A Study of Students' Performance in Supplementary Mathematics and Various Branches of Chemistry

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AN INDEPENDENT STUDY SUBMITTED IN PARTIAL FULFILLMENTS OF THE REQUIREEMETS FOR THE AWARD OF MASTER OF EDUCATION IN SCIENCE EDUCATION

FACULTY OF EDUCATION

AHMADU BELLO UNIVERSITY

ZARIA

1984

APPROVAL SHEET

The undersigned certify that they have read and recommend to the Faculty Board of Education for acceptance, an independent study entitled "A study of students' performance in Supplementary Mathematics and various branches of chemistry" submitted by MRS. V.I. EZENWA in partial fulfilment of the requirements for the degree of Master of Education in Science Education.

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ACKNOWLEDGEMENT

My very sincere thanks go to Dr. D.P. Brown, my supervisor, whose continuous assistance and direction were invaluable to the success of this study. My thanks also go to the staff of Chemistry Department, Advanced Teachers' College Zaria, whose students were the subjects of this study, for their co-operation.

Special thanks go to the Director, Institute of Education, for the approval given to complete this programme. I am also indebted to my family whose continued support led me through the programme.

ABSTRACT

Chemistry and Mathematics are the basis of some of the most revolutional recent developments in our society and in the everyday lives of young people.

This study was carried out with 32 Part III N.C.E. chemistry major students of A.T.C. Zaria to find outs

(i) a way of improving the quality of their understanding of chemical concepts.

(ii) the mathematical skills and concepts required by students taking chemistry at N.C.E, level,

(iii) the type of mathematics required for different areas of chemistry,

(iv) how integration could be achieved between the two courses.

(v) the problems of providing mathematical training to N,C,E, chemistry students and developing materials for their own situation.

The need for the three basic areas of chemistry with mathematics to be arranged and taught in such a way that each depends to a large extent to the science that proceed it.

The examination scores of students in supplementary mathematics and the three different areas of chemistry for each of the three years were collected. In addition tc obtaining the scores some questionnaires wore developed for both the chemistry lecturers and Part III major students to got their reactions on

the effectiveness of supplementary mathematics to the understanding

of chemical concepts.

The study attempted to answer these questions

(i) Is there a justification for the inclusion of supplementary mathematics into the chemistry syllabus?

(ii) What mathematical concepts do staff identify with the different aspects of the course?

(iii) What mathematical concepts do students need most for the study of chemistry?

Supplementary mathematics scores in Parts I and II were correlated with scores in the various areas of chemistry for different sessions using Pearsons Product Moment Correlation.

The overall performance was also regressed on the various areas of Part III chemistry results. The data was analysed at the 0,05 level of significance.

There was high correlation between supplementary mathematics I and II scores with all the branches of chemistry in Parts I_s II, III sessional and final scores. The exception was physical chemistry which did not correlate v/ith any item.

The trend held was organic Physical Inorganic chemistry

An interesting point indicated was the high correlation between W.A.S.G. mathematics and only

physical chemistry.

The following conclusions were drawn from the study

(i) Students with high supplementary mathematics scores will in all probability do well in different areas of chemistry.

W.A.S.C. mathematics is fundamental and forms a basis for

supplementary mathematics and is not in .any way a substitute.

(ii) Overall performance of students could be predicted from the Part III results.

(iii) Supplementary mathematics enhances the study of chemistry,

(iv) Students who have completed the supplementary mathematics programme may enter for B.ED or B.Sc. programme without any fear of an inadequate mathematics background for the researcher has identified the essential mathematical skills which chemistry students need in order to appreciate the qualitative and quantitative aspect of their chosen science,

(v) A deep mathematicalknowledge of mathematics is unnecessary

for students at thestudied level, but only, numerical methods, simple algebra, statistics and elementary calculus, could be used to handle the kind of problems emerging in N.C.E. chemistry.

(vii) The effective implementation of the revised supplementary mathematics programme and recommended suggestion will result in students better performance, understanding and the removal of most of students problems.

Some recommendations were made on how to stimulate effectives

(i) use of the language of mathematics.

(ii) applications of the study to other colleges and science areas.

(iii) applications of mathematical concepts to be more relevant to students interest, background and discipline.

(iv) resolution of problems encountered in teaching., mathematics to chemistry students.

(v) co-operation between the departments so as to improve teaching methods.

It is the researcher's opinion that the revised supplementary mathematics is very vital to the study of chemistry. The limitations of this study suggests some areas for further research,

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Chapter 1

THE PROBLEM

1.1 Introduction

Classroom teachers are key agents to the effective use of billions of naira expended every year on education. The society of which we are part is the direct result of the interaction of science and people. The culture of our time includes science, and the political decisions which are taken by people must be made by a scientifically literate population.

Modern science is responsible for the prosperity and the power of a nation. It is necessary therefore to find ways to enable students to live at the height of their time for science is part of their life. Science content gives students a lever for manipulating and understanding the environment. It also produces students opportunities to use their skills to the degree that the teacher provides the opportunity. The faster the advances in science knowledge the greater is the need for wisdom and skill in deciding what to teach and how to present it. The burden of responsibility falls upon the teacher for understanding the different ways in which students learn and to arrange instruction accordingly.

Chemistry is a branch of the sciences which deals with substances and their properties. At the Nigeria Certificate of Education (N.C.E.) level, the chemistry can be subdivided

into four main parts; Organic, Inorganic, Physical and Analytical (Practical); but because the practical aspect involves all the other three, the study of chemistry is traditionally limited to the three other areas.

Mathematics is a deductive science while chemistry is essentially an inductive science. Many students struggle against the handicap of an inadequate preparation in mathematics, spending more effort in avoiding it than is needed in learning it. Mathematics is used as a "spade" to unearthen" the hidden treasures of chemical behaviour remembering always that a chemical reaction will take place because of the chemical nature of the reacting substances and not because of any picturesque mathematical concepts that may go with it, (Mathew and Seeds, 1970).

To understand chemical reaction one must employ quantitative terms and suitable mathematical equipment as an aid to clarify one's own thinking and a means for effective communication of one's observations. Daniel (1920) once said . . . "Science is best expressed when it is mathematically expressed" - therefore the ability to state a problem in mathematical language is invaluable.

The basic problems encountered by chemistry teachers with their students in these areas demanding mathematical ability appear to be:

(i) a lack of transfer of mathematical skills learned in a mathematics lesson to the chemistry lesson.

(ii) The feeling on the part of the chemistry teachers that computational skills are lacking in today's students.

(iii) the need to develop a mathematics syllabus to be taught in line with chemical concepts, thus the cry "why have not they done decimals, prop rtions etc".

Mathematics courses for chemistry students usually aim at providing a level of competence in basic analysis, calculus and providing an introduction to statistics. The principal objective is to increase awareness and practical experience so as to develop the student's ability to solve unfamiliar problems. This is precisely why the problems and examples should be rooted firmly in chemistry since their relevance to the students main subject gives him the interest and motivation essential to developing problem solving skill.

> "Paul (1950) sees science as . . . "a body of knowledge and hypothesis concerning the material world. It should be the general aim of science instruction to make the above definition clear to students and to give them an appreciation of the hierachy of nature and its reflection in the hierachy of science. He suggested that science instruction in general education should be characterised by broad integration of elements, the comparison of science with other modes of thought, the comparison and contrast of the individual science with each other, the relation of science with its history and of science and problem of human society."

Kolb (1976) indicated that learning science requires the learner to have certain abilities in using mathematics, for example, an integral part of the process of science are fundamental element to mathematics such as measurement, quantitative description, manipulative operations, communication, and determination of relationships from observed data. This is in line with the aim of chemistry education in teacher training colleges which aims to fulfil demand made by future science and technology.

Chemistry uses mathematics skills in many ways, for example;

(i) To reveal relationships between variables for example, Volume, Pressure and Temperature as in Boyles/Charles law etc.

(ii) To extrapolate data,

(iii) To present laws and theories economically mathematical notations are used.

(iv) The process approach uses mathematics for one can not measure, organise, summarise data with graph without mathematical background.

Therefore mathematics is essential to the study of chemistry. This does not mean that mathematics is all that is needed for the study of chemistry but that it is essential for effective understanding and appreciation of chemistry as well as other science. Therefore it is good to determine the topics in supplementary mathematics which are required in the various

areas of NCE chemistry in order to develop a programme that will aid transfer and appreciation. In this respect Advanced Teachers College, (A.T.C.) Zaria is used for it is the only A.T.C. that offers supplementary mathematics programme for its chemistry students in addition to other subject combinations offered.

1.2 Background of the Study

Within the last decade the A.T.C. Zaria has gone through changes which on the one hand have imposed considerable demand upon those responsible for developing courses, but which on the other hand have provided a tremendous stimulus for curriculum development and experimentation. In the 1960's, the college was small and was mainly concerned with the training of teachers leading to the N.C.E. Certificate. Of the total intake each year, students offering chemistry or Physics are the smallest percentage. This is because the college finds it considerably difficult in recruiting as many students of the right academic calibre as they would wish.

One small factor in the growth of the College but a large one in terms of the teaching function was the introduction of the course leading to the degree of Bachelor of Education, (B.ED). The aim of the programme is to enable intending teachers to experience a continuing development of intellectual interest

and to become relatively proficient in at least one academic disciple.

At the N.C.E. level, students follow two academic subjects as part of their education. Subjects chosen are usually one that has been offered at West African School Certificate, (W.A.S.C.) or Teachers Grade II with preliminary science study. About one third of the students time is spent on the main subject which runs through all three years. In addition to the main subject is a **minor** subject. The minimum qualification for entry is two credits though some enter with much better qualification. For those offering chemistry as their main subject, the following combinations are possible: Chemistry/Mathematics; Chemistry/Physics; Chemistry Biology.

The students offering mathematics as a second subject are usually much stronger in mathematics than those offering biology as a second subject. This difference in mathematical ability, of students offering chemistry as a main subject, also creates problems for the teacher. Irrespective of a student's background, it was decided that all students should take supplementary mathematics as a firm grasp of the concepts of mathematics is considered essential for the successful teaching of chemistry.

The introduction of supplementary mathematics for the students offering chemistry is to build up competence in

the quantitative areas of the subject as well as providing the students with a basis for which to building the work they do with their students.

The majority of students are trained to teach in secondary schools where they will be required to spend up to an hour per day on chemistry. Some schools on hearing that one did science, will, straight away put the teacher in a mathematics class. Right now in the A.T.C.'s there is a need to study mathematics with some interest, understanding and satisfaction as a way of improving the quality of our understanding of chemical concepts, their mode of operation and to achieve higher standard of reliability in reaching deductive conclusions.

1.3 Study Rationale

In recent years, there have been attempts to modify syllabuses and training programmes to reflect modern academic and Industrial needs which require the professional to become familiar with related disciplines and techniques. Right now, Nigeria is in need for manpower especially under science and technology with a view of using local materials for industries and schools to save our sagging economy. This has resulted in science being emphasised more, in different levels of our educational system and has led to the development of new Colleges of Science and Technology at both Federal and State

level to fulfil the manpower vaccum. The quality of the personnel to fill the vaccum depends on efforts of our students teachers who turn out to be the teachers of our future scientists.

To get the quality required in our future leaders and scientists, our student teachers must be trained well enough to understand and appreciate the situation, and what they are learning, especially, the reason for study chemistry and the emphasis on supplementary mathematics by showing the correlation between them while teaching.

Braumfield (1972) once said . . . "the modern world is permeated by the consequences of science and technology, Mathematics lies at the basis of science and technology, hence every citizen must know some mathematics if he is to cope with the world in which he lives." It is evident in our National Policy on Education (1983) that schools should:

(i) equip students to live effectively in the modern age of science and technology.

(ii) develop the intellectual capacity of individuals to understand and appreciate their environment.

(iii) raise a generation of people who can think for themselves.

These objectives are in line with objectives of science teaching and reflect some attributes of the scientist. The nation is strongly of the opinion that if these objectives are taken care of while teaching, students will enjoy learning and there will be fewer drop outs who turn out to bo a liability in the society.

In most science professions, problems concerning chemistry occur repeatedly, for instance, whether engineering, doctors, etc, one needs to be familiar with many chemicals, their properties and behaviour under varying conditions so as to give some intelligent interpretation of the situation*

Solutions are often expressed mathematically. The agricultural and soil specialists need to understand the complex make-up of the soils and their influence on growing plants, all were related to chemistry. Chemistry can therefore be seen to touph on nearly every aspect of life and discipline in just the same way as mathematics.

Also in almost all institutions of higher learning in the country, the following combinations of subjects among others are available, Chemistry/Mathemati cs/Physics/Iliology/ Agriculture, It is evident that chemistry is extremely important in the study of other sciences as is mathematics, hcnee the researchers decision to integrate the two, in addition to the fact that it is the researchers area of teaching and. interest. The researcher is of the opinion that existing syllabuses and, teaching methods are still not good, enough for a majority of students, and that it is vital that the supplementary mathematics course concentrates on an agreed core syllabus, avoiding superficiality and breadth,

%

Modern science is the systematic examination of natural phenomena. It is in the nature of science that its problems first become divided into parts for the purpose of more manageable research, Howevor as research progresses the need arises to relate the parts* Therefore the three basic areas in chemistry (Inorganic, Organic and

Physical) with mathematics can be arranged mid taught in such a way that each depends to a large extent to the science that proceeds it. The mathematics in chemistry has been widely accepted that its effectiveness in achieving educational objective has hardly been questioned. (Redlich,, 1972)

literature reveals that little research has been carried out to study the various area of chemistry in relation to its relevant mathematics background as one of the factors motivating students and influencing their performance.. The investigator hopes to reduce the tendency for students to study mathematics blindly by making it more relevant. What has also impressed this investigator is how little attention has been directed towards the effective teaching of mathematics to our chemistry students at the IJ.C.E, level. Perhaps one of the reasons for
this might be that chemistry department have not clearly defined the goals of mathematics for chemistry students.

Otto (1972) is of the opinion that establishing a relationship between any science and mathematics is not easy except by dividing it into parts and critically lookin'* at it* With this view, the researcher feels that the various areas of chemistry can' be correlated with supplementary mathematics to find out areas needing more mathematics and this will aid in the development of appropriate instruction for the chemistry student teachers*

1*4 Sta'bemejit jof the Problem

The chemistry and mathematics taught at IT*C*E* level up till now is "stay at your own corner and I stay at mine".
This has resulted in students shying away from Mathematics/ Chemistry, Those who study them, study them blindly. They see them as different subjects without any relationship. We know that there.'is a gap between Chemistry/Mathematics course

developed and there is need to bridge it* Therefore it is the aim of the study to:

(i) look into the mathematical requirements of those taking chemistry courses at NCE level,

(ii) find the type, and iaal.ee suggestions as to the range *and* depth of mathematics required by these students for the different areas of chemistry.

(iii) exploit the strength of mathematics and adopt its method and language in order to "build on foundation for tackling chemical problem,

(iv) to 3how how integration can be achieved between mathematics and other subjects,

(v) to report on problems of providing mathematical training for chemistry students,

(vi) to produce materials guide or outline which would enable mathomatic and, chemistry courses at A.T.C. to bo matually helpful by bringing out relationship between mathematic and chemistry.

(vii) to help students eee the relevance of mathematics to chemistry.

It is therefore the objective of this study to look into the mathematical requirement of those taking chemistry course at NCE level, and to make recommendation for improving this provision by suggesting range, depth and type of mathematics required by these students and encourage some activities which will aid the co-operation of the departments involved.

My observations and thoughts regarding the training of chemistry teachers has led me to look into the problem faced by these students and to find a solution to it. Many students struggle against the handicap of an inadequate preparation in mathematics, From discussions it was found that these experiences were common to other higher institutions.

Mathematics is useful but the science teachers often have not effectively used this and students see the course as very difficult. Often mathematics is taught by different people without relating it to chemistry and some time

students go without any lecturer in supplementary mathematics and hence suffer. Those and other observed problems are to be looked in t o,

An examination of the course content shows interaction of chemistry and mathematics. Therefore there is need to analyse *the* syllabus to identify mathematical knowledge required for effective learning. Curriculum is not just development of ideas but selecting appropriate materials and making it work. Education influences people, their beliefs and attitudes, therefore there is a need for chemistry to be taught as a human activity not just as an abstract discipline, therefore to teach chemistry effectively there is a need to develop, and approach it in a small scale by making innovations that can match the aspirations and needs of chemistry students especially at A.T.C, Zaria.

The study will attempt to answer these questions;

0, Is there a justification for the inclusion of supplementary mathematics into the chemistry syllabus?

And if so this will be indicated by a significant correlation between supplementary mathematics scores in the year I and II, and examination scores in

(a) Physical chemistry Year I

(b) Inorganic chemistry Year I

(c) Organic chemistry Year I (cl) Physical chemistry Year II

(e) Inorganic chemistry Year II

(f) Organic chemistry Year II

(g) Physical chemistry Year III

(h) Inorganic chemistry Year III

(i) Organic chemistry Year III

(;j) Physical chemistry N. C, E. final Year III (k) Inorganic chemistry iT.C.E, final Year III (1) Organic chemistry 1T.C.E. final Year III

1, What mathematical concepts do staff identify v/ith the different aspects of the courses?

3. What mathematical concepts do students say they need most for their study of chemistry?

1*5 Assuctions

For the purpose of this study the investigator will make the following assumptions;

(i) The college has qualified and capable teachers and they have *covercd* the required syllabus in both chemistry and supplementary mathematics.

(ii) The question paper and marking schemes were reliable mid valid.

(iii) The students did the examination without any .fraudulent acts such as being involved in exarain at i on 1 o ak ag e,

(iv) The A.T.C. Zaria is a long-standing institution with many permanent staff so that teacher movement will not affect the department or the students.

1.6 Significance of Study

An understaning of relevant mathematical concepts will greatly help in understanding chemistry.

The findings from this study may be of significance in a number of ways. The findings may:

(i) help to identify which areas of chemistry need more mathematics than, others and suggestions can be given on how to improve the existing situation and arouse interest.

(ii) help in predicting the extent to which a student will perform in the area of chemistry knowing his mathematical ability.

(iii) help students who do independent study to build up the areas they are deficient in.

(iv) be a tool for guidance and counselling of students.

(v) be an inspiration for other teachers in other sciouco areas to work out subjects relevant to tlicir own areas and seek co-operation,

(vi) Stimulate further research to make chcmi^treeducation more meaningful and interesting to students.

The present study recognises that the investigation will in addition to saving time and increasing performance in the oognitive domain, (that is subject matter performance), the , integrated programme have desirable outcome in the effective domain, Supporting this is the recent discovery of Kuhn (1973) and Johnson (1972) who suggest that additional subject matter integrated into a life science courses may promote not only subject matter learning but objectives in the effective domain such as an appreciation, understanding and enjoyment of science as well#

If students understand arid appreciate they can effectively train other students especially as they are responsible for teaching students in secondary schools who later become candidates for University admission#

1*7 Scope

The scope of the study is however limited to 'the establishment of the relationship, if any, between Mathematics and Chemistry, using supplementary mathematics grades as the criterion variable# The investigator wishes to find out whether there is significant relationship between supplementary mathematics taught in Part I or Part II and tb.o

various areas of chemistry/final results of students. Prom the findings suggestions can be made on ways to improve the teaching of chemistry to make it effective.

The study will start by looking at the grades of chemistry students in the various areas and then relating this to their supplementary mathematics grades with a view of finding areas that correlate more than others, A questionnaire is designed too, to gather the opinions of students as regards the problems encountered in both areas and what they expect of the course,

A teacher questionnaire is designed too for teachers to list out the mathematical requirements of the chemistry areas they teach and rank them in order of importance. They will also comment on the performance of students with respect to mathematics and areas students find problems in. With this information the researcher hopes to develop s. materials that will make for effective teaching and learning.

,8 Limitations

The study was limited to students of A.T.C, Zaria and to ncmistry and supplementary mathematics for the .following \ •cason:

only A.T.C. Zaria an of now offers supplementary mathematics to its chemistry major students as a means of improving students interest and performance. Other A.T.C,'3 or Colleges of Education do not offer this programme.

The study is limited in the number of sample used for the study because it is always difficult to get students of the right calibre as most go through teachers college without any background in chemistry,

1,9 Definition of Terms

\7.A_._S._C. means West African School Certificate, a cetificate obtained after a successful completion of a 5 year programme now after a 6 years programme.

Grade. .II: Is a certificate awarded to students who have gone through a teacher training college either directly from primary six or after school certificate,

H^C.E. means Nigeria Certificate of Education, similar to College of Education which offers

a 3 years post secondary school programme.

AjJT.C, is Advanced Teachers College which offers a throe year programme leading to *ii*, 0.E!. iL*A»JLs£* ^'he 'Joint Admission and Matriculation Board, a board that organises tho admission to post secondary institutions#

<fcSIP is a computer package system standing for ''Statistical Inquiry Package". It is an interactive system which does some but not all of the things which S.P.S.S. does. It does in a less cumbersome fashion. For the some data, Asip and S.P.S.3. will give the same results, although they will bo arranged somewhat differently.

3. P,Sr.S, it stands for "Statistical Package for the Social Sciences"# It is a system of computer programmes for data manipulation and statistical analysis, l'ho use is not limited, to social sciences alone, it is also of groat value to other disciplines involving statistical survey.

I. Q. stands for "Intelligent Quotient" it measures ability of individuals to reasons. Anyone with I.Q. loss than 50 is regarded as subnormal. Higher I.Q. indicate some degree of reasoning.

REVIEW OF LITERATURE

2.1 Introduction to Literature

In rcccnt years, groat concern has "been expressed by science teachers about the apparent inability of their students to handle the simple raatlicratical manipulations required in chemistry. A large proportion of teachers blame students for spending more time avoiding mathematics than is needed in studying it, while others fool that the teachers are not effectively utilising the mathematical techniques and are not aware of the reason for teaching the subject. Some researchers suggested that the above has to do with intellectual development. They are of the opinion that most students operate at concrete rather than formal stage, so that some chemical concepts which wore abstract could not be handled by those students. Hence the need to assist students in the development of reasoning by organising instruction appropriately, Lawson and Renner (1975), Level et al (1961).

Some other opinions on this matter have to do vdth the relation of high I.Q. vdth recognition of science concepts, (Lynch and Dick, 1980). Other researchers say that cognitive

development is not the only factor but physical interaction* (Charles and Du.bley, 1980).

The co-existence of mathematics and chemistry up to now has all too often consisted of a detents, "You stay in your corner and I will stay in mine". The impression left is that these mysteries seem to he "like second cousins who for some reasons are not on speaking terms". The problem students encounter is the inability to apply the mathematics learned to chemistry problems, due to a lack of understanding and relevance. Teachers on the other hand feel that students just lack basic computational ability. But who is to make these links, aftera.ll there can be few people who would happily volunteer to teach both mathematics and chemistry. Might it not be- possible for the m at h on at i c s teacher to discover some science application of his theory or vice versa. To this end many researchers have suggested that out task is impossible and capable of no solution if it is thought that only a mathematician can mathoma•ically educate our studentQ. Others suggested team teaching exchange of teachers and materials etc. Some other investigations carried out in Nigeria gave the same suggestion too (Olonire, 1976; Elechi, 1977; Ojo'kuku 1978), It is hoped that the present study will stimulate effective use of mathematics in chemistry by applying some of the research findings, A look at the historical matheraatication of chemistry shows that it was not easy initially but later with relevant application, it was accepted world wide.

2«2 Chemistry: Historical Perspective

From the time of the Renaissance, science has been developed into an important social institution particularly, since the industrial revolution when science has boon applied extensively to human problems# In the 1960's arid 70's the public hat; come to realize the importance of science and technology to society. Research into the cause of disease has resulted in longer life and loss illness; technology has brought better living conditions and made work more efficient.

Science Education therefore has a crucial role since public understanding of science is largely as a result of scicnoo education through both formal classroom experiences .and informal experience.

Hjlgeson ot al (1977) say that for most students, scionce education consists of minimal experience in elementary school, a couple of years at secondary school usually few years of

biology/chemistry/physics but mainly biology. At most 4055 of students enroll in high school chemistry and fewer than 20% enroll in physics, with the majority in biology,

A profound revolution in chemical philosophy was initiated during the latter three decades of 19th century, prior to this period, powerful forces had built up for a new dispensation in the prevailing outlook of chemistry# The interaction of chemical thought at this time with evolving mathematic formalisms is a fascinating study and one now rich in interest to the chemical historian.# Following many utterances on the role of mathematics in the physical sciences from such eminent figures as Bacon, Newton and Descartes, the German philosopher Kant (1786) expressed himself in similar vein:

> I maintain that every b:.auch of natural science contains only as much actual science as the amount of mathematical content to be found there in.

With this view point, it is hardly surprising that ho concluded, chemistry must definitely remain excluded iron other disciplines, which are called the natural science.

The chemistry of his time, still steeped in alchemical speculation was by modern standard highly unscientific.

Strongly opposition to the introduction of mathematical concepts into chemistry persisted for a long time. Thus in 1842 the french natural philosopher Auguste Comte could write,

> All attempts to bring che-.-.ical equations into tho domain of mathematics must be regarded as profoundly irrational and antipathetic to the nature of these phenomenon.

When chemistry broke free finally from the shackless of its alchemical past during the middle 1870's, a process of gradual mathematization ensued. This process has continued a pace and at present appears to be accelerating and this has brought attendant difficulties and a plea was made for a bettor mathematical training for chemists. Sven as late as 1874, Crum Brown, in his Presidential address to the chemical society in London could state that,

> We cannot attain a real theory of chemistry until we are able to connect the science by sono hypothesis with the good theory of dynamics • . • • chemistry will then become a branch of applied mathematics, but it will not cease to be an experimental science; mathematics may enable us retrospectively to justify results obtained by experiment, may point out useful lines of research and even sometimes predict entirely novel discoveries, we do not

> known when the change will take place or whether it will be gradual or sudden; but no one can doubt that ultimately the theory of chemistry ... * will be absorbed into tho one theory of dynamics.

Tho application of mathematics to problem of chemical nature

was now gaining rapid acccptanco« Among the first to comment

was the Mathematician Frankland who in 1870 wrote,

> I am convinced that the future progress of chemistry as an exact science depends very much indeed, on the alliance with mathematics#

Soon after, in 1879, French chemist Schutzenberger asserted that

> before long mathematics will be as useful to the chemist as the balance.

But in spite of tho awareness of loading thinkers of these changes taking place, the

corpus of chemists as a whole remained largely unaware of their significance.

Accordingly, little was done to improve tho mathematical education of chemists which at

the time was minimal. However as the need for mathematical skill became more

pressing, a movement grow to exhort aspiring authors to produce a textbook which would provide a basis for the formal nathcnatic education of the chemist.

An important milestone was achieved by 193S, and significant examples include the development of the periodic ta^le by Mendeleev,

tho pioneer work of Gibbs in chemical thorraadynamic 3 etc.

The crucial importance of collaboration between chemists and in at homat i c i an nay bo illustrated by reference to a .distinct aroa of chonical endeavour; the Is oner enumeration. Shirs was doveloped by English mathematician Sir Arthur Gaylcy by representing members of alkane homologous series with tho general formula On II $_0$n + 2.

After this, there was a standstill. Rouvray (19C0) feels that one major drawback in the development of chemistry is the inadequate mathematical background of most chemists. This ho said has boon responsible for both the lack of initiation and pursuit of novel ideals. Ho is of the opinion that tho aroa lying between mathematics and chomistry is akin to a no man si and whore cho-rd^ts, mathematicians and others tako oocasional pot-shorts aimod at a number of specific targets.

With those views tho researcher is of tho opinion that this problem still exists with us and therefore needs immediate attention. To attempt a solution is to first *look* at tho problems encountered in toaching mathematics to scienco especially chemistry students with a view of finding a lasting solution.

2.3 Problems encountered and suggested solutions J;eaching .Mathematics

Scott and Walkcndon (1975*),* say, that well known problems onecuntorod in teaching courses including mathematics courses

that make use of ideas from mathematics arise from "inadequate •understanding of ideas in earlier courses consisting of tho slow or non-existent assimilation of new knowledge and the inability to apply knowledge from the earlier work.

Over a period of time, he obtained consistent views of the problem from:

(i) teachers of physics who have boon frustrated in their students effort to use relatively simple algebra and have had to resort to teaching the necessary mathematics again*

(ii) teachers in secondary schools*

(iii) lecturers in mathematics and engineering in v&rious

univorsities.

Ho disc , 'Vored that tho success of the students seem to bo due to their ability to remember some results and to reoogniso cues which initiate appropriate responses o*g* gradient y differentiate. He also observed that, when stud onto are ■* deprived of cues they arc unablo to proceed because they lack basic comprehension which would allow them to make use of the results and formulae which they have painfully memorised in their mathemati e s *

He also pointed out that a related consequence of the lack of comprehension is tho ability of students to select anc carry out appropriate mathematical operations in applications where the cues arc not in a form with which they are familiar, so that when shown a solution, most students readily admit that it is not the knowledge of the re sr. It s or formula but a lack of understanding and insight and skill needed to apply tho knowledge.

He observed that most teachers reaction is that ;if only they had been taught properly it would have saved a lot of trouble, I shall have to teach again things they should already know and understand^" This reaction must be identical.to/the reaction others can give when they want to use mathematical ideas in a class but cannot because the ideas are not understood well enough*

The question now is what level of understanding is needed *if* mathematics *taught* in one course is to be used in application or in a later course?

Scott and Walken (1900) identified two obvious factors which make a significant contribution to the difficulties above*

(1) The first concerns depth of understanding of mathematical concepts possessed by students*

(2) The second arises from the practice of allowing students to proceed to a higher level with insufficient mastery of the whole content at the level of testing*

Gonzalez - Leon (19G0) liar.: shown that the problem students find in mathematics application is that some tend to forgot much of the mathematics they have learnt in school

duo to the fact that between secondary school .aid higher degree they spend some time on activities quite different from their studies*

Ho suggested that attempt should be made to determine what piece

of mathematics, students have difficulty with, by giving them some kind of test in their first week*

A study reported by Renner (1976) showed that *r-0%* of the students in an introductory collego physic course could not solve a simple - c typo ratio* Ho suggestod b~ d~ that task be structured to maintain identical elononts in teaching to avoid memorisation*

Lawson and Renner (1975) in contrast indicate that tho concept of ratio permeates chemistry and physics as indeed, it does everyday life, but they believe that tho problem is related to intellectual development* To them, tho majority of science concepts at high school and college Level arc abstract and many students find abstract subjects such as chemistry and physics difficult to learn and there is reason to believe that part of tho difficulty is associated with students intellectual development* They went on to show that correct classification of such concepts cannot be based on 'identification of relevant and variable attributes through direct observation because these concepts lack perceptible examples or tho defining attributes are not perceptible in the examples* For instance, if one wishes to teach the concept of ideal £as, it is impossible to show students that particles of mi ideal gas occupy no space and exert no force on one another* One, ideal ftases do n,;t exist, even if examples did exist, we could not show these attributes, "bo cause onr cons os are unable to detect atonic particles. Ideal gas is abstract because there are no perceptible examples and the attributes are not perceptible. They, therefore, concluded that clearly, understanding abstract concepts requires more than performing logical operations on concrete reality. It requires hypothoticodeduo- tivo reasoning about unseen entities v/hich is characteristic of formal but not concrete operational thought. Also other X* *U* O v. *J1* 0 In. AXC l* s shown that substantial percentage o;C high school or college students are not formal thinkers (Lovell, 1961; Elkind, 1962; ITckinnon and Renner, 1971; Tomlinson- Koasoy, 1972; T owl or and Wheatley, 1971), In view of tho number of abstract concepts encountered in science, the learning difficulties inherent in those concepts, and tho number of students who function at

the concrete level, they suggested that to increase students understanding science teachers must either assist students in their development of reasoning or learn to organise raid teach instruction appropriately so that ideas are clearly understood.

Gharlesward and Dubley (1900) have indicated that inadequate cognitive development is not the only reason that students have trouble with chemistry, though it is an important part of the problem, but "physical interactions" as a procedure which will enhance intellectual development and which assist students in appling formal,operational logic to science problems.

Algo several studies have reported a doc lino in students interest in science Ahlgon, 1269; Maokey, 1970; Pella find Shorriia, 1969. According to thorn too r.iany students view science courses as stumbling blocks rather than as bv.ildi.ng *j* blocks towards a certificate.

Lawrenz (1976) suggested that one variable which might bo affecting students interest is the learning environment of the science classroom. Tho loss of interest he observed appears more pronounced in tho physical sciences than in the biological sciences.

Loon (1976) has shown that physical chemistry is certainly one of tho most significant courscs in science raid engineering students curricula, for it combines and applies their previous exposures to mathematic, physic and chomistry toward an understanding of chemical phenomena on .a ''ol ocular basis. According to him, most students regard this course with at least ‘'mild trepidation". Part of the reason for the trepidation he said is undoubtedly due to tho fact that the phrase " exposures to" is on appropriate phrase rather than "understanding of". IIo suggested the development of a physical chemistry course with a structure as flexible as possible to increase the probability of complete class motivation, Pic believes that once motivation is accomplished tho teachers role becomes tli. t of a guide.

Lynch and Dick (19?'0) found a high relationship between high I.Q. and the recognition of science concepts.

Since tho 1950*3 dovclrpnont in school science and mathematics have been rapid* Tho spur of sputnik prompted curriculum development projects such as P..3*S*C,, chom bond otc. But contact between the mathc'r.atic raid science projects were dismal#

Nigel (1975) has suggested tliat it is now up to teachers within individual schools to take up tho challenge raid, bridge this gap existing between science and mathematics in their particular 10aching situati on.

Ko attributes tho gap or difference to four factors:

(i) Science teachers unfamiliar with symbols, mathematical language and method now used a 0 that when Co student docs not understand, the science teacher, may be unable to help in a way that would assist transfer of skills from the mathematics class to science lesson and to the laboratory*

(ii) Secondly tho timing and development of certain mathematic topics do not match up with the needs of science t each0rs.

(iii) There are usually insufficient examples*

(iv) Lastly the mathcma,tic teacher fail to relate his mathematics to other subject*

In a school at Oakham, the science and raathonatio staff succeeded in tackling tho problem. They suggested a number of ways to solve it, but warned that tho success depends on

personality of teachers involve cl., their willingness to look outside the conference of their own subject and to approach the problem of co-operation v/ith humility*

Mathew and *Soed (1970)* also outlined various approaches which have proved successful in their school too:

(i) Co -ordinating science and mathematic syllabus,

(ii) Meeting of teachers and exchange of tost matorial end teacher,

(iii) Making detailed notes on application of mathematic_ to subject as they arise in course of his teaching,

(iv) Department to have copies of mathematics books for reference,

David (1975) approached this differently, he has shown that much of the reluctance of many pupils to study mathematics is related to the seeming irrelevance of the subject to their general experience of life and their own preferred career.

To this end, the project team of Nuffield "0" level biology course tried to use mathematics as an integral part of the course but the trouble according to him was arid still is to a large extent that though those who designed and developed "0" level Nuffield biology wore coripotont at handling mathematical tools, the average biology teachers were not.

Too often in the past, students wore encouraged to take biology at school because their mathematic was weak, and those people make up a large percent of present day biology teacher.

It seems to him that at tho reonont wo havo on tho one hand, mathematicians designing courses concerned more v/ith the understanding of principles rather than emphasising manipulat i 011 and t e chili qu o ,

Biologists recognise the need for tho usefulness of mathematics but they realize their inability to marry tho two. It is this researchers viov; that mathematicians and chemists also lack this ability,

Webb (1975) describes mathematics as a "service subject and a mental discipline in its own right", though a tool for tho sciences, but the problem is that:

(i) chemistry teachers need to bo familiar with and make use of mathematics,

(ii) chemistry teachers fail to relate teaching of mathematics to other subject adequately,

(iii) mathematics teachers uses symbols different from chords try.

(iv) the timing and depth of development of certain mathematical topics does not match up with tho needs of tho chemistry studentc.

(v) the chemistry teachers use insufficient simple examples. He found that students main problem seem to bo associated with standard form, log, algebraic manipulation, transformation of formula and solution of equation, ration and proportions. He concluded that solution can bo achieved by following tho below stopsj Teachers 'to

(i) •recognise ^roblens

(ii) willingly j look out aide conference of own stil\ject and approach problem with co-operation and humility

(iii) informally met v/ith each others to talk and admit ignorance of tho other subject.

(iv) exchange test materials

(v) make detailed notes on application of mathematics to his subject as it arises and then ask the mathematician to help comment on method of presentation and these will aid understanding.

Hudson (1975) found that the main reason why it is difficult to teach mole concept, for example, is associated with the inability of some people to cope v/ith the mathematical ideas such as ratio and tho chemical ideas such as tho minuteness of atom.

2*4 Suflfies10d Areas j:>f Mathematical emphasis for Olicmicai Coneeot s

Research has shown that the mathematics in chemistry involve mainly ratios, proportions, decimals, logarthm and indices, graphing, unitary operations, percentages and. simple a.lge'bra* and Scot (1980) emphasised that degree of mastory of those level of mathematics is necessary for application. He cited evidence to show that oven whon students have acquired certain mathematics skill, they cannot use it due to lack of "basic comprehension mad understanding of concept.

Derek (1973) gives a chemist viewpoint to the issue of mathematics in chomi..,try tcaching* Ilo sees the basic require-

1.1 ont as a chemist to bo straight forward; an ability to relate the four rules:

(i) Direct and inverse proportion

(ii) Decimal and use of logarithms

(iii) Perc ont age s

(iv) Indices and graphs

Ho feels that studo.its usually have moot these topics earlier but cannot make satisfactory use of thorn because they wore taught in abstract manner with insufficient opportunity to develop facility through practice. Ho also noticed tho difficulty of transferring knowledge from a mathematical to a chemical context. Ho therefore suggested that we should not expect our mathematics collea'"'[1] os to resolve our difficulty for us, but to recognise tho need for increased dialogue and co-operation. In addition to his above suggestion bo mentioned that help is needed at two levels:

(i) Caiiooiling:| *'.c£o&a* multiplying, moving *fron* de cimal point,

(ii) vocabulary and method of modem mathematics and tho use of its idea,

M alp as (1973) suggested that schools should make it a standard practice to list the mathematical topic with v/hich students must be familiar.

Lawson and Renner (1975) have shown u!r»at tlio concept of ratio permeates chemistry*

Newbury (1966) indicated that it is difficult to think of a subject in which mathematics docs not play a part and this is in line with tho investigators viow that mathematics ploys a key role in the understanding and appreciation of chemistry# He observed that chemistry students encountered difficulty with mathematical operations involving percentages, docirtal and unitary operations*

2.5 Usefiilnoss of 1'J.athpmatlcs in Chemistry

Mathematics is used as a tool of science. It has contributed to advances in science. Science uses mathematics iii a variety of ways; for example,

(i) in scientific Asvtfjtd,;;ati , u&fchenctij&c is used to reveal relationship between variables such as Volume, Pressure and Temperature, (Charles, Boyles law etc),

(ii) to extrapolate and interpolate data.

(iii) mathematical notations used in presenting scientific laws and theories economically.

According to Abdullahi (19G2), one cannot realistically understand science without considering tho important role played by mathematic, just as science itself would not develop to its present strvpo v/ithont mathematics# But despite the usefulness of mathematics as a tool in learning science, ho is of tho opinion that teachers have not effectively conveyed to their

students an understanding of the role of m* ■'•hematics in science. The present emphasis on [sl]inquiry approach" provides numerous opportunities for the use *of* mathematics for science students cannot either measure, quantify observation, organise and summarise data with graph v/ith out a sound mathematical background, He suggested that proper orientation be given to science teachers at pre-service training level so that they can acquire necessary background in mathematics to help them function effectively as science teachers*

In addition to the above mentioned knowledge and skills which are also widely applied in the study of chemistry, chemistry uses mathematics in a number of ways,

Kalojaiye (1979) outlines some 7/ays in which chemistry u s e a matliemat i c s,

According to him, mathematics knowledge is used in:

(i) setting up chemical models or formulae,

(ii) solving chemical problems for example

(a) ratios and proportion used to describe chemical lav/s and equations etc,

(b) Quadratic formula used for calculation of oquilibria problems•

(c) Calculation used in. working out kinetics and thermodynamic problems in physical chemistry.

(d) Statistical technique applied to data oollcction and laboratory practicals etc.

Ho suggested that it is desirable that students should learn tho mathematics ideas and skills which arc applicable to their science disciplines because attainment of scientific progress will depend to some extent on their mathematical competence.

2.6 How to toagh M%thona.tics .c.ffo.oti.voljy;

Mathematics is soon as a language wxth basic functions of codification and. decodification of messages and patterns. Research has shown that in designing instruction, symbols can be arranged in a flexible naimor taking into account tho existenoo of levels of understanding in other to improve teaching. Others are of the opinion that for a teacher to asist a student he should first understand why he is teaching a course, Somo researchers

have advised that science/chemistry teachers should teach the mathematical technique they need or start a service mathematics". It was found that mathematical concepts constructed on selected science behaviour occurring at the same time aided positive transfer especially where both courses were taught by same teacher, while others are of the opinion that teachers have made no effort to use tho now topics and, techniques offered by modern mathematics and have not related, instruction to physical world, students interest, background and disciples,

Gupta (1930) describes mathematics as a language and outlines three basic functions of mathematics, Tho first deals with communication of message which includes codification and decodification into and from signs, i'he second deals with operation upon the basis of the message and thirdly the genetic of patterns and those are

2,6 How^ to teach M at he; m at i c a off o c t iv o ? ,7

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Tho first deals with communication of message which includes codification and decodification into and from signs.

Tho second deals with operation upon the basis of the message and thirdly tho genetic of patterns and the s 0 a.r c

similar to functions of language as shown below.

Language

(a) Tho syntacto-semantic Operative symbols, -
$+_s$ ♦, x, y , log, ( )
proposition - , V ,u,n,
u,n,sin

(b) Pragmati c and .Relation symbols -•
(verbs)
Auxiliary symbols: V

(e) Liter ary funct ions
of language

Those symbols according to Gupta can bo

arranged so as to build thorn on symbolism learnt earlier, for instance,

(i) X and + built on + and - respectively

(ii) logarithm can be expressed in various forms say:
R(2, 3, 8) as (a) $2'^3$ =* 3

(b) yr «

(c) lor^a = 3 or 5 = 4+ 1 - 10 + 2« *sTFT* = logp 32.

Thorofore by designing instruction and operative symbols in a flexible manner, it con gonerato an unending sequence of synonymous expression* This the research feels can help students to understand and therefore appreciate if instructions are organised sequentially to allow flow of information while relating topic to appropriate chemical concept,

Gupta is also of the opinion that an understanding of mathematics must take into account the existence of levels of understanding from simple to complex with free forward and

background flow of communication in other to gain flexibility and reduce fixation. For when students learn another language they must also learn to translate *from* the now language back to tho old and vice versa.

Omnoll (1972) is of t he opinion that teachers need to understand more clearly why a course should be taught, because as presenters of tho subject to students, there is a need to be able to call upon an independent source of material within the consciciico of each student. This according to him will reduce the tendencies for students to study mathematics blindly. Usually resulting in an absence of understanding, lie suggested that mathematics at tho level of arithmetic and simple algebra could be used to handle the kind of problem emerging in chemistry,

May (1972) also Indicated that teachers job is to assist the learner to acquire knowledge, skill and understanding mathematics. The teachers need to be able to solve such equation as a quadratic equation and to explain the corresponding algebra. He needs to know the theoretical results and how to prove them but it is equally important to know the motives for studying quadratic equations, their relevance to applications, for without knowledge of this kind to motivate students, the teacher is hardly more than a mere technician drilling students in calculations and manipulation of terminology, e.g. chemical equilibrium calculation — quadratic equation.

Gollagch (196?) has shown that mathematics courses oaii

be programmed not as an abstraction but rcther as it specifically

relates to problems in tho physical world.

Rouvray (1974) in attempting to improve tho teaching of assess

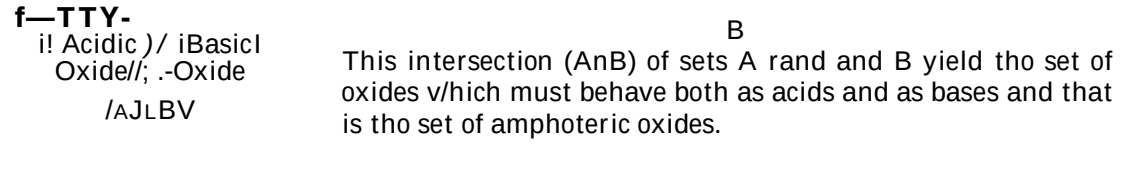
chemistry tried to / tho present relevance and status of a number of mathematic disciple to

tho field of chemistry, using the role of set theory as in tho below example:

Amphoteric oxides can bo taught using venn diagrams e.g. A n B = (Zno, ASgO^, Sb„0 etc)

= amphoteric oxide

3



This intersection (AnB) of sets A rand and B yield tho set of oxides v/hich must behave both as acids and as bases and that is tho set of amphoteric oxides.

Rouvray (1974) has shown that oven most

mathematicians experience some difficulty in toaching mathematics to engineers who are less receptive than the mathematics major for they feel that the mathematics is not relevant and often comment. * , ,

"I an not going to bo a mathematician 9 I do not need all that mathematics. Therefore, if applications could be made more relevant to students interest, background and disciple, this will improve the teaching of mathematics.

Duffin Janet (1974) advises that science, industry and others should themselves undertake the task of teaching particular mathematical techniques they require or on the alternative start a "service mathematics course".

; DavicT (1975) says that mathencLics is necessary, it must bo addition to, not replacement Tor a practical mathematics for all. Ho is of the opinion that the situation is worse because teachers are trying to teach the various standards of mathematics to loss abled pupils and to the fact that physicists and others have made no effort to uso the the new topics and new techniques offered by modern mathematics.

Some researchers are of tho opinion that mathematics is too important a subject to be left to mathematician.

Harvey and Har'pew (1974) suggested that science teachers should ask themselves in designing instruction, "How can the current approaches in mathematics holp us". Students arc more likely to develop a liking for a subject, if the teacher has a thorough understanding of it.

f . Kolb (1967) in his article on "t'ho effect of relating mathematics to science instruction on the acquisition of quantitative science behaviour", indicated, that learning science requires the learner to have certain abilities in using mathematics, The analysis showed that an instructional sequence in mathematics constructed 011 the basis of a mathematical hierarcy and assumed to be necessary for selected quantitative science behaviour will facilitate the acquisition of tho quantitative science behaviour more than an instructional sequence in mathematics not directly related to the science behaviour that happen to be occuring at tho same time.

He algo found that tho m&thematical hierarchy constructed on selected quantitative science behaviour that happen to bo oocuring at the sano time aided positive transfer. This he attributed to tho fact that one of the teachers taught ail of tho mathematics and science during the course of the experiment.

2.7 Other researches in tho. Nliierioji _Con_t_oxt

There has been research carried out on the relationship of chemistry and mathematics, but to *the host of the* knowledge of the investigator, no previous study had been undertaken to establish tho relationship betv/oen mathematics and the various areas of chemistry v/ith a view of determining problem areas and finding solution to them.

The relationship between mathematics and chemistry has been interpreted in various ways. The study by Oloniro (1976) represents an attempt to ascertain the relationship between V/.A.S.C. grades of students in chemistry and mathematics. He concluded that an understanding of mathematics will greatly help in tho understanding of chemistry and suggested that co-operation should exist between the head of department of mathematics and chemistry. This way while the chemistry teacher is teaching the gas laws for instance, mathematics teacher will concentrate on teaching of ratio, proportion and logarithm which arc related to solving problems of gas law. He concluded that there is a positive relationship between mathematics and chemistry and further agreed that a chemistry student' who is good in mathematics will in all probability do well in chemistry.

Elechi (1977) in his study of the attitude of students toward the study of chemistry wanted to find out why the percentage entry for chemistry was so low tsriih tho solo aim of finding ways to encourage students. He found among other reasons that many of tho students had a poor physics and mathematics background and this influenced their attitude t o\ ards choraist ry.

Ojokuku (197S) studied the relationship between the performance in physic and chemistry in W.A.S.C. by students of secondary schools in Zaria. Ho found a substantial relationship botwoon physic and chemistry grade in W.A.S.C. results of June 1975, and

1977.

Olajide (1974) found a negative attitude towards chemistry and this led her to investigate the effect apparatus and visual aids would have on tho teaching and understending of ohomistry in Queen Amina College Xaduna. Findings revealed that many secondary schools see chemistry as a rigorous process of memorising forrnular, equations and laws. She indicated that with good methamtics examples in class, those formulas, equations and laws will be understood with these we will lack at psychological views on the topic.

2*8 Psychological J^ho orio s, and j^pli option. toi Chemis fc ry/M at hemal; i c s t e aching

Learning according to the bchaviorist schocl of psychology is an 'individual exportenco and whenever an individual behaviour is modified, learning is said to have taken place* Science teaching is not simple presenting materials but requires understanding of classroom practice and developing ways to facilitate effective learning* The learning theories of Ausubel, Robert Gagne, Piaget etc have had a profound impart on curriculum development and methods of teaching science. According to Ausubel (1963) meaningful learning occurs when there is interaction between the students, appropriate elements in tho knowledge that already exists and the now materials to be learned. He is of the opinion that now learning must be linked to existing knowledge to create meaning. Ho advocates for nadvance organisers" *trhcre* relevant subsumors do not exist to link new materials with previous knowledge on same or related concepts.

Gagne's theory of learning assumes that any piece of knowledge can be acquired by students who posess certain prerequisite piece of knowledge which have their own prerequisites in turn* According to his theory prior knowledge determines what future learning may take place and. Gag.no believed that this type of looming structure is particularly important for subjects like tho natural sciences. Central to

Gagne's theory is his concopt of task analysis of skill and knowledge to bo taught. Analysis of task is begun by formulating an answer to the question, ''what would an individual need to be able to do, in order to perform this task after being given instruction? Gagne predicts that the acquisition of the formal task is dependent on the attainment of the hierarchy of subordinate behaviour.

Ausubel and Gagne are concerned about moaningfulnoss of material to be taught to the student. This has implication for chemistry teachers to plan, and organise their work from concrete material to abstract material while bringing out the link between the studied materials to aid positive transfer. This can bo effected by selecting ideas which student will bo familiar with and then adding appropriate examples to it. For instance, Daltons Atomic theory subsumes several chemical laws. This means that the mathematics teacher has to teach topics like preportion, ratios etc before the chemistry teacher starts teaching Boyles and Charles law, this way students can apply the mathematics at the same time, see its usefulness and relcvance.

Another psychologist called Piaget has characterised human intellectual development in torms of four stages* The first two called sensory motor and preoporation are usually completed when child is 7-8 years* Following those are the two stages of logical operations called concrete thought and formal thought which are relevant to Advanced, Colleges and University students* Piaget has also ascribed the process whereby individuals advance from one stage to the next to four contributing factors: maturation, experience with physical environment, social transmission and equilibration. The last item designates an internal mental process in which now experience are combined v/ith prior expectation and generates new logical operation. Research has shown that most of our students are concrete operators but they can bo assisted, to move to a formal stage, Tho teacher can help by identifying the conceptual emphasis and demands of the subject matter, then help the students develop more advance reasoning pattern than they use currently by organising instruction accordingly and making it more relevant,

-1

2.9 U3j3£utej?j3s of_ .Stjud£

It is necessary to look into students work bo find solutions by introducing suitable educational method so that the meaningful learning in the classroom is comprehended and remembered by all.

Both mathematicians and chemists are looking for what is boot for their students«

Chemistry and mathematics arc tho basis of some of tho most revolution of recent development in our society and in the everyday lives of young people* Therefore the attempt of research to find a, way to enable students to discover their value, enjoyment and live- at the height of development. Most developed countries of the v/orld realise that science and technology are far from being firmly established in their midst, consequently, they fool that efforts should bo made to change tho situation. Science popularisation is essentially to stimulate development and establish a science culture,

The prestige and political power of any nation resides in its level of science activities. The necessity for popularising science *of which* chemistry *is j*art is obvious *in* a world dominated by technology so that children born in such a culture must of necessity think of their future careers in terras of such environment -and appreciate the fact of science as being a moans of achieving technical development and economic survival. Moreover chemistry plays a treujtfadoue role in the totality of experience essential to educating citizens. We live in a country which is over dependent on oil. Latest statistics show that about 94$ of our foreign exchange now derived from oil v/hich is being tapped, at almost two million barrels a day (Ozoro 1977),

Tho exploration and. ^rocossinf! of tho oil and other related, products c.g. fort iii nor, cosmetics, glass, drugs, pesticides, dyo otc dopond a lot on the science of chemistry.
So chemistry stands in a central position among the basic sciences. As we live in an ambivalent society where the impact of science has not boon sufficiently felt, it is therefore necessary to find ways of teaching chemistry effectively so that students can understand and apply it, Nigeria needs scientists mid technologist and those professions could only be obtained through affecting the teaching of chemistry in our schools.

The greatest impact will be made towards that direction if our Advanced Teachers Colleges and Colleges of Education will look into their syllabus and identify mathematical skills required for their science courses and sit together to work out a co-operative syllabus that will aid transfer of learning from one area to the other.

One form of tho role the ATC can play is in the immediate review of the admission requirements for their prospective science students. This is necessary not because there ore more science places but because some students are victims of poor staffing, lack of suitable facilities, a deplorable situation too common in our schools. Such students can still benefit by working hard through participation in supplementary mathomatics programme,

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PROCEDURE

3.1 TIIG Sample

The sample for this study was made up of 32 Part III ITigeria Cortificate of Eduoation (N.C.E.), chomistry major students of the A.T.C. Zaria. The sample was randomly selected from this particular college because that was the only known A.T. where chemistry ma;jor students were required to take compulsory supplementary mathematics in addition to their other course combinations. This was considered important because it suggested, that there would not bo a variation in tho nature of instruction. All tho subjects were Nigerians, although no specific information was available on the subjects average intellectual level.

3•2 Data. .Collection

Examination scores of students in supplementary mathematics and the three different areas *o£* chemistry for each of the three years were collected from the academic records of the chemistry department at the A.T.C. Zaria.

Scores in organic chemistry, physical chemistry, Inorganic chemistry in Parts I, II, III scssionals and the Part III

final **rr.C.E,** chemistry examinations were obtained baaed, on percentage scores. The sessional Part IIT chemistry scores are different from tho Part III final N.C.E, chemistry scores. The Part III sessional examination was taken at tho end of the third, term course and was internally moderated, while the Part III final N.C.E. sessional examinations wore taken at the end of the third term and wore externally moderated.

In additional to obtaining the scores, some questionnaires were developed and given to both the chemistry lecturers and the Part III chemistry ma;:or students.

The chemistry lecturers wore to:

(i) identify the mathematical concepts needed for the particular area of chemistry they taught,

(ii) comment on their students performance in chemistry vis-a-vis their ability in tackling the mathematical aspect of chemistry,

(iii) give their reactions to the usefulness arid effectiveness of supplementary

mathematics in relation to the acquisition and understanding of the chemical concepts taught.

The Part III chemistry students were to:

(i) identify the areas of supplementary mathematics v/hich aided their understanding of chemistry and finally^

(ii) rank them from most useful to the least useful, (The questionnaires are shown, in the appendix I).

3*3# Procodure for Data ..Analysis

Reference was made to the records of results of student offering chemistry and supplementary mathematics.

Supplementary mathematics sc ores in Parts I and II v/oro correlated with scores in the various areas of chemistry.

The correlations used for this study were defined, for variables X and Y, by,

$$r(x,y) = 2"i_a i \ ^{(Xi} \ " \ ^ \ ^{(Yi} \sim \ ^$$

$$l\!\!\ll\!\!i \ ' \qquad ' \qquad \pm^{\wedge}{}_{L} \qquad (Yi \ - \ Y)$$

where X and Y arc tho mo tins for X and Y respectively*

Nuncrous variables v/oro treated at once by computing r(x.j,xk) for j = 1 . ,

., ?!

k « 1 , , ., IT

This correlation is called the "Pearson Product Moment Correlation." Pearson's correlation technique was used to correlatesupplementary mathematics scoros and tho scores from different areas of chemistry. Thistechnique was utilised because it was more reliable and accurate than the rank correlation method. The Pearson's product moment correlation takes into account the absolute size of the measures and not merely 'their rank order,

Tho data was analysed at tho 0.05 level of significance using J&SIP[1] package, a

procrammo package available in the A.B.U. Computer.

In order to identify tho mathematical knowledge and skills required for learning chemist 17/, the supplementary mathematics and chemistry syllabuses of the Advanced Teachers College Zaria wore acquired and studied. Six chemistry teachers of tho college assisted in the analysis of the mathematics abilities and skills applicable in the subject. They were all holders of a degree in chemistry v/ith specialisation in different areas of chemistry* They were given the syllabuses in chemistry and supplementary mathematics and wore asked to determine the mathematical knowledge and skills which were required in the study of the topics listed in the scheme of work for each year*

The questionnaire consisted of a table (see Appendix III) showing the chemistry topics and a largo space for the teachers to fill in the corresponding mathematical knowledge or skills required in teaching the students effectively. After each chemistry teacher had identified the mathematical knowledge required for learning each chemistry topic, one other experienced teacher in the same field was asked to judge whether the appropriate mathematics has boon identified for the topic. The agreement of the staff members and the rcsearcher guided the compilation of the mathematical concepts required in chemistry*

Tho data correlation matrix contains all the information which has been used in thin study. The chemistry r;corcs wore the dependent variables while supplementary mathouatics wore the independent variables. The data matrix and analysis of data are treated in the next chapter.

ANALYSIS OP DATA

4.1 Introductions

Tho study was designed to find out tho relationship Detwcon suppi*en017*1*ary* mathematics raid tho var icu s branches of chemistry. The supplement ary mathematics Part I (X3) scores were correlated with tho various broncho in Parts I,' II, III sessional and Part III certificate examination scores. Below are coded variables: 'nd Part II (X4) j of chemistry

Tablo^ I

Jfio ailing of Variables

sxi student [1] *S* NUMBER
XI WAS a MATH •
X2 V/ASC CHEM .
X3 SUPPLEMENTARY MATE-; PART I
X4 SUPPLEMENTARY IIATIt PART II
X5 PHYSICAL PART I
X6 INORGANIC PART I
XT ORGANIC PART I XS
PHYSICAL PART II X9
INORGANIC PART II X10
ORGANIC PART II
XII PHYSICAL SESSIONAL PART III X12
INORGANIC SESSIONAL PART III X13
ORGANIC SESSIONAL PART III X14
PHYSICAL FINAL N*C.i;. PART III X1?
INORGANIC, FINAL N.C,E_a_ PART III X1S
ORGANIC, FINAL N.C.2. PART III X1? FINAL
NCE OVERALL

Tho data was analysed using Pearson Product Moment Statis*[1] \ct at the *QLQ5* level of significance. Below is the correlation

liict *o*

Analysis of the Correlation Matrix

Supr> 1 omontary Mathematics Part I with .Part I Chemiatry Sc ores

There was high correlation between supplementary mathematics Part I scores and all tho branches of chemistry in Part I, This shows that the effect of supplementary mathematics starts appearing from Part I with tho effect boina more pronounced in Inorganic chemistry, (X6), r - 0,679 significant a try..« 0.0001, This was followed by Physical chemistry 1(325), r sa 0,380 significant at'\ ~ 0,015 and then organic chemistry, r * 0,359, cx« 0.018 (Table II).

Suppiementary Matlioi.igtics XJffJ?) Scores jrith varioug
br?^chesr^of.J?ort // chemistry jJcojnpjs

Inorganic chcmistry II soer^s showed a very highly significant correlation with supplementary mathematics I, r » 0.532 significant at oil. ~ 0.0001, There is also a significant correlation between supplementary. Mathematics I and organic chemistry II, r = 0*338 significant at ex. - 0,029*

Physical chemistry II did not correlate with supplement .ary mathematics I, r « 0.256 significant aJr v>. - 0.078. ihie is unusual, Imtwing very well that this aspect involves more chemistry than other areas. This could bo oossibly duo to tho fact that sections of mathematics required for the chemical concepts wore not

handled properly or ovon omitted because of tho difficulty 121 seouriiig a permanent chonistry toaoher who could teach supplementary mathematics as wo 11# According to tho students, Table 8 there wore two terras they did not got anyone to teach supplement-ary mathematics because their teacher loft tho college*

Supplementary Mathematics Scores v/ith various T>rrjiohoJ"of dio^stry' iff TfI^TI2. X13T

Table II indicates that the effect of supplementary mathematics programme seems to appear most towards the last session.

There were highly significant correlations between physical chemistry and mathematics r ~ 0*50o at 0*001, In ore ani c chem j. at ry and mathomat i c s r = 0*551 at ,3v~ 0.0001 end Organic chemistry and mathematics i? - 0*427 at <;)• .. = 0*007.

Supplement ary. Mathematics Sc ores with br anchors of* final N_*C.EV ^ghqristi-/; III TxiT, X15. ~ XITT'

There were high correlations between X3 'aid the various branches of the final Part III certificate chemistry$_t$ The highest correlation shown was between supplementary mathematics and Inorganic chemistry, (X15) r ~ 0*523 significant at.-X^s 0*001, followed by physical chemirtry(xi4) r - 0* 434 significant at$_v$-),.~ 0*002 and then organic chemistry$_3$ r « 0»37t significant *at{/X* =* 0*01/-,*.

It aan be seen that there was high correlation between X3 and each of the various branches of chemistry in Part I, (X|5, X6, XT), Port II (X8, X9, X10) , Part II (X11, X12, X13) and *f* in al N • *0. E*• e xamin at i o n (X14, X15 and X16),

The trend being Organic ,/ Physical <r Inorganic« In the opinion of the

researcher there is a justification for the inclusion of supplementary mathematics I into the chemistry syllabus,

A look, at the correlation result between Part II supplementary mathematics (X4) and the various areas of chemistry in Parts I, II, III and III final will support or discard the idea of the inclusion of supplementary mathematics in chemistry syllabus.

(0) Supplement ary Mathemat i os *IS* _(,X4). Scores with branches of Chemistry; li^ .Parts I r II t> III.*,, .and final H.C,E. results.

(1) X4. with. Part I ,chemistry, (_X5,_ X6 .and. *$-1)*

Supplementary mathematics scores showed very high correlation with;

Physical chemistry I, r w 0.367 significant at ck» 0.019 Inorganic chemistry .1, r » 0,612 significant at'>..= 0.0001 Organic chemistry I, r -- 362 significant at 0,020

(See tables I and II),

(ii) X4 with Part II chemistry (X8,_ X9 and X1Q)

There v/ao a high correlation between X4 and Inorganic II, r - 0,494 significant at *,jr-,* - 0.001.

This section like the correlation result in Part I above records an unusual result. For there was no correlation between either X4 and PhysicVI II or X4 and Organic II. The result (see table II) shows the following.

X4 with Physical II, r = 0.176 not s ignifi cant at . = 0.05.

X4 with Organic IT, r ~ 0.264 not significant at 0.05 but significant at

r ~ > 0 * 0 7 1 .

These could be attributed *to* some mathematics not covered in physical chemistry paper. The result for organic II though not significant at ,r5k. = 0.05 is a much better result than that of Physical,

(£) X4 with Part III Chemistx^ (11.,_ X12 and XI3)

There was generally high correlation between X4 and the various areas of Part III chemistry. The correlation result of X4 with Physical III, Inorganic III was highly sign i f i c an t •

r = 0.54>3 for X4 with physical III significant at c:>-= 0.0001

r=e 0. 571 for X4 v/ith Inorganic III significant at
X..=* 0.0001

This result v/$_{Q}$g not unusual as the syllabuses for the physical and Inorganic chemistry indicated a good knowledge of mathematics to he able to understand the chemical concepts, derivations and formulae,

(g) X.4 .with Pcg:t_III II.C.IJ. Chemistry

Data Matrix Table II indicates that the cumulative effect of supplementary mathematics programme I and II manifests itself most in the final N.C.E. chemistry result thus:

X4 with final Physical III, *r* « 0.533 significant at >*r* « 0.0001 a4
with final Inorganic III, r « 0.550 significant at,X 0.0001 X4 v/ith
final Organic III, r - 0.470 significant at *Ox* « 0.003.

(Table 3 and 4) below indicates effect of cumulative mathematics (X34) on tho moan of different chemistry areas*

Table 3a

Effect of Cumulative Mathematics on mean of different areas of chemistry

C0RR'X3l+ X5811 X6911 X7 1013'

	X3U	X5811	X6911	X7 1013
X3U	1.000			
X5811	0,585	1.000		
X6911	0.683	0.800	1.000	
X7 1013	0,558	0.7U5	0.677	1.000

SIGNIFICANCES LEVELS (PROBABILITIES OF NO CORRELATION)

	X3U	Mean Phy. X5811	Mean Inorg X6911	Mean Org. X7 1013
X3^	0.000			
X5811	0.000	0.000		
X6911	0.000	0.000	0.000	
X?_ 1013	0.000	0.000	0.000	0.000

32 CASES.

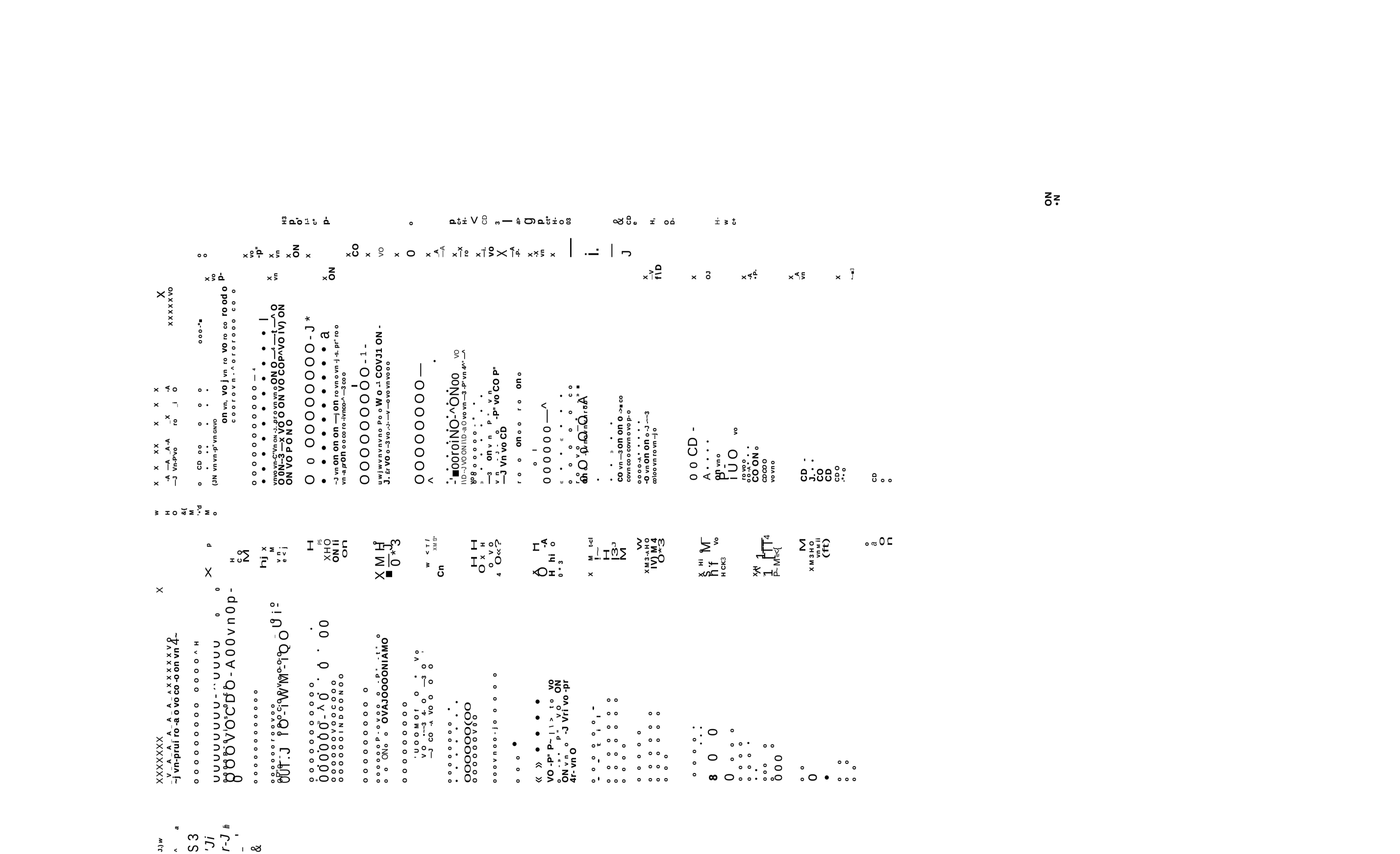
C0RR.·X3U X581111 | X691215 X.7101316

	_ X3t„	Mean Phys. X58111U	Mean *Incrg,* X691215	Mean Org. X7101316
X3U	1,000			
X58l11li	0.612*	1.000		
X691215	0.671	0.770	1.000	
X7101316	0.600	0.81U	0.766	1.000

SIGNIFICANCE LEVELS (PROBABILITIES OF NC) CORRELATION)

	.. *34 -	X58*111k*	X691215	X 7101316
X3U	0.000			
X581111+	0.000	0.000		
X691215	0.000	0.000	0,000	
X7101316	0.000	0,000	0.000	0.000

32 CASES



(Ii) Below are the cor-os for the means of various branches of chemistry for Parts I, II, III -and Parts I, II, III and final III as indicated in tables (ill and IV) .

X34 * mean supplementary Mathematics I Part I mad Ilj*

X5S11 = mean physical chemistry \Part I, II and III;.

X6912 « mean Inorganic chemistry [Part I, II and III).

X71013 “ mean Organic chemistry'.Part I, II and III,

X581113 = mean physical cliomistry (part I, II, III and finaj,

X691215 -- mean Inorganic chemistry[Part I, II, III and final X7,10,1316 - mean Organic chemistry(Part I, II, III and finally.

Tables III and. IV correlation matrix indicate a very high correlation between X34 and tho cumulative results of the various branches of chemistry,

X34 with cumulative physical chemistry gives r » 0.505 significant at ^V" - 0,0001,

X34 with cumulative Inorganic chemistry gives r ~ 0.633 significant at--— = 0,000

X34 v/ith cumulative organic chemistry gives r r> 0.558 significant at i-V* 0,000.

Below shows regression of overall performance X17, with various branches of Part III Chemistry result.

4•3 Refiro gsion R<u>esu</u><u>l</u>ts (Sossi onal)

X^{17} = -7.278192443 + (0.33012245 x X11) + (0.09907359809 x X12) + (0.102788 7446 x X13).

R*2 = 0.974680729 R: 0.9872592003

StaMoxd ffrr or$_r$o.f Co<u>effic</u>ient

X11(Phy III)	X12 (Inorg. Ill)	X13 (Ore. HI)
0.0436	0.0314	0.0379

5..V Stpatjjstlc:

7.5574	14.73	2.7072

T<u>. Proba</u>bilities: (Probabilities of each coefficient *zero)*

0.000	0.0027	0.0072

The above shows regression of overall performance X17 with Physical III, Inorganic III, end Organic III, v/hich was very significant using the above.

The above reveals that the overall performance is dependent on tho listed variable physical III (X11) , Inorganic III (X12) and Organic III (X13).

4.4 Effect of Overall Performance on the final

_ Chcmi stry re suit s The overall performance was regressed on chemistry marks obtained in the final N.C.B. Chemistry examination, (Tablo V).

REGRESS [f]X17 X14 X15 X16[1]

X17' =24.27956036 + (0,3535001298x14)+(0.164346o630x X15) +
(0,07538459465 x X16)

ANALYSIS OP VARIANCE

	D,F,	SUM OP SQ.	MEAN SQ.	FRATIO
REGRESSION	3	2569.49	856,4980	61,80
RESIDUAL	28	388.00	13.8573	
TOTAL	31	2957.50		

P-PROBAB.ILITY (PROBABILITY OP ALL COEFFICIENTS ZERO):
1,Q18E**12

R*2: 0,8688061394 Rs 0.9320977092
S.E.: 3.722546376

	X14	X15	X16
	0.0679	0.0465	0.0555
T-STATISTIC			
	5.2051	3.5286	1,3577

T-PROBABILITIES (PROBABILITIES OP EACH COEFFICIENT ZERO):

0.	0000	0,0007	0,0926	32
	CASES			

It was found that the overall mark could be predicted from the marks obtained in Part III final N.C.E. results using the above regression. Also observed on the table are the following results R*[2] a 0.8688061394, S.E * 3.722546376, F Ratio » 61.00

It can therefore he seen that all independent variables were significant at least at 0,05 level. (T-statistic Table 5).

Tho F - ratio also shows that tho overallperformance is cl o pond on t on variables listed X14, X15, X16.

There wore generally high correlations between the supplementary mathematics Port I .and II scores v/ith various area of chemistry throughout the

N.C.33. programme,

(Tables I, II, III).

It can be concluded that in this study it would appear that supplementary mathematics concepts enhance tho understanding of chemical concepts as evidenced in the data matrix* (Tables I - 6).

The interesting points indicated on the matrix (table II) were:

(i) the high correlation between W.A.S.C. mathematics (X1) and Physical Chemistry .. ; Part I (X5) only.

(ii) no correlation between W.A.S.C. Chemistry X2, and any variable in the matrix.

Those show that the W.A.S.C, mathematics (X1) was different from tho supplementary mathematics (X3) and the H.C.E. Chemistry,

Prom the table 2, possibly good background in W.A.S.C. mathematics can only aid students understanding of only the physical chemistry I (X5).

A look at the physical chemistry Part I syllabus (see appendix) shows that the mathematics required were just, proportions, ratios and simple algebra which wore taken in W.A.S.C. examination and tho students are already familiar with*

This goes a long way to emphasise the hoed for the right type of mathematics (different from W.A.S.C. mathematics) to aid the effective und erst raiding of N.O.B. chemistry v/hich is also different from W.A.S.C. chemistry, (nee tabic II)

(X1 with each variable)
(X2 with each variable)

It is therefore tho opinion of the researcher, from the above evidences, that there is a ;jnstification for the inclusion of supplementary mathematics in the chemistry syllabus.

4.5 i\^alxsisUJaf J^cturcrs '/Students Herons es

The questionnaire analysed is shown in the appendix-I#

Out of tho six lecturersj the least teaching experience possessed was four years. Others ranged from five to fourteen years experience, teaching different areas of chemistry - physical, Inorganic and Organic. They all had Masters degrees in different areas of chemistry. Throe of them in analytical chemistry, one in physical chemistry, one in Inorganic chemistry end the other in Organic chemistry.

They all taught years I, II and III, N.C.ft. students besides the B.Ed (Bachelor of Education) students. The table below gives a summary of their responses.

jE able *1*

Re sp on so Summer;/

in (•••>n'hinnnrnTO^

Section in questionnairo	KGaponses
Relevance oi‘ supplementary { mathematics to the under-standing and appreciation	All agreed that a bettor un-i or at .raiding of various chemical concept a especially in area of physical chemistry require a of chemistry* mathematical background#
Teachers response as to tho degree of usefulness.	% responses
Numbers \ 100 °/o [\	l Mathematical areas !Most j [Not ___ jjJsofi Of JJseful {Useful
Algebra Statistics Graphs Trignometric [function | Permit at ions I Sequence and. Series ‘ Binomial Differentiati on Integration Probability i 16.67$ wanted determinants added	1iw/t’ , . j, [C6.67 | 33.33 ; f100$ i - - !> I! ■ » * '66.67 (16.67 (16.67) 16,67 !16.67 I 1 • | 66.67 i - j16.67 i 83.33 j - 133.3 3 ! 66.67 10055 j - ! 1005* K-5. - J |83.3
Topic/s to bo added	Comments on - mathematical background was a I .fnnctJ.oii ... of their ormanco in chemistry iper.f H
students performance in chemistry vis-a-vis their ability in Mathematics. Lecturers indicated that students? - had J very poor performances in the mathematical aspects of chemistry, - with a good mathematical background more often than not did bettor than those without good mathematical background especially in physical and practical ch orris try. - of 33 i ol ogy/ chemi stry c ombina ‘c i ons v/oro below average while Physic/chemistry and Mathematics/chemistry students were on the average with some above average*	

Section in questionnaire	They stressed, the need for chemistry teachers to take up the teaching of mathematics*
Oth e r re lev a comments Response:	40$ wanted the supplementary mathematics to continue as part and parcel of N.C.E. chemistry syllabus,
00% of the lecturers indicated that uniformity in giving tho instructions affects the efficiency of the course.	60# suggested that students taking chemistry as a major must be mo.de to have a credit in mathematics while the minor students must have a pass in mathematics*

Prom the analysis of the lecturers questionnaire, it can be seen that all the lecturers agreed that a hotter understanding *of* various chemical concept,:-? requires good mathematical st anding •

They further went on to identify the mathematical concepts needed for the various areas of chemistry,

(see Appendix

The order of mathematical usefulness was given as: Sequence and sense Binomial /_ Trignometric Functions — Permutation /_ Statistics /., Integration /_ differentiation f_t Graphs /_ Algebra Numbers.

The identified topics most useful to the different aspects of the course were given as:

Organic: - numbers, algebra, graphs, permutation and statistics

Inorganic: - numbers, algebra, graphs, statistics, integration and differentiation.

Physical: - differentiation, integration, trignomtric functions, algebra, numbers, graphs, and binomial•

Table S

■Analysis of Students Rosponsos:

Questions	..Ro	r3 pons os
lias supple~ mont ary mathematics in of studying chemistry helped	Yes C7."5?	1 2 ‴ H7^o i ^, j/ ″
Reasons for above	They all agreed that supp1ementary mathematics has helped in aspects of physical chemistry, kinetics, volumetric analysis, plotting of graphs especially v/ith fractional figures and the deduction of relevant inf orniat i on fr orn graphs, data, formulao otc.	Would have helped but did not due to-.the following reasons: (i) The timing was not suitable. (ii) Supp 1 omcnt ary ma-thematic was not taught in confor mity with mother iat i cal asp e ct s of chemistry. (iii) The lecturers assumed too much

r mt - r ~~ <*,- «» ••■i.V'*'

Table G (cont'd)

JMat hemat i c *t*il j Areas	Moat Useful	Useful	ITot Uscfu
Indication of jtTunbors	35?!	! 50#	15/5
us ofuIncss ;Alg ebra	4-5.555	I 36*4#	18.155
with respect «Statistics	11.195	I 33.3#	55.655
to the study {Graphs	70$	30#	055
of chemistry. 'Trignomctrie			
j Function	26.355	31.6#	42.155
| Permutation	5/5	40#	5555
Sequence and			
jj Scries	9.3053	31.25#	59.3755
(Binomial	8.755	47.3#	43.555
jIntegration	7555	20#	555
jDifferenti ation	5555	30#	1555
1Probability	4.055	61.9#	33.355

is a

the course0

Sat is-
faction
v/ith
instruc-
tion

4~~ ■

Probability Scquonee and Series Differenti at ion logarithms and Indices			
There need to revise!			
Yes 100%	No -		
13.3%	86.7%		

T ab 1 c 8 (c ont ' d)

	Areas	Ranking
Ranking 1 in order! of j applica- bility		1si-12nd! 3rd! 4th feth j6th }7th bthj 9th hotll 11th
	Numbers	
	Algebra	
	Statistics	
	Graphs	
	Trigonometric	
	Function	
	P ermu.tati on	
	j Sequence	
	i Binomial	
	Different!at:	
	Integration	

Ranking order was.

Integration * Graphs > algebra-^ number ^ differentiation

I statistics"^ binomial'^? trignonotry'^> probability | p ermu t at 1

on so qu *o* nc c.

General j Most students saw mathematics as very useful but some students Commentqj felt that they had not gained much from some aspects of tho on j course. Belov; wore the reasons and suggestions put forward,

choice. \ (i) some lecturers openly discourage biology students ; in physical chemistry and did not attend, to their problems.

J (ii) j Lecturers assumed too much background knowledge

Their (iii) mathematics lecturers loft at the middle of the term and no one was brought to take up the remaining t opi cs.

T *i* ibl g 8 (*on* t ' *d)*

Questions	Responses
	(iv) Tho timing was not convoninot for classes were schoduled at tho end of tho day, when overyone was tired v/ith tho result that moot students did not turn up,
	(v) Tho mathematics wore taught without adequate examples resulting in lack of und or starling and application to problem situations*
Suggestions:	To this end, *bhe* students gave the following suggestions:
	The course should.-start from fundament al as most students did not do well in 0 Level mathematics.
	(i) Lecturers should take car© of individual differences, and more attention should be given to the biology students.
	(ii) The physical chemistry lecturer should bo charged with tho teaching of supplement ary mat he mat i c s,
	Alternatively the chemistry department should seek help from the mathematics department,
	(iii) The course though compulsory should, form part of the continuous assessment and not a necessary condition for moving to another session.
	(iv) More periods should bo allocated, for supplement ary mathematics and there should be at least two period, a week.
	(v) The mathematics should be taught v/ith application to specific areas in the chunistry syl1abus «
	(vi)
	(vii)

l[1] rib I e 8 (c ont' d)

Quostions	Responses
	(viii) Adequate assignments should bo given as a way of helping tho students*
	(ix) Textbooks should be designed or written for supplement ary mathematics with respect to chemical concopts to enable students to have a clear knowledge of the main purpose of the c our so*

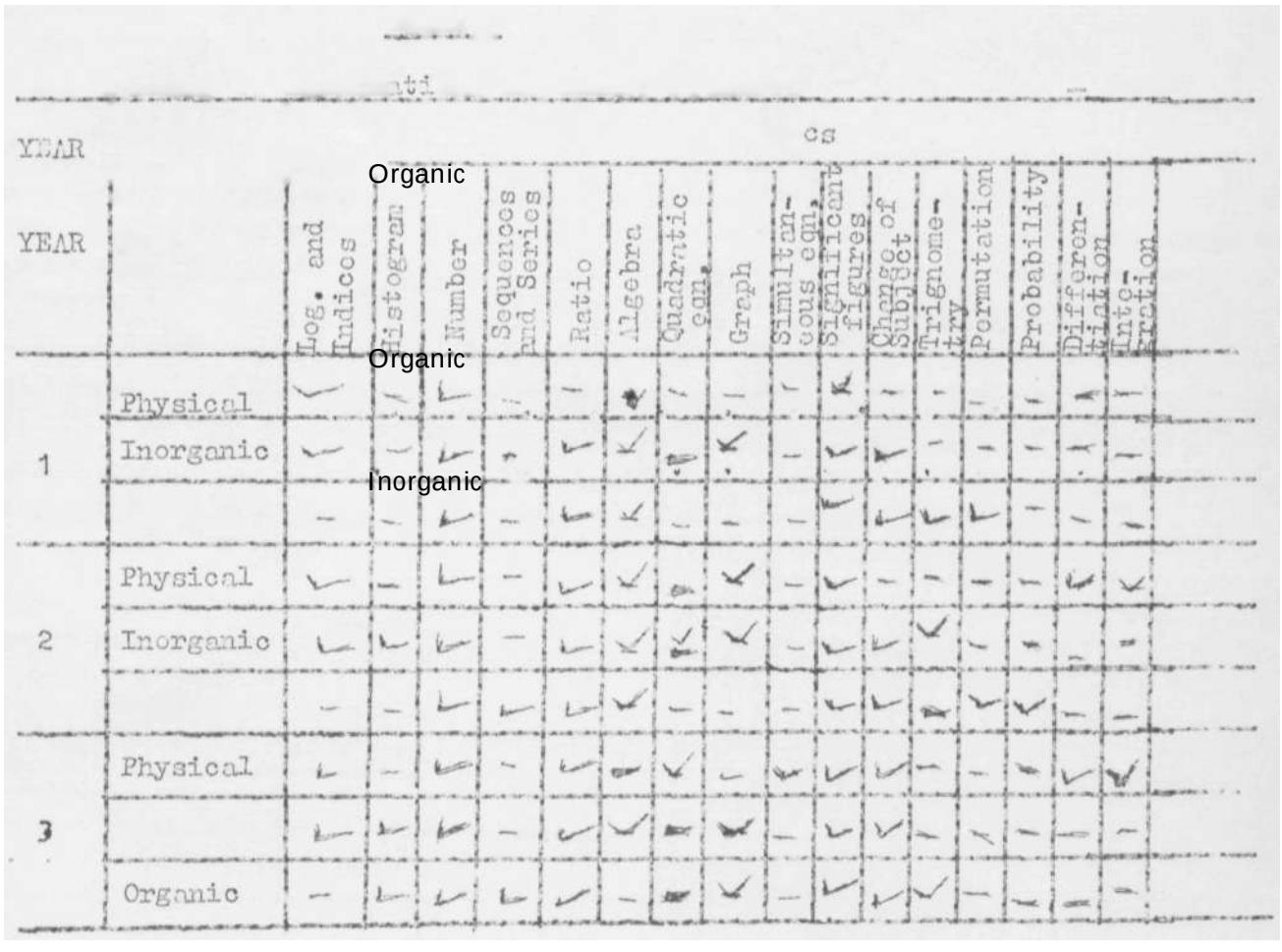
Table J)

Summary of Mat hem; jAreas of | j Chemistry J----------~~~r

cal Knowledge required

Mathomati cal Topi

Areas of Chemistry



SUMMARY, CONCLUSION AND RECOMWDATIOHS

5#1 Summary of Discussion ..Result

The analysis of data showed significant correlations between soores in supplementary mathematics (Part I, X3, II X4, and tho mean X34) and the various branches of chemistry in Parts I, II, III and final W.C. 15, III results* (See tables I, II, III, IV and V).

The trend held was Inorganic chemistry ^Physical • chemistry Organic chemistry.

The result has shown that:

(i) a student who is good in supplementary mathematics will in all probability do well in the different areas of chemistry. This w^s in accordance with most research findings that stude.its v/ith good mathematical background do well in the sciences, Derek, 1973? Gupta, 1980; Kalejaiye, 1979; Lav/son and Renner, 1975; Hudson, 1975; Malp as, 1973; Newsbury, 1966; We bb, 1975; and Rouvray, 1974.

(ii) The pre-entry mathematics (W.A.S.C. mathematics) was fundamental and forms a basic for supplementary mathematics programme and is not in any way a substitute for supplementary mathematics. Table II shows that W.A.S.C. mathematics (s 1) correlated with only physical chemistry I (X5) indicating that supplementary mathematics was different from the secondary school mathematics.

(iii) Though a significant correlation was obtained generally, as shown in the tables (I, II, III and I V) , tlie reverse was observed when physical chemistry Part II (28) was correlated with both supplementary mathematics I and II,

In fact physical chemistry I (X5) did not correlate with anything on the data matrix (table I I) . A look at the syllabus (see Appendix 3) shows that Part l'l physical chemistry involves mathematics in areas like, enthalpy, thermodynamics, nuclear chemistry etc, but not as much fundamental mathematics as is required for physical Parts I and III. It could also possibly be due to some mathematical concepts not covered in the course.

Research has also shown that students generally have problems with physical chemistry due to their inability to cope with the calculations involved (Lawronz, 1976).

(iv) Also tho regression results (Table V, VI) s'! how that tho overall performance of students can bo predicted from the Part III sessional and Part III final cert if icat e ciauninati ons •

In addition to the analysis of tost scores an attempt vrao made by means of quostionnairo to ascertain the reactions of tho groups involved (Table 7 and 8),

From the students responses it was obvious that supplementary mathematics has indeed helped their study of chemistry as reflected on the Tables (III and IV), Rcsearchers had indicated a positive effect of mathematics oil the study of chemistry, (Renner, 1970; Webb, 1975; Derek, 1973; I-lalpas, 1973; Newsbury, 1966; Rouvray, 1974; Lawson wd Renner, 1975.)

But things do not always go so smoothly for all students, though the supplementary mathematics did in fact help students generally* The main problem they had seemed to bo associated with:

(a) wrong timing of the supplementary mathematics programme,

(b) relevance of the supplementary mathematical concepts taught with the chemical aspects. The researcher is now of the opinion that relating supplementary mathematics to chemical concepts will aid understanding and result in students bottor performance, This idea is in line with those researchers (David, 1975? May, 1972; and Duffin, 1976) who had indicat ed that the degree of relevance of mathematics to science concepts did influence students performance*

(c) Inadequate and insufficient examples, this was confirmed by Nigel (1975) whose study indicates that the lack of ability (as tho teachers see- it) is to calculate and manipulate and this ho attributes to insufficient examples especially simple examples related to the science areas,

(d) Poor background in W.A.S.C, mathematics, this has an impact on students

understanding of chemical concepts especially as most students are victims of poor staffing in the secondary school, Shis was evidenced in oho study of Rouvray (19C0) who indicated that the major drawback . in the development of mathematics was an inadequate mathematical background which resulted in a lack of initiation and pursuit of novel ideas#

The students therefore suggested among other things that:

(i) Physical chemistry lecturers should be made to teach, the supplementary mathematics, This suggestion according to tho researcher indicates that students find physical chemistry more difficult than ether branches of chemistry due to the mathematics involved and they fool that when tLu, physical chemistry lecturer handle the mathematics their understanding of both areas will bo facilitated,

(ii) There should be an allocation of more periods to the study of supplementary mathematics in contrast to the one hour a week being observed now. The rose arc-- or is also of the viow that if the periods could bo scheduled for morning hours when tho weather is cool and the studont3 are still fresh thoy would bo more alive and participate more- than when thoy arc already tired, as thoy arc in tho afternoon or evenings.

(iii) The application of supplementary mathematics concepts should be made to specific areas in chemistry to aid maximum understanding[9]

(iv) Physical interaction and the looming environment 'should be improved. Those two conditions wore mentioned by Dubley (1930) and Lawrenz (1976) as factors affecting the mathematics - chemistry relationship.

In addition to the analysis of students responses, tho responses of lecturers were analysed too.

The analysis indicated that supplementary mathematics was necessary for the understanding of various areas of chemistry. This was in agreement with tho students opinions. They rated students with the chemistry/physics and chomistry/mathornatics combination highly and concluded that students with a good mathematical background did very well in physical chemistry and practical work,

They associated students problems to a poor mathemr/fcical background. This was in accordance with Hudsons' (1975), findings.

The students/lecturers ranking of mathematical concepts in order of usefulness or effectiveness revealed that numbers, algebra and graphs wore highly rated.

This is in accordance with most rose arch finding s that chemistry at tho studied Ic-vol does not require deep mathematical cornpotoncc but requires simple mathematics like a knowledge of ratios, numbers, proportions, percentages, cross multiplication, standard form, indices and logarithms, lino,or graphs, simple algobra and calculus, and trignometry, (Hudson, 1075; Scott and Walkondon, 1975; Malpas, 1973 etc.)

5*2 Penelusions

This study was carried out to find out whether there is any correlation between performance in chemistry and supplementary mathematics. This study was limited to A.T.C, Zaria, Reference were made to records, and, correlation between supplementary mathematics and various branches of chemistry was calculate d.

From this we can predict students performance in chemistry from knowledge of his performance in mathematics.

Extensive writings have been carried out on how students are often handicapped through tho chemistry course by tho difficulty of carrying out particular arithmetic operations involving #, decimal calculation otc.

There seems to be a unanimous concensus of opinion rnons roknowned chemists that chemistry is a science built on tho foundation of experiment and experimental observation into v/hich mathematics superstructure must bo correctly integrated.

Several papers have appeared in science and educational journal concerning mathematics/science; mathematic s/chemistry etc. Many have been completely negative, merely suggesting that a deterioration of the ability of students to make simple calculation has taken place (Rinnor 1970) *

Some suggested introducing mathematics course at an early stage. Some others even see mathematics as a bridge between gathering knowledge and the formulation of chemical theory Coulson (1974).

This view is in line with researchers opinion that the language of mathematics is extremely useful, for students can use it effectively in tho formulation and presentation of concepts in chemistry. The process of forming concepts is one of the most crucial in the learning and teaching of chemistry and science. It is therefore important that all possible methods of improving it must be explored.

It is hoped that part of the students problem will be over or will even disappear as more of them are exposed to supplementary mathematics following the revised supplement ary mathematics syllabus enclosed in the appendix 3 with, relevant ohemi s t ry e xarnp 1 e s.

Finding has shown that to provide for the need of students, the mathematics in the first year should include logarithm, indices, simple algebra, statistics sequence, series ratio, proportions, graph, use of formula, and substitutions.

This is because these mathematical ideas occur very often in chemistry lessons and seer.; to bo the most important group of mathematical ideas am* skills, required in chemistry (table 9)* It is therefore necessary that chemistry tochers should have some competence in teaching mathematics v/hich they need especially if there is no co-operative mathematics 1'eacher available,

This is important as a c'...emistry teacher who can supply all the mathematical needs of his science students will be able to stimulate the students to higher achievement *

The researcher has tried to rather all tho essential mathematics which the chemistry students need in order to appreciate the quantitative aspect of his chosen science, (Table 9)

I'rom the correlation of W.A.S.C, Mathematics scores (X1) with supplementary mathematics scores (X3) , it can be seen that any mathematical knowledge that the student has previously learned seem to he divorced from the chemistry and mathematics he is at present studying, (Table II),

It is hoped that the present work will do mu oh to effect a happy union between the two courses by constantly applying concepts, (see revised supplementary syllabus in Appendix 3), Problems of students with respect to mathematics in chemistry is widespread and. factors which limit the attainment has been described, viz students responses (table 7),

A possible link connecting this has been outlined.

(Table 9 and Appendix 3).

The most important conclusion is that our teaching method are still not good enough until some of tho suggestions arc put into practice.

There was a high correlation between supplement ary mathematics and the various area of chemistry in Parts I, II,

III and final IT, C. E« results.

It can. be seen that supplement ary mathematics knowledge is necessary for the study of various branches of chemistry.

The principal aim is to increase awareness and practical experience so as to develop students ability to solve unfamiliar *problems*, for mathematics can be user! even to surmarize so many concepts by a single equation.

This is why tho mathematical problems should bo rooted firmly in chemistry since thuir relevance to the students main subject gives them the interest and motivation essential to developing problem solving *skills*.

In solving any problem, the initial perception may not be far from complete but must be sufficient to enable students to formulate the problem correctly and propose methods of solving it. This approach is also recommended, by some psychologists *like Gagne**, Ausubel and Piaget who by emphasising the meaning-fulness of material to be taught, suggested that work should be planned by selecting ideas which students are familiar with and then linking -them to new ideas. The only way knowledge is acquired

is when one possesses certain prerequisite pieces of knowledge. This is why the supplementary mathematics syllabus starts with numbers which students are already familiar with and then gradually novo;" to ot'hur connected concepts* (see Appendix 3)

It is therefore sufficiently clear that mathematics at tho studied level require simple algebra, graphs, numbers, and simple calculus to handle the kind of problem emerging from the N.C.E. chemistry* (see Table 9, and Appendix 3).

Table II, shows that as early as the first year tho offeet of supplementary mathematics programme starts manifesting itself in the chemistry results.

There was a high correlation between scores in supplementary mathematics I and II, and, those of various areas of chemistry in Parts I, II, III and final I'T.C.E. results*

Tho effect very pronounced in the students Part III ohemi st ry re sults *

The highly significant correlations shows that students who do well in supplementary mathematics will perform well in chemistry/mathematics related problems and will have, no difficulty in tho course.

It can therefore bo concluded that an understanding of supplementary mathematics programme would greatly help in the understanding and appreciation of chemical concepts in addition to their other course combination.

We can also conclude that students who have completed the supplementary mathematics programme may enter for a degree course directly without fear of an inadequate mathematics ■background for such topics as differentiation and integration, needed for higher level chemistry have boon covered.

Tho students and teachers responses (Table 7 end 3) uphold tho above viow and thoy have also listed ways of improving the programme. All those views seem to point towards the need for co-existence and co-oporation between supplementary mathematics and chemistry taught, so that while the chemistry teacher is teaching chemical thermodynamics for instance, tho mathematics teacher should concentrate

on linear and quadratic equation, integration and differentiation of functions to aid transfer of learning.

This idea has been talc on into account in the development of tho ik;v» supplementary mathematics programme (see Appendix 3#)

Table 9) shows some areas of mathematics which \nust be familiar to a student who wishes to follow with profit the chemistry course in Advanced Teachers College leading to an IT.C.E. Certificate.

On the basis of the above we can conclude that thoro is a justification in including supplementary mathematics in the chemistry programme and recommend that all other A.T.C.*a should do the same using this study as a guide.

Prom the findings therefore it seem reasonable to encourage students to think more about the problem of formulation and loan about formal manipulation ospecially in regard to real problems' and to point out that numerical methods give great scope for reaching a greater understanding of the physical system*

5*3 Critique

The sample of 32 subjects used, for this study v/oro A.T.C. Part III chemistry sti'dont s. The sample may appear small but when compared against a background of Piagets 3 subjects or Hochborgs' one child study, the number could bo considered large enough.

Also chemistry is one of the few departments where students number is so small compared to other departments*

The sample was selected from tho particular school offering supplementary mathematics programme as a compulsory course for its chemistry major students in

addition to their other course combinations*

Since a particular school is used there v/ill not bo mu cl. variation in tho nature of instructions received by ' students# Therefore this was the only school to tho best knowledge of tho rosearcher mooting tho requirement for tho study.

5*4 ImpAi, cation

As of now, chomistry and supplementary mathematics are taught independently and as on related discipline and therefore

tho Institute of Education, Ahmadu Bollo University should bo well informed of tho relationship an encouraged to integrate the so.

In rocruting chemistry staff therefore, preference should be given to those with combinations involving mathematics.

In the school, supp 1 orient ary mathematics should bo taught by some teacher* If not possible, co-operation should exist between the chemical and mathematics teachers to enable transfer of knowledge*

This study could bo an inspiration for other teachers and schools in other science areas to co-opcrato and work out a feasible curriculum or instructional material for tho effective teaching of soienco.

The Institute of Education should therefore adviso all other A.T.C.*s to effect tho result of this study.

5*5 Recommendati ons

The objective of this study was to look into tho mathematical requirements of those taking chomistry coursos at 3ST.C.E. level and to make recommendations for improvements.

Table 9, shows the range and type of mathematics required by those students* On tho basis of tho study tho following recommendations aru put forward.

(i) There is a need for a better system of retrieving data and records* This will play an increasingly important role especially with refer .nco to students personal files*

(ii) There is also a need for sono contact v/ith rose nr ch- typo work to ho introduced as early in the course as possible.

(iii) Laboratory oasporimontal v.ork, involving calculations occurs at tho start of tho course raid for this tho first three mathematics topics should bo dovotod 'bo use

of logarithms, choice of units, theory of errors otc. so that right from tho beginning the students nay appreciate tho importance of those. This would bo followed by some easier mathematical theory, its significance in chomistry problems emphasised, and this will prepare tlu ground for the teaching of more difficult topics like differentiation and integral calculus.

(iv) There is a need for interdisciplinary communication (chemistry syllabus devised v/ith rospcct to tho sequence of tho mathematics syllabus) to avoid tho cry :?why have not they done decimals, proportions, ratios eta", (Appendix 3)«

(v) There is a need for exchanging information about chemical education and particularly for tho publishing and. republishing of suitable source books.

(vi) Another variable, but time consuming oxcorciso, is for tho teacher to make detailed notes on an application of mathematics to his subject as it arises in tho course of his teaching and thon aslc tho mathematician for a written, commcnt on the pro sent at ion*

(vii) A new small working party of mathematicians and chemists should bo set up to study mathematics needed and used by chemists. Tho intention would bo to write, validate tho the classroom and eventually publish students and teachers texts and other supplementary materials for the teaching of mathematics to chemistry students.

(viii) As a first step, a group of interested lecturers should develop a field test study skill programme for INT.C.E. chemistry/mathematics students nationwide*

Seed and Mathew (1970) emphasised T'teacher quality rather than academic ability". They believe that our task is impossible and capablc of 110 solution if it is thought that p. mathematician can mathematically educate our students.

Tho investigator is therefore suggesting that in addition to tho afore/mentioned.

(ix) A reasonable system of inservice training should bo established for the chomistry teachers to bo able to provide materials needed and. also to got chemistry teachers who can v/illin.gly teach supplementary mathematics*

(x) Other science areas like biology, physics etc should .also look into the mathematical requirements of their students.

Also certain activities should he oncourgcd,

(xi) Joint mooting of chomistry and mathematics teachers to establish how the mathematics required is to bo presented, the common problems encountered by teachers and therefore contribution towards easing them.

(xii) Seminars to bo organisod where tho mathematically inclined chemistry teachers chemists or mathematicians sympathetic to chomistry should speak.

From the following discussions and suggestions so far the following research recommendations are made,

(i) Future research in this aroa could compare tho performances of chomistry students with raspect to their various course combinations e.g. chemistry/ Biology, chemistry/physics, ancl chemistry/mathematics,

(ii) It may be interesting to find ou.r whi«h homo background factors hinder or facilitate.progress in

mathematical aspects of chomistry.

(iii) For too long now, mathematics for chemistry students has been virtually left to tho mathematicians. Ii* wo are to reach an understanding of tho ways in which students work could bo made easier and relevant, tho chomistry teacher has to find, a way to link the chemical concepts with relevant ureas of mathematics.

(iv) It could bo possible- that tho differences in students achievement wore not entirely due to the matheriaticg course factor, other possible factors from several other sources should be investigated.

(v) It would be equally important to explore tho considerable overlap between mathematics and other disciplines like physics and biology.

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AjK^n.djLx JEQUEST I OMAI&a ?0R LECTURERS

Lear Sir/Mad an:

An investigation is being carried out into the relationship between T-i at hematics and the different areas of Chemistry, It would he highly appreciated if you could complete tho attached questionnaire. Attached is a copy of the Mathematics syllabus.

Section A: Personal Information

Aroa of Specialisation: ___

Teaching exporionce:

Which area of chomistry do you teach: - Organic /_____/

Inorganic /__/ Physical _____/

VThioh year do you teach: Year I / Year II J

Ye.ar III /

Section B:

1. Is tho supplementary Mathematics course relevant to your students understanding end appreciation of chemistry.

Yes *L_J* I'To If Yes, to the above, how is it relevant?

If No, why is it not relevant?

Identify aroas/topics in tho cttachod syllabus most useful to your aroa of Chomistry?

3* Which topics could be omittod?

4* What additional topics could ho added to tho supplementary Mathc-mation syllabus?

5. What aro your general comments on the performance of your students in chomistry,
vis-a-vis their ability in mathematics?

Are there any other relevant comments you wish to pass not specified above?

Chemistry A.T.C. Stua0.ntj3. Q.'!lestionnalro
regard in// the suppl omont ary mat homat 1 c s .0 our go.

A11 investigation is being carried out to look into ways of improving chemistry instruction with regards to supplementary mathematics course. It would bo highly appreciated if you could oomplote the attached, questionnaire. Attached is a copy of tho supplementary mathematics syllabus.

1. ITar nc
2. Sex:
3. Are Yes /–7 110 /–7
4. Are

5. Has the supplementary mathematics course ^ono^rallj; helood you in tho study of chemistry? Yes Ho

(a) If Yes, to tho above, c,vl you give reasons.

(b) If Ho, to tho above, con you give reasons,

G, With reference to tho syllabus, can you identify'those areas of supplementary mathematics that wore most useful, Useful, Not usefull to you in the study of chemistry.

		Most Useful	Useful	Not IJ_seful
0.01.	Numbers			
6.02.	Algebra			
6.03.	Statistics			
6.04.	Gr aph s, V ari fit i on Am c t i on al i t y			
6.05.	Elementary T r ignn omt r i c Functions			
6.06.	P e rmu t at i on s and 0 ombinati on s			
6.07.	Sequence and Seri			
6.08.	The Binomial Theorem			
6.09.	Di ff G rent iati on			
6.10.	Integration			
6.11.	Probok.il ity			

(b) Could you rank the abo 0110 to the least usefu 6 * 07 ..... 6.10.

from r»ocrt us-ef'nl as number
o oming 1 *cat*q . 6.02.....

7. Are there any specific mathematical topi c*s or concepts which you do not think are adequately conorod to 7x>lp you in tho study of chemistry?

8, Would you liko to coo tho supplementary mathematics courso revised?

CJJCJJ

9« Are you satisfies with the way this course is tau;.:ht? Yea // No £'^7

the tho t.<^chin£ of this course?

10. What suggestions can you nako for improvement of th*

1 .

2.

3.

Thank you for your cooperation

Appendix II

CHEIvIISinY DE^AI^HENT

ADVMCI5D TEACHER* S COLLEGE
/#1ADU B^LLO ' UN^iyglgIj?
Y Z A R I A

S>1EL*U^ J1ATCT.1ATI_CSFOR CHEMISTRY IJAJCR
STUDENTS

1. TONERS:

(a) Scales of counting in different bases (base not greater than twelve). Conversion from one baso to another.

(b) Fractions, decimals including approximations and significant figures, no ailing of ratio and proportion; calculation of average and percentages. Significant figures and their relation to acouranoy of data or experimental rosuIts.

(c) Indicos, Lor gar it liras and surds:- The relations between logarithms end indices, arithmetic of curds in simple cases, How to use coma on logarithms, squares and square roots.

2. ALGEBRA:

(a) Evaluation of algebraic expressions; change of subject in a formula.

(b) Common factors. Simple equations and simultaneous linear equations in two variables. Solution of qu ad r at i c o qu ations.

(c) Manipulation of simple fractions with monoi.rial donominators

(c.g. £+J£ " lit.x)

' U. V uv

(d) Linear equalities in one variable.

3• STATISTICS

(a) Presentation of data by pie and bar charts. Arithmetic moan, aedian. and mode (excluding grouped data) • Calculation of arithmetic mean for a given sot of numbers. Finding the median and mode for a sot of numbers.

(b) Frequency distribution and Histogram,

4. GRAgiS^ VARIATIONv ffUITCT 1 QUALITY

(a) Graphs from numerical and statistical data (drawing and interorot ation),

(b) Translation Into symbol a of relations such as ;$y_{o;;}$ is inversely proportional to $x^{!M}$y varies . as x^ , and thoir illustration by sketch graphs*

(c) The idea of a function of a variable and its graphical ropresent ation,

(d) Graphical treatment of tho functions y - CX, Y - BX^ + Cx + D, Y = D (x - o).

(o) Elementary rectangular co-ordinate geometry of points and linos, Distance between two points and midpoints of a line segment. Equation of a straight lino in the forms: Y « mx; Y-Y = m (x - x) and ax + by +.c = 0,

(f) Graphical representation of linear inequalities in two variables,

5, ELEMENTARY TRIG-ONOlfCTRIC. JUNCTIONS :

(a) Definition of the sine, cosine, and tangent of an acute angle, Tho properties of vertically opposite and adjacent angles,

(b) Circular measure of angles. This should be restricted to angles between 0 and 360 (02 radians) inclusive,

(c) Trigonometric ratios of 30°, 45° 60,

(d) Use of the formulae for sin (A-B) and Cos (A-3)

6• ™^-JATI0Ij[S AND .COMLJjIAJ'IONS

(a) Arrangements,
(b) The factorial Notation,
(c) Permutations,
(d) Combinations,

'< • .SEQUMCES Aim EH I EG

(a) So qu one e s, Arit hmet i. e al pr ogre si on,
(b) Geometrical Progression,
(c) Formulae for A, P.s and G, P.s.
(d) Arithmetic and geometric moan.

0• THE BITOjlAL. THEOREM

(a) Pascals triangle
(b) Tho binominal theorem,
(c) Convergent series.

9 • DIFFERENT I,AT I PIT

(a) The idea of a limit; informal treatment by examples#

(b) The derivative of a function - its moaning and its determination fron?first principles, in simple cases only, c.g, x".

IP

(c) Differentiation of ax' and their suns and differences for integral n. Gradient of a curve (determined by different iat ion and drawing) and its meaning. Curve sketching, turning .points (maxima, and minima only)* applications to problems involving small changes and rates of change and to linear kinematics.

10. INTEGRATION

(a) The definite integral end its representation as an areal

(b) Approximate evaluation of integrals - Trapezuim Rule only,

(c) Integration as the inverse of differentiation. Applications to linear kinematics (calculus and graphical methods) and simple problems involving plane areas and volumes.

(d) Integration of ax^{11} for integral n and of sums and differences of such expressions.

11. PROBABILITY

(a) Simple problems on probability involving both equally likely and non-equally likely events.

(b) Sun and product laws.

(c) Simple cases of conditional probability.

Appendix HI

CONCEPTS, AND

REIAT5J3 Yo ar I

… ….. "T ….. .		Physical Chemistry	Aspect cf M athemat ic s ro quirod
------ toms and olocules	1.1	El orient s, c omp ounri s and mixtures	Numbers
	1 2	Dalton's atomic theory and later dofications	ITumbors
	1.3	Laws of chemical combination	Numbers
	1.4	Atomic mass based on 12	Numbers
	1.5	Determination of relative atomic and mol ocular masses by mass spectrometry	
	1.6	Atomicity	Numbers
		Av o gadre's c onstant	Indices
	1.8	The mole concept emphasised	Numbers and Indices
it onic tructure	2 1 ..1	Electrical nature of matter. The fundamental particles.	
	2.11	Evidence from electrolysis, discharge tubes and thermionic emissions	-
	2.12	Electrons - tho work of J.J, Thomson	
	2.13	Atomic number, Experiments of Mi11ikan, Ruther ford and Moseley	
	2.14	The neutron the work of chad- wick.	—
	2.15	The position and the meson	-

1“ I		
3.1	Iootronio energy levels, Bohrs postulates*	
‘ 3.2	Arrangement of the electrons j in theenergy levels.	
3.3	Quantum theory, quantum numbers and the exclusion principle	
	3o4 *i*Shape and symmetry of S and P a orbitals.	
3.5	Periodic lav/ and table	
	3.51 Relation of filling of jorbitals to their energy and]position in the periodic jtable	
	ij 3.52jThe periodicity of electronic structure leading to periodicity of properties such as atomic radius and, ionisation energy.	
States j of natters	Gases, Pressure, Volume, and 4.1 jtemperature relationships	
	4.11 Boyle's 1aw, Charios' law ab solute t emporaturo j S c al e, Dalt on¹ s 1 aw, jGraham's law, Avogadro²s ı ^ lav/, MolecularVolume,	Humber;
; 4 *i*	jgoneral gasequ ation PV=nRT] j	Numbers
	j 4.12]Kinetic Molecular theory J j and application to gas laws	
	jj 4*13j Real and non-iooalgas I contrasted. Deviations from ideal behaviour and Vandor Waals* equation of state	Numbers
.1	ij	
	j 4.142 Liquefaction of gases - \ j continuity of state and the critical state	

Liquids as intermediate phase S between gases and solids J

4*21! Boiling point and freezing | point- latent heat

Numbers

4.22 Viscosity and surface tension

Numbor

4*3 Solids.

j 4.311 Lattice structure, atomic j and ionic radii, interi- \ j onic distances

! 4.32^ Molecular nolids

4.33 Extended structures sucli as two dimensional structures such, as graphite

4.34. Interstitial structures e.s. | hydrides raid err hides of j some transition elements > *i*

4.35 j Is on or phi sin

Acids, j 5.1 bases and Salts

5.12 Behaviour of electrolytes

5.14 Tho nature of strong and we ale 01 e c t r o ly 10 s

Nature and structure of wat or

.13 Evidence for electrolytes versus non electrolytes

3.0/t ar i t lim and number

5.15 J Evidence for strong versus I wo ale electrolytes from: j Colli{;ativo properties of <| solutions

5.151 Heat of neutralisation 5*152} 0s-trv/ard.'s dilution 1 aw 5 >> 1531 Molar c onduct ance

Number
Number
Numbers

i

i

5.2 jConcepts of aoidos and bases

- Arrhenius
- Br on s'10 d - J j ovjry
- Lcvd..:

Year II

	j j Physical Chemistry -u.	r	Aspect of M athomati os re qu ir od
Ohomical bonding	j Forces v.dtlml tho molecules ! | Rol at ion ship bo two on typo of* j ii bonding and tho properties I ? o *f* snbst ancos.		Humbers, Algebra
	1.1 *t* Eloctrovalont (Ionic 3 bonding) /		
	1.11 j Ionization Energy, Eloctron j affinity, Polarizability of j j anions, Polarizing poy/or of j J cation		iJunbors, Algebra
	1.2 i Covalent bonding		
	1*21 J Overlap of orbitals, j including hybrid orbitals j (S' 3, s. 2, sp) orbitals and I P P electron pairing I		I'Tumbor s
	5.22 j Po1orization of bonds; diodes		
	1,23 Co-ordinate bond 1,24s		o £ sub j o ct binomial expansion.
	Bond anglos/Lengths »	Nur.bc r s	Numbers
	1.3 J M c t al1i c b onding *t*		
	1,4 5 Hydrogen bonding		
	I !		
	1.5 | Valid or Waal s' forces		
Energy offoctj	2.1 i Thermochemistry: Sign ! convention.		
	2.11 Enthalpy changes, heats of j i hydration, solution and ! j noutrailcation		
	2.12J Hess lav/s and applications ' incalculaticn 3		
	ITumbcrs		
	Signs, units, minbors, algebra		
	proportions, summation add i t i on, su bt ract i ons d i*x*feronti at i on chang o		

	■T jj Gen 01" c.1 illusoration cyclic J process of Born--Haborcyole i j p.13] Bond dissociation oncrgies. *I ,* Their use		in cal cu 1 at i on of hoat s of rcaction. Numbers, Algebra and Graphs, functionality variation.
	£.14 ! Use of onthalpydate for *i* j predicting s'oontoniety of J reaction < *t*		
Thermo- dynamics	^.2 jj First lav/ of Thermodynamics *'.21 | Second lav/ of Shormodynaciic i		Different iat i on and Integration (basic idea only),
Aleobra, numbe r s			
Proportiosp.1 of a quo or sj Solutions J3.2	▪ SoIntion oquilibrium Influence of pressure on solubility. Dalton's law of partial pressure Methods of expressing concentration		ionality,
	;3.3 4 I b.4 i b.5 Polar and non Polar solvents Raoults lav;		proportions, inter- ac t i on cr o s s mu It ip 1 iat expression Algobra, Numbers
	- Colligativo properties		number, intogration d i f f o r on t i at i on
Nudcar M.1 Chemistry *I* j	Radioactivity; stable and unstable isotopes,		1 og arit hri, ind i c o s proportions
	;4.2 Ilass spoctror.iotcr as tool for study of isotopes		Proportions
Mudoa r reac- tions	L Native of alpha, beta and gammarays Numbers and Algebra graph variat i on funct		Graph., L ogari thins Integration logarithm
	34.G Solar energy 4.4 Half life		
	Pr odu ct i on and u s e s. of radioisotopes e.g. 'C J4.7		Charact c'ri st ic of simp 1 e nulo ar rcacti ons•

	Physic;il Chord stry	*f*Aspcct of	0. 1 athomat ic s re qu ir ed
Chemical equili brium	5.1 ^Equilibrium constant and !properties e.n:#		1 ogarithmet ic
	\ *A.* G° =RTlilk⁰ where \ / \ G° and K° indicate how j far reaction may •proceed. *i* ♦	*V-**	Algebra
	(5.2 jLe chatelier principles	j 3 *i-J* •	Statistics

Ye ar III

Bohavioun of elec-trolytes	1,1 j Factors involved in soluli- ■ ility of ionic compounds | including lattice energy, j su.blir.ic.tion energy, « ionization energy and electron J i affinity.	b ; j	
	! 1.2 J Hydration end hydrolysis of ⌡ ⌡ ions		
	jj 1,3 * Complex ion stability constant I j I ⁵	5 • « s	
	j 1,4 * Solubility product common ionj effect	Humbers, quadratic J bases and their relation to ; 3	
	1.41 j Ioni sati on c onst ants of *i* acids and bases >a and kb	structure *i* formula, Indices \ logarithm and | Indices	
	r 1.42. Strengths of aoids and	proportions J and cross mu It ip li ca tion i i	
	1,43 3 Ionic product of water, The j concept of PH.	j Logarithm and i Indices,	
	1.44| Indicators in acid base i titration and in measurement 3 of PH. Use of calorimeter 1 for PH measurement	j Indices ! logarithms	
	1.451 Bufferj simple calculation to show how a butter solution of a given PH may bo j prepared	1*og*arithm and indices	

Phaso Equili brium	1	Tho 11 ondorson oqu ation.	water j (iv) aniline -rwater . !
	*46	Phase ulo	
	2.2	I Single conp oncnt systoras !?	2*31 j Solubility of solids in liquids ! solubility curves and deduction 'lumbers
	2.1	(a) wator systom- vapour prosrjuro diagram	
		(b) allot, opy as in sulphur | aid phosphorus	
	2.3	j MuIt iconponcnt systoms. jj M ixt ur o s o f 2 1 i qu i cl. s, mi s c i b 1 o j and immiscible - fractional j di s tall at ion end stc.im dis-) tIllation* Azootropic mixtures, tho following examples may bo jconsidered j (i) methyl alcohol + wator j (ii) othyl alcohol + wator j (iii) Hydrochloric acid +	Ratios and proportions
	2.32	Solid systems' alloy formation C omp ou nd fomnati on	Numb orc, Ind ices logarithm.
	.33	Dictribu I; ion of a solute between 2 liquid, phases. - Partition coefficient - associi it i on and dissociation - Partiti on chronet ography - Ad s orpt ion chroraatography and its uses. - preparation and properties of hydrophobic and hydrophilic colloidal systoins - olectrophorosis - stability ond precipitation of colloids	
Chemical Kinotics I	3.0	Sato equation - Distinction between molecu- larity and order of tho reaction. Number	

	T First faid s o c ond or cl or reaction factors influencing rate- simple collision theory end its use to explain tiio effect of concentration, t empcratnre Catalysis-1 aworing tho energy of activat ion.	Int e g r at i on and differenti ati on graph; Graphs, differentia- tion ond integration and logarithm
Rolox j roac- S tions p ! I	4*1 | J Exp 1 an at i on s of oxidation ond • reduction in terms of elect- i rons transfer. *i* 4.2 (Faraday's law of electrolysis ⌊- principles of electrolysis	- calculation / Numbers I ii Dimensions and Units j Indices (lumbers simple algebra
	4.21 | factors affecting tho product j Sinultoaoua equation of electrolysis \	
	4.22« Relation between faraday, *i* charge on tho election#	
	4.23| Molar conductance, transport \ number, kohlrauscb[1] s law E	Numbers
	4.3 Standard electrode ond red ox p o l; ent ial s, the electro-chemical series and sign convention	Numbers 1ogarithm
	4,31? Electrochemical cell K potentials as the combine- I tion of two electrode | potentials e.g. Daniel Coll#	Numbers Logarithm
	4.4 Corrosion of metals treated j from the stand point of \ electron transfer# Proven- j tion of corrosion.	

Inorganic Year I

		Inorganic Chomist ry	
			ASP energy*
PeriodicJ law and | PeriodicJ Table	1*1 !	Electronic energy levels, I evidence from omission j spectra, Bohrs postulates*	set of Mathematics »Jrl9.QHfeᶜA.
	1*2 |	- delation of filling of \ orbitals, according to j their energy and position h in the periodic table	Fractions, ratios, proportions, significant figures positive and negative int o g c i* s • EVGIU at i on of algebraic expression * Change of subject in a formula*
	*j ^	The Periodicity of electronic structure loading to periodicity of properties such as atomic i&dius and ionization	
Hydrogonj and hydrides	2*1 j	The chords try of hydrogen.	ii?S, 1101 v/ith those of first row elements
	2.2 |	Gradation of properties of first row elements leading to the gradation of properties of their hydrides	| Linear graphs 3 and Piccharts
	J	Comparison of the hydrides o sewndrow elements, particularly PE^, Properties of hydrogen halides	Line ar grap7 ıs and Pie charts
Oxides	3 * 1	Gradation of properties of second row of elements and their oxides	Linear graphs
		- Discussion to include acid*, and base character, the acidic and basic character | Logarithm of hydroxides being treated | in terms of its structure, particularly the size of charge of central ion.	J
	6*2 j	Comparative account of oxides of carbon (00 00), Nitrogen (!T₀0 MO, ITO) 'and *Phost)horos (i°3 ' W-	

Motall Extraction sy	1.0	General principles extraction of j metals based on rod ox series and J free energy chcn&c j form of occu- j ronco, distribution and methods of] concentration and smelting of ■ common cases particularly those ofj: ~ Iron ~ Aluminium - Tin - Gold - Copper	- Complex form at-ion - P ar ankgne t i 3r.i' " Linear graphs, ITumbers Evaluation of algebraic expression Hist ygrcun pie and bar charts
S~block Element ;	2.1 I!	A Group 1 * chemistry and extraction of sodiun and potassium	Some element ary trirnometrjr.#:
	2,2	Group 11^ chemistry, extraction of rlagnosium or calcium.	
d--block elements	I	First transition series, Eloctronic structure and its relationship to variable oxidat ion state, - Colour - Metal1ic prcportio s	
P-block El orient s	3 3.1 !	Yc/irlll Group II. S?8 K? Group S® Grouu .13 VII" - halogen and their compounds comparison chioridcs of the following elements of period III nc | Mg, A1, Si, P, S	Linear graphs and Pie Charts of tho I !

Molecular C onp o sit ion ! end Structure	i 9,1 (Purification of organic jcompounds		*structure Fractions, Ratio and. proportion, significant figure s, positive and negative intogrep, Evaluation of algebraic » expression change of subject in a formula.
	9.2	jDotoction of olomonts, jC, H, 0, IT, S_5 and Imtogons j i *i*	
	9.3	iDotermination and calculation. inf ftRinr'i nnl •I'nT'rail n .onrl iof emyiric al formu1a and	
	9#31	Isomerism |	Elementary trignomctry
	9.32	iHybridisation Sp, Sp2, Sp3 1	Permit a'i;ion and combination co~ ordinato goometry.
	9.33	j Classification of organic ;c ompounda, funoti onal jgroups, »	
	9.34	iNoraonclatv.ro of organic s c onp ouiid s (IUPAC) J	Numbers
j Hydrocarbon	10,1	jAliphatic */-* Alkrno jj - homologous series | " gone ral propcrti cs, preparation and rcactions - petroleum chomistry and oc onoralc inoort one c	Ratio and proportion Evaluation of algebraic expression
	10,12'	O^fin ' */ ~ Aikones J- General properties and i| preparation and roac- 5 tion mochanism	
Goonetrie Isomorion	10,3	*i* ~ Alkynos - Preparation and properties - ! Prilyricfcr'i srocbxon , Rat i o, pr< >p ort ion	Evaluat1on of | algebraic expression

Mochanism of organic roaction

2.1 j Inductive, stericoffect otc.

2.2 j Resonance

2.3 j Bonding, bond energies and boats

2.4 J Carbenium ion rc err ring omont

2.5 j Conjugation

; j

? 2₀b j Reaction mcchanism,

~ SM1, SIT2, El, *E2*

I i

<2,7 ? Free rodical chain and addition reactions

2*8 j Aromatic substitution and orientation effects, steric hind or o;ac o and reactivity,

Aromatic hydrocarboh

5 2*10 ! Benzene structure, resonance and aromaticity as exemplified by lengths, heat of combustion, reactions with halogen and hydrogen compared with similar reactions of the aliphatic hydrocarbons, The phenyl group as a functional gr...up should be emphasised

2,1011 Isomerism, Ivmologuos of benzene

2,102 'Theory of aromatic substitution

2.103 Sources and preparation of aromatic compounds

Hydrozyl Compound s

2.11 J Effect of OH* group on physical proportios hydrogen bonding, j

- Acidity of alcohols, metal alkoxides compared with phenols
- Basicity of alchohols, salt formation with Bronstod acids
- formation of alcohols Oxidation of Primary, Secondary and t e t i ary alc oho1 Industrial sources of alcohol ond uses

~ - E t ho r - p r o p ar at i on and p r op o rt i e jj - Synthetic polytncrrr, nature and us

Y nnr

bonyl "^3*0

Carbonyl c omptrand — J StrJi.otu.ro of c-rbonyl group; polari- J zation of foot on physical properties

3-1 Preparation fron alcohols .and salts of corresponding acids

j 3.2 3 Chemical proportion of carbonyl group:
roactions with
■ - NaHs03
- lTaOH/1.
2
Poll ling[1] s s olut i on
- To11on[1]s roacont

Mono-Carboxyl ic acides

3.3 Structure .and physcial properties, ac i d i t y and r o s ■ :n an e o.

3 • - preparation
- d e rivativo s

4 - reaction of derivative S' by attack of nucleophitos at the carbonyl group:-

3.5 hydrolysis, reactions of aoide chlorides, anhydrides with alcohols, reduction vrith LIAIH4 or BoBK4*

- *Fata, soaps* and sooploss dotorients, nature and uses

3.6 Structure and physical properties, basicity and. resonance

Amine Catalytic reduction cf aldehydes and ketones

Preparation fonalkyl *inn* lidos and nitro c onpound*a*

Reaction with nitrous acid, iso cyanido roact ion

Oxidation of aldehydes and ketones

Reaction cf primary, secondary and tertiary arnines with alkyl halides, acido, chlorides, and acid a anhydrio s, Qu at omary very brief treatment of thoir phamaccl.^y.

Properties and. uses of formalde-hyde, acctaldehy ole, acetone ond bonzoldoh ydc comparati ve account,

3.81 |

3.82 |

3.83 I
I

Protoinn J 3*9 and arbo-ydratos	3.91 3.92 3.93	An ino acidos. Their dipolar nature raid their relationship to proteins. Nucleic acids, vitamins and Homone a S imp 1 o gu& ar a. Th o ir re ducin,-;; proyort ic a ?md structural relationship to sucrose, starch and cellulose. The sugar, paper ond t ext i1o indust rio a•	T"	Sequences end Series 120

Revised Syllabus in Supplementary Mathoinat 1cs

1. How to study problems.

2. *1.1* o asu r om ont s

(i) Units of scionco measurements (ii) Use of Dimensions (iii) Conversion of units
(iv) Standard forms and exponents

3 • Ro liability _of_ Jfeasi^c^oir^s

(i) Rounding off
(ii) Significant figuras - addition, subtraction, multiplication and divisions and their relation to accuracy of experimental results*

4. ITumbors

(i) Positive and negative integers

(ii) Zero index
(iii) Fractions, decimals, cross multiplications, ratios pr op ort i ons and p or c ont ag os *

(iv) Scale of counting in different bases (not creator than twelve.[1])•

5• Indices and Logarithms

(i) Negative indices
(ii) Operating rules for logarithms
(iii) Hyporb o1ic functiona (iv) App 1 i c at i. rn t o bo 1 lavi ou r of elect rolyt o s, rod ox reactions. otc.

b. Surds

(i) Multiplication and division of surds
(ii) Conjugate surds.

'7. Algebra

---

1 Evaluation of simple algebraic expressions change of subject in a formula in simple equations o.g.
PV =nRT, n s pv RT

(ii) Use of brackets

(iii) Simultaneous linear equations in two variables Factoring -

(iv) completing tho square Quadratic oquat ions

(v) Manipulation of simple fractions vdth monomial don omiriatore.

(vi) Linear equaliti:*s* in one variable. Applications to chemical concepts o#/.-:. chemical equilibrium otc.

(vii) Frequency Distribution

(i) Pictorial presentation of data by pio chart, bar charts mid hist ogram.

(ii) Averages - no an, modi an. and rnodo.

Graphical Representation of Equation

(i) Uses of graph

(ii) Uso of leg graph

(iii) Root,angular co-ordinates

(iv) Straight linos

(v) Gradient - slope and intercept equations

(vi) The derivative, as a rate of chsjige

(vii) Application to all properties gradation either in group or along tho period of the periodic table o•g. 1oni zati on potoutial graph etc*

.Ocuoulus

Djfforonti at 1.on

(i) Symbols ond their noonings o*g. dx, $\int$ etc.

(ii) Rato of chango

(iii) Graph!c al roprosontati on

(iv) Derivatives of a function

(v) Basic derivatives

(vi) Derivative fron first prinoiplo

(vii) Basic rules of different iat ion
(Reciprocal; , Product, Quotient and chain rule)

(vi i i) Irip 1 i c i t d i f f or out i at i on

(ix) Applications of maxima and minima
-* idea of a limit to
thermodynamics

(i) Summary of basic functions o. ,o. f
du ~ ln/u/+c
J u
(ii) Rules for integrating
(iii) Integrating by parts
(iv) Substitution mothod
(v) Use of partial fractions
(vi) Application to chemical concepts e.g. Order of roact ion, nu.c 1 oar roact ions ot c •

Element ary I'rigiaomctric Functions

(i) Definition of sine, co sine and tangent.
The properties of vertically opposite and adjacent angles«

(ii) Circular measure of angles
(iii) Laws of sines, cosines otc. Application to c omp lex f orm at i on, m o 1 e or 1 ar c omp o s i t i on and structure etc.

So.iuonce,

(i) Sequence and series
(ii) Arithmetic progression
(iii) Sum of an Arithmetic progression
(iv) Geometric Progression
(v) Sum of Geometric Progression

Application to organic chemistry

Binomial Theorm

(i) Pascal traingle (i i) B in

omi al t he orm.

Permit at i oris and 0 onbinat i ons

(i) Arr angomcnt s

(ii) Tho factorial notation

(iii) Pormut • vb i

on (i'v) C oiri'b inat i

on.

Application to organic chonistry concepts.

Probability

bility

(i) Definition and simple problcns on prob;

(ii) Sun and product laws

(iii) Sinplo case of conditional probability Application t

rosonar.ee

Permit at i oris and 0 onbinat i ons

mechanism of organic reactions c.g.

Table of Statistics

X.t	9	F • * ■"**	r	6*5625	r 5.2218	i 2.2851	I 1.6797		7 * *–
X2	I 3	ô	1 9	5.0312	6.0958	2.4690	I 1.3438		5.5
X3	32 1	*25	;57	52.25	186	13,6382	:10.9063		50.5
X4-	39	25	64	51.7188	236.3377	15.3733	1 o poo7 1		50.5
X5	87	38	49	56.9638	170.9990	13.0767	10.4062 i		56.5
X6	72	34	38	54.9688	100.1925	10.4495	8.5977 j57		
X7	72	43	29	53.6875	52.6733	7.2576	1 5.6640		59
aLO	80	20	60	53.875	136.6290	11.6888	a O p C Q		59
X9	74	26	48	57.000	129.8710	11.3961	1 * i		-
X10	04	36 j	43 «	66.000	137.2258	11.7143			-
X11	80 j	31	49	56.062?	209.8024	14.4346	12.25		58
X12	06	32 |	54	57.5938j	162.9183	12.7639	10.2188 j		57.5
X13	91 ! i	16 j	75	59.5938!	302.7651	1 17.4001	13.0313 ! j		60
X14	?6 ; J	17 i	r: q JJ	51.2813:	245.2409 !	15.661	_		-
X15	95 ! i	15	80	69.2188 !	402.7571	20.0688;	j «		-
516	otu 4 j	18 j	70	57.5938	289.2877j 1	17.0025;	J - y		-
Mj	ill	iii	41	-ii	58 ! 95 J	1 9.75	■ j		-

v_o vo vo ro i \) ro ro ivs ro ro ro ro ro -ⁱ —ᵏ pa

W

i\3 -a o vo oo -4 oo vn 4- vo ro ~v o vo co -4 co vn 4--* vo ro —o vo co —3 cr> vn -p* vo ro tej
o vn -J CA co o co oo vn vn oo vo oo OA co vo vn oo vo oo VD —3 co ~4 ~4 vo co -4 vo co vo oo

vo -p* -r-* v3 oo O Co -> -41 co. o vn oo co -4 vo vn vo o CA CO -p» 4^ co co vi co vo vn go co on ro

CA oo vn vo -!-• CA -o vn vn CA CA co •£> vn --I ro 4^ vo VJ 4^ vn oo vn CA •> -P* 4=* vn ro -£* t:
-3 co o vo iv) vj 00 co vo 03 vn -•* r \ j oo co ro co -4! vn co ro CA VO o ro co o vn co vo

v3 Vo oo CA -r ■ ro -v'- —J ~4 -£» oo -41 vn CD vn 4»' co vo 4*> v3 vn oo — i vo GO vn vo vn -P*. Vo vo H
CA oo co 4=* rovnrooOCDOrovovD-j-CA oo ro O ^ O w o vn -->3 to o co ro O vo CA 4^

vn co -P- vn CA -T=- -f% oo -J —J CA CA 4-> -4> vn vo GO CA -F=» vn •> vn oo Co -£* ->• -> vn vn -> vn oo W
0j -4 vn CA o o vn vn '■r. vn o vn vji vo ro co o ■£* 4=» -J -ˣ CA ro vn co o co vn -!'■* go —3 vn

co -p* vn <T \ oo vn CA --J CA OO V3 GO vn --5 4'- vo vn vn -£• vo -> vn OA CA vo v n GO -i^ Vo -r-^ M
O -4i co vn -f-* co ro o vn vo co o —-I ro vn ~o o vo vji -*■ ro -* —* co fo -~j -a vn CA oo

oo oo oo -vI-nvii caco vn oo oo vn -£=* -3 4^ vn vn ca-> •4* vn vn ~3 co vn go vn go vn vn vn vn M
ro vnroooroCroCAvn ro vn vo ro vn vo co -* CD vo vn co O vn (V) vj vj vo VOO—J -4

vn v3 oo vi ' o vn a? oo CA CA vn vn oo 4^ vn vn vn 4:^ vn w oo vn OA GO -|s» -pa. vo vi vji vo vn oo M oo i\3 CA oo -o vo 0O vn CA ro CA VO -r-> vn oo ro ro o

jp

vn vi oo CA oo ro vn —J vn oo vn oo vn -4j 4>- vn oo co 4^> vn vo vn vn CA -4 vn vo -j vn vn Vo vn M
oo -i-o. vo vn o oo oo vj ~4 ro vo ca —j VO VO -*■ co oo co O —3 vn ~o -!-■> vo vo o vo vo co vo vo

GO -4 -4] CA VJ -41 -J -41 -3 -4 vn OO -3 OO -4] CO -4 CA -41 V.O 4~ OO -41 -J ON OA VJI OO -4 -£> VO CA
M
OJ vn OA -a vo co oo vn vo o vo - o co vn ro 4^ Co —1 O oo —3vnovn vo o vn vo voCA-4j vn
—i [ca O

oo oo -4! -j vn voVJI CD oo oo oo -4 vn oo vo vo oo oo vo CA vn GO -4 v_o -IA OOvn v.) 4^>
co —n ^:| VJ -a io oo VO VO o vn o ai vn 4., > _n ca -4 -i oo vi ~vvovo vo ro vo O ---Ioo —^ vn

vn vn co-4 CAVO -f»CD oo -cu CA 4^ oo -0- CA vn CA 4"* -P-- vn vn oo ~o 4--* 4-- vo co vn -> -F* vn
ro -i -4 m -4 oo ca VO co oo ca —j vd o o -*• Co ro vo —j vo o ro ^ vo w vi -4 vo ro co r 1 —i ro

4 -=■ ca -0 —1 co 4=* oo —j —4 vn vn vn vn Co 4^ oo vn oo vjn oo oo 4-^ ca vo rv> vn —V -4] vn -P* ~I I^j
vn oo-4 vo \o -i oo o vo vo co vn oo oo v.o vn ro co co oo no vo a) vn o —i vo

oo vn vn ca vn —v 4'=* ~J oa ca -41 oo vi vn -P 4-~* ~'j 4^* 4^ ca -P~ ro ~o rv> vn 4^ vnui Ia-p* M
4* -4 vo --3 vn -4 O oo o CD .O ~4 4^■—1 A.) O O vn oo co o —I vo 4- vn rovo CD VO VO 4^. VJ I -A -F*

OO oo VO CO co VO oo CO -41 —J CD vo CO vo OO VH CO vo vn -4 —J -4 A3 VO OO O 4» -41 CA CA -4 M
V^J O vo vn '-o VJ Cj co O vn A)C3 --3 vn vo ro -o co o o vn vo —i o o ro vo vn o co vji v.o -i vn

-4 vn vi co —3 ro 4' oo vn oo CD ~4 vn vn vo vn co CD -> oo vji vn oo co ->• ca 4^* 4^ 4'-- 4-- 4^ o-. M \yi\jn O
O --4 co Vo vji -4 o -I** vn vn co ro vo vo o ro vo vo vo o co CD vn 0D O o CD vo co

Score

oo rv>
CA

Table of Statistics

oo vn oi(nowui-4 oo oo GO oo vn GO vn vn G'H vn vn oo 4^* vn vn -4 4^ oo 4>* GO ca vn vo GO M O CD oo VO VJI ^ 01
VI -3 VO 4^ -41 -1 -41 -i ro CA vo ro O CD O VJ ro ro Vo o CD vo CO -i
-4J