy skills which could be used to best advantage in the teaching of geography.

4.2 A Review of Past School Certificate Geography Papers

The role of external examinations in geographical education in New Zealand has been emphasised already. It was stated that an examination is so designed as to evaluate the relative achievement of educational objectives set in geography teaching. If this view is accepted, then in order to identify the types of number skills, or numeracy skills, which are currently being used in secondary schools' geography, it is useful to review the content of past external examination papers. It is reasoned here that, in the absence of any specific guidelines offered in the present geography prescriptions as to the types of numeracy skills required to be performed by students, the numeracy skills which have been set in external examination papers in recent years will be the skills that teachers are presently including in their geography lessons.

The seven School Certificate Geography Examination papers, 1969 to 1975 inclusive, have been selected to provide examples of the types of numeracy skills which have become part of geography teaching at all levels generally, and at the fifth form level of study particularly, in New Zealand.

4.2.1 Year 1969

The School Certificate Geography paper is traditionally divided into three sections; South West

Pacific, Monsoon Asia, and North America. Sections A and B of the 1969 paper contained a total of eleven questions each requiring the then conventional sketch map, definition of terms, and essay-type responses. By way of example:

8. East and West Pakistan

(a) Draw a sketch map of both East and West Pakistan and mark and name the Sunderbans, Karachi, Dacca, the Punjab and the direction of the summer winds. (5 marks)

(b) Explain briefly the meaning and importance of TWO of the following items. Head each paragraph with the term it explains.

barrage; kharif; delta; industrial crops; tube wells. (5 marks)

(c) For both East and West Pakistan, discuss the extent of industrial development. (5 marks)

In Section C of the 1969 paper, three questions contained parts involving numeracy skills. Part C of Question 13 presented a 2 x 3 data matrix whose elements were to be used to decide if eight statements were true, false, or undetermined ('you cannot tell'). The third part of Question 15 involved the exercise of calculating from a plan diagram the area (in square miles), given a linear scale (in yards), of a steel works. The third numeracy skill in this section of the 1969 paper was the construction of two simple (as opposed to composite) bar graphs, each from two sets of data.

This School Certificate paper introduced to fifth form geography an example from each of the three groups of number operations by which numeracy in this work has been defined. The interpretation of the data matrix required that the relationships between its elements be recognised, the calculation of area involved an arithmetic operation, and the construction of the bar graphs entailed distributing and organising numbers.

4.2.2 Year 1970

In this paper, Section A remained traditional while in Section B, the second part of each of the five questions was headed 'Interpreting Statistical Information'. Then followed a data matrix from which sentences were to be completed. By way of illustration:

7. Population Distribution and Growth

B. Interpreting Statistical Information

Selected Population Figures
for Certain Countries

	Ceylon	Burma	Malaya	Thailand
Birth Rate (per 1000)	3.7	5.0	4.0	3.6 (29a)
Natural Increase (per 1000)	2.8	1.5	3.1	2.6
Urban Population (percentage)	15%	N.A.	42%	12%
Population Density (per square mile)	413	88	146	140

From what you understand about population growth in Asia and the relationships indicated above complete the following sentences ...

1. The country with the highest birth rate in 1962 was ......
2. The country which had the highest death rate in 1962 was ......
3. Though Malaya and Thailand have similar population densities, Malaya in 1962 was much more ...... than Thailnad.
4. The actual numbers of people living in a country is not a good indication of how "over-populated" it is because this depends on ...... as well.

(4 marks)

(29a) an incorrect expression of birth rates and rates of natural increase; an error not unique to extrenal examination papers.

This paper, with its explicit use of 'statistical information', marks the beginning of the move to 'mathematise' geography in New Zealand secondary schools. In response to this, it is reasonable to assume that from 1971 onwards, most geography teachers will have endeavoured to include such numeracy skills in their teaching; but no lead appeared then (or has it since) to advise what numeracy skills should be taught in fifth form geography. There seems to have been little effort made by those authorities responsible for the content of geography syllabi to direct and order the use of numeracy skills in geographical education. A point that will be discussed later in this work is that the need to ensure that numeracy skills are appropriate - in other words, have they a relative (to geography) purpose, and does the performing of them satisfy this purpose? - has not been given due attention.

4.2.3 1971

In this School Certificate Geography paper, each of the 17 questions involved numeracy skills which were conspicuous by their variety of type and their varying degrees of difficulty. Coupled with the fact that fifth-form geography teachers had generally no inkling during 1971 that numeracy skills would become so widespread in the paper that they were teaching towards, it can be quite safely asserted that in 1972 the 'mathematisation' of geography became a reality for both teacher and student.

In Section A of this paper, the numeracy skills included estimating fractions from pie graphs, calculating annual temperature range from a given climograph, and interpreting line graphs and bar graphs. In sections B and C, all questions each contained a data matrix from which information was to have been extracted.

While the types of number operations tested in this paper fell generally within the three categories of numeracy skills as they have been defined in this work, the inclusion of line graphs and bar graphs from which interpretations were to have been made has forced the extension of the definition of the first group of numeracy skills to 'recognising relationships between numbers and their representations'. These graphs have been taken arbitrarily to be forms of number representation rather than to be inverse operations of the second skill group, organising and distributing numbers.

Some examples have been selected from the 1971 School Certificate Geography paper to illustrate the degrees of difficulty students may have encountered in answering the questions requiring numeracy skills to be performed. It was stated earlier that the one advantage numbers have as the 'alphabet' of a language is that they are precise and unambiguous, in contrast to our use of words which may for a number of reasons be quite ambiguous. Ambiguity results generally from improper - that is, inaccurate and incorrect - usage. Examination papers should, of course, be completely free of such ambiguity, but the School Certificate Geography paper does not altogether satisfy this condition. Under a very untidily drawn set of composite bar graphs showing Fiji's population size in each of four census years, the question is posed (in reference to racial element): Which element of the population showed the most rapid growth at the 1966 Census? Since comparative rates of growth (and numerical growth is presumed required) must be made relative to a common period of time, and no time interval is specified, the question in its present form cannot be answered.

The operationalisation of the concept of average annual percentage increase may well have defeated a good number of fifth form geography students in 1971. Question 8 asked that given Japan's population of 101,408 (thousand), and that the average annual percentage increase from 1963 to 1973 was one per cent, 'what increase in population is expected in Japan, each year?'. Admittedly there is just half a mark at stake here, but its acquisition is more likely to have been the prerogative of the 'mathematical' geographer. This same student had the opportunity to gain another half -mark at the expense of his less numerate colleague in part (c) of Question 14, which follows:

New England Land Use

	1880	1910	1945	1954	1965
Land in Farms (% of New England area)	53	52	34	29	20
Land in Farms (thousand acres)	20,725	20,566	13,948	11,121	7,745
% of this farmland which is woodland	35	43	51	51	60

(1) Study the above table and answer the following questions.

(i) In which period was the greatest decline in farming?

(ii) What was the actual area of horticultural farmland (not in forest) in 1965?

(2) Briefly discuss the reasons for the early development of secondary industries in New England.

(3 marks)

Attention is to be focussed on part (ii) of (1) above. The question requires the student to carry out the operation: $\frac{40}{100} \times 7,745,000 = 3,098,000$ acres.

The solving of this type of problem may not be within the capacity of the majority of geography students in

New Zealand because the results of a numeracy test administered to 3823 fifth form geography students show that less than ten per cent of students tested were successful with a similar calculation.[30]

Questions 16 and 17 of the 1971 paper contained number operations which can be considered more relative to geography, and of a more reasonable degree of difficulty. Question 16 required that students first be able to recognise export commodities according to general categories; for example, that iron ore, non-ferrous minerals, and oil and natural gas were all of the 'minerals' group. In Question 18, students were required to identify given states of the United States according to their general location in the north, south, east or west of the country before embarking on the specific number operations called for.

4.2.4 Year 1972

The School Certificate geography paper in 1972 continued with the extensive use of numeracy skills which had been initiated in the 1971 paper. New developments, however, included the need for students to draw pie graphs and line graphs, but with the introduction of these, it is necessary to comment critically on the design of some of these questions.

The main faults of the questions which call for line graphs to be constructed liw with the range in magnitude of the elements given in the data matrices and with the 'exactness' to which the elements are expressed. These views can be illustrated with reference to Questions 8 and 15 in the 1972 paper.

The elements of the data matrix in Question 8 -

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[30] Question 6 of the Numeracy Test (Appendix 4).

$$\begin{pmatrix} 474 & 576 & 737 & 937 \\ 168 & 219 & 293 & 394 \\ 588 & 654 & 746 & 849 \\ 120 & 141 & 164 & 190 \end{pmatrix}$$

– show the fault of 'exactness'. When, as in this question, it is necessary to construct a vertical axis with a scale of from zero to over 900 (million), values approximated as they are to the nearest million are too exact, given that graph paper is not provided and that marks are allocated for the general trend (or appearance) of each line graph drawn.

The relevant elements in the data matrix for Question 15 –

$$\begin{pmatrix} 150 & 154 & 243 \\ 1000 & 2243 & 3200 \end{pmatrix}$$

– illustrate the fault of too great a range in magnitude of the elements in the matrix. Constructing a vertical scale upon which to plot the values of '150' and '3200' cannot be considered, in the context, a reasonable exercise.

By comparison, the two data matrices from which pie graphs were to have been drawn (Questions 3 and 16) contained elements expressed as percentages which, if this number skill had been adequately practised during the year, should have presented few problems for most of the students.

One further criticism of the design of questions in this examination paper relates to the presentation of the data matrix in each of Questions 11 and 12. The columns of the matrix in Question 11 were headed:

China's Trade with Selected Countries, 1967-69

China's Imports			China's Exports		
1969	1968	1967	1969	1968	1967

There appears to be no justification for this reversal in the sequence of years heading each column. Why was the matrix in Question 11 not titled: China's Trade with Selected Countries, <u>1969-67</u> ? The resulting presentation of data in this matrix, and in the one for Question 12 -

Japan's Trade (US $million)			
1970	1969	1968	1967

- is misleading and contrary to the natural (and accepted) tendency of reading chronological sequence from left to right.

Finally, considering the relatively large size of some data matrices in the 1972 paper - particularly Question 9 (11 x 6 matrix), Question 12 (10 x 4) matrix, Question 14 (5 x 8 matrix) and Question 17 (8 x 6 matrix) - it might be interesting to speculate on what effect the confrontation with these masses of numbers may have had on some students.

4.2.5 Year 1973

Not all questions in this paper carried a part that involved numeracy skills. The interpretation of topographic maps, aerial photographs, and models, the analysis of relief cross-section, and the use of oblique photographs, accounted for seven of the 17 questions in the paper. The numeracy skills in nine of the remaining questions included drawing line, bar and pie graphs, and the interpreting of composite bar graphs and a data matrix.

Comment is necessary here on the drawing of pie graphs. In the 1973 School Certificate geography paper, the sectors of the pie graphs required to be drawn were to have been estimated from percentage values given.

This is the most convenient method of providing information for pie graphs - and perhaps the most appropriate at the level of fifth form geography - because it can be fairly readily recognised, for example, that 34 per cent is about one-third the way round the circle, and so on.

The construction of the pie graph using the information that was presented in Question 9 should have proved rather demanding:

9. Malaysia and Indonesia

(c) Population of Indonesia: 1971

Java-Madura	80 million
Sumatra	20 million
Sulawesi area	9 million
Bali-N. Tengarra	7 million
Kalimantan	5 million
West Irian	1 million
	122 million

In estimating Sumatra's share of the circle, for example, the student had either to recognise 20 million as being approximately one-sixth of the total, or derive a scale factor of three (the approximate ratio of 122 to 360 degrees) and then estimate 60 degrees (20 million times the scale factor of three) around the circle.

Similarly, the construction of the pie graph required in Question 12 depended upon the students' recognition of the relationship between each population figure and the total of 150,000 (thousand); for example, that 37,500 was one-quarter of the total, that 12,500 was one-twelfth, and so on.

The new numeracy development here in this 1973 paper is the estimation of ratio, or proportion, involving the derivation of scale factors. This particular numeracy skill appeared also in Question 7 where five composite bar graphs were presented. The two pertinent problems here were:

(1) deciding on an approximate scale factor for reducing 470.4 to 107.5, given as possible solutions: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{5}$, $\frac{3}{4}$

(2) deciding on an approximate scale factor which reduced 1020.5 to 524.2, given the same set of possible solutions.

Before arriving at the values of 107.5 and 524.2, the student needed first to identify the sub-groups of 'metalliferous ores', coal, 'briquettes, petroleum, etc.', and 'non-ferrous metals' as belonging to the 'metals and minerals' group. While this grouping activity can be endorsed as a relevant geographical exercise, the deriving of scale factors from pairs of numbers may well have been beyond those students not versed in approximating number relationships by inspection.

4.2.6 Year 1974

This was the year of the photograph; eight of the 16 questions used aerial of oblique photographs. Number operations and mathematical concepts, having peaked in the years of 1971 and 1972, were confined in the 1974 paper to just four questions in Section C. The one new development among the literacy skills was the drawing of a pie graph from information presented in a composite bar graph. The data given in the matrix for Question 13 can be criticised as being too 'exact' for the construction of the bar graph required. And this same 3 x 5 matrix demanded a 'bar' for each of its 15 elements.

4.2.7 Year 1975

The range of practical skills tested in this paper included the interpretation of models, topographic maps and aerial photographs, oblique photographs, data matrices, a roughly-drawn line graph, and an equally crudely-drawn age/sex pyramid. Six of the 15 questions involved numeracy skills as they have been defined already in this work.

The age/sex pyramid, in making its first appearance in a School Certificate Geography paper, was not particularly complicated but the operations required would have proved 'fiddly', and a range of answers must have been permitted.

The line graph in Question 9 tested the mathematical concepts of numerical increase and percentage increase, but its design and function will have done little service at all in promoting the acceptance of numeracy skills generally, and graph work particularly, in School Certificate geography. It would be difficult to justify it as a relevant geographical exercise.

4.2.8 Concluding Comments

This brief review of the School Certificate geography examination papers for the years 1969 to 1975 has identified the types of numeracy skills employed. Two general assumptions must be made here: that the particular numeracy skills which have been identified are:

(1) the skills which the examining authorities consider to be appropriate at the fifth form level of geographical study.

(2) the skills which fifth form geography teachers in New Zealand will be endeavouring therefore to inculcate.

It has been demonstrated in this review, too, that the numeracy skills as they are presented in the papers are not altogether without fault, both in their design and in their purpose. Further discussion on the nature and function of numeracy skills in secondary school geography is included in the final section of this work. At this stage it is useful to take stock of the position reached.

Numeracy has been considered to involve three groups of number operations, defined as:

(1) recognising relationships between numbers and their representations

(2) organising and distributing numbers

(3) performing arithmetical operations.

New geography is essentially geography which has been 'mathematised'; that is, it has come to make much greater use of numeracy skills in general, while at the more advanced level of study and research, theoretical structures with mathematical bases have evolved.

The widespread adoption of numeracy skills in the School Certificate geography examination papers of 1971 and 1972 has been taken to signal the acceptance, at the secondary school level, of the new, mathematised geography. The frequency of appearance of numeracy skills in the examination papers of the two subsequent years, 1973 and 1974, waned somewhat with the introduction of models and photographs which tended to test non-numerate skills in geography, but numeracy skills can be expected to remain now as essential skills in geographical education.

The shift of attention is now made in the direction of the geography students themselves in order to gain some measure of their ability to perform numeracy skills. To this end, Section 5 of this work is concerned with a review of a questionnaire that was administered to geography students in a random sample of 150 secondary schools in New Zealand in 1974.

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5. SURVEY OF SECONDARY SCHOOL GEOGRAPHY STUDENTS

5.1 Introduction

Within the context of geographical education in New Zealand, there are moves being undertaken at present by a geography curriculum development committee of the Department of Education to revise the geography syllabi in secondary schools, with a view to integrating the syllabi from forms five to seven. There has also been established by the Board of Geography Teachers a curriculum committee which over the past three or so years has conducted basic research into geographic skills in the present curriculum, the origin and destination of geography student, and the qualifications of geography students. This research is aimed at providing a basis upon which curriculum revision may be carried out.

Of relevance to this work on numeracy in school geography has been the research carried out by the curriculum group of the Board of Geography Teachers into teachers' perception of geographic skills. The questionnaires used in this group's study listed a variety of skills alongside each of which teachers were to indicate the level at which each skills should be explicitly taught. From the results of this questionnaire it was found that in addition to such 'geographic' skills as graphs, measures of central tendency (mean, median, mode), measures of dispersion (standard deviation), demographic ratios, and sampling techniques, some teachers added voluntarily to the list given the following skills to be taught in the sixth and seventh forms:

regression equations, nominal and binomial distribution, location quotients, nearest neighbour analysis, Pearson's correlation coefficient, indices of specialisation, significance tests, and rank-size analysis. As Burridge and Jones (1974) rightly conclude, "to what extent these responses reflect carefully thought-out ideas is a moot question."(31)

Many of the geographic skills which the majority of teachers replying to the survey perceived as being in need of explicit instruction involved mathematical concepts and number operations. If these skills are to be included in the new integrated geography syllabus, then numeracy will become an essential part of geography teaching.

5.2 Survey Design

The main research exercise in this work centres on the designing of a questionnaire that would glean information relating to the geography and mathematics experience - past, present and proposed - from geography students in New Zealand secondary schools, and with this background so established, the intention was to then administer an arbitrarily designed numeracy test. The results of this test could then be used to guide in part the formulation of a set of numeracy skills to be incorporated in the new integrated geography syllabus.

The design of the survey questionnaire itself was conditioned by a number of constraints, the chief ones of which related to the context within which the

(31) Burridge, G., and Jones, A., 1974, 3.

survey population presented itself, and to the method by which the survey was administered.

The Directory of Secondary Schools and Technical Institutes, published by the Public Relations Section of the Department of Education, lists a total of 392 secondary schools in New Zealand in 1974, distributed as follows:

TABLE I Distribution of Secondary Schools in New Zealand, 1974

School Type	Boys	Girls	Mixed[a]	Totals
State Secondary	25	25	186	236
Private Secondary	45	59	6	110
District High School	-	-	46	46
Totals	70	84	238	392

[a] Coeducational

Source: Dept. of Education

Rather than include al secondary schools in the survey, which would have involved, within a limited period of time, a major logistics operation in administering by mail nearly 400 questionnaires, it was decided that a random sample of 150 schools be taken to constitute the sample population. In setting the size of the survey population, from which the sample population was to have been drawn, the total of 392 schools was first reduced to 328. The 64 schools eliminated were done so mainly on the grounds of roll size. In the first place it was argued that rolls of less than 100 students[32] would not contain a balanced representation of geography students in each of the

[32] as at July, 1973.

fifth, sixth and seventh forms. As it happened, there were to emerge 17 schools included in the sample population (and which replied to the survey) with rolls of more than 100 that did not contain any seventh form geography students. In terms of the arbitrary cut-off figure of 100, some injustice may have been accorded the smaller schools, predominantly District High Schools, with rolls of say 80 to 100, but this treatment may in fact be part of their lot because their exclusion from other surveys is noted.(33)

In addition to the schools then with rolls of less than 100, three so-termed Area Schools were omitted, as were the four new secondary schools which had opened in 1974. Following on from this elimination there remained 328 schools to constitute the survey population. These schools were then stratified according to type, as shown in Table II.

TABLE II Distribution of Secondary Schools in Survey Population (by school type)

	Number of Schools	per cent of total Survey Population
Coeducational	178	54.26
Private Girls	50	15.24
Private Boys	42	12.80
State Girls	25	7.62
State Boys	25	7.62
District High School	8	2.46
	328	100.00

Source: Dept of Education

In order to obtain as near a representative

(33) See footnote, page 54.

sample as possible from the survey population, the 328 secondary schools were stratified according to type and then , for each type, ranked according to mid-1973 roll size. A table of random numbers was used to obtain a random sample population of 150 secondary schools, proportional in its composition to the composition (by school type) of the survey population. The outcome of the random sample selection of 150 schools is shown in Table III.

TABLE III   Distribution of Secondary Schools in Sample Population

	Number in Survey Population	Number in Sample Population	Per Cent of Total Sample Population
Coeducational	186[a]	85[b]	56.67
Private Girls	50	22	14.67
Private Boys	42	18	12.00
State Girls	25	13	8.67
State Boys	25	12	8.00
	328	150	100.01

[a] included are 8 District High Schools
[b] included are 4 District High Schools

The numeracy survey was conducted using a questionnaire which was mailed to each of the 150 schools in the sample population. It was necessary to design the questionnaire according to the requirements of a postal survey since a direct survey of the 150 schools was impracticable. Chief among these requirements were the need for concise and unambiguous

(33) For example, Board of Geography Teachers' Questionnaire on External Examinations (1973), roll size cut-off - 150; BOGT Report No. 4 - 150; BOGT Report No. 5 - 100.

instructions for the survey administrators to follow, a not too lengthy set of response operations to perform, and a straightforward system of collecting and grouping individual responses.

The questionnaire consisted of five sheets, three white and two blue. The coloured sheets were the two to be returned carrying the responses to the questionnaire entered upon them. A covering letter, addressed to the head teacher in geography in each of the sample schools, served to introduce the main ideas of the survey (see Appendix 1). The first of the blue sheets (see Appendix 2) requested information, to be entered in tabular form, on the geography and mathematics background and intentions of geography students at each of the three levels; fifth form, sixth form, and seventh form. The third sheet (see Appendix 3) outlined the procedure desired for administering the numeracy test to selected geography classes. The numeracy test, composed of six questions, was detailed on the fourth page of the questionnaire (see Appendix 4). The fifth sheet, the second blue one, was the result sheet which made provision for the frequency of correct responses to the numeracy test questions to be recorded (Appendix 5).

The design of the numeracy test, however, requires some brief explanation at this point. It was not possible to test the students' abilities at performing all the types of numeracy skills which have been identified in the review of past School Certificate geography examination papers. To do this would have required too lengthy a test. Also, since the teachers administering the test to each of the classes were to collect and summarise the test results before returning them, it followed that some of the skills such as the drawing of of graphs could not be included in the test. Finally, the interpretation of graphs and matrices could not be satisfactorily included in the test because of the time involved for each administrator in reproducing each of these particular exercises for each student. Accordingly, the scope of the numeracy test was somewhat limited and the conclusions drawn later in this section of work from the test results will be of a tentative nature.

5.3 Survey Response

Survey research is one method of empirical research available to the geographer. Unlike a census, though, which usually involves the enumeration of a whole population, a survey typically examines a part or sample from a population. Conclusions drawn from the results of a survey of a sample population are referred back to the population at large in order to make descriptive assertions about that population. In order that these assertions be as meaningful and as reliable as possible, the sampling procedure on which the survey is based is of critical importance. In addition to this requirement the success of the survey research depends on the nature, ordering and format of the questions to be asked and, of no less importance, on the response rate achieved from such a survey.

The body of inferential statistics used in connection with survey analysis assumes that all members of the sample population complete and return their questionnaires. Since this is almost never the case in reality, "response bias becomes a concern, with the researcher testing (and hoping for) the possibility that the respondents are essentially a random sample of the initial sample, and thus a somewhat smaller sample of the total population."[34]

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[34] Babbie, E.R., 1973, 165.

Since this numeracy survey of geography students in New Zealand secondary schools involved a self-administered questionnaire, there was no direct control to be held over the completing of the questionnaire and its return mailing. An important factor whose influence had to be minimised in order to elicit an unbiased response from teachers administer- the questionnaire was the element of self-indictment or implication. If, for example, a response was required which would directly reflect the effectiveness or quality of individual teaching methods and standards, then the reluctance to administer for this response by teachers who felt themselves so affected would bias the averall set of responses, in that only those teachers who felt themselves exempt from or beyond implication would voluntarily respond. Fortunately, in the set of responses required for the numeracy survey, no teacher-implication as regard pedagogic efficiency or otherwise in geographical instruction could arise. Any teacher bias, therefore, was likely to be minimal.

Despite efforts by way of survey design to gain a high response rate to the questionnaire, there were other factors which must be taken into account when examining the response rate and which no amount of survey design refinement could have successfully eliminated altogether. In the first place it is probably fair to say that not all geography teachers are proficient bookkeepers. It is not difficult to imagine - as was later confirmed by those heads of departments who wrote for a second copy of the questionnaire on receipt of the reminder note - the original questionnaire being swept up in the relentless barrage of the 'paper war' which continually assails teachers in secondary schools, and being mislaid as a result of this. There will have been, too, some recipients for whom time and inclination are never simultaneously in ascension.

It appears that in some instances the questionnaire dispatch coincided with senior internal examination programmes. From the point of view of the time available for questionnaire completion, collection and analysis of results, further delays in the posting out of the questionnaires to schools until after the August-September vacation would have created difficulties. It was heartening to note - and encouraging for future research in this field - that some heads of geography departments wrote advising of this state of affairs and offered to return the questionnaire completed after their respective senior examinations had concluded. Such was the case for eleven secondary schools replying to the survey.

In addition to the attempts made to streamline the administering and response operations for the questionnaire, every effort was made to promote efficient postal movement. According to Babbie (1973), "the methodological literature on follow-up mailings strongly suggests this is an effective method for increasing return rates in mail surveys. In general, the longer a potential respondent delays replying, the less likely he is to do so at all. Properly timed follow-up mailings, then, provide additional stimuli for responding."[35] For this numeracy survey a stamped self-addressed return envelope was included with each questionnaire, and 17 days after posting out the questionnaires a reminder note (see Appendix 6) was sent out to 60 of the 93 secondary schools which, at that date[36], had not replied to the survey.

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(35) Babbie, E.R., 1973, 163-4.

(36) August 19, 1974.

It is difficult to assess the true effect of the follow-up reminder letter. In four instances it produced replies from schools which reported to having not received the questionnaire to begin with. These four schools, on receipt of a second posting, each later returned the questionnaire completed. The seven questionnaires returned in the fourth week (see Table IV) came from schools which had been posted a reminder note.

TABLE IV Monitoring of Questionnaire Returns

Week in which Return Received	Number of Returns	Cumulative Frequency (Cf)	Cf as % of total Returned
1st Week (August 5-11)	11	11	11.95
2nd Week (August 12-18)	33	44	47.80
3rd Week (August 19-25)	21	65	70.65
4th Week (Aug 26-Sept 1)	7	72	78.56
5th-12th Weeks (September 2 -Nov 19)	20	92	100.00
	92		

While Table IV above indicates that nearly half of all the 92 questionnaires returned had been received within the first two weeks of their having been posted out, and that 70 per cent had been returned by the end of three weeks, it must appear rather disconcerting to future survey researchers in this field to note that it took eight weeks to gather in the final 20 returns.

In all a total of 92 questionnaires were returned from the sample population of 150, representing a response rate of 61.3 per cent. Although outwardly not a particularly high response rate, this figure does compare favourably with response rates for other similar surveys that have been carried out in recent years.(37) There is no standardised set of acceptable response rates for mailed questionnaire surveys and no value established above which a response rate can be termed high. Babbie (1973) considers that "a response rate of at least 50 per cent is adequate for analysis and reporting. A response rate of at least 60 per cent is good. And a response rate of 70 per cent or more is very good."(38)

Since the random sample was made on the basis of schools stratified according to type, it is relevant to examine the composition of the response population on the same basis of stratification. This exercise is demonstrated in Table V. Although an overall response rate of 61.3 per cent was achieved, responses by school type varied from as low as 54 per cent for coeducational schools to as high as 77 per cent for private girls' schools.

The stratification of the survey population was carried out to ensure that the sample population contained a representative proportion of all school types. To determine whether the response population contains an equivalent representation of each school type, a chi-square significance test was applied.

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(37) Response rates for BOGT surveys, 1973-74, were:
 i) External Examinations (1973); 47 per cent (sample population = 300)
 ii) Origin and Destination of Geography Students (1973) (50 per cent - sample population = 84)
 iii) Qualifications of NZ Geography Teachers (1974); 47.7 per cent (sample population = 308)
 iv) Teachers' Perception of Geographic Skills (1974); 42 per cent (sample population = 130).

(38) Babbie, E.R., 1973, 165.

TABLE V Distribution of Response Population

	Number of Questionnaires Out	Number of Questionnaires Returned	Response Rate (%)
Coeducational	85	46[a]	54.1
Private Girls	22	17	77.3
Private Boys	18	10	55.6
State Girls	13	10	76.9
State Boys	12	9	75.0
	150	92	61.3

[a] includes one District High School

If, for example, the number of coeducational schools contained in the sample population represented 57 per cent of that sample population (Table III), then for this representation to be maintained the proportion of coeducational schools responding would need to be 57 per cent of the total response population. In fact the 46 coeducational schools (Table V) account for 54 per cent of the response population. So, in this example, the observed frequency of coeducational schools is 46; the expected is 52.

For the null hypothesis (H_0) that there is no difference between the distribution of schools (by type) in the sample population and in the response population, a chi-square value of 2.49 (with four degrees of freedom) was obtained. This suggests that there is no significant difference at the five per cent level, and so the null hypothesis is accepted.[39]

From this discussion on the response rate obtained in the survey, it is suggested that not only is the overall response rate of 61.3 per cent an acceptable one upon which analysis may follow with some confidence, but also the composition of the

[39] See Appendix 7.

response population itself is representative of the sample population, and of the survey population.

5.4 Survey Results

The results of the numeracy survey which are commented on in this section of the work were collected from the 92 questionnaires returned from a random sample made of 150 secondary schools in New Zealand. A description of these results follows.

5.4.1 Geography and Mathematics Experience of Geography Students

At the fifth form level of study, the survey questionnaire requested from each school the numbers of students currently studying fifth form geography and, of these, the numbers studying (or who had studied) fifth form mathematics, and the numbers intending to study sixth form geography and sixth form mathematics.

Of initial interest are the numbers of fifth form students studying both geography and mathematics. The results of the survey show that nearly 70 per cent of all fifth form geography students were also studying fifth form mathematics.

TABLE VI Numbers of Students Studying Both Geography and Mathematics in the Fifth Form, 1974

School	Numbers: Geography	Numbers: Geography and Mathematics	G + M / G %
Coeducational	3840	2562	66.71
Private Girls	654	375	57.34
Private Boys	680	652	95.88
State Girls	1499	807	53.84
State Boys	798	769	96.37
	7471	5165	69.13

While the information contained in Table VI tends to suggest that geography students in the fifth form may be generally capable of performing – or of at least learning to perform – the types of number operations which have been defined as constituting numeracy, this may not necessarily hold true. The problems associated with learning and retaining number operations and mathematical concepts have been outlined already. It is argued that unless particular number operations are being regularly performed and reinforced – and this occurs almost exclusively during formal mathematics instruction – the facility to carry out these operations deteriorates. This means that while a particular skill, say calculating percentage increase, may have been learnt in years prior to a student taking fifth form mathematics, unless this student encounters this skill during his fifth form mathematics study, he may not necessarily be any more capable of performing the operation than a fellow student who is not studying fifth form mathematics.

Another point of qualification is that while a student might be currently studying fifth form mathematics, it does not hold in all cases that he is capable of succeeding – that is, able to pass examinations – at that level, and so again he may be at no particular advantage when compared to a student who is not taking fifth form mathematics.

One further consideration, too, is that generally the more 'mathematically competent' student continues mathematics from the fourth form into the fifth form, while the student having little aptitude in the subject chooses some other subject-offering. But students from both these categories may come equally to geography in the fifth form.

Other background information which was obtained from fifth form geography students is tabulated in Appendices 8 and 9. It can be summarised as follows:

From a total response population of 7471 fifth form geography students:

1) 3741 (50.07 per cent) indicated that they intended to study sixth form geography

2) 2790 (37.35 per cent) indicated that they intended to study sixth form mathematics.

At the sixth form level of study, the 92 secondary schools replying to the survey yielded 3208 geography students, whose distribution according to geography and mathematics studied in the fifth form, mathematics being studied in the sixth form, and intentions of studying geography in the seventh form, is shown in Appendices 10 to 13. A summary of this information follows:

From a total of 3208 sixth form geography students:

3) 2788 (86.92 per cent) indicated that they had studied fifth form geography

4) 2489 (77.61 per cent) indicated that they had studied fifth form mathematics

5) 1761 (54.89 per cent) indicated that they were studying mathematics in the sixth form

6) 887 (27.65 per cent) indicated that they intended to study seventh form geography.

The responses made by the 647 seventh form geography students, while appearing in more detail in Appendices 14 to 19, can be summarised as follows:

From a response population of 647 seventh form geography students:

7) 502 (77.59 per cent) indicated that they had studied fifth form geography

8) 582 (89.95 per cent) indicated that they had studied fifth form mathematics

9) 524 (80.98 per cent) indicated that they had studied sixth form geography
10) 463 (71.57 per cent) indicated that they had studied sixth form mathematics
11) 314 (48.53 per cent) indicated that they were studying seventh form mathematics
12) 207 (32 per cent) indicated that they intended studying university geography.

5.4.2 Implications for an Integrated Syllabus

The summarised results, items (1) to (12) above, provide information which can be used in two ways. First, there are the implications these findings have for an integrated syllabus in secondary school geography and, second, the extent to which geography students in the sixth and seventh forms have studied mathematics may well influence the types of numeracy skills which can be introduced to geography at these more advanced levels.

If an integrated syllabus in geography from form five to form seven involves the development of sequential skills, then it will be of advantage to a student entering sixth form geography to have successfully studied geography in the fifth form. From the survey data, it appears that at present nearly 87 per cent of all sixth form geography students in New Zealand secondary schools have studied fifth form geography. The remaining 13 per cent may be expected to have some difficulty in mastering the practical skills of the subject in the sixth form if these skills are so designed as to represent an extension of fifth form skills.

Nevertheless, this relatively high proportion of sixth form geography students who have already studied fifth form geography suggests that an integrated syllabus from fifth form through sixth form could be operated practicably with perhaps the recommendation rather than the prerequisite that students intending to study geography in the sixth form should first have been credited with a pass in fifth form geography.

The summary data shows that of the 647 seventh form geography students responding to the survey, 77.59 per cent had studied fifth form geography and 80.98 per cent sixth form geography. With approximately four in every five seventh form geographers having studied sixth form geography, the case is presented again for an integrated syllabus and for the sequential development of skills in geography from fifth form through to seventh form.

The tentative conclusion that can be drawn from this brief discussion is that around 80 per cent of all geography students who study at either the sixth or seventh form levels are in at least their second year of consecutive, progressive study in the subject. While this situation will foster the introduction of the proposed integrated syllabus, there remains the need to consider the 15 to 20 per cent of sixth and seventh form geographers who will be in their first year of study. This group cannot be expected to appreciate fully the integrated nature of the geographical study they undertake and there could well arise serious inadequacies in their background. Rather than overcome this problem by attempting to make the integrated course exclusive, it would seem more appropriate to ensure that within the programme of skills there is a provision for the reiteration of skills encountered at earlier stages in the syllabus. This would serve not only to introduce the first-year geography students to the subject skills but also to reinforce these same skills for second or third year students.

The second consideration which arises from the summary items is the incidence of the geography/mathematics subject combination. If it can be assumed that studying mathematics in the fifth and sixth forms will serve to sharpen and reinforce the facility for performing numeracy skills in geography, then geography students who are also studying mathematics will hold an advantage over geography students not taking mathematics. The data from the survey show that almost 70% per cent of geography students in the fifth form are also studying fifth form mathematics, and that over half (54.89 per cent) of all sixth form geographers take sixth form mathematics too. In the seventh form, geographers indicated that 71.57 per cent of their number had studied sixth form mathematics, while just under half (48.53 per cent) were currently studying seventh form mathematics.

It is not possible, however, to say to what extent a mathematics background is of benefit in studying geography. From observation, the present numeracy skills performed in sixth and seventh form geography have generally very little in common with the topics taught in sixth and seventh form mathematics. While this may suggest that the background in mathematics of geography students is not a major consideration in the formulation of an integrated syllabus, the incidence of almost a 55 per cent geography/mathematics subject combination in the sixth form and a 71 per cent geography/sixth form mathematics combination in the seventh form does suggest that perhaps some of the more interesting quantitative and statistical techniques — random sampling, rank correlation, testing for significance — could be developed in geography at senior levels, geography teachers willing and, more importantly, able.

5.4.3 Comments on the Numeracy Test

The design of the numeracy test was influenced by three considerations arising from the way in which the questionnaire survey was carried out. First, it was not possible to test the students' abilities at performing all the types of numeracy skills which were identified in the review of past School Certificate examination papers. To have done this would have required too lengthy a test. Second, some numeracy skills such as the drawing of graphs could not have been included in the test because of the added load this would have placed on the teacher who had already to administer the test to the class, collect the test results and make a summary of them before returning the questionnaire. Third, the interpretation of graphs and data matrices could not be successfully included in the test because of the time involved for each administrator in reproducing each of these exercises for each student.

The results of the numeracy test can be taken to reflect in general terms the ability of geography students to correctly complete a set of arbitrarily composed number problems. There was no provision made in the test for the steps involved in the solving of the problems to be shown, and so from a correct solution it is inferred that the method of derivation was sound. A correct solution to problems in the test implies, too, that the relevant mathematical concepts were successfully operationalised, that relationships between numbers were recognised, and that the arithmetic operations required were correctly performed.

The first number problem in the numeracy test will serve as an example:

Find the average of these numbers -

9, 16, 12, 8, 14, 11, 3, 12, 5

To have obtained the answer of 10, the student is presumed to have understood the mathematical concept of average (arithmetic mean) in dividing the sum of the numbers by nine. An error in finding the sum of the numbers will have resulted in an incorrect answer even though the concept of average may well have been understood to begin with. An incorrect answer, recorded in the results of the numeracy test, may therefore be due to either the inability to recognise the concept and to perform the necessary operations, or simply a 'chance' factor of error.

So that although 77 per cent of all fifth form geography students tested were able to obtain the correct answer to this first problem in the numeracy test, it cannot be concluded that the remaining 23 per cent of students failed solely on account of their inability to understand the concept of 'average' and to perform the necessary arithmetic operations. It is necessary to allow for the chance factor of error; the 'careless mistake'.

For Question 3 of the numeracy test –

> In 1965, the area of wheat planted in New Zealand was 94,022 hectares. If the area under wheat increases by 50 per cent between 1965 and 1975, what area of wheat will be planted in 1975?

– the main steps involved were:

(a) understanding the mathematical concept of 'increasing by 50 per cent'

(b) finding 50 per cent of 94,022

(c) adding 47,011 to 94,022 to obtain 141,033 hectares.

Although Table VII which summarises the results of the numeracy test shows that almost 62 per cent of fifth form geography students tested obtained the correct answer to this problem, again it cannot be claimed that the remaining 38 per cent were unable to work the problem. But in a test where only the final derived answer indicates a correct result, failures due to both error and lack of understanding cannot be separately determined.

TABLE VII Numeracy Test Results

	Fifth Form Geography Students (3823)		Sixth Form Geography Students (1739)		Seventh Form Geography Students (612)	
	Correct	%	Correct	%	Correct	%
1	2958	77.4	1509	86.8	560	91.2
2a	2702	70.7	1412	81.2	544	88.6
2b	2080	54.4	1151	66.2	474	77.2
3	2368	61.9	1309	75.3	528	86.0
4	1385	26.2	961	49.5	404	65.8
5	1613	42.2	1025	58.9	450	73.3
6	336	8.8	206	11.8	185	30.1

The summarised results of the numeracy test which are shown in Table VII above reveal a number of points of comparison that can be made abouth the success of each group of geography students in the test. Seventh form students, for example, score a greater proportion of correct responses for each question than do either sixth form or fifth form geography students.

It is interesting to compare the two parts of Question 2, viz.:

The formula for converting degrees Fahrenheit to degrees Celsius is -

$$^{o}C = (^{o}F - 32) \times 5/9$$

Convert a) $41^{o}F$ to Celsius
b) $70^{o}F$ to Celsius

Part (a) requires the substitution of $41^{o}F$ in the given formula to yield the operation: $9 \times 5/9$.

Part (b) requires the same operation except that the subtraction (70 − 32) gives a value of 38 which yields a more complex operation: 38 x $^5/9$. Since both parts of Question 2 involve the same substitution activity, and then similar arithmetic operations, the difference in frequency of correct responses for each part must be due to the more 'complex' arithmetic operations (where cancelling is not possible) in the second part. This difference, according to Table VII, is most marked at the fifth form level where although 70 per cent of the students tested obtained the correct answer for part (a), only 54 per cent were correct for part (b).

Questions 3 and 5 continued the same trend in the observed frequency increase in proportion of incorrect responses. Only one-quarter of all fifth form geography students tested were able to derive the correct answer to Question 4 which was expected, admittedly, to prove difficult because of the concept of proportion which had to be operationalised within the context of a conversion of units. The responses to Question 6 were not good; some teachers appended to the results' sheets they returned their disbelief that the students should have fared so badly, especially, as one in particular commented, when " they had done the same calculation only a few days ago in class."

In drawing conclusions from the results of the numeracy test, it has been necessary to bear in mind the rather restricted range of numeracy skills represented in the test, and also to appreciate that the results do not allow for any comparative study of say biology students in secondary schools to see if this group is any more 'mathematical' than the group of geography students.

What the numeracy test results do suggest is if skills involving mathematical concepts and number operations are introduced in the new integrated geography syllabus, then formal instruction in these skills will be necessary, and provision for this instruction in the geography teaching programme must be made.

6. A PROPOSED GUIDE FOR NUMERACY SKILLS IN SECONDARY SCHOOL GEOGRAPHY

6.1 Introduction

Increasingly, geographical information is being collected, measured, analysed and presented in numerical form. This has been considered largely the result of "external developments in technology ... [which] ... have suddenly opened up new possibilities for the large scale manipulation of data." (40)

At the elementary level of geographical education in schools, geographical data often appears in textbooks in the form of data matrices and graphs. While these are not geographical devices in themselves, the fact that they do present geographical information in a numerical form strongly suggests that their interpretation and use should be included in the geographer's set of practical skills. And so the case is simply put for the need to develop numeracy skills in secondary school geography education.

But a warning is to be sounded at this point. Geography has been regarded by some non-geographers as a 'filching' discipline; intent on borrowing non-geographical devices here and non-geographical techniques of data manipulation there, and all too often using these improperly, as much through ignorance as disregard. This has been particularly so when mathematical and statistical techniques have been employed by geographers. The rules set down for the operation of statistical techniques of data analysis in their own discipline are not infrequently to be found contravened in the hands of

(40) Ambrose, P.J., 1969, 15.

geographers. In struggling, as some would have it, to establish geography as a 'science' in its own right, geographers can ill-afford to appear so casual and careless in their use of non-geographical techniques of data collection and manipulation. Using a statistical technique to analyse or test some geographical problem does not make the technique then a geographical one; in its use the geographer must ensure that the specific rules set down in statistical procedure which govern its application are adhered to.

Geographical education in secondary schools should appear as no exception to this. If non-geographical techniques of data manipulation and presentation are to be included in the geography syllabus as skills required to be developed, then those charged with the preparation of the syllabus should exercise care in selecting these non-geographical techniques that are rule-bound from another discipline.

The non-geographical techniques of data manipulation and presentation referred to in this introduction are considered synonymous, for the most part, with the numeracy skills already defined in this work. These skills have been divided into three broad groups of number operations. The intention now is to examine examples drawn from each of these groups to identify the rules by which the numeracy skills are bound and to comment on the relevance of the skills to geographical education in New Zealand secondary schools.

6.2 An Examination of Numeracy Skills

Past examination papers in geography have been used as a guide to identifying the types of numeracy skills currently being tested in secondary school geography. While comments here will be confined generally to the numeracy skills tested in fifth form geography, it is necessary to appreciate that in the sixth form more emphasis is placed on the manipulation of quantitative data, and the student is expected to understand " techniques of condensing and presenting graphically some factual data ... [and to] ... make tentative generalisations from data, draw inferences and compare items of information ... "(41) In the seventh form there is no specification made in the syllabus of the types of numeracy skills required but instruction generally includes exercises involving the collection. measurement, analysis and presentation of geographical data, and the interpretation of maps, graphs and diagrams containing numerical data.

The first group of numeracy skills includes those number operations concerned with the recognition of relationships between numbers and their representations. The two main activities in this group are interpreting data matrices and graphs. The second group includes number operations centred on the organisation and distribution of numbers. These are represented by the construction of graphs and by activities such as the collection, measurement and analysis of numerical data which, although not formally tested, are nevertheless carried out during programmes of geographical field work, or in operational games, or in the application of research techniques to some particular problem. The third group is concerned with understanding mathematical concepts and performing arithmetic operations that may be explicit in themselves or implicit in a mathematical concept.

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(41) Jones, A., 1973, 9.

6.2.1 Interpreting Data Matrices

A data matrix is basically a table of figures which represents a collection of related geographical data presented in numerical form. The matrix is the most commonly used form of data presentation.

Successful interpretation of a data matrix depends on the student's ability to understand that each element in the matrix represents a specific relationship between two variables. For example, the element '81' in the set of climate statistics below has meaning only when it is related to both variables of rainfall and month of the year.

	Month of the Year											
	J	F	M	A	M	J	J	A	S	O	N	D
Temperature (oC)	16	16	15	13	11	9	8	9	10	12	13	15
Rainfall (mm)	79	84	81	97	124	117	137	117	97	108	86	89

The first two prerequisites of a data matrix are that there should be a logical relationship between each variable, and that the labelling of the variables should be precise and unambiguous. Once these have been satisfied, the task of interpretation is mainly one of identifying relationships between elements in the matrix. Interpretation is considerably aided by the ability both to recognise the relative magnitude of each element and to perceive single elements, or groups of elements, as a proportion of the sum of all elements in the matrix. Simple relationships between elements can be identified by inspection, but more complex ones may require one or more arithmetic operations to follow the inspection before the relationships are rendered explicit.

Using the data matrix of climate statistics given above, a number of relationships between the elements can be drawn which collectively serve to interpret the data contained in the matrix. Consider the following:

1) the month with the lowest mean rainfall is January
2) the mean rainfall total for April is the same as for September
3) the month with the coolest mean temperature is July.

Each of these statements has been drawn by inspection from the relationships that exist between the elements in the data matrix. Now follow some relationships that cannot be drawn by simple inspection:

4) the annual temperature range is 8 Celsius degrees
5) the mean total rainfall for March (81 mm) is three-quarters of the mean total rainfall for October (108 mm)
6) twenty-one per cent of the annual rainfall falls during the three months of summer
7) annual rainfall distribution is characterised by a winter maximum.

In these four examples, numbers 4 to 7, inspection has been followed by the manipulation of selected elements which has tended to render the implicit relationships in the data matrix explicit. So, in number 6, the total mean monthly rainfall for the three summer months can be expressed as a percentage of the annual rainfall total.

The operations involved in the interpretation of data matrices have been simplified into two groups of activity; identifying explicit relationships by inspection, and implicit relationships between elements by inspection and manipulation. Both are of value in geographical education while they relate specifically to geographical phenomena. For example, the annual temperature range recorded for a climate station is an important climatic variable because it may well influence say the length of the growing season or indicate say whether a station has a continental or coastal location. But it would be well to question the relevance of the relationships described in numbers 2 and 5 above since both have little geographical significance.

From this brief discussion, two main points emerge which should influence the selection of exercises for geography students involving the interpretation of data matrices. First, explicit relationships which are identified solely by inspection of the elements in the matrix should be of geographical relevance; that is, clearly of purpose to geographical study at a particular level. Second, implicit relationships are more difficult to identify because arithmetic operations – themselves not always explicit – must first be performed before identification can be made. Unless the relationship proves to be both of geographical relevance and clearly able to be understood by the student, this exercise of identification by inspection and manipulation is a numeracy skill not warranted in secondary school geography.

6.2.2 Interpreting Graphs

A graph is basically a diagrammatic representation of a set of related variables. It is essentially an extension of the data matrix and as such it can be a useful and acceptable tool for presenting geographical data. A graph, when properly constructed, indicates the trend of a relationship between two variables with more visible immediacy than does a data matrix.

Three forms of graph have been used in past geography examination papers. In addition to these - the line graph, the bar graph, and the pie graph - there exist modifications such as the compound bar graph, the age/sex pyramid, and the tri-graph.

As was found with the data matrix, inspection can yield explicit relationships between variables on a graph although, instead of appearing as numbers as in a data matrix, the elements of a graph are plotted as coordinates (for a line graph), or drawn as rectangular cells (for a bar graph), or drawn as sectors (pie graph). Generally, exercises set for geography students to derive implicit relationships from data sources are better applied to data matrices than to graphs because the elements in the matrix appear already in the precise form which readily lends itself to the performance of arithmetic operations.

The successful interpretation of relationships between variables which have been presented in graph form rests largely on the accurate construction of the graph. The purpose of a graph is to present data clearly and precisely; if a graph (like a map) is poorly constructed, it performs no useful function in geographical education.

6.2.3 Graph Construction

Graphs are generally constructed from numerical data organised in the form of a data matrix. The type of data matrix closely defines the type of graph which can be drawn. If the frequency distribution of variables in the data matrix is measured on a continuous scale - that is, frequency distribution against time or weight or magnitude - then the line graph (or frequency polygon) is the graph best suited to depict this continuous data, although the bar graph will also serve in some instances. If the frequency distribution in the data matrix is measured on a discontinuous scale, then the bar graph and the pie graph should be used to display this discrete data.

Tables A and B below are used to demonstrate how the choice of graph can be made.

Table A Percentage of Total Exports (1967)

Commodity	
meat	31
dairy products	31
wool	19
others	19
	100

Table B Percentage of Total Exports

Commodity	1967	1968	1969
meat	31	32	36
dairy products	31	23	21
wool	19	21	20
others	19	24	23
	100	100	100

Table A contains a frequency distribution (percentage of total exports) measured on a discrete scale (export commodity). This data matrix cannot be converted into a line graph because the frequency distribution is not measured on a continuous scale. In Table B, the frequency distribution is now plotted against a continuous scale - time - and so a line graph can be drawn for each of the four export commodities. The data from both Table A and Table B can be drawn on a bar graph with the horizontal axis in each example bearing the discrete variable, although each export commodity in Table B would support three cells; one for each year. A pie graph would be particularly suitable for presenting the data in Table A because the elements are expressed as percentages of the total exports, although three separate pie graphs would be required for Table B.

Not only does the structure of the data matrix tend to determine the type of graph which can best be drawn, but also the properties of the elements in the data matrix influence the size, shape and complexity of the resulting graph. There is greater ease to be had in constructing a graph from a data matrix which does not contain a large number of elements. Graph construction is made difficult and complex when the relative range in values between elements is great, and when the values of the elements are expressed to a greater accuracy than two significant figures. The two data matrices, Table C and D below, illustrate these determining factors.

Table C — Crop Yield ('000 kg)

	1965	1970	1975
sugar cane	35	48	60
tobacco	16	20	28

Table D — Population (millions)

	1950	1960	1970	1980
South Asia	474	576	737	937
South East Asia	168	219	293	394
China Area	588	654	746	849
Japan Area	120	141	164	190

Table C is defined as a 2 x 3 matrix and Table D as a 4 x 4 matrix. They therefore contain six and 16 elements respectively. The range of elements in Table C is from 0 to 60 ('000kg). This would require on a graph a vertical scale of six major increments, each divided – by measurement or estimation – into ten minor increments. The range of elements in Table D is from 0 to 937 (million). A vertical scale on this graph of ten major increments, each divided into ten minor increments, would still not transfer to the graph the degree of accuracy to which the elements in the data matrix are expressed. At best, the graph of the data in Table D would approximate to two significant figures the value of each element.

The operations involved in constructing a graph are determined in number and complexity by the size and properties of the data matrix. It is suggested that graph construction should not constitute an important practical exercise in secondary school geography. Graph construction is clearly a well-used device for presenting geographical data in a diagrammatic form and under supervision in the class room it can prove an informative and interesting exercise to be included in practical sessions, but there is not the need for students in a formal geography examination to labour through the construction of a graph using a data matrix that, if examples from past examination papers are to be any guide, is often ill-conceived.

6.2.4 Data Collection and Analysis

Field work exercises in geography usually involve the observation and measurement of geographical phenomena. Subsequent analysis of this data so collected provides the student with a practical awareness of the relationships between geographical varibles, and with material to support or refute hypotheses which may have been formulated earlier. For these exercises to be carried out with some success, it is necessary for students to become familiar with the systematic approach to data collection and analysis that any form of geographical research requires.

Techniques of data collection and analysis are, however, the domain of statistics, a field of science into which few geography teachers have been equipped to venture safely. This and the fact that undergraduate geography courses assume of the student no previous statistical experience may well be points in favour of keeping instruction, and therefore examination, in the statistical manipulation of data in secondary school geography at a basic level.

Rather than propose a set of statistical techniques which could be used for data collection and analysis in secondary school geography, and then provide a guide to their use, it might be more expedient here to suggest that geography departments develop their own sets of techniques in accordance with the nature and scope of field work available in their particular area, and with the ability of teachers to provide guidance in elementary statistical techniques and research procedure.

6.2.5 Mathematical Concepts and Arithmetic Operations

The mathematical concepts most commonly used in secondary school geography are those which tend to define relationships between the quantitative properties – expressed as measurements or scores – of geographical phenomena. In past geographical examination papers, the main concept tested has been that of proportion. This is a broad term which includes ratios, fractions and percentages. It has been shown that while these concepts may be learnt during formal mathematics instruction, the understanding of them in a non-mathematical context - such as during a geography lesson - may not necessarily be retained. These concepts of proportion must therefore be reinforced by the geography teacher so that each concept can be made operational and the arithmetic operations it contains performed.

In addition to being able to perform successfully the four basic arithmetic operations, the geography student must also become familiar with the physical constants of measurement, particularly during this present transition stage from imperial to metric measurement.

6.3 Conclusion

The main purpose of this work has been to show that it is necessary to identify and examine the types of numeracy skills which have been used in past geography examination papers, and which are therefore implicit in the existing geography syllabi, before proceeding generally to the formulation of an integrated syllabus for forms five to seven and, specifically, to the programming of the sequential development of skills within this syllabus.

It is suggested that the types of numeracy skills already tested in past geography examination papers are generally relevant to geographical education in New Zealand secondary schools, but since these skills are rule-bound from areas of mathematics and statistics - and are therefore essentially non-geographical techniques of data presentation and manipulation – it is important that geographers show a greater awareness of the procedure involved in applying each of these skills in geographical education. An examination of the three main groups of number operations into which numeracy skills have been distributed has attempted to articulate the rules by which each is bound. Modifications are suggested so that these skills, and related quantitative techniques, can be usefully applied in geography at the secondary school level.

The view is expressed that formal instruction in numeracy skills during geography lessons will be necessary because of the problems inherent for some students in the learning of mathematics and in the retention of this understanding later in non-mathematical situations, and also because of the range of mathematics experience accumulated by geography students.

Many parts of this study into numeracy in secondary school geography have been necessarily limited. The numeracy test itself is a source of dissatisfaction. The difficulties of finding reliable and valid measures of numeracy have become apparent. As it was, the administering of the numeracy test contained a number of potential sources of error which cannot be expected to have not affected some of the results obtained.

The School Certificate examination has been used as the major criterion in this study. Recognition must be made, however, of the present moves to introduce a system of internal assessment in the fifth form and so replace the external examination system. The development of the integrated geography syllabus, with curriculum development on both a national and a regional basis, is an attempt to provide a structure for geography teaching once the School Certificate framework has been removed. Even though the set of numeracy skills which have been examined was drawn from past School Certificate examination papers, the proposal for its inclusion in the new syllabus is made with the belief that the appropriateness of these skills is independent of their external examination context.

There is much room for further study and research into numeracy skills in geography. The transfer of learning from mathematics to geography is in need of investigation. At present it is not clear whether geography students who also study mathematics are more able to perform numeracy exercises in geography simply because they are in daily formal contact with abstract structures in their mathematics lessons, or whether they are more able because the less 'bright' students generally do not continue with mathematics after the fourth form, or whether in fact they are demonstrably more able anyway than geography students not taking mathematics. It is likely that there exists an optimal sequence of development in the learning of numeracy skills. If this could be established, then the conceptual elements of numeracy would be acquired more easily and effectively.

There are two main problems which may confront the inclusion of the proposed set of numeracy skills in the new geography syllabus. The first relates to the ability of geography teachers to impart these skills confidently and effectively. There may well be a place here for the establishment of an in-service course for geography teachers. Guide-lines in the teaching of numeracy skills in geography could also be made available from geography resource centres. The second is the time that can be devoted during lessons to learning and practising numeracy skills in a new syllabus whose content may well remain quite considerable. This could be overcome, however, by ensuring the full integration of numeracy skills within the new geography syllabus.

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APPENDIX 1

Geography Department
Massey University
Palmerston North

August 2, 1974

Dear Head Teacher of Geography

You may be aware that Geography has lately emerged from what some geographers have called a 'quantitative revolution' - essentially the introduction of numerical techniques so that scientific methods of research and data evaluation can be made use of in the study of Geography.

This move towards a greater numerical content in Geography requires that the student be not only literate in his subject but also that he have some ability at working with numbers.

I am attempting in my work to assess the present state of numeracy among geography students in secondary schools. My research is based largely on survey work, but rather than survey all 392 secondary schools in New Zealand, I have taken a random sample of 150 of these schools. Because your school appears in this random sample, I would be most grateful if you could, at your earliest convenience, complete the included question-naire and return it to me in the enclosed stamped envelope.

Yours sincerely

Russell J. Stewart.

NOTE: 1) please return the blue sheets of paper only

2) please return the information requested by WEDNESDAY, AUGUST 14.

APPENDIX 2

Second Page of Questionnaire

PART I

I wish to determine here the number of pupils presently taking geography at your school, and what geography and mathematics they have studied.

Perhaps if each of your geography teachers provides you with the counts from his/her class(es), you could then fill in the information as set out below.

FIFTH FORM GEOGRAPHY

	No. in class	No. studying or have studied 5th form Maths	No. intending to study 6th form Geography	No. intending to study 6th form Maths
Class A	____	____	____	____
Class B	____	____	____	____
Class C	____	____	____	____
Class I	____	____	____	____
Totals	____	____	____	____

SIXTH FORM GEOGRAPHY

	No. in Class	Number having studied 5th form Geography	Number having studied 5th form Maths	Number studying 6th form Maths	Number intending to study 7th form Geography
Class A	____	____	____	____	____
Class B	____	____	____	____	____
Class C	____	____	____	____	____
Class D	____	____	____	____	____
Class E	____	____	____	____	____
Totals	____	____	____	____	____

Continued/

APPENDIX 2
(continued)

SEVENTH FORM GEOGRAPHY

	Class A	Class B	Class C	Totals
No. in class	____	____	____	____
Number having studied:				
5th form Geography	____	____	____	____
5th form Maths	____	____	____	____
6th form Geography	____	____	____	____
6th form Maths	____	____	____	____
No. presently studying 7th form Maths	____	____	____	____
No. intending to take Geography at University	____	____	____	____

+ +

APPENDIX 3

Third Page of Questionnaire

PART II

Numeracy can be defined simply as the ability to handle numbers.

In order to assess the state of numeracy among geography pupils, I have compiled SIX questions. I have outlined below the method by which I would appreciate your administering these questions.

a) at FIFTH FORM level

i) please administer to TWO fifth form classes (preferably not streamed), or so as to cover a minimum of 30 pupils.

b) at SIXTH FORM level

i) please administer to ONE sixth form class, or so as to cover a minimum of 12-15 pupils.

c) at Seventh Form level

i) please administer to ALL seventh form pupils.

I suggest that the teacher concerned with each selected class prints the questions supplied (see QUESTION SHEET) on the blackboard and allows the class sufficient time (say 15 minutes) to complete the problems.

Perhaps the pupils could then be instructed to 'change papers with their neighbours', and then mark the questions at the direction of the teacher according to the ANSWER SHEET PROVIDED.

APPENDIX 4

NUMERACY TEST

Please print the following questions on the blackboard:

(1) Find the average of these numbers -

9, 16, 12, 8, 14, 11, 3, 12, 5

(2) The formula for converting degrees Fahrenheit to degrees Celsius is -

$$^{o}C = (^{o}F - 32) \times {}^{5}/_{9}$$

Convert: a) $41^{o}F$ to Celsius
b) $70^{o}F$ to Celsius

(3) In 1965, the area of wheat planted in New Zealand was 94,022 hectares. If the area under wheat increases by 50 per cent between 1965 and 1975, what area of wheat will be planted in 1975?

(4) If one kilogram = 2.2 lbs, express 2 stones 5 pounds in KILOGRAMS.

(5) The ratio of the numbers of dairy cattle to beef cattle in a certain farming district is given as 5 : 2. If there are 360 beef cattle in this district, how many dairy cattle are there?

(6) Population of Taupo Borough (in '000s)

	1966	1972
Taupo	8.5	11.0

Calculate the percentage increase in Taupo's population from 1966 to 1972.

-+-

ANSWERS:

(1) 10 (2) a) $5^{o}C$ b) $21.1^{o}C$ ($21^{o}C$)

(3) 141,033 hectares (4) 15 kg

(5) 900 dairy cattle

(6) 29.4 per cent (allow 29 per cent)

APPENDIX 5

RESULT SHEET

Number of students tested at each level:

FIFTH FORM ___ SIXTH FORM ___ SEVENTH FORM ___

	5th form (1)	5th form (2)	6th form (1)	7th form (1)
QUESTION ONE Number with correct answer (ie 10)	___	___	___	___
QUESTION TWO a) Number with correct answer (ie 5°C	___	___	___	___
NUMBER TWO b) Number with correct answer (ie 21.1°C)	___	___	___	___
NUMBER THREE Number with correct answer (ie 141,033 h)	___	___	___	___
QUESTION FOUR Number with correct answer (ie 15kg)	___	___	___	___
QUESTION FIVE Number with correct answer (ie 900)	___	___	___	___
QUESTION SIX Number with correct answer (ie 29%)	___	___	___	___

APPENDIX 6

REMINDER NOTE

Massey University
Palmerston North

August 20, 1974

Dear Head Geography Teacher

You might have received from me just over two weeks ago a questionnaire, and covering note, in which I requested information relating to the numeracy levels of your geography students. I also enclosed a stamped self-addressed envelope in which the return was to have been made.

If you have been able to complete this questionnaire, I should be grateful if you could return it to me as soon as possible.

If you have mislaid the questionnaire, I would be pleased to issue you with a new one, at notice from you, to be administered in the first week of the third term.

If you have already returned the completed questionnaire, please disregard this reminder note, and thank you for your participation in my survey.

Yours sincerely

Russell J. Stewart

Geography Department.

APPENDIX 7

Chi-Square Test

Frequency Distribution of Schools

	Observed (O)	Expected (E)	$\frac{(O - E)^2}{E}$
Coeducational	46	52	0.69
Private Girls	17	14	0.64
Private Boys	10	11	0.09
State Girls	10	8	0.50
State Boys	9	7	0.57
	92	92	2.49

$$\chi^2 = 2.49 \text{ (d.f. = 4)}$$

APPENDIX 8

Number of Fifth Form Geography Students intending to study Sixth Form Geography

	Numbers		
	5th Form Geography	6th Form Geography	$\frac{6G}{5G}$ %
Coeducational	3840	1779	46.32
Private Girls	654	367	56.12
Private Boys	680	450	66.18
State Girls	1499	661	44.10
State Boys	798	484	60.65
Totals	7471	3741	50.07

APPENDIX 9

Numbers of Fifth Form Geography Students intending to study Sixth Form Mathematics

	Numbers		
	5th Form Geography	Sixth Form Maths	$\frac{6M}{5G}$ %
Coeducational	3840	1312	34.50
Private Girls	654	211	32.26
Private Boys	680	420	61.76
State Girls	1499	332	22.15
State Boys	798	515	64.54
Totals	7471	2790	37.35

APPENDIX 10

Numbers of Sixth Form Geography Students who have studied Fifth Form Geography

	Numbers 6th form Geography	Numbers 5th form Geography	$\frac{5G}{6G}$ %
Coeducational	1533	1333	86.95
Private Girls	268	201	75.00
Private Boys	303	281	92.74
State Girls	650	568	87.38
State Boys	454	405	89.21
Totals	3208	2788	86.92

APPENDIX 11

Numbers of Sixth Form Geography Students who have studied Fifth Form Mathematics

	Numbers 6th form Geography	Numbers 5th form Maths	$\frac{5M}{6G}$ %
Coeducational	1533	1199	78.21
Private Girls	268	144	53.73
Private Boys	303	267	88.12
State Girls	650	432	66.46
State Boys	454	447	98.46
Totals	3208	2489	77.61

APPENDIX 12

Numbers of Sixth Form Geography Students who are studying Sixth Form Mathematics

	Numbers 6th Form Geography	6th Form Maths	6M / 6G %
Coeducational	1533	788	51.40
Private Girls	268	88	32.84
Private Boys	303	241	79.54
State Girls	650	292	44.92
State Boys	454	352	77.53
Totals	3208	1761	54.89

APPENDIX 13

Numbers of Sixth Form Geography Students intending to study Seventh Form Geography

	Numbers 6th From Geography	7th Form Geography	78 / 6G %
Coeducational	1533	336	21.92
Private Girls	268	46	17.26
Private Boys	303	165	54.46
State Girls	650	124	19.08
State Boys	454	216	47.58
Totals	3208	887	27.65

APPENDIX 14

Numbers of Seventh Form Geography Students who have studied Fifth Form Geography

	Numbers		
	7th Form Geography	5th Form Geography	5G/7G %
Coeducational	236	181	76.70
Private Girls	40	31	77.50
Private Boys	101	72	71.29
State Girls	134	99	73.88
State Boys	147	119	80.95
Totals	647	502	77.59

APPENDIX 15

Numbers of Seventh Form Geography Students who have studied Fifth Form Maths

	Numbers		
	7th Form Geography	5th Form Maths	5M/7G %
Coeducational	236	194	82.20
Private Girls	40	35	87.50
Private Boys	101	95	94.06
State Girls	134	112	83.58
State Boys	147	146	99.32
Totals	647	582	89.95

APPENDIX 16

Numbers of Seventh Form Geography Students who have studied Sixth Form Geography

	Numbers: 7th form Geography	Numbers: 6th form Geography	$\frac{6G}{7G}$ %
Coeducational	236	180	76.27
Private Girls	40	34	85.00
Private Boys	101	82	81.19
State Girls	134	122	91.04
State Boys	147	106	72.11
Totals	647	524	80.98

APPENDIX 17

Numbers of Seventh Form Geography Students who have studied Sixth Form Mathematics

	Numbers: 7th form Geography	Numbers: 6th form Maths	$\frac{6M}{7G}$ %
Coeducational	236	159	67.37
Private Girls	40	25	62.50
Private Boys	101	71	75.27
State Girls	134	86	64.18
State Boys	147	122	82.99
Totals	647	463	71.57

APPENDIX 18

Numbers of Seventh Form Geography Students who are studying Seventh Form Mathematics

	Numbers		
	7th form Geography	7th form Maths	7M/7G %
Coeducational	236	117	49.57
Private Girls	40	17	42.90
Private Boys	101	59	58.42
State Girls	134	46	34.33
State Boys	147	75	51.02
Totals	647	314	48.53

APPENDIX 19

Numbers of Seventh Form Geography Students intending to study University Geography

	Numbers		
	7th form Geography	University Geography	UG/7G %
Coeducational	236	75	31.77
Private Girls	40	15	37.50
Private Boys	101	29	28.71
State Girls	134	36	26.87
State Boys	147	52	35.37
Totals	647	207	32.00

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