A Study of Factors Affecting a Curriculum Innovation in University Chemistry

by

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A thesis submitted in part fulfilment of the requirements for the degree of Doctor of Philosophy (Ph.D.)
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Abstract

This thesis reports the need for, and charts the subsequent development of, a new Level-1 (First Year) chemistry course at a Scottish University for those students who have less than Standard Entry Qualifications and/or little intention of studying chemistry beyond this stage. The course is put into context in terms of both current (and proposed) curricular and examination arrangements for senior school studies, and in terms of other science courses at the University of Glasgow. Possible implications of this course for both its home institution and tertiary education in general are discussed.

The design work was undertaken by a team of lecturers. In order to help shape this new course, ten educational principles (The Ten Commandments) were drawn up from experience of research in science education and the relevant literature. The Ten Commandments are stated and the thinking behind them (largely arising from the work of Johnstone and his Centre for Science Education) is described. This encompasses research spanning around 20 years, including topics such as Concept Development, Assessment and the use of a model of Information Processing in a variety of teaching contexts.

The final design of the course is described in terms of the input from The Ten Commandments and the features they inspired – Pre-Lecture sessions, revised Workshops and Diagnostic Tests.

Student opinion of, and attitudes towards, General Chemistry-1 were evaluated from a number of standpoints, including questionnaires and interviews. The response to the course was very positive. This attitude to the course was consistent over a two year period of investigation.

Examination results were investigated to ascertain if a student's success was largely pre-determined by the standard of his/her Entrance Qualifications in Chemistry (and Mathematics). General Chemistry-1 was intended to give those with Non-Standard Entrance Qualifications a realistic goal which they could achieve, without compromising the general standard of the chemistry taught. In five exams over a two year period there was essentially no link between Entrance Qualification and ultimate exam achievement found. Hence General Chemistry-1 had achieved one of its key objectives.

The existing chemistry course, Chemistry-1 was also examined to discover if examination performance was similarly independent of entrance qualification in that class. Again

results over a two year period were analysed, but with very different findings. In this case there was a strong link between the standard of an individual's entrance qualification and his/her exam performance.

The study of General Chemistry-1 was expanded to encompass a number of other factors (Age, Gender, Personality Factors, Cognitive Style and Educational Maturity). All of these factors are discussed and the reasoning behind their inclusion stated.

No clear single factor emerged as having any more influence on examination performance than Entrance Qualifications. However, different factors did show a link to performance in different exams, which examined different parts of the course. Similarly, combining Gender with the factors showed different links between the combinations and each exam.

Acknowledgements

In a research centre such as the one I have been privileged enough to study in, no Ph.D. is totally the work of one individual – rather it is shaped, influenced and guided to varying degrees by those in the centre, and the work described in this thesis is no different.

I would like to thank my numerous fellow students for their friendship and support. I have learnt much from the international nature of the group which has allowed me to meet people originating from exotic Eastern locations such as Pakistan, Brunei Darussalam and even Leith. I wish to single out Dr. F. F. A. Al-Naeme for his valuable advice and friendship.

Two members of the Centre for Science Education's staff, Dr. R. A. Hadden and Dr. P. R. P. MacGuire deserve special mention and thanks, without whom I am sure my research would be a lesser work.

Finally, but (as the cliché says) by no means least, I must express my eternal gratitude to the head of this Centre – Prof. A. H. Johnstone. His kindness, generosity (and patience!) I can never hope to repay. I have been fortunate to partake of a little of his knowledge, experience and thought processes in the last few years and it has been a truly enlightening time.

I would like to thank Glaxo Wellcome Ltd. (formerly Glaxo Group Research Ltd.) for their generous support of my work.

Without the co-operation and input of the students and lecturers of the Chemistry classes I was interested in, there would be no thesis. I thank them for giving me their valuable time.

The support of my mother and grandfather has been constant and unwavering (despite my own Bohemian brand of hedonism!) and I thank them for that.

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Chapter One

Background Information

1.1 Introduction

The purpose of this chapter is to describe the background to, and define the researcher's objectives in, the investigation detailed in the later chapters.

In doing this the recent events that have re-shaped, and indeed are still shaping, Higher Education today will be reviewed. The influence these events had on the new chemistry course detailed in this work will be highlighted.

The approaches employed by the University of Glasgow's Faculty of Science to student entry and a student's suitability to a particular course (where multiple courses exist within a first year, Level-1 subject) will be described for the Mathematics and Physics Departments. The situation existing within the Chemistry Department prior to the introduction of the new General Chemistry-1 course will be discussed, as will the reasoning behind its inception.

General Chemistry-1 itself will then be described - detailing how it was conceived, who was intended as its potential clientele and what educational principles were used to guide its creation.

Finally the researcher's role will be defined, indicating the initial research questions under consideration and where they led the rest of the work. The possible relevance to Higher Education in general will also be highlighted.

1.2 Review of Recent Events in Secondary and Tertiary Education

The last few years have been a time of much upheaval in upper secondary school, Further and Higher Education. This upheaval is likely to continue for the foreseeable future as more changes proposed to post-age-16 education will have a knock-on effect in all universities. The impact of three of these recent events will be described:

- the impetus to revise post-16 education in Scotland, which introduced vocationally based qualifications, and produced the Howie Report and Higher Still proposals for secondary education;
- the increase in the student population (and the change in nature of those gaining entry to university);
- the creation of "new" universities.

1.2.1 Revising Post-16 Education in Scotland

The area of post-16 education in this country has seen a number of changes since the early 1980s. The use of modular courses and introduction of qualifications based on them, such as the SCOTVEC system (described later), has brought to a number of people, opportunities that did not previously exist. This system, its creation and what that system has meant for Higher Education is described below.

The last decade has also seen a number of changes to secondary school education in Scotland – the introduction of Standard Grade and subsequent revision of Higher Grade courses to name but two. Although these alterations will have affected Higher Education to some extent, further changes have been prompted and advocated in the last few years (which could have profound effects on the HE sector) in the Howie Report (Howie, 1992) and its successor Higher Still (The Scottish Office, 1994).

1.2.1.1 Vocational Education and SCOTVEC Modules

The importance of education for post-16 year olds was highlighted by the Government in a 1979 consultation document, which looked at issues surrounding the subject and raised a number of questions. Although there was a general desire for change in response to the paper, there was no clear agreement as to the nature of the changes required. However, there was enough consensus on some of the ideas to justify further work on preparing new, vocationally oriented, post-16 courses. This led to the production of *"16 – 18s in Scotland – An Action Plan"* in 1983 (SED, 1983).

This document, which became known simply as Action Plan, reviewed the (then) existing provision of education for the target group. It found a complex system involving a range of executive and advisory bodies presiding over courses and qualifications offered in schools, Further Education Colleges and by employers' own training centres. Frequently these bodies had differing, but overlapping functions.

The Scottish Examination Board (SEB) had the responsibility of administering exams and certification in the secondary education sector.

The Scottish Business Education Council (SCOTBEC) and the Scottish Technical Educational Council (SCOTEC) had a remit to devise, prepare, organise, review (and develop), direct examinations and make awards in the business and technical sectors respectively.

SCOTEC was also beginning to take over from the City and Guilds of London Institute whose courses for craft and technical interests were being phased out.

Other organisations with an input of some form or another to this sector of education included the Manpower Services Commission, the Scottish Community Education Council and Industrial representatives.

It was clear that no coherent provision for 16 – 18 year olds existed, with a large number of courses and certificates being available.

Previous studies of the senior secondary school described in Action Plan (SED, 1983) suggested that a significant proportion of those entering 5th year and undertaking Higher Grade examinations, failed to achieve any qualification. There were also students remaining in 5th year until Christmas (when they would reach the minimum age for leaving school) who would leave with no qualification, and would often be poorly motivated during this period. It was suggested that assumptions of all S5 students being academically inclined was false and that some alternative to the SEB's examination framework was required.

Other problems existed in the FE sector for this age group.

Frequently courses on offer were of two years duration and did not offer a certificated exit point at the end of the first year. Transfer opportunities between courses, or between departments were poor. Both of these factors meant students were locked into a particular course, at a particular institution.

Separate courses with a common content element did not often take advantage of this, leading to a duplication of teaching.

Complete FE courses may not have been suitable for those in work. These students may not have needed or wanted the whole course, but found that components were not free-standing.

Action Plan put forward a new framework which considered the following issues:

- opportunity for improved progression to higher levels and greater freedom of movement within the system;
- creation of clear entry and exit points which could take into account a student's achievements;

- a simple, unified national certificate to record a student's attainments during a period of study;
- effective and efficient use of available resources.

The framework Action Plan proposed was based on the use of modular courses, which it was felt could achieve the necessary goals.

A modular scheme allowed clear opportunities for a linear progression within a subject or area of study. With a large menu of available modules (which are) flexible enough to fit together in a variety of ways, a programme of study matched to an individual's level of previous study, interests and future intentions could be contructed (SED, 1984). Single modules, however, could be used by those who required a specific course alone.

The framework also allowed for a rationalisation of courses in terms of common content. For example, the mathematical requirements for a range of engineering or science courses could be delivered in a single module (or group of modules), rather than have the material taught to each course separately.

Although principally intended for 16 – 18 year olds, the framework offered good opportunities for adults returning to education. Adult students would be able to enter at an appropriate level to update existing skills or undertake a longer period of study.

Appraisal of a student's work for these modules (SED, 1984) would be carried out in the form of internal, criterion-referenced assessment, i.e. measuring a student's performance against some established criteria. The criteria against which students would be judged were to be laid down in a "learning outcome" (a general statement of what is required) and elaborated upon in "performance criteria" (statements concerning the qualitative and / or quantitative standard required of the students). A record of all achievements would be given on a student's certificate, issued regularly and offering information on all modules and groups of modules successfully undertaken.

Although the Action Plan was created by the Scottish Education Department (SED), responsibility for all aspects of the system was taken up by the Scottish Vocational Educational Council (SCOTVEC), formed by the merger of SCOTEC and SCOTBEC, in 1985.

1.2.1.2 The Howie Report

The Committee to Review Curriculum and Examinations in the Fifth and Sixth Years of secondary education, under the chairmanship of Professor J. M. Howie, was commissioned in 1990 with their remit requiring them:

> *to review the aims and purposes of courses and of assessment and certification in the 5th and 6th years of secondary school education in Scotland;*
> *to consider what structure of courses and what forms of assessment best satisfy these aims and purposes taking account of the needs of pupils of varying ability and background, the demands of employment and the requirements of, and developments in, higher and further education;*
> *to recommend necessary changes.*
>
> (Howie, 1992)

The committee's final report, published in 1992, considered the increase in student numbers and examined whether the needs of these students were being adequately met by the current school system.

The report found the situation wanting. The committee identified what it viewed as key weaknesses in the existing school system.

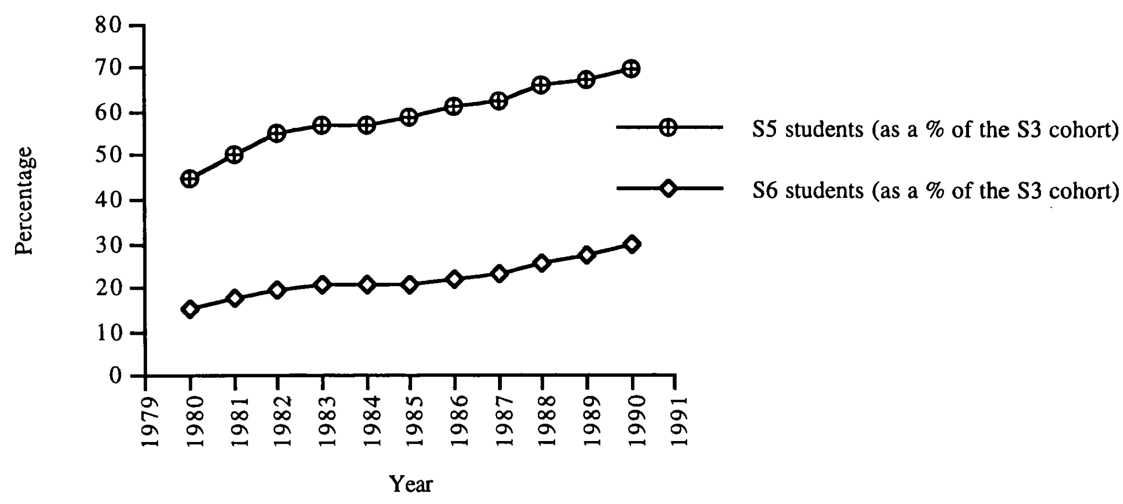
Scotland has often prided itself on the advantages of having its own unique education system, citing the breadth of students' study as one such advantage. However, the committee's finding was that whilst breadth was certainly on offer, in the shape of the Higher Grade syllabus students studied, that breadth was not reflected in actual student attainment. In fact, what was identified as one of the most worrying and damning statistics of Howie's report was that more than half of Scottish students complete a fifth year at secondary school gaining only one Higher grade pass or less – as can be seen in Table 1.1 (Source: Howie, 1992). Another problem was that frequently where students did achieve passes at Higher Grade, these passes did not necessarily make up a logical grouping of related subjects.

Table 1.1 The Percentage of S5 Students Presented for and Actually Passing Higher Grades in 1990

Number of H-Grades	% of S5 Students Presented	% of S5 Students Passing
0	15.5	34.2
1	11.8	17.9
2	14.6	13.6
3	18.9	11.2
4	21.1	10.6
5	17.3	11.9
6+	0.8	0.6

The main reason identified for these worrying trends was clear. As Figure 1.1 shows student numbers increased throughout the 1980s.

Figure 1.1 Graph of the Percentage of S3 Students Remaining in School to S5 and S6 in Scottish Secondary Schools 1980 - 1990



The reasons for such increases were attributed to several factors. These included:

- uncertainties in the job market;
- increased motivation and expectations among students caused by the introduction of Standard Grade and;
- an increase in the number of students who had not made a decision about their ultimate career choice by the end of S4 or beginning of S5.

As the number of students increased so the range of ability and previous educational experience and attainment of those entering the later years of secondary began to widen. The report noted that there was a sharp increase in the amount of material covered between S3 and S6. Higher grade is frequently referred to as "the two-term-dash" because the material to be taught has to be squeezed into the first two terms of the 5th year to allow for an examination period in April/May. Whilst the most able students could cope with the increased S5 work-load (compared to S3/4), many less-able students could not.

It was concluded that whilst the current system was probably acceptable for the most able, it was the weaker students now present in number in the upper school system who were suffering most.

The Committee also commented on the use of SCOTVEC modules and vocational education in general. Although the number of student enrolments for SCOTVEC qualifications had increased dramatically over the years since their introduction, the average number of modules undertaken by school students remained low even though these modules may have been a more attainable goal for some S5 students. One reason for the limited up-take of modules was almost certainly the perceived lower status of vocational qualifications among parents and some students, when held in comparison with more academic qualifications.

The Committee proposed radical changes to the structure of courses and examinations that they felt would solve the problems they had highlighted. They called for the abolition of both Higher and the Certificate of Sixth Year Studies (CSYS) and the creation of two new qualifications – the Scottish Certificate (SCOTCERT) and the Scottish Baccalaureate (SCOTBAC). One of the consequences of these proposals would have been to move Standard Grade from S4 to S3. The key features of the proposed qualifications were:

SCOTCERT: a one or two year course, beginning in S4, aimed at around 60% of students;
primarily aimed at preparing students for work or further training, but may allow entry to some Higher education courses;
core subjects plus options structure;
courses constructed form National Certificate modules covering general and employment related core skills;
assessment based on SCOTVEC's existing arrangements with a heavy emphasis on internal assessment;
group awards available in related subjects.

SCOTBAC: a three year course, beginning in S4, aimed at around 40 % of students;
intended to be the normal route to Higher education, but also suitable for employment;
core subjects plus options structure as with SCOTCERT;
based closely on existing Higher and CSYS courses, but reaching above Higher and even above CSYS in some subjects;
assessment to be a mixture of internal and external, again with group awards available.

Whilst the Committee's findings regarding the weaknesses in the current upper secondary school courses, assessment and certification found general agreement in the education community, their proposed remedies were rejected on two key issues. (The Scottish Office, 1994)

Firstly, the suggested movement of Standard Grade to S3 met with widespread opposition. It was felt that to achieve this would require re-working of the S1-S3 curriculum, which would interfere with new age 5 – 14 Guidelines, and that not every subject could reach Standard Grade targets by S3.

Secondly, the separate SCOTBAC and SCOTCERT qualifications were totally rejected. The main criticisms included:

1. The two qualifications would not be held in equal regard.
2. This difference in status would make parents encourage students to study SCOTBAC, when it may not be appropriate – leading to similar problems of achievement as was identified under Higher Grade.
3. Although it had been proposed that students could transfer between courses, the methods by which this would be achieved were not clear. There was also concern that movement would be one-way (from SCOTBAC to SCOTCERT).
4. The different methods of assessment employed by the courses would increase the divide between the two.

In the light of these views the Government published its response to the Howie report, *"Higher Still – Opportunity For All"* in 1994 (The Scottish Office, 1994).

1.2.1.3 Higher Still – Opportunity For All

The Government's response to the Howie Committee took on board their criticisms of the current arrangements, whilst offering a very different remedy to the problems identified. The new system described in *"Higher Still – Opportunity For All"* (The Scottish Office, 1994), and extended by publications from the Scottish Consultative Council on the Curriculum (SCCC), is intended to be in place by the end of the present decade.

The Higher Still reforms will bring about the following changes:

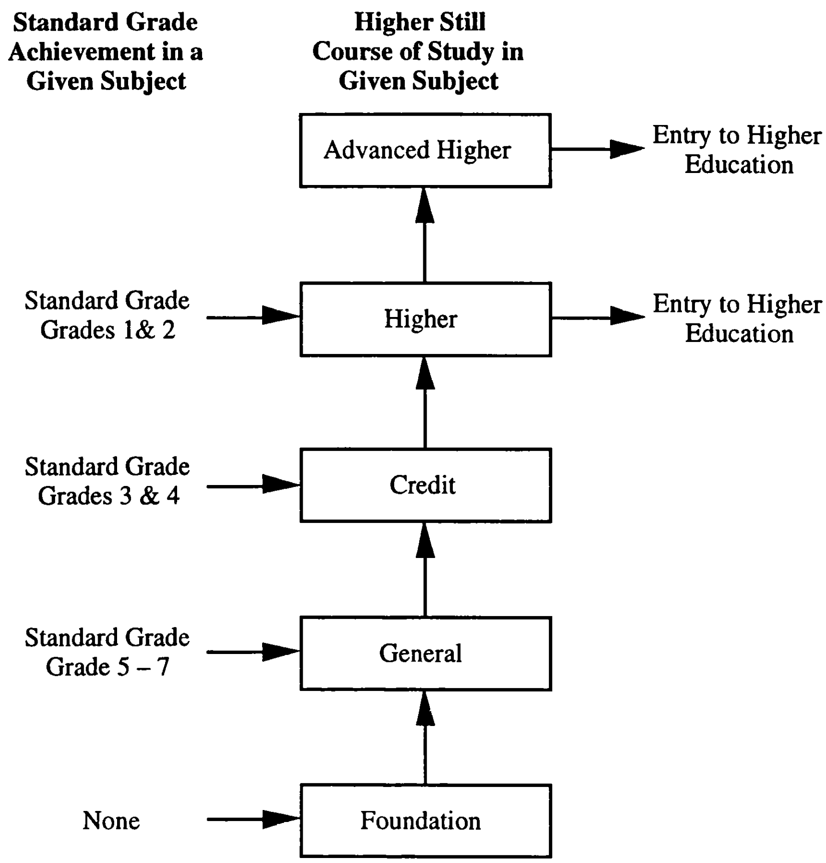
- Standard Grade courses will not be altered from S4 to S3, as Howie suggested, but remain as they are (in terms of timing);
- Scottish Examination Board (SEB) and SCOTVEC courses will be amalgamated to produce a single curriculum and assessment system;
- a framework of levels will be introduced to ensure that there is a realistically attainable qualification for all in S5 and S6;
- Higher Grade will remain, in a modified form, but CSYS will be replaced by a new 2-year qualification, Advanced Higher.

The framework of levels proposed is in essence an extension of the successful Standard Grade arrangements (Johnstone, 1986). Standard Grade is (generally) offered at three levels of attainment, namely Foundation, General and Credit. The Higher Still framework will offer five levels – Foundation, General, Credit, Higher and Advanced Higher.

It is hoped that this framework will allow "less-able" students to progress to courses they can realistically expect to cope with, and provide the more even learning gradient required. As those being awarded General level Standard Grades are among those failing to achieve Higher Grade within their 5th year, for example, this new system would allow progression to an intermediate level, Credit. Students could then opt to leave school following this or remain to study Higher in 6th year, when they may be better prepared to do so. It is claimed the new arrangements will give improved continuity and progress in post-16 education by offering an appropriate level of study, which is neither too difficult nor too easy, for all (Lord Douglas-Hamilton, 1994).

A student's progression through S5 and S6 in a particular subject may be as suggested in Figure 1.2.

Figure 1.2 A Possible Progression Through S5 and S6 Following the Introduction of Higher Still



(Adapted from Higher Still – Chemistry Consultation Document (SCCC, 1995a))

Progression from the end of Standard Grade would be to a level appropriate to their experiences (the grades quoted are intended for guidance only). At the end of the S5 year of study students can move up a level for their S6 year. This creates the two year Advanced Higher and allows other students to take an extra year before attempting Higher.

Each of the five course levels will be constructed from modules of 40 or 80 hours in length. These modules will be developed from existing SCOTVEC materials and (in the case of Higher and Advanced Higher) from Higher and Certificate of Sixth Year Studies courses. Student performance in modules will be internally assessed, whilst courses will be examined externally with success in both modes of assessment being required for the award of a certificate for a particular course. Students opting to study Advanced Higher are to be encouraged to by-pass the S5 external assessment to create a full 2-year course, although some form of "safety net" is proposed to guard against any adverse effects as a result of this by-passing.

It will also be possible to take modules and courses individually or opt to study for National Certificates (SCCC, 1995b).

National Certificates will be a specified set of courses and separate modules that fit together to form a natural grouping, to achieve the consistency of qualifications Howie noted was lacking in many cases. These National Certificates will be available at three levels, indicating that a student has undertaken a coherent programme of study and achieved a particular level of overall educational attainment in that programme.

It is foreseen that a National Certificate at Level 2 should incorporate at least two courses at Credit level, whilst the other topics studied need only be at the General level. Level 3 National Certificates, however, would comprise of at least three Higher courses.

Progression from school to Higher Education is still envisaged as using Higher grades as the standard entry qualifications. However, in an attempt to give a value to Advanced Higher that Howie found lacking in CSYS, it is suggested that Universities should give consideration to recognising student achievement at this level in some way (e.g. by direct entry to second year of degree courses or exemption from some first year subjects).

The Howie report identified the importance of "core skills" required by every student and Higher Still also acknowledges this (The Scottish Office, 1994; SCCC, 1995c). These core skills are broad skills and abilities that will be of value in a variety of situations in employment and other aspects of life. The skills identified are defined as:

> *Communication*
> *The ability to produce written and spoken communications appropriate for a range of purposes and audiences and to respond appropriately to a range of messages through reading and listening*
>
> *Numeracy*
> *The ability to use a range of fundamental arithmetical and mathematical (including statistical) skills to reach conclusions in a range of situations.*
>
> *Personal and Interpersonal Skills*
> *The ability to work independently and co-operatively with others and to use self-awareness and social awareness to guide action.*

Problem Solving
The ability to identify and clarify the nature of problems, to plan and to implement strategies to address problems and evaluate the effectiveness of strategies and solutions.

Information Technology
The ability to use new technology to input, process and output information and to perform basic operations.

(SCCC, 1995c)

Higher Still has been (and is currently) under-going a process of consultation which will lead to more concrete developments. Materials have to be designed and courses will require at least minor modifications to meet the framework proposed. Changes in the current arrangements are expected to be evolutionary and limited to "that which is necessary for the attainment of the aims of the reform" (The Scottish Office, 1994).

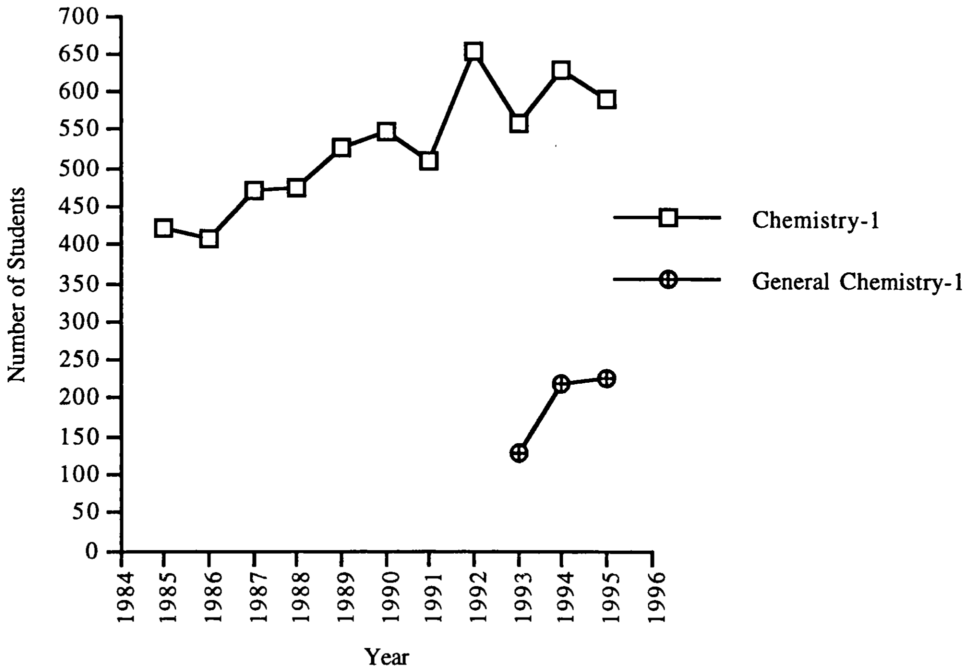
1.2.2 The Growing Student Population

Just as the population of the upper secondary school is Scotland has grown so this has had a "knock-on" effect on the population of the universities. Indeed the same can be said of the rest of Britain's Higher Education community.

For example, the University of Glasgow has seen a rise in total student numbers from 9739 Undergraduates in 1985/86 to 14308 in the academic year 1995/96. Similarly the Faculty of Science has seen an increase in Undergraduate numbers of just over 50 % in the same period of time (1985/86: 2593 Undergraduates; 1995/96: 3956 Undergraduates).

Figure 1.3 below shows the changes in the total number of students studying Level-1 (First year) chemistry at the University of Glasgow over the last 10 years.

Figure 1.3 Graph of the Number of Students Undertaking Level-1 Chemistry Classes at Glasgow



In light of the changes in post-16 education, Universities have had to change entrance policies and become more flexible, to accommodate qualifications such as SCOTVEC and the entrance courses and schemes run by universities themselves, such as ACCESS.

Just as uncertainties in job markets and a desire for more advanced qualifications have attracted more school leavers, so the adult population of universities has grown for the same reasons, together with more accessible entrance routes.

This change has led to two obvious problems. Firstly, a strain on university resources by the increased numbers entering a system (which was) originally intended for many fewer. However the second, and more fundamental problem, is the same as the Howie Commission found – the (increased) spread of student ability within the system.

Students no longer come as a (largely) homogeneous group in terms of their qualifications. As Howie's Report found, students do not always achieve a cognate collection Highers across a wide spectrum of subjects. Although students may have achieved a certain level of proficiency in one area of study, another may be much weaker. For example, a student may have Higher Grade Chemistry, but not Higher Grade Mathematics.

These "gaps" in a student's background can be even more profound in (for example) SCOTVEC students who may show great understanding of some topics but complete ignorance of others which were covered in a module they did not study.

This lack of homogeneity may cause exactly the same effects for student success as Howie found at the secondary school level. An Honours degree (or even Ordinary Degree), they they currently stand, may not represent a realistic goal for many of those entering University.

1.2.3 The "New" Universities

Another major change in the Higher Education landscape has been the increase in the number of institutions with university status.

Changes in Government policy, in 1994, have allowed polytechnics to become universities. The Glasgow area is now home to four universities rather than the two it has been familiar with for so many years. Indeed, Scotland now boasts a total of thirteen universities:

"Ancient":	Aberdeen, Edinburgh, Glasgow and St. Andrews
1960's:	Dundee, Heriot-Watt, Stirling and Strathclyde
1990's:	Abertay, Glasgow Caledonian, Napier, Paisley and Robert Gordon

Whilst this has opened up a more competitive market in pursuit of students, the perceived status of some of the "new" universities may count against their being the first choice of some of the more able students. This may drive these new institutions to offer more esoteric courses in an attempt to capture a special interest group.

However, their experience of teaching students at lower levels and more flexibility in their approaches may improve the standing of these ex-colleges and indeed show the way forward in how to teach a wider ability range.

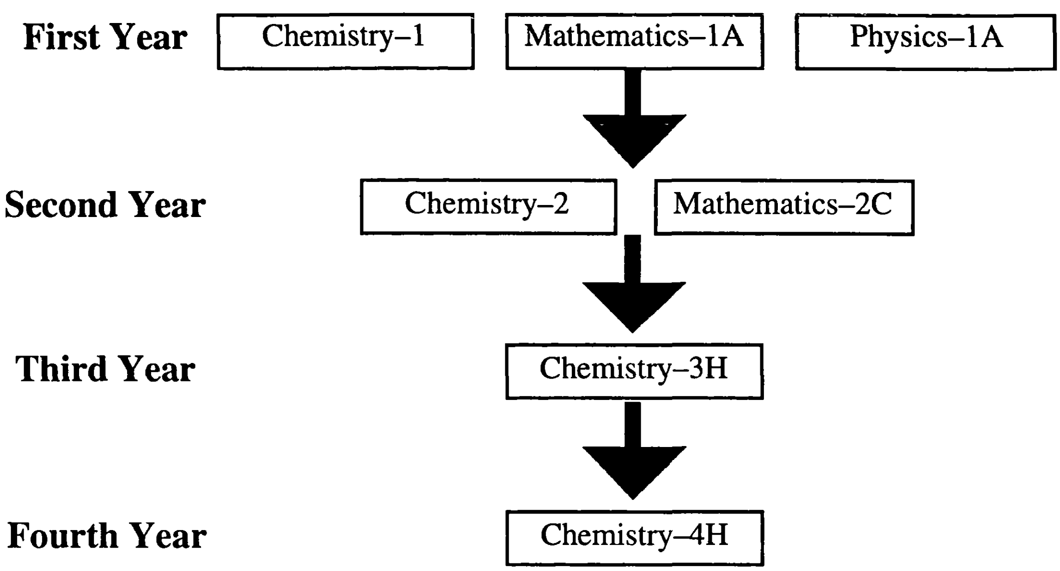
1.3 The University of Glasgow Situation

The University of Glasgow admits students to a Faculty and a degree (rather than to an individual department). This arrangement allows a great deal of flexibility within the subjects which make up a Faculty, and this is particularly true of the Faculty of Science.

The Bachelor of Science degree (BSc) has been available either with Honours (a more specialised four-year degree) or as an Ordinary Degree (a fairly general curriculum studied over three years). However, radical changes are being made to the "Ordinary" Degree in an attempt to overhaul it and re-affirm its standing within the university (University of Glasgow, 1995a). The university year consists of three terms: Martinmas (October to December), Candlemas (January to March) and Whitsun (April to June).

Virtually all of those studying to a Single Honours degree within the Faculty will take three Level-1 courses in their first year of study, two Level-2 courses in the second, and one Level-3H and Level-4H courses in their third and fourth years respectively, as indicated in the example in Figure 1.4.

Figure 1.4 One Possible Progression to an Honours Degree in Chemistry Within the Faculty of Science



Combined Honours degrees are also available, such as Chemistry and Geology, for example. Students choosing such an option will follow a slightly different route, usually studying two courses modified to suit the requirements of their degree in their later years.

Assessment of student performance varies from department to department, but generally consists of one or two Class Exams and a final Degree Exam for that subject. In many courses exemptions from the Degree Exam (and hence passes in that course) were given to those whose performance in the Class Exams was deigned to be worthy enough. The remaining students, who would sit the Degree Exam, were given final grades according to their performance in that exam only. The Faculty moved to a system in 1994/5, whereby most subjects have only one Class Exam and a Degree Exam, with the exemption system being phased out in favour of more continuous assessment.

The Faculty of Science, as its entrance standard, usually calls for three Scottish Higher Grade Science subjects (or two plus two other Highers) at a minimum of grade B, with other subjects at lower levels. Individual departments may make specific demands about what subjects they require. Other qualifications such as SCOTVEC, Higher National Diplomas as well as English A-Level qualifications will also be considered.

1.3.1 Other Science Departments With Multiple Level-1 Courses

The major Level-1 Science Faculty subjects – Chemistry, Physics, Mathematics and Biology – naturally attract large numbers of students each year. Although many students have indicated an initial intention to study one of the subjects to Honours level, all will take two more subjects as a prescribed requirement for later studies or simply as subjects that they have an interest in. This is especially true for Mathematics and Chemistry, which naturally have a "service course" element to them providing support for other subjects in the Faculty.

Although Chemistry (pre-1993) and Biology have dealt with all first year students in one single class, Physics and Mathematics have offered more than one Level-1 course for many years. Before reviewing the reasoning behind the introduction of the Chemistry Department's second Level-1 course (General Chemistry-1), it would seem prudent to describe the approach to second Level-1 courses used elsewhere, to allow a comparison with the model Chemistry adopted.

In both cases the systems described are broad guidelines only. They are not inflexible rules, as any special cases which arise would be dealt with on an individual basis – e.g. if a student wishes to move from a B class to the Honours stream for a particular subject. However, the vast bulk of students in these courses would follow what is described below.

1.3.1.1 The Mathematics Department

The Mathematics Department offered three Level-1 courses (at the time General Chemistry-1 (Gen Chem) was introduced) those being Maths-1A, B and Introductory Maths-1.

Entry to these courses depended on a student's entrance qualifications and future intentions regarding the study of Mathematics.

Mathematics–1A is the stream which will, if followed, ultimately lead to Honours or Combined Honours in Mathematics, and is suggested for those intending Honours in Physics or Statistics. Entrance to this course is therefore open only to those with a minimum of Higher Grade Mathematics at grade B (or equivalent).

Entry into Maths-1B is open to those students who have a minimum of Higher Grade Mathematics at grade C. This course does not (normally) allow progression to Honours in the subject.

Both the A and B classes will admit students with "non-standard" qualifications, such as SCOTVEC modules. If these students persevere they can generally succeed in Maths-1B, but few can cope with the demands of 1A.

Introductory Mathematics-1 is intended for students without Higher Grade Mathematics who discover they will need a stronger background in the subject than they currently have, for future studies.

Progression into Level-2 courses is controlled (largely) by the level of success achieved in whichever Level-1 course is undertaken. The Maths Department offers four Level-2 courses, Maths-2A (the Single / Combined Honours stream), Maths-2B, Maths-2C (a service course for the sciences) and Mathematical Modelling-2.

A Pass in Maths-1A or B will give entry to any of these courses, except Maths-2A. Entry to 2A is limited to those with an exemption or minimum of grade C (in the June exam) in 1A, along with passes in two other Level-1 subjects.

1.3.1.2 The Physics Department

There have been two different Level-1 Physics courses, Physics-1A and 1B, for some time at the university. As with the Mathematics Department entry to these courses is (ordinarily) controlled by guidelines relating to students' entrance qualifications and intentions.

Students who hold good Higher Grades (i.e. usually a minimum of a grade B) in Mathematics and Physics, and are intending to study Physics to Single or Combined Honours level, can gain entry to Physics-1A. This course is also suggested for those studying the Physical Sciences along with a Level-1 Maths course.

Physics-1B is a less mathematical course, which students with no physics (but Higher Maths) should find suitable if they require one year of the subject (perhaps in support of an intention to take a Life Sciences degree).

Progression in the Honours stream, i.e. entry to Physics-2, requires a pass in 1A and either Maths-1A or B. Two Level-2 half courses, Physics for Technology-2 (½) and Environmental and Biological Physics-2 (½), are open to anyone who gains a pass in either Level-1 course.

1.3.2 The Chemistry Department (pre-1993)

Until the academic year 1993–94, the Chemistry Department offered only one course at Level-1. Documentation available to students concerning entry requirements for the Department stated:

> *Four Highers at grades BBBB, including two chosen from Maths, Physics, Chemistry, Biology, Geography, Geology, Computing Studies (at least one of Maths, Physics or Chemistry is desirable)*
> *or*
> *three of these Maths / Science subjects at BBB or ABC*
> *or*
> *Maths at A plus two non-Science Highers at BB.*
>
> (source : A Brief Guide To Entry in 1995, (University of Glasgow, 1995b))

Chemistry-1 (Chem-1) served the twin purposes of preparation for Single and Combined Honours in Chemistry, and as a service course for those in Biological or other Sciences. This dual role has meant that the class is one of the largest Level-1 courses in the Faculty, and the number of students including Chem-1 in their time-table has increased over the last few years.

Students could progress to Chemistry-2 by acquiring a pass in Chem-1, hence (unlike Maths and Physics) students did not have to decide before beginning their studies whether or not they intended to leave open the option to study Chemistry to Honours level. This policy also meant that students could progress to Honours in Chemistry directly, regardless of their qualifications on entry into the class.

1.4 The Creation of General Chemistry-1

The Department of Chemistry launched General Chemistry-1 (Gen Chem) at the beginning of the academic year 1993/94, for a number of reasons.

Firstly, as indicated earlier, recent years have seen the already high numbers of students taking the existing Chemistry-1 course grow even further. The sheer weight of numbers was becoming a logistical problem, in terms of lecture theatre accommodation, for example. As is common with the other major Level-1 subjects in the Faculty of Science, Chemistry lectures were delivered twice a day – 10 am and repeated at 3 pm – but numbers were beginning to reach a point at which even this arrangement was becoming unworkable due to overcrowding.

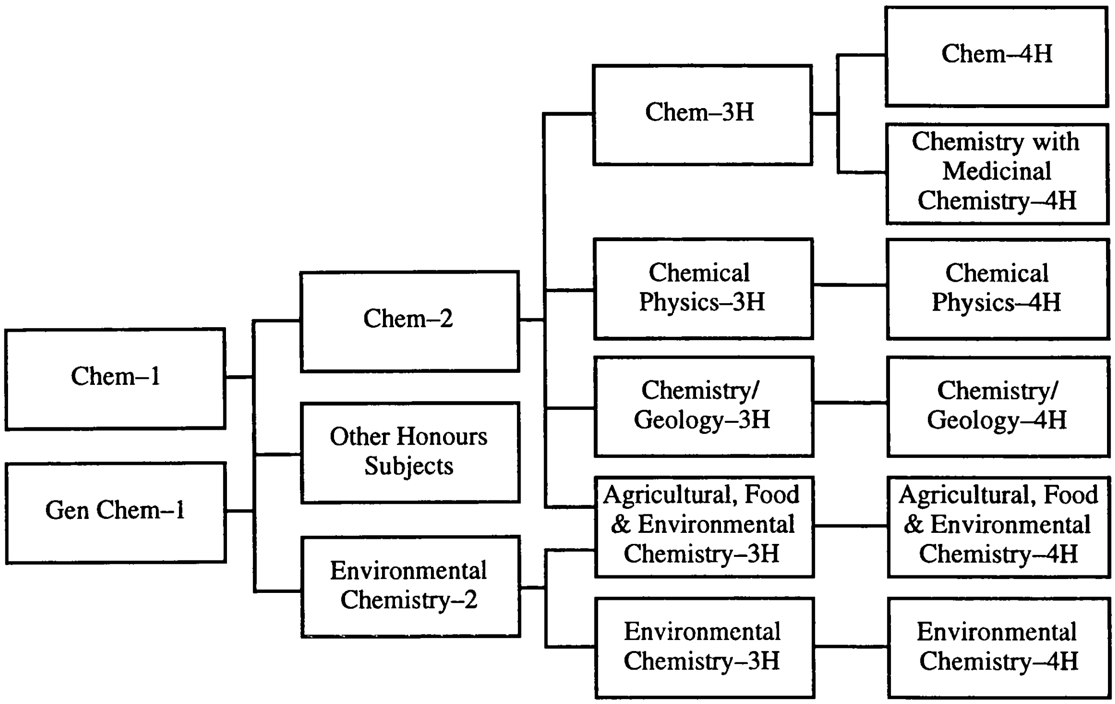
However, a much more serious consideration was the "preparedness" of the students entering Chem-1, as indicated above. With a Higher Grade pass in Chemistry being a preferred option, rather than an essential requirement for entry, the proliferation of different qualifications had increased the number of students with weak or no background in Chemistry entering the class. Prior to the introduction of Gen Chem some of these students required extra tutorial sessions to help put basic Chemistry and Mathematical skills in place.

Most of the students falling into this category (and indeed, the majority of the class) were undertaking the subject for a year, in order to support a related science that was their intended honours subject - such as Biology or Geology.

It was against this backdrop that General Chemistry-1 was conceived. Gen Chem is a self-contained one year course aimed at those with no previous experience or poor qualifications, and those interested only in the subject as a "service course".

However, it was felt important that students in Gen Chem should not be denied the opportunity to continue with their Chemistry studies should they so wish. Should a student decide to progress to Chem-2, and perform well enough in Gen Chem examinations, then he or she may do so. Figure 1.5 shows the options open to Chem-1 and Gen Chem students.

Figure 1.5 Options for Future Studies For Level–1 Chemistry Students



This means that a clear route to an Honours Degree in Chemistry (or a Combined Honours) is available to anyone entering the Department, regardless of previous qualification, unlike Maths and Physics.

A team of lecturers within the Chemistry Department was assembled to design the new Gen Chem course, the first time such an integrated approach to curricular design had been attempted within the Department.

To guide the design process the team drew up a set of principles based on educational theory and practice, and previous research findings. The principles became known as "The Ten Commandments":

Figure 1.6 The Ten Commandments

(1) What you learn is controlled by what you already know and understand
(2) How you learn is controlled by how you have learned successfully in the past
(3) If learning is to be meaningful it has to link on to existing knowledge and skills, enriching and extending both
(4) The amount of material to be processed in unit time is limited

(5) Feedback and reassurance are necessary for comfortable learning and assessment should be humane
(6) Cognisance should be taken of learning styles and motivation
(7) Students should consolidate their learning by asking themselves about what goes on in their own heads
(8) There should be room for problem solving in its fullest sense
(9) There should be room to create, defend, try-out, hypothesise
(10) There should be opportunity given to teach

Fuller details of The Ten Commandments and the ideas behind them will be discussed in Chapter Two.

The course aimed to include enough background and supplementary support material for those who needed it to make the Chemistry accessible to them, whilst not requiring any extra hours of staff time outwith that normally devoted to Chem-1 teaching. Obviously to do this would require the removal of some material from the existing course in order to find the time.

However, Gen Chem was not to be considered an "easy option" for students. Approximately 80% of the material covered in Chemistry-1 was also covered in General Chemistry-1. Apart from starting at a more elementary level, the key difference in the material covered by both courses was to be one of emphasis.

To take cognisance of the fact that virtually all of Gen Chem's potential clientele were "non-Chemists" (i.e. not wishing to pursue the subject beyond one year) the Design Team decided that it would be useful to give a broader structure to the course by showing how Chemistry relates to other areas of science. In particular if the links to Life Sciences and Geology could be emphasised (as most of the students' declared interest lay in those directions) this may help to enhance interest in and realisation of the relevance of the Chemistry taught.

Initially it was felt that students with "non-standard" entry qualifications (i.e. less than Scottish Higher Grade Chemistry) or less than a Higher grade B would be joined by those with (perhaps) more advanced qualifications who had already decided against a future in Chemistry. In practice, however, entry to Gen Chem has been determined more by entry qualification than by intended Honours option.

General Chemistry-1 began in academic year 1993/94.

1.5 The Researcher's Role

As mentioned previously, one of the key aspects of the new Gen Chem course would be the use of appropriate support material to meet the needs of students with a variety of educational backgrounds. The nature of this material (discussed more fully in Chapter Two) meant that some of it would have to be created whilst other parts could be adapted from existing material in use in Chem-1.

The author undertook the task of designing and writing most of this support material (with an input from the lecturers involved in Gen Chem who would be using the materials with the class). Having created this material, students' attitudes and opinions to it were sought by a number of methods, including questionnaires from the Chemistry Department and originating from this research.

During the first year of Gen Chem, the main research task was to discover if the course did indeed, as the designers had hoped, offer a Chemistry course in which success was achievable by the wide spectrum of students entering the class.

An attempt to build up a picture of students' views and thoughts on the course was made. As well as the questionnaires mentioned this was achieved by interviewing a small representative sample of the class.

Examination results in class and degree exams were analysed (in terms of entry qualifications) in an attempt to find any correlation between entrance qualifications and examination success. This year of work is detailed in Chapter Three.

Following on from this, the second year of the project attempted to build up a picture of which factors were important in governing student success (as measured by exam results) in the course. A variety of factors were considered and they are discussed in Chapter Four. Chapter Five considers the findings of this part of the project.

The final year of this investigation considers changes made to Gen Chem and what effect they appear to have had on the course.

1.6 The Relevance of this Project

The possible impact of General Chemistry-1 in terms of both the University of Glasgow, and Higher Education at large, must be considered in the light of the changes described earlier in this Chapter.

The problems associated with students currently entering Higher Education are clear. The large numbers in the system are likely to continue for the foreseeable future. Likewise, the wide range of entry qualifications will remain. It is interesting to note that, in a statement from the Government concerning Higher Still, there is some indication that attainment of standard entry qualifications (i.e. Higher Grade) is seen as an ultimate aim of the changes proposed:

> *I believe that these arrangements will lead to students being better prepared for Higher Education. More able students will have the chance of in-depth study through Advanced Higher. Other students will have a better chance of progressing at a suitable pace towards the attainment of entry qualifications.*
>
> (Lord Douglas-Hamilton, 1994)

One possible implication of this statement is that those not currently achieving university standard entry qualifications may do so under the new framework. If such students require an extra year to make the transition from Standard Grade to the successful completion of Higher Grade then it would seem unlikely that they would be able to deal with the increase in material and pace of delivery between Higher and most Level-1 courses at university. Institutions will have to recognise this and find ways of dealing with it.

If the new Advanced Higher is to be given the enhanced status the Government hopes for by universities then this will have a profound effect on entrance policy (as the existing CSYS was not intended to be used as an entry qualification) and course design (McGettrick, 1994; Carter, 1994).

In giving "appropriate recognition for earlier achievements such as those in Advanced Higher" (Lord Douglas-Hamilton, 1994) it is suggested allowing such students direct entry into Level-2 courses. Whereas some institutions may balk at this idea, they may be more willing to contemplate entry to an intermediate module in a modular Level-1 course. Modularisation has been increasing in Higher Education courses for a number of years now.

One aim of Gen Chem's Design Team was to create a course which may be more resistant to variations in entry qualifications. If this can be achieved then General Chemistry-1 could provide a model on which other courses could be based. Its intentionally broader, less intense course could also be more palatable to those entering with a 2-year Higher Grade.

Other factors which must be considered by institutions are the intentions and aspirations of students entering Higher Education. Just as Howie concluded Higher Grade was not a realistic goal for many students to aim for in secondary education, then the attainment of an Honours Degree may be a similarly remote possibility for some of those now in Higher Education. One of the key features of the Action Plan was to create more certificated end points than had existed previously. It may now be time for Higher Education to contemplate offering a wider range of qualifications to students than just Degrees (McGettrick, 1994).

The University of Glasgow has found the numbers of students undertaking an Ordinary Degree has decreased over the years – being seen as a "failed" Honours rather than a qualification in its own right. Plans have been published in an attempt to end this situation.

A new 3-year degree framework will be in place for 1996/97 offering students the opportunity to study a broader curriculum than that followed by the Honours student. These new degrees, which will no longer be called Ordinary degrees, will be available both as a general and as a designated degree (the latter containing slightly more of one particular subject).

The Faculties of Science, Arts, Social Science, Engineering, Divinity, and Law and Financial Studies will offer the new degree. Cross-subject and cross-faculty study will be possible and encouraged.

The university hopes this move will cope with the high numbers of students with diverse educational backgrounds and reasons for entering HE (Bone, 1996).

General Chemistry-1 – with its intended student base, its broader treatment of the subject and its aim to be accessible to even the lowest entrance qualification – would appear an ideal model for other courses in this new degree framework, should it prove successful in its own right.

It is clear that, as well as being a curriculum innovation in Chemistry, that General Chemistry-1 has the potential of being a useful model for other Tertiary education curricular developments in the future.

Chapter Two

Literature Review I

2.1 Introduction

One of the features that made General Chemistry-1 unusual, at least as far as the Chemistry Department at Glasgow was concerned, was that those involved in the course worked as a team to shape its development. In the past other chemistry courses had been overseen by a class head whose role was to ensure the smooth running of that course, with other members of staff being responsible for the individual (organic, inorganic and physical) laboratory components of the course. There was no formal, conscious effort to co-ordinate lecture material between individual lecturers, who were left (largely) to construct the material on their particular topic as they saw fit.

Having recognised the need for a new Level-1 chemistry course, a team of lecturers was formed to consider how to meet this need. For example, it was a stated intention that these lecturers would attempt to integrate their courses much more than had been the case previously, as this was recognised as of potential benefit to the students who would undertake the new course. In the past it was not unknown for one lecturer to assume that another had covered a particular topic to a particular depth and attempt to build on from that point, when in fact that was not the case. Increased communication between the lecturers was meant to dispel such problems.

The Design Team also decided to incorporate educational theory and research findings into the new course to help forge their ultimate blueprint for it.

To appreciate the Design Team's planning it is necessary to review the development of the so-called "Ten Commandments" listed in Chapter One, which helped shape the course.

This review is, in essence, a review of some the work carried out at the University of Glasgow's Centre For Science Education, under the directorship of A. H. Johnstone, in the twenty or so years it has existed. During that time research leading to more than 50 Ph.D. theses (and many more M.Sc. dissertations), in all branches of science and at all educational levels, has been carried out.

As well as reviewing the key findings of some of these works (in a variety of areas of study), reference will be made to the literature and ideas that drove those investigations. Material of relevance, i.e. the Perry Scheme of Intellectual and Ethical Development, which is fairly new in the Centre's studies will be discussed in more depth with regard to its origins than material with which the Centre has a longer history.

The links between previous findings and how they were intended to be put into action in General Chemistry-1 will also be described.

2.2 The Areas of Research Reviewed

In a 1979 review of the work carried out by the Centre, Johnstone stated:

> *The work of the Glasgow science education group is very varied and very much of an applied nature. The research is not seen as an end in itself, but is aimed at improving teaching at all levels of education by increasing our understanding of learning problems and finding remedies.*
>
> (Johnstone, 1979)

This is as true a statement of the Centre's perceived purpose today as it was then. During its existence the unit has covered a wide range of interests within the field of science education. This review, however, will focus on work in the following areas:

- Students' attempts at concept formation
- The influence of Working Memory and the use of an Information Processing Model as a research tool
- Student assessment in general
- Student attitudes and attempts to change them
- Development of students' critical thinking skills and general education through the medium of chemistry

2.3 Concept Formation

The earliest work undertaken by the Centre was in the field of what could be broadly termed *Concept Formation*, or *Concept Development* – in other words an attempt at probing the processes of students' understanding of science. MacGuire and Johnstone (1987) defined a "concept" as "...a generalisation of information about some aspect of our physical or biological world. We form concepts quite naturally to enable us to make sense of our observations". A concept, then, could be the understanding of a word; a representation of a group of facts or observations that are related; or the representation of an image or non-visualizable / observable idea (e.g. an atomic orbital).

2.3.1 An Investigation of School Syllabuses

Having been involved in the development of the new Alternative Higher Grade and Certificate of Sixth Year Studies syllabuses, it is perhaps unsurprising that an evaluation of these courses was the first area Johnstone's work probed. By building up a picture of these courses through the school pupils' eyes it was hoped an impartial view of the designer's successes could be drawn. Any problem areas that were discovered could be of interest to teachers and future curriculum planners.

The key questions under consideration in such a study of the syllabuses were (Johnstone, Morrison and Sharp, 1971):

- had the (mainly) intuitive planning used in the new chemistry syllabuses been as good as the designers thought;
- was the psychology of the average pupil sufficiently taken into account;
- had what the designers considered a logical and coherent order of topics actually proved to be so from the pupils' viewpoint;
- were certain ideas introduced to pupils at a time in their development that was too early, raising possible barriers for future study ?

In order to attempt to answer these questions, three surveys were conducted to investigate pupils' views of 'O'-Grade (the forerunner to Standard Grade), Higher Grade and the Certificate of Sixth Year Studies (CSYS). In each case the respective group was asked to complete a questionnaire that asked them to judge their reaction to certain topics within the course they had studied. Topics could be classified in three different ways:

(i) Easy to grasp – the topic was understood from its introduction;
(ii) Difficult to grasp – the topic was understood only after much study;
(iii) Never grasped – the topic was still not understood after much study.

As some pupils were still studying the traditional Higher Grade course, a fourth category, "Never studied" was also used in the Higher Grade questionnaire to take into account the differences in content between the traditional and alternative syllabuses.

From these questionnaires graphs of the frequency of category three responses (i.e. "Never grasped") was plotted against each topic under consideration.

For 'O'-Grade pupils, the most difficulty was found in calculations arising from chemical equations and calculations involving the molarity of a solution; redox reactions, ion-electron half equations; "cracking" hydrocarbons, addition and condensation polymerisation, saponification and ester formation (Johnstone, Morrison and Sharp, 1971).

Higher Grade responses highlighted calculations from chemical equations and volumetric work involving molarity; the mole and Avogadro's number; Hess's law; redox reactions and E° values; esterification, hydrolysis, condensation, carbonyl compounds and fats, soaps and detergents as being the most difficult (Johnstone, Morrison and Sharp, 1971; Johnstone, 1980 and 1983). It is worthy of note how many similarities appear in both lists. It would seem that frequently problems encountered at 'O'-Grade remained for future studies, answering one of the questions the research hoped to answer.

The CSYS pupils' responses indicated that the mole was finally conquered by this stage and the two areas of real difficulty reported were in atomic orbitals and organic chemistry.

This initial study raised some pertinent questions for further work concerning the ordering of topics within the syllabuses, methods employed to teach certain topics and the work load placed on students in general.

2.3.2 Focusing on Difficult Concepts

Workers within the Centre for Science Education used the findings of the study to probe deeper into the problem areas identified in chemistry over the next few years. These areas were the order of concept introduction, the mole, ionic equations and organic chemistry.

2.3.2.1 The Effect of Order of Concept Introduction

The 'O'-Grade syllabus of the time and its accompanying texts offered a particular order of topics, and this was the normal route taken by those teaching the course. This route began with atomic structure, ionic and covalent bonding, equations and balancing. The course then moved through the inorganic / physical chemistry topics – such as the reactivity series, corrosion, acids and bases, moles in solution, sulphur and nitrogen chemistry – before rounding off with organic topics.

It was hypothesised that the reason some of the concepts students identified as difficult at 'O'-Grade were due to their introduction coming at the wrong time in the course for the students to cope with. An experimental version of the syllabus was prepared to investigate this idea. Preliminary work had suggested that students did well if the organic material was taught before the inorganic material – i.e. directly after the atomic structure, bonding and chemical equation material. A second change made to the experimental version was to break up the initial theoretical block at the beginning of the course. Instead only enough theory to allow interpretation of observations made in the laboratory was introduced at any one time. By having organic chemistry at the beginning of the course, meant it was possible to consider only covalent bonds for some time before introducing ionic bonding. Under the original order students met both concepts at the same time and would have to reconcile both simultaneously. By gradually moving from a simple covalent model of hydrocarbons towards organic acids and eventually ionic bonds gave a potentially more even learning gradient.

In comparing students who were using this experimental programme with those studying the normal one, significantly better performances in every test was recorded for those studying the experimental version (Johnstone, 1980). With these results in mind, the revised order was put forward in the textbook "Chemistry About Us" (Johnstone, Morrison and Reid, 1980).

2.3.2.2 The Mole

Having uncovered the concept of the mole as one which was not only the source of problems at 'O'-Grade, but that those problems persisted into Higher Grade, Duncan (Duncan and Johnstone, 1973) began to investigate the nature of the difficulties pupils faced at the lower level.

Using a series of tests in which the level of difficulty of the questions steadily increased, Duncan was able to separate out several different strands within the cover-all term of "the mole".

His initial test involved simply asking pupils to work out the mass in grams (gram formula weight) of compound, given its formulae. The complexity of the formulae used ranged from simple binary compounds to those containing complex oxyanions. Student performance on this task was high, even when the term "gram formula weight" was replaced by "mole" in similar questions. However, performance was reduced dramatically in questions where the formulae were removed and students had the extra step of recalling them. It seemed clear, though, that pupils were happy enough with the concept of a mole of a compound being numerically equal to its formula mass in grams and were quite capable of calculating this from a formula.

The next skill to be probed was that of producing mole calculations from given balanced equations, but excluding the mole in solutions at this stage. It was observed that equations with a 1:1 relationship between components offered little challenge, whether students were asked to supply mole ratios or masses of one component as an answer.

When given a situation other than a 1:1 relationship, performance decreased and the most popular incorrect response was to assume that the reaction had a 1:1 relationship regardless of the equation presented.

If students were asked to balance an equation before performing calculations based on it disaster struck with most students floundering.

Another test Duncan used examined how pupils dealt with calculations involving the molarity concept. Whilst reactions involving 1:1 relationships and solutions reacting with solids were well within most students' abilities, the same problems as before appeared as the level of challenge was increased i.e. non-1:1 relationship and reactions between two solutions caused the most problems.

One interesting observation was that pupils raised on the traditional syllabus reverted to an algorithm from their work on normality ($N_1V_1 = N_2V_2$, where N is the normality of solution and V is volume of solution) to cope with the most difficult questions. However no such method was available to those studying the alternative Higher.

2.3.2.3 Ionic Equations

One of the innovations introduced in the new syllabuses was the use of ionic equations and net ionic equations to describe precipitation or neutralisation reactions.
For example, what students had previously encountered as:

$$AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$$

became:

$$Ag^+_{(aq)} + NO_3^-{}_{(aq)} + Na^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)} + Na^+_{(aq)} + NO_3^-{}_{(aq)}.$$

By recognising and eliminating the spectator ions, students would come to:

$$Ag^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)}$$

Whilst this was undoubtedly a unifying idea that allowed a focusing in on the actual reaction occurring, Garforth (Garforth, Johnstone and Lazonby, 1976a and 1976b) was of the opinion that such an idea would not appeal to pupils.

In order to test this hypothesis, a study involving four different questionnaires was devised. This involved teacher and student questionnaires and two students' question papers probing preferred form of equation presentation and ability to recognise net ionic equations.

The second question paper asking students to identify the correct net ionic equation – for a given reaction – was used with students at the three examination levels under consideration, i.e. age 15+, 16+ and 17+.

It was found that success in this second paper was poor at the 15+ age group, but generally improved with age. It was suggested that poor performance at the 'O'-Grade level could be attributed to the fact that very few questions of this nature were found in examination papers at this stage. However as Garforth et al. (1976a) pointed out, if students have difficulty understanding such equations and they represent such a small part of the final examination, then is it really worth teaching this concept at this stage ?

One other noteworthy result from analysis of the results from this test, which supported Garforth's view, arose when the researchers considered topics within the idea of net equations. They broke the concept down into equations involving electrode equations, precipitation, neutralisation, metal/acid, redox half-equations, metal/salt solutions, halogen/halide, acid/carbonate, and ammonium/alkali. When examining the percentage of incorrect responses to each of these topics, the general trend of improvement with age was observed. However another trend that was discovered was that the relative difficulty of each of the topics was very consistent – e.g. halogen/halide equations remained the second most difficult type of equation for the students to deal with in each age range. There seemed to be a persistence of topic difficulty, which was established from when the topic was first taught. This effect was also picked up on comparisons between pupils' test scores and teachers' replies to a questionnaire asking them to state their confidence in their students' understanding of the topic. Again teacher confidence in material pupils had met earlier was not borne out in terms of the percentage of correct answers to questions on that material.

2.3.2.4 Organic Chemistry

Although work on concept development in other areas of chemistry and physics has been carried out at the Centre (Johnstone, MacDonald and Webb, 1977a and 1977b; Johnstone and Mughol, 1976, 1978 and 1979) perhaps one of the most important contributions came from a study of organic chemistry.

In identifying difficult concepts (2.3.1 above) condensation, hydrolysis and esterification reactions were highlighted by pupils at all levels under investigation. Kellett (1978) began to investigate the nature of the difficulties reported.

Kellett initially proposed two hypotheses, based on consideration of syllabus content and interviews with pupils and teachers. Those hypotheses were:

- the "Visual Difficulties" hypothesis – this proposed that difficulties arose in organic chemistry due to the variety of visual representations used to convey chemical structures and pupils' inability to recognise the same compound(s) drawn in different orientations.
- the "Conceptual Difficulties" hypothesis – difficulties arose due to conceptual problems pupils had with the material under consideration and as a consequence were unable to extract or interpret chemical information from formulae.

In order to test these hypotheses, two tests were constructed – the "Pattern Test" and the "Molecule Test".

The Pattern Test was designed to determine whether pupils were so confused by the visual pattern of an extended molecular formula that this inhibited their understanding of the chemical content it contained. The test called for pupils to recall immediately a target pattern after a few seconds exposure to it. The patterns, each of known complexity, were chemically content-free but designed to reproduce the characteristics of extended structural formulae.

The Molecule Test was constructed with the same rationale as the Pattern Test and sought to ascertain pupils' ability to recognise chemical groupings within a structural formula. If pupils were unable to recognise chemical groupings then they would treat the extended structural formulae as they had done the shapes in the Pattern Test and there would be (effectively) no difference in their performance on the two tests. If the test participants could recognise entities, such as a carboxylic acid grouping, as a single item then this should enhance their performance in the Molecule Test (relative to the Pattern Test).

In practice, Kellett found no evidence to support her Visual Difficulties Hypothesis. There was no effective difference in the mean Pattern Test score across the age range studied ('O'-Grade, Higher Grade and CSYS), although chemistry performance increased with age. In fact the realisation that performance seemed to be limited by the capacity of the individual's Short Term Memory (Ashcraft, 1994; Eysenck, 1994), as opposed to any innate "Visual Ability", would prove to be the beginnings of a key finding.

The Conceptual Difficulties Hypothesis was more fruitful, however. Different levels of recognition of coherent functional groups within a molecular structure were identified, allowing pupils to be classified. Very few of those tested in any age range were capable of the highest level of functional group recognition. This, coupled with the suggestion that pupils did not separate out any functional groups present first when considering a molecular structure, seemed consistent with the Conceptual Difficulties Hypothesis.

The ability to identify functional groups was studied further with the following findings:

- pupils significantly failed to treat the functional group as a single unit, rather they considered a formula bit-by-bit;
- there was also a failure to choose the functional group as a characteristic property of a compound and hence relate observed chemical behaviour to its presence.

However, as all organic molecules have (effectively) a functional group, why should this cause condensation, hydrolysis and esterification reactions to be regarded as particularly difficult by pupils ?

At various stages during Kellett's investigations, pupils had indicated that the "size" of molecules or equations were perceived as a particular problem. It appeared that the key difference which marked out condensation, hydrolysis and esterification (as opposed to other organic material) was in the sheer information load related to these topics. It was in considering this load placed on pupils that Kellett's attention returned to Short Term Memory, or more appropriately Working Memory.

2.3.2.5 Working Memory and the I.C.C.U.D. Hypothesis

In constructing the Pattern Test used to evaluate Visual Ability, Kellett considered the role of Short Term Memory (STM), as this was relevant to the immediate recall task involved in the test. The existence of Short Term Memory (as distinct from Long Term Memory) has been recognised for some time (Kintsch, 1970). The features of Short Term Memory pertinent to the Pattern Test were:

- STM is used for holding information for a short period of time (Sperling, 1960), as the test's subjects would be required to do;
- STM has a limited, finite capacity of 7 ± 2 "chunks" (Miller, 1956), where a "chunk" is an arbitrary unit of information.

In identifying average performance in the Pattern Test as being close to the limits of STM capacity, Kellett realised that this psychological factor could be more of a limitation on performance that her proposed Visual Hypothesis (Johnstone and Kellett, 1980; Johnstone, 1983).

If, as suggested by pupils, the problem areas in organic chemistry were due to the amount of information in these areas, then consideration of the capacity of STM could help explain the problems.

Miller's "chunks" of information are not fixed; rather they are dependent on the individual and represent what that individual perceives as a comprehensible unit of information. A chunk can be a word, a letter or number, or a functional group. The total amount of information the STM can hold at any one time will therefore depend on the amount of information in each chunk.

For example, the sequence of letters:

T D A T C M

could be considered as comprising of six chunks, as could the sequence:

THE DOG ATE THE CAT'S MAT

but clearly there is more information (letters) contained in the second sequence. By recognising the collection of letters in the second sequence as words (chunks) then more information can be held.

It is in this ability to recognise or construct chunks (chunking) that Kellett's new hypothesis to explain pupils' behaviour lay. As pupils' conceptual understanding of functional groups as distinct pieces of information within an extended structural formula was poor, then they would not treat these groups as chunks and hence reduce the informational load to be considered (Johnstone and Kellett, 1980; Johnstone, 1980 and 1983).

It was at this stage that Kellett began to use the more modern, and comprehensive, term Working Memory rather than Short Term Memory. An instant recall task involves no actual mental processing – i.e. carrying out some form of transformation or interaction with information in the Long Term Memory (the repository of an individual's knowledge) on the data stored in STM. However, a true learning or problem solving situation will involve some form of processing. For this reason, Working Memory would appear a more apt description. Ashcraft (1994) describes Working Memory as "the mental workplace for retrieval and use of already known information". He then goes further to point out that STM implies a static, short-lived store; Working Memory implies action – a busy place limited by how much work can be done. The more information to be held, the less processing can occur and vice versa. Workers like Baddeley (Baddeley and Hitch, 1974; Baddeley, 1992) have confirmed this dual role and indeed Baddeley has presented quite detailed models of Working Memory (Baddeley, 1995), although that level of detail is not of relevance here.

Kellett called the new hypothesis the I.C.C.U.D. Hypothesis as it proposed a relationship between Information Content, Conceptual Understanding and Difficulty (Kellett, 1978). This hypothesis stated that where pupils had a lack of conceptual understanding then those pupils may perform reasonably in low information load situations, but their performance would decrease in high information load situations, causing complaints of difficulty.

Those with high conceptual understanding could use this to chunk information, and thus reduce the information load to one which their Working Memories could handle. High conceptual understanding would also allow pupils to separate relevant from irrelevant and so focus in on the relevant only, which would also reduce the information load burden.

By re-examining the results of her tests, Kellett felt the I.C.C.U.D. Hypothesis gave a model to explain why pupils found condensation, hydrolysis and esterification reactions an area of particular difficulty. In the Molecule Test, the average complexity of molecule reproduced correctly, by pupils studying for Higher Grade, was greater than mean Working Memory capacity. This suggested that some simple strategies had been used by test subjects. Similarly, in a test of functional group recognition and matching, the results suggested some form of strategy had been deployed. In both these cases, however, the level of information content was such that the test items were not considered to be difficult.
In examining condensation, hydrolysis and esterification by interview, the situation was different. The formulae involved were much more complicated (as interpreted by the pupils due to poor understanding of the functional group concept) and would exceed Working Memory capacity, causing the claim of difficulty. Strategies used by such pupils were observed to be cumbersome and inefficient. A higher level of conceptual understanding would have allowed adoption of a more successful, stream-lined strategy to solve the task, which would then have been seen as less difficult.

2.3.2.6 Further Examinations of the I.C.C.U.D. Hypothesis

A reappraisal of the earlier work of Duncan (et al., 1973) and Garforth (et al., 1976a and 1976b) on Concept Development in the light the I.C.C.U.D. hypothesis was carried out by Kellett (1978). Kellett argued that, although none of her predecessors' studies were constructed specifically to test her hypothesis, they did involve collection of data concerning difficult areas of chemistry and so the results could be consistent with the hypothesis.

As discussed before (2.3.2.2. The Mole) Duncan's test instruments increased the difficulty of task the pupils faced as they progressed. The tests suggested that pupils had a low level of understanding of the mole and molarity concepts. Kellett noted that performance dropped off as information and processing load increased – in terms of information to be processed to separate relevant from irrelevant, and information to be supplied from an individual's Long Term Memory (Johnstone, 1980). It was observed that the highest scoring parts of Duncan's tests were those which allowed the simplest mathematical strategies to be deployed.

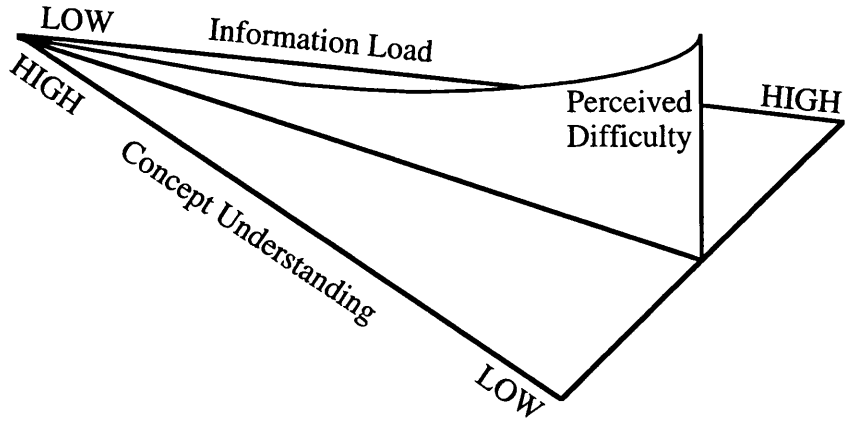
Garforth's results also showed a limited level of concept development in ionic equations. Kellett pointed out that pupils opted for molecular equations rather than the more information heavy ionic equations which included state symbols. As Johnstone (1980 and 1983) reiterated, if arriving at a "simplification" (e.g. net ionic equation) required an intermediate, high complexity stage (e.g. full ionic equation), then this offered a great challenge to students.

Kellett concluded that these results supported the I.C.C.U.D. hypothesis which, as it suggested a general relevance of its use in explaining performance, strengthened its use in the specific area of organic chemistry.

Johnstone summarised the relationship between Information Content, Information Load and Perceived Difficulty in the "Concorde" diagram (1980) shown in Figure 2.1. As the Information Load increases for a student with low Conceptual Ability, so the Perceived Difficulty barrier increases, the reverse being the case for a student of high Conceptual Understanding.

A new learner is naturally at the LOW end of the Concept Understanding axis. If the teacher presents this new learner with material at the HIGH end of the Information Load, then the Perceived Difficulty barrier will prevent the learner from "seeing" what is going on. If this continues then a student's complaint of "I don't understand" could easily become "I will never understand" – an attitude towards a topic which may prove difficult or impossible to alter later. If the teacher adopts a lower Information Load, increasing it only as a student's Concept Understanding develops, then the difficulty should remain (essentially) constant

Figure 2.1 "Concorde" Diagram - The Variation of Concept Understanding, Information Load and Perceived Difficulty



(From Johnstone, 1980)

Kellett's research and where it led the thinking of the Centre was to have a most profound effect on the direction of future work carried out there.

2.4 Working Memory and a Model of Information Processing

Fuelled by the success of considering the role of Working Memory, other researchers began to explore its usefulness.

2.4.1 Working Memory and Laboratory Work

Laboratory based practical work has been considered one of the "Sacred Cows" of chemistry teaching for many years. However, attempts to measure the benefits of the laboratory experience to which students are subjected, with regard to how much learning actually occurs, showed what Johnstone and Wham (1982) described as a "pessimistic picture". Whilst practical work is generally popular with students and can, to varying degrees of proficiency, engender hand-skills, its ability to generate much active thought or teach theory appears at best questionable.

Anyone who has ever spent any time in an undergraduate laboratory class will undoubtedly have their own anecdotal evidence of student behaviour which suggests a lack of appreciation or understanding of what is happening. One very common sight is the student who follows the instructions given in the manual or worksheet line by line; blind recipe following ensues with the student totally at a loss as to the bigger picture the experiment may encompass.

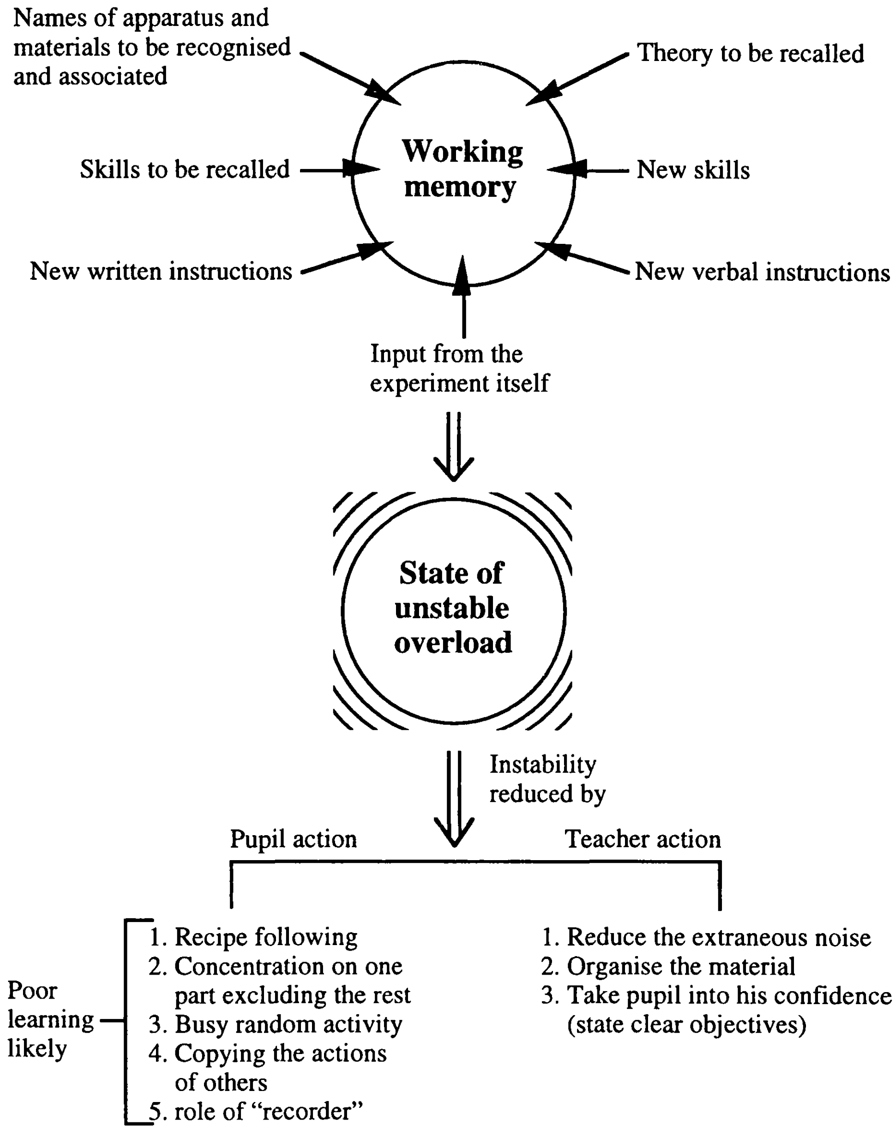
What may be clearly organised and understood by the teacher may not be so for the student. Information received by the student may have no apparent structure since the material being taught is actually required to make sense of the information! As the important cannot be distinguished from the irrelevant, the point of the lesson is lost to the student. The laboratory is, perhaps, the most common place for this situation to develop in chemistry education.

Considering Kellett's hypothesis, Wham (Johnstone and Wham, 1982; Johnstone, 1983) turned his attention to laboratory work and the influence of Working Memory on student performance in the lab. Wham recognised that in a laboratory situation the Working Memory is bombarded with information from a variety of different sources. That information would include:

- understanding and following written instructions and verbal instructions (which may be in addition to or amend the written ones);
- recall of existing relevant skills and techniques, theory, apparatus and chemicals required for the experiment, whilst new skills are introduced in the experiment;
- observations made from the experiment, which could include colour or temperature change, gas evolution, precipitation formation, etc.

He represented the situation found in the lab by a diagram, Figure 2.2.

Figure 2.2 The Effects of Practical Work on the Working Memory



(From Johnstone and Wham, 1982)

This overload of information would be too much for students to cope with and so some form of action to alleviate the situation must be undertaken. If the student is left to deal with this situation on his or her own, then the strategies generally observed will likely lead to poor learning. Students may follow instructions line by line, as mentioned before; give one section of the experiment an inordinate amount of time and attention, whether it warrants it or not; copy nearby students' actions; volunteer to act as the recorder of information for group experiments. All of these are attempts to lessen the load.

However, Wham suggested actions open to the teacher which may be more beneficial. If the extraneous material which causes so much of the overload is regarded as "noise", and the important material as "signal", then enhancing the signal, or reducing the noise (or doing both) would seem a useful exercise. The effect of noise in the laboratory, and possible ways of reducing it, is discussed fully by Wham (Johnstone and Wham, 1982). He does point out, though, that once students have become competent with lab skills and have a grasp of relevant theory then noise can be increased in the lab (in, say, a project or open-ended investigation).

Other suggestions were the careful organisation of material into as logical an arrangement for the student as possible and making clear statements of an experiment's objectives.

Letton (Johnstone and Letton, 1990) undertook an investigation of laboratory manuals from the students' point of view to investigate whether or not the laboratory designers' intentions were clear. Students were asked to keep a diary of their experiences in practical classes for a year, allowing Letton to follow them through physical, organic and inorganic courses.

Following an analysis of the diaries, it was clear that the physical chemistry lab course had proved the least popular, followed by inorganic, with the organic course coming in for little criticism. In an effort to explain these results, the individual experiments were examined to evaluate the information load each placed on the students. This load would include what had to be processed, recalled, digested and interrelated within the space of a single lab class, broken down into Theory, Experimental and Report demands. The physical lab course was found to have the largest load (coming mainly in the Theory component), with inorganic being the second largest.

Whilst not implying a simple causal relationship between load and student dissatisfaction with physical chemistry practicals, Letton pointed out its influence should not be underestimated (Johnstone, 1984). Re-examination of the diary responses were consistent with students being frustrated by a situation of total overload for the duration of an experiment. With a Theory load, which had to be kept in mind to make sense of the overall experiment, it is perhaps no surprise that students resorted to recipe following. Letton concluded that lab manuals and experiments should be redesigned to take cognisance of the psychological load placed on students, as well as being true to the science which was supposed to be taught.

Some of the recommendations of Wham and Letton would resurface to be put into practice in future research on undergraduate laboratory classes.

2.4.2 Working Memory and Examination Performance

Having looked at laboratory work in terms of Working Memory and found some evidence of a link between information load and the learning problems observed in practical sessions, attention moved to study Working Memory overload in chemistry examinations.

Working from data collected by Duncan in his study of areas of difficulty in the curriculum, a surprising and (then) inexplicable result was discovered (Johnstone and El-Banna, 1989). The Facility Value (F.V.), a measure of the percentage of a class scoring full marks in a particular question, had been calculated for a set of questions in order to aid the construction of suitable test items for Duncan's work. When a histogram of the spread of Facility Values was plotted the pattern observed was completely unexpected. Rather than the broadly even distribution that might have been predicted, the questions were separated into two clusters. One cluster showed questions in which students had been very successful, with F.V.s of greater then 0.6, whilst the other represented questions with F.V.s of less then 0.3. No questions generated F.V. of between 0.3 and 0.6, giving a gap or hole in the middle of the distribution. This pattern was also found in different areas of the syllabus by other workers.

With Kellett's hypothesis in mind, chemistry questions (including some from the Scottish Examination Board's national examinations) were reviewed by El-Banna to determine their information load. This load or demand (Z) was defined as the maximum number of thought steps which were used by the least able, but ultimately successful student. A jury of researchers examined an assortment of randomly chosen scripts in which full marks had been obtained for a given question. The questions considered were usually numerical in nature as they readily lent themselves to such an analysis. Jury members would agree to what constituted the longest route to solve the problem and this would be regarded as the demand of that question (Johnstone and El-Banna, 1986 and 1989).

Whilst this method of assessing question demand does not take into account any processing required to sequence the individual steps, and so may actually underestimate the demand, it did give a fair relative measure which was viewed as superior to an estimate.

A typical analysis of a question, as a student may attempt it, would run along the following lines:

> *What volume of 1.0 M hydrochloric acid would react with exactly 10.0 g of chalk ?*

1. *Chalk is calcium carbonate (recall)*
2. *Calcium carbonate is $CaCO_3$ (recall)*
3. *Formula mass = 100 g mol^{-1} (calculate and recall)*
4. *Therefore 10 g is a tenth of a mole*
5. *Write equation for reaction (recall products and formulae)*
6. *Balance (recalled skill)*
7. *Deduce mole relationship*
8. *Therefore one tenth of a mole of $CaCO_3$ = one fifth of a mole of HCl*
9. *One fifth of a mole of 1.0 M HCl is 200 mL*

(From Johnstone and El-Banna, 1986)

Similarly, an expert (teacher, say) would attempt the question slightly differently:

1. *10 g of chalk is one tenth of a mole of $CaCO_3$ (recall from frequent use)*
2. *Mole ratio of HCl to $CaCO_3$ is 2:1 (experience)*
3. *One fifth of a mole of 1.0 M HCl is 200 mL*

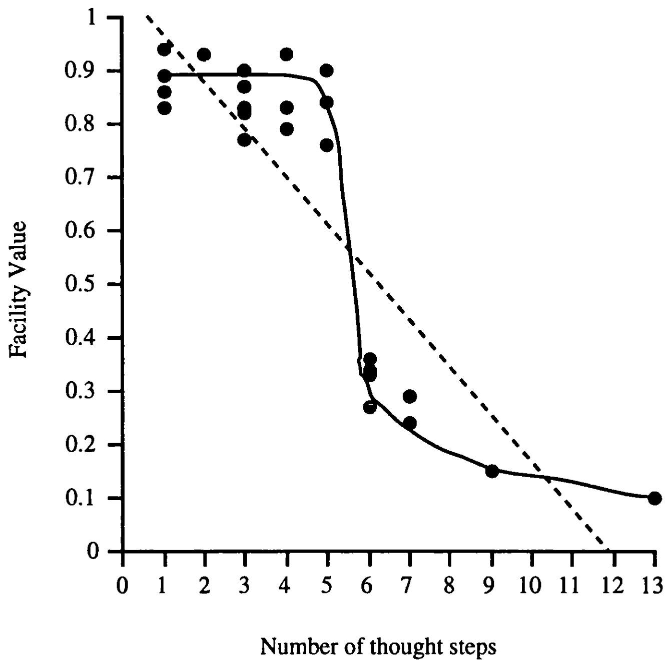
(From Johnstone and El-Banna, 1986)

This is in keeping with Kellett's observations; an increased level of concept development, such as that of an expert, reduces the information load on the Working Memory, leading to improved performance.

Using these demand-rated questions, Facility Values were calculated and plotted against the demand. Kellett's hypothesis would predict a negative correlation between F.V. and demand and, indeed, this was found but not in the way expected. Rather than a simple linear correlation, a reversed S-shape (reminiscent of a strong base / strong acid pH titration curve) was obtained, Figure 2.3 overleaf.

Consideration of this curve shows that the questions are grouped into two clusters – one of high achievement and one of low achievement. Just as in the analysis of Duncan's data, the inexplicable "hole in the middle" of the range of Facility Values was observed. The curve suggested a phenomenon in which a limit is reached followed by a rapid change. The vertical drop in performance occurs between a demand of 5 and 6, tantalisingly close to Miller's 7± 2 chunk STM capacity measurements. One interpretation of these results was that the researchers were observing the overload of Working Memory and corresponding drop in performance predicted by Kellett.

Figure 2.3 The Correlation Between Facility Value and Question Demand



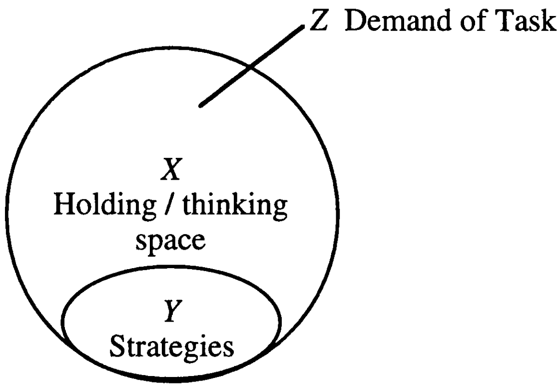
(Adapted from Johnstone and El-Banna, 1986)

The examination data used in this graph was supplied from a large sample (~20,000 pupils) undertaking national examinations. With this in mind it is clear that, although the low demand questions would be within the Working Memory capacity of all, other factors such as carelessness or forgetfulness could depress performance. The lower cluster of points indicated that even though question demand was very high, there were still some students who could succeed in such questions. Another factor to be borne in mind from the graph is that the sample would contain a range of Working Memory capacities and the observed pattern was due to an amalgamation of these factors.

Using suitable tests of the Working Memory capacity, El-Banna hoped to separate out students of differing capacity for further analysis. The tests used, the Digit Span Backwards test and the Figure Intersection Test (Johnstone and El-Banna, 1986), required both holding and processing of information within a subject's Working Memory. The Digit Span consisted of giving students strings of numbers, which increased in length, and asking them to give the numbers back in reverse order. The upper limit at which students could achieve this was taken as their measure of capacity. The Figure Intersection Test required students to shade in a common area from increasingly complex patterns of overlapping shapes. The level of agreement between the two measures was found to be high (with a correlation coefficient of around r = 0.75).

A model of Working Memory was proposed to aid hypothesis formation, Figure 2.4

Figure 2.4 A Simple Model of the Working Memory



(From Johnstone and El-Banna, 1986)

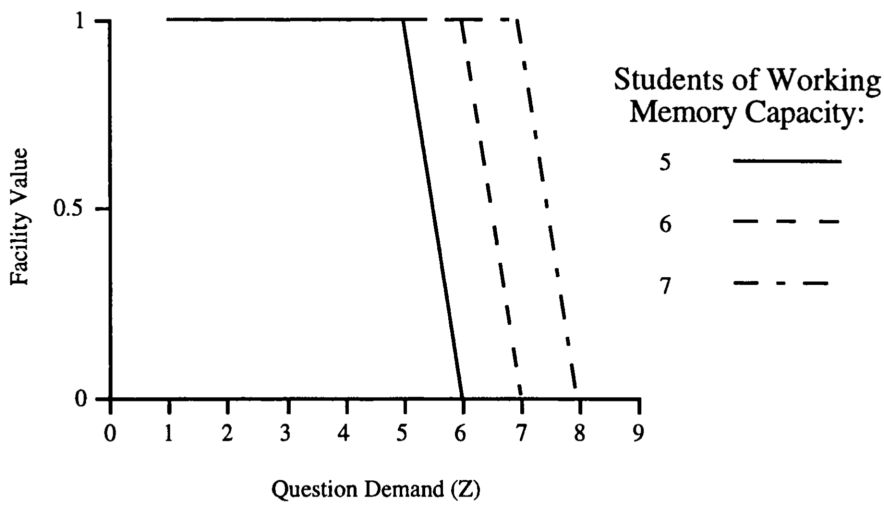
Using the model (where the Working Memory is represented by the circle), Johnstone and El-Banna (1989) hypothesised that:

> *A necessary (but not sufficient) condition for a student to be successful in a question is that the demand of the question* [Z in Figure 2.4] *should not exceed the working memory capacity of the student* [X]. *If the capacity is exceeded, the student's performance should fall unless he has some strategy* [Y] *which enables him to structure the question and bring it within his capacity.*

From this, an idealised set of curves for a Facility Value versus Question Demand was hypothesised, Figure 2.5 overleaf. As can be seen, it was predicted that those of a certain capacity would succeed until that capacity is exceeded by the relative demand of the question, at which point performance would fall off dramatically.

El-Banna analysed data arising from both school and university chemistry examinations in this way. In all cases the general trend found for each of the groups of students followed the pattern predicted – a level, or gently decreasing, Facility Value as Question Demand increased until the groups' capacity was exceeded when a rapid decrease occurred followed by a levelling off. The university sample's results fitted the predictions even more closely that the school results (Johnstone and El-Banna, 1986 and 1989). Similar results have also been found in University of Glasgow Physics students and Algerian mathematical baccalaureate students (Johnstone, Hogg and Ziane, 1993).

Figure 2.5 Predicted Performance in Chemistry Students with Different Working Memory Capacities



(From Johnstone and El-Banna, 1986)

The researchers took heart from the fact that the Facility Value never actually fell to zero, even after the groups' capacity was surpassed. In every case examined there always remained a small proportion of students who had found a way of coping with questions beyond their measured Working Memory capacity. This suggested that this fraction had, consciously or not, learned to operate successfully beyond the limitations of their Working Memory. If this was true, it raised the obvious question of whether or not strategies could be taught to the majority to improve their performance.

To strengthen the findings further, it was observed that overall exam performance increased with capacity, i.e. capacity 6 students performed better than their capacity 5 counterparts. This gross effect was also shown in the variation of the composition of the university chemistry class, in terms of capacity, over three different year groups; each year was richer in higher capacity students than the preceding one. The more successful, higher capacity students passed exams and continued to further years, whilst the lower capacity students did not.

These findings raised several implications for teaching and learning (Johnstone and El-Banna, 1986 and 1989; Johnstone, 1984), including:

- First time learners must encounter new material in such a form as to keep a task's demand within the capacity of the learner;
- As a learner's understanding of a subject increases, the teacher can increase the amount of noise to allow the student the opportunity to extract the (useful) signal;

- Formal teaching of chunking techniques, or encouraging students to form their own, would appear to be an essential part of developing mastery of a subject;
- Assessment materials containing high demand questions should be carefully considered. Such questions may not be testing subject content understanding, but rather be separating students according to their Working Memory capacity. High demand questions test both content and strategies for dealing with that content. If the development of strategies has not been actively taught or encouraged, then are such examinations fair ?

These ideas would be put into practice and underpin future development, such as some of the Ten Commandments.

2.4.2.1 Field Dependency – A Limiting Factor

El-Banna's work had clearly shown that an overload of a student's Working Memory capacity led to reduced performance in assessments. Although strategies intended to group information so as to ultimately reduce load demands can help to overcome this problem, one factor which may lead to the inefficient use of Working Memory is in the process of selecting that which is deemed relevant or important. If Working Memory is to be used as effectively as possible then this information selection stage would appear crucial. Irrelevant or useless data would consume precious holding / processing space in Working Memory, thus reducing its limited capacity still further. Whilst some established model or concept in Long Term Memory is required to help students select relevant signal, another limiting factor may operate to limit this (and ultimately limit performance).

The work of Witkin (Al-Naeme, 1991) suggested that some individuals have difficulty in distinguishing required material from a confusing background. Witkin termed such individuals as Field Dependent (F.D.).

Al-Naeme considered the interaction of Working Memory capacity and Field Dependency, building on El-Banna's findings concerning the relationship between capacity and examination performance. Al-Naeme hypothesised that those who have difficulty in selecting out relevant data from complicated stimuli will not perform as well in a task as those who can be selective (Johnstone and Al-Naeme, 1991; Al-Naeme, 1991).

An individual's level of Field Dependency can be determined via a paper-and-pencil test, the Group Embedded Figures Test (GEFT) developed by Witkin *et al.* (1971). Witkin's test involves test subjects being asked to recognise and identify a target shape from within a complex pattern. The more target shapes correctly found, the better the individual is at this process of separation and is said to be Field Independent (F.I.), and vice versa for Field Dependent subjects. Those of intermediate ability are classed as Field Intermediate (F.Int.).

El-Banna (1987) had developed and tested a version of the GEFT using more complicated complex patterns than the original. In his study, El-Banna used this test to determine the correlation between Field Dependency and performance in chemistry exams for those of Low, Medium and High Working Memory capacities. He found a clear relationship between Field Dependency and performance among the Low capacity students, with performance decreased when the student is more Field Dependent. The same relationship (although not as strong) was observed for the Medium capacity students, however High capacity students showed no correlation between the two factors.

Al-Naeme suggested a possible interpretation of these results; that Low capacity students cannot afford to waste any Working Memory space on the irrelevant. Hence Low capacity F.I.s would naturally fare better than their F.D. counterparts. For High capacity students, if the demand of the task under consideration was within their capacity, then spare capacity existed to deal with excess, unnecessary material so that no real drop in performance due to F.D. was observed.

When considering data from tests involving a higher information load demand, Al-Naeme obtained another view of the same phenomenon. A typical set of data is reproduced in Table 2.1.

Inspection of the table shows some interesting trends. In each column there is an improvement in performance as capacity increases (although not always statistically significant). Across each row there is also an improvement in performance when the student is more Field Independent. These observations are in keeping with El-Banna's findings.

Table 2.1 Mean Chemistry Examination Scores For Students of Different Working Memory Capacities and Degrees of Field Dependency.

	Mean Scores %		
Capacity	**F. D.**	**F. Int.**	**F. I.**
Low	36.3	38.2	45.2
Medium	42.1	44.8	47.4
High	45.6	47.0	49.1

The largest changes in mean performance occur along the diagonal running from top-left (Low capacity, F.D.) to bottom-right (High capacity, F.I.), as predicted. Across the other diagonal, however, performance is almost constant – High capacity, F.D. students are performing only as well as Low capacity, F.I. students.

These same general trends and results were replicated in companion studies in chemistry, biology and physics (for example, Johnstone, Hogg and Ziane, 1993).

The results suggested that a distinction should be drawn between a student's potential capacity (total Working Memory capacity) and his or her usable capacity (Al-Naeme, 1991).

When confronted with a noise-free task (i.e. one free of unnecessary or confusing information), such as in the Working Memory capacity tests used in this work, subjects can use their full capacity. In real problem solving situations, however, both noise (the unnecessary) and signal (the necessary) are present, and a fall in performance occurs. How large that fall in performance will be, will depend on the Field Dependency of the individual. As Field Dependents have a problem extracting the signal, they may inadvertently take in noise as well as signal, reducing their already limited mental work space still further to leave an even smaller usable capacity. Low capacity, F.I. students appear to have the same usable capacity as High capacity, F.D. Those in the High capacity, F.D. category are not gaining the benefit of their larger Working Memory because it is being reduced by the presence of useless information.

Several implications arising from this study are of relevance to what would eventually become the Ten Commandments for General Chemistry-1:

- New learners don't have any concepts or information to help act on the filtration system of separating signal from noise. At this time the difference between potential and usable capacity is likely to be at its greatest Such students in a learning situation, unable to disregard the irrelevant, may waste time trying to incorporate and process noise.

- As highlighted before, the teacher has an opportunity to help students by acting as an external filter; by carefully and actively trying to eliminate as much noise as is possible from the earliest lessons. This should allow students to maximise their potential capacity.
- Once concepts are well developed, the teacher can introduce and increase noise levels to allow students to develop discriminatory skills.

2.4.3 An Information Processing Model

From further consideration of Working Memory and the implications of the work they had carried out in the field, the Centre's thinking moved to a fuller model of Information Processing. Such models are found at the heart of much of the work carried out in the field of Cognitive Psychology, of which the core areas of interest are memory, attention, psycholinguistics, thinking and reasoning (French and Colman, 1995), concept formation and problem solving (Eysenck, 1994).

These areas of study, and the models which researchers have devised to help form hypotheses and understand cognition, owe much to parallels drawn between human mental processes and the operation of computers (Ashcraft, 1994). Justification for such analogies is drawn from a consideration of the "hardware" and "software" (to use computer terminology) employed by both systems.

In terms of hardware, actual physical components, required by both systems include:

- an input system of some kind to accept external stimuli (e.g. keyboard, card reader; ears, eyes);
- a translation unit to convert external stimuli into an understood language used internally by the system;
- a central processing component where operations on admitted stimuli are performed (CPU; Working Memory);
- an external output for what has been processed (e.g. printer; voice);
- bulk storage device for data, information and software (e.g. disk; Long Term Memory).

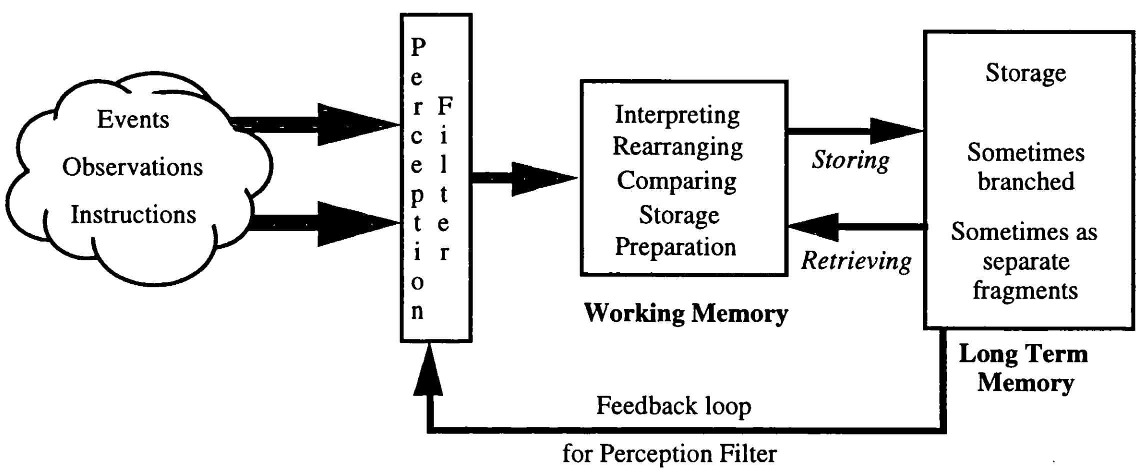
Software, instructions to control or operations which can be carried out by the system, required by both include:

- translator to convert external signals to internal language (and vice versa);

- controller for central processor which allows retrieval of material from bulk storage, interaction between retrieved and received material, transmission of material to external output or bulk storage;
- cataloguer to help store bulk material in a way which can be accessed and understood by the system later.

In what Ashcraft describes as the Standard Theory in the field, a model of Information Processing should include three components: a Sensory Memory (or Register), a Short Term (Working) memory and a Long Term Memory (LTM). Information enters the system via the Sensory Memory into Working Memory which can interact with LTM in a two-way transaction of data. These key features were included in the Centre's own model of Information Processing, Figure 2.6

Figure 2.6 A Model of Information Processing



(From Johnstone, 1993a)

The Perception Filter, Ashcraft's Sensory Memory, receives signals from the outside world and admits some of them to the Working Memory. Ashcraft describes two types of Sensory Memory, Auditory and Visual, which he defines as the components that receive auditory and visual stimuli respectively. Clearly the Perception Filter is bombarded by stimuli constantly, but an individual is able to select or filter out certain signals for further consideration (Johnstone, 1993a). As mentioned previously, information held in the Long Term Memory can guide the Filter, so what signals an individual might choose to focus on (or attend to) will be determined by what that individual already knows or understands about the situation they are in. Clearly this is crucial in a learning context, where a novice may not be able to select the proper stimuli when he or she has little or no information to guide the filtration process.

The Working Memory's role and function as perceived by the researchers in the Centre has already been clearly described above.

The Long Term Memory is described as a storage system of (effectively) infinite capacity, although the retrieval system employed to recover information may not always be perfect, (Johnstone, 1993a). The LTM can be considered as an individual's repository of knowledge, facts, concepts and attitudes. Information held in LTM can be stored as isolated material or incorporated into a network the individual has constructed for him or herself. Such mental networks may be linear or branched in nature and may (of course) include incorrect linkages between ideas (misconceptions, misunderstandings).

Consideration of the model put forward by the Centre provided researchers with a mechanism (and framework for change) against which hypotheses could be raised. One such researcher to use the model in this way was Vianna (Johnstone, Sleet and Vianna, 1994).

2.4.3.1 Applying the Information Processing Model

Vianna's work revisited the area of undergraduate laboratory work, building on the efforts of Wham and Letton. Using what was already known about the problems in practical work, the model of Information Processing was used to develop strategies to bring about the design of an effective laboratory experience in Level-1 inorganic chemistry.

As the Perception Filter requires relevant information in the LTM which may not be present for a student, irrelevant information from the experiment may not be recognised as such and so will contribute to the overload Wham described (2.4.1 Working Memory and Laboratory Work, above). If a "priming" of the LTM (and so of the Perception Filter) could be carried out prior to the practical session, this would allow students a more expert view of the experiment and give some guidance as to what to focus on. Pre-laboratory exercises, Pre-labs, were proposed as a method of giving the necessary priming.

The prevalence of "noise" in the lab and, in particular, the manual or instructions was identified by Letton as a key source of the Working Memory overload. Her work suggested that careful revision of instructions could be of great benefit to improving students' experiences.

Kempa and Nicholls' (1983) work suggested that a student's performance was linked to the complexity of his or her LTM network. Problem-solving is also improved by experience and the development of a rich mental network. It was proposed that the introduction of Mini-projects would allow students to revisit ideas taught in the lab and use them to solve practical problems. It was envisaged that such an activity would reinforce and enrich the learning experience in the lab.

Letton's new manuals incorporated an improved page layout to form coherent blocks of instructions, icons to direct attention to special precautions or apparatus required, and clear statements of the experiment's purpose. In preliminary work these features were found to be popular and an improvement on previous manuals. The manuals were used in the research which followed, with minor modifications arising from this study.

Pre-lab exercises were introduced, with students required to complete them and have them marked before they were permitted to begin practical work. The Pre-labs, together with a range of Mini-projects, were included in some lab sessions to evaluate their impact.

Vianna collected data from a variety of questionnaires, diaries and checklists completed by both students and laboratory demonstrators to evaluate the revisions. The results of this work were clear (Johnstone, Sleet and Vianna, 1994):

- Pre-labs were universally beneficial, improving performance whenever they were used. Students reported an increased appreciation of the purpose of the experiment they had undertaken; demonstrators reported a drop in the number of questions concerning the experiment.
- Mini-projects were a qualified success – students recognised the benefits associated with them (such as forcing them to plan experiments, illustrating practical application of the formal lab work and retrospectively adding to their understanding of the experiment). However, students were less positive about such exercises being used throughout their laboratory course and reported some insecurity in attempting them.

2.4.4 Conclusion

The redesign of the inorganic laboratory course followed a number of the ideas and theories developed by the Centre over many years, from the identification of problem areas in chemistry to considering their effects on the role and psychology of the learner. Many of these same ideas would be used by General Chemistry-1's Design Team in forming The Ten Commandments and the actual teaching methods and strategies employed.

2.5 Assessment

Another strand of research pursued by the Centre – which partially developed from the work on Concept Development – involved looking at assessment. Several of the findings from this work would be used by the General Chemistry-1 Design Team in their formation of the Ten Commandments and so ultimately shape the assessment procedures they employed. The Centre's key areas of study involved considering the role and use of Multiple-Choice format questions.

2.5.1 Multiple-Choice Testing Materials

In recognising Multiple-Choice (MC) items as the most common form of objective testing used in schools throughout the U.K. at the time (Friel and Johnstone, 1978a), the Centre attempted to investigate the suitability and limitations of such questions.

One criticism levelled at MC items was the opportunity they afforded students to guess the correct answer rather than show that they actually knew it. The general question of the reproducibility of MC items was studied by Handy (Handy and Johnstone, 1973), by considering the use of a correction factor as an "anti-guessing" measure. However Handy's work showed that corrected scores and raw test scores did not differ in the relative rankings produced by test subjects – i.e. there was no change in the effective discrimination of this testing method by using guessing corrections.

Another researcher, Friel, considered MC items at some length. His work included considering effects of allowing students to change their initial response (Friel and Johnstone, 1978a); changing the position of the answer within the options offered to students (Friel and Johnstone, 1979); and scoring systems that recognised partial knowledge (Friel and Johnstone, 1978b).

Friel's efforts uncovered a number of potential pitfalls in using MC test items.

For example, he found that when the most plausible distracter was placed immediately before the correct response in the response set, the Facility Value of the test item was increased: the test item "became" easier (Friel and Johnstone, 1979).

One method proposed to recognise partial knowledge is to use Differential Weighting of the responses. Friel considered such a system, and two modifications of it, in comparison with the conventional marking scheme. Although such systems would only add fractions to a student's total score, the sum of these fractions may make a difference. He concluded that a comparison of the rank orders of conventional scores with modified ones indicated no difference. The procedure only produced a scaling of the marks. However, the modified total mark may be a more accurate measure of the individual's performance; i.e. the role of the assessment was crucial as to whether or not the assessment of partial knowledge was warranted. If the assessment process was intended to discriminate between individuals within a group then modifications for partial knowledge were an unnecessary step: however, if the assessment was intended to determine the level of individual's ability, then modification may give a truer picture.

2.5.2 Criterion-Referenced Testing

As the actual role to be played by the assessment process is an important consideration, workers in the Centre voiced their concerns over the use of MC items in Criterion-Referenced (CR) testing (Johnstone, MacGuire, Friel and Morrison, 1983).

This group of researchers were worried that there was an implicit belief in the teaching profession that CR questioning had to be in the format of Multiple-Choice, as this was the format used in the few examples of CR test items available in the literature. It was felt that educators might take the view that existing MC items, available from banks of test items, would be natural items to be used in CR test construction. Johnstone *et al.* argued that this assumption was actually invalid on several points, in addition to those arising from Friel's work (above).

2.5.2.1 Nature of Criterion-Reference Testing

Again the nature of the test is crucially important – CR testing is designed to test the individual, not a group. The statistics involved in constructing and maintaining a normal MC item bank refer to a population as a whole rather than the individuals who make up that population. Hence, items suitable for Norm-Referenced testing, and kept in such banks, may not be suitable for CR purposes. There should be no spread of scores in a CR test (by definition) as such a test is not designed to discriminate (in the sense of arranging students in a rank order), so normal statistics of reliability and validity are of little use.

An ideal CR item should have a Facility Value of 1.0 (i.e. all students tested have achieved the criterion required). In a Multiple-Choice item a Facility Value of close to 1.0 can occur from two distinct reasons:

(i) the students are so secure in their knowledge that the distracter offered do not deflect them from the correct answer, regardless of the plausibility of those distracters;

(ii) the distracters included in the response set are so implausible that they are incapable of distracting students from the correct answer.

The normal procedure of pre-testing and the associated statistics cannot determine which of these two to be the case.

2.5.2.2 Language Effects

The importance of language in teaching seems almost ludicrously obvious – either in a written or verbal form it is the method by which (virtually) all teaching occurs ! However, it is equally obvious that language may be the very barrier to students' progress and understanding. With this in mind, it is perhaps understandable that a study of language usage in teaching and learning in science was a major field of study by the Centre. Cassels' work in this area was extensive (e.g. Cassels and Johnstone, 1978, 1980, 1983 and 1985a) and included looking at language in MC testing.

An original argument in favour of MC methods was that there would be a reduction of the language load on students. However, this load was not removed, but simply shifted from making students express themselves to making them interpret what an examiner's question actually meant. What would seem on the face of it fairly innocuous changes in wording were observed to have profound effects on student success (Cassels and Johnstone, 1984 and 1985b). When reviewed in terms of Working Memory capacity it appeared that certain phrases or forms of wording could lead to an overload of information, and the corresponding drop in student success established by El-Banna and Johnstone.

2.5.3 Diagnostic Testing

Johnstone *et al.* (1983) argued that Criterion-Referenced testing was in essence for the individual: to encourage and give an efficient and unambiguous self-diagnosis.

If an individual has obtained an objective or understood a concept, then MacGuire and Johnstone (1987) felt that the individual should be able to:

(i) name, describe and define the concept;

(ii) recognise instances of the concept (and as a corollary of this be able to distinguish between instances and non-instances);

(iii) solve problems related to, and expand on, the concept.

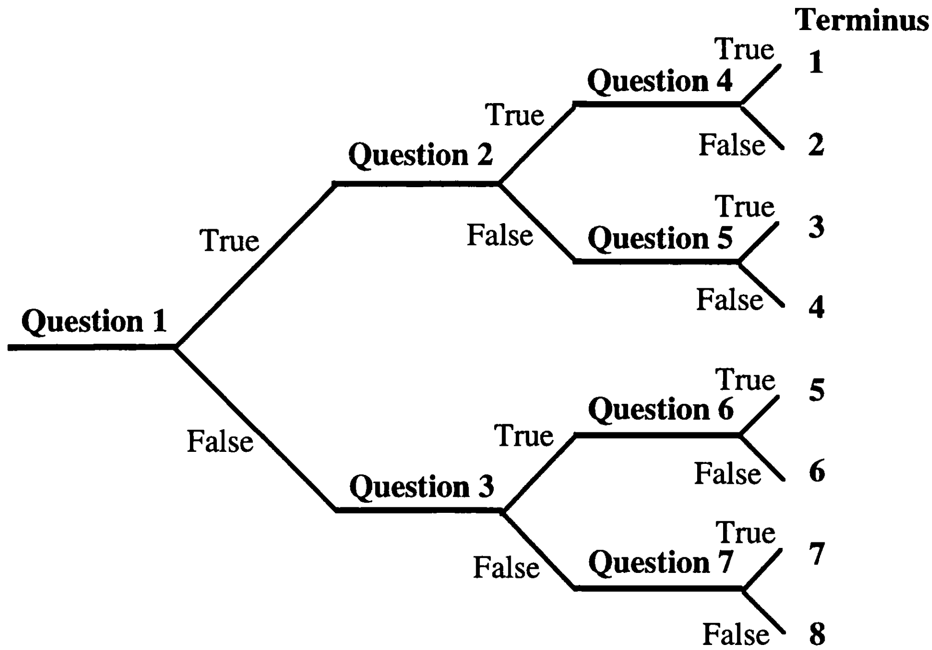
In designing material to use in studies on Concept Development a number of instruments were employed to probe a student's knowledge and understanding. Many of these techniques would lend themselves to the role of diagnostic testing material. The Centre suggested four diagnostic techniques in particular (Johnstone *et al.*, 1983); Linked True / False items, Structural Communication Grids, Concept Linkages, and potentially more valuable ways of using Multiple-Choice.

2.5.3.1 True / False Items

As students are frequently able to reduce Multiple-Choice items to a choice between two distracters, by elimination of the others, it would seem logical to use true / false items instead (Johnstone *et al.*, 1983). By interlinking such items a network of branched responses can be created, as indicated in Figure 2.7 (Johnstone, McAlpine and MacGuire, 1986).

Each series of responses leads ultimately to a unique terminus, hence blind guessing by students will show up as gross inconsistencies. Diagnostically such a system offers a way of building up an accurate picture of a student's grasp on the material being tested. Wrong answers given by an individual are as important as correct ones as they will lead to a specific terminus which will define clearly the path taken. The termini would form a range of end points, including a "best" end point, representing the required level of understanding had been reached, and a "worst" end point indicating a complete lack of understanding of the material.

Figure 2.7 An Example of Using True / False to Create a Network of Responses



(From Johnstone, McAlpine and MacGuire, 1986)

Such "trees" of questions could be integrated to provide students with questions that made a higher demand in terms of understanding and thinking about a concept, so as to test a student thoroughly on different levels of thinking. A system like this could easily be adapted for use on a computer which could perform the testing, recording and analysis of results (Johnstone, McAlpine and MacGuire, 1986).

2.5.3.2 Structural Communication Grids

The work of Egan (1972) formed the basis for the Centre's development for this method of testing. Students are presented with numbered grids (see Figure 2.8) which display an array of information, and then are asked questions about the material appearing in the grids (Johnstone and Mughol, 1979; MacGuire and Johnstone, 1987).

Figure 2.8 Example of a Structural Communication Grid

propanol 1	methanoic acid 2	methanol 3
butan-2-ol 4	methyl propanoate 5	propanal 6
propanoic acid 7	ethanol 8	methyl ethyl ketone 9

(a) Which compounds would you use to make the ester in box 5 ?

(b) Which compounds contain a carbonyl group ?

(c) List in ascending order the homologous series which includes the compound in box 1.

(From Johnstone, 1988)

This way of presenting questions to students offers two different ways of using the grids:

(i) Students are asked to select the box(es) from the grid which contain the information required to answer a question;

(ii) In addition to selecting information, students are required to place it in a particular order to give a correct procedure, i.e. to place a structure on their answer (hence Structural Communication)

Students are not given any indication of how many of the boxes may be required to form a complete answer and so have to decide for themselves. This removes the guessing factor from students' responses – in MC items only one of the response set is correct, but here there is no such guarantee. The contents of each box must be evaluated, then accepted or rejected as the individual sees fit. One of the key problems of traditional MC items is that (by their very nature) only one answer is correct, which can only help foster the students' belief that a unique answer always exists. However, in real life this is far from the case and Structural Communication grids can allow more detailed questions with several possible answers to be presented to students.

By considering the selections a student has made, insights into that student's thinking can be reached. Test results can show correct responses chosen, incorrect responses chosen and correct responses omitted. This then allows an observation of how complex and developed a concept is – choosing only some of the correct response to a question would indicate features or ideas not realised and hence lacking form the student's understanding.

The grids can be used in a variety of ways to test different skills (Johnstone, 1988). A student can be asked to:

(i) recognise examples of a concept (from non-examples);

(ii) sequence information to give a coherent procedure;

(iii) select information which gives a description;

(iv) make deductions and inferences from information given.

2.5.3.3 Concept Linkages

Johnstone *et al.* (1983) argue that if a concept is firmly understood then it will exist as part of a branched network of interconnected ideas, a view put forward in other areas of the literature (e.g. Ausubel, 1966; Kempa and Nicholls, 1983). By probing these linkages a picture of the network held in an individual's LTM can be developed and poor or incorrect associations (misconceptions) identified.

One method for doing this sort of investigation was employed by MacGuire (MacGuire 1981; MacGuire and Johnstone, 1987) in his study of physics students. Students were given a series of clues that would identify a particular concept, X. The earliest clues were deliberately vague and should have generated a range of possibilities for X (e.g. X is proportional to mass). As the number of clues given to the students increased so the exact nature of X was revealed (e.g. X is defined by X = mg). A student's answers as to the identity of X as the number of clues increases gives some indication of his or her internal organisation of concepts. As early possibilities are eliminated this method allows a check on not only the concept X in question, but the other concepts the student suggests – a concept may be inappropriate for the clue or be rejected when it should not be.

An additional step which can be added to such a test is to ask the student for an indication of how confident he or she feels in their response. MacGuire asked students to give an indication of confidence on a five-point scale, ranging from "I am just guessing" to "I know I am right". As well as finding out how quickly a student manages to identify X, this has the benefit of indicating if the student is sure of their deductions or blindly guessing.

2.5.3.4 Alternative Uses of Multiple-Choice Format

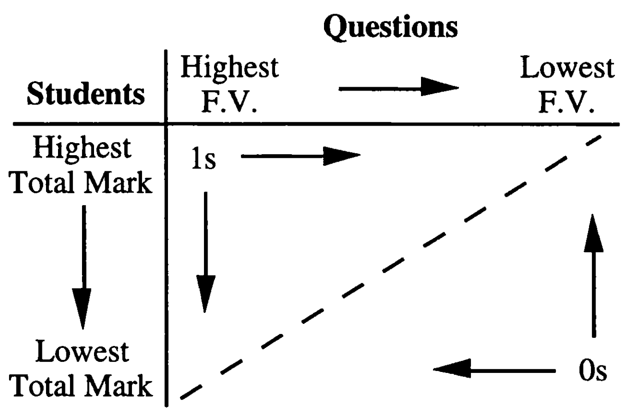
Although a number of weaknesses in the use of Multiple-Choice items were identified by the Centre and their use in Criterion-Referenced Test material cautioned, the group put forward alternative uses which may overcome some of these problems for diagnostic assessment.

As suggested earlier (Friel and Johnstone, 1978b) scoring systems that allow for partial knowledge recognition in MC tests may give a truer picture of each student's ability. As well as the system investigated by Friel, another possibility for assessing partial knowledge was described by Johnstone *et al.* (1983). Students could be asked to select the smallest response set to a MC item which they believed contained the correct answer. Choosing all the possibilities would score zero, but the score is increased as the student's chosen set excludes the incorrect with a maximum score being given for the smallest possible set – the single correct answer.

Another method of analysing the MC test results suggested by Friel (Friel and Johnstone, 1988; Johnstone, 1988) used a traditional marking scheme (i.e. one mark for correct answers only), and considered an individual's pattern of scoring questions.

By entering each student's mark (as a 0 or a 1) to each question in a grid, then patterns may be observed. As indicated in Figure 2.9, the students are arranged in order of their overall scores, and the questions are arranged in order of their Facility Values.

Figure 2.9 The Layout for an Array of Students' Scores to Analyse Response Patterns



It would be reasonable to expect the highest scoring students to get all the easiest questions (highest F.V.) correct and also pick up marks on some of the most difficult (lowest F.V.). Conversely, the weakest students would score on some the easy questions and get all the difficult ones wrong. This should generate an ideal pattern of 1s at the top left of the array and 0s in the bottom right. Any deviations from this ideal could be worthy of further consideration.

Students, for example, who score on difficult questions, but actually lose marks on easy ones may simply have missed the material on which they were based. Weak students who score on difficult question may be guessing.

This method also offers a check on any questions that are causing problems, by identifying individual questions which have a strange scoring pattern. For example, a question which has defeated the best students but has been successfully attempted by their lower scoring counterparts may be poorly constructed. The level of sophistication of the distracters offered in such a question may draw the attention of better students, whereas the weaker ones will take the question at face value.

2.6 Attitudes and Change

The attitudes held by students, towards the subject of chemistry (and science in general), the courses of study they undertake and their approach to that study would seem logically to be of crucial importance. Such factors as these could make considerable differences in determining success or failure.

Underpinning the so-called Ten Commandments used by the General Chemistry-1 Design Team is the implied desire to change or modify such student attitudes in one or more of these areas. General Chemistry-1 would be made up (mainly) of "non-chemists", i.e. those who had made a conscious decision not to continue chemistry studies beyond that initial university year, and those with limited (or no) previous chemistry experience. The backgrounds and future aspirations of such students could potentially engender in them certain (negative) attitudes to chemistry and their ability to study it which may not facilitate their progress in the course.

In recent years there has been an increased interest in not just cognitive development in formal education but attitudinal development as well: not only is knowledge itself of importance, but an appreciation of that knowledge is a key part of education (Johnstone and Reid, 1981). This increased interest in attempting to develop the attitudinal aspects of science education and research sparked the work of Reid (1978) and Hadden (1981).

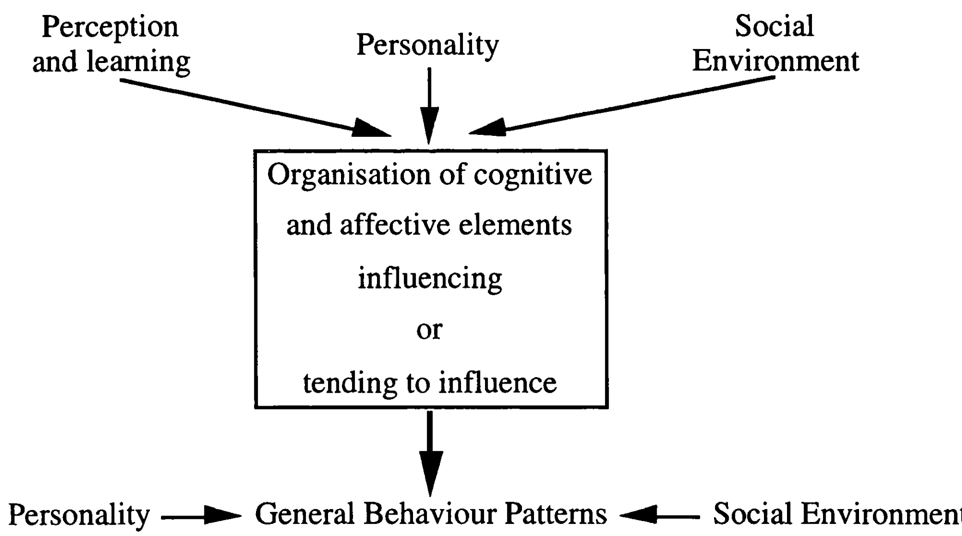
2.6.1 A Definition of Attitude

The term "attitude" is, however, somewhat vague. It is an everyday, common-place word but within a scientific, research context is in need of a more technical and precise definition, as Reid himself pointed out (Reid, 1978). In reviewing some of the many different definitions of "attitude" put forward by various researchers and writers over the years, Reid noted that most agreed on attitudes are composed of three components:

(i) a knowledge component (the cognitive);
(ii) a feeling, or emotional, component (the affective);
(iii) a tendency towards action component (the conative).

Both Reid and Hadden adopted a definition of attitude put forward by Allport (1935) for their work, citing it as having gained wide acceptance and shown to be robust. This definition was pictorially represented by Reid, Figure 2.10.

Figure 2.10 A Definition of the Term "Attitude"



(from Reid, 1978)

Allport's definition of the term "attitude", then, becomes the contents of the rectangle in Figure 2.10, and indicates that factors such as perception and learning, personality and social environment can all shape an attitude. It also indicates that whilst external behaviour patterns may be influenced by attitudes, circumstances arising from personality and / or social environment may modify that behaviour, so as to reduce its connection to any genuine underlying attitude.

A model of this type offers the possibility of a wide range of attitude types. The relative importance, and relationships between, the three factors feeding into the box (the attitude) can obviously vary. These variations are not indicated in the model. Whilst some attitudes will be dominated by affective inputs (e.g. personal or social opinions), others might be more cognitively derived (e.g. awareness or appreciation).

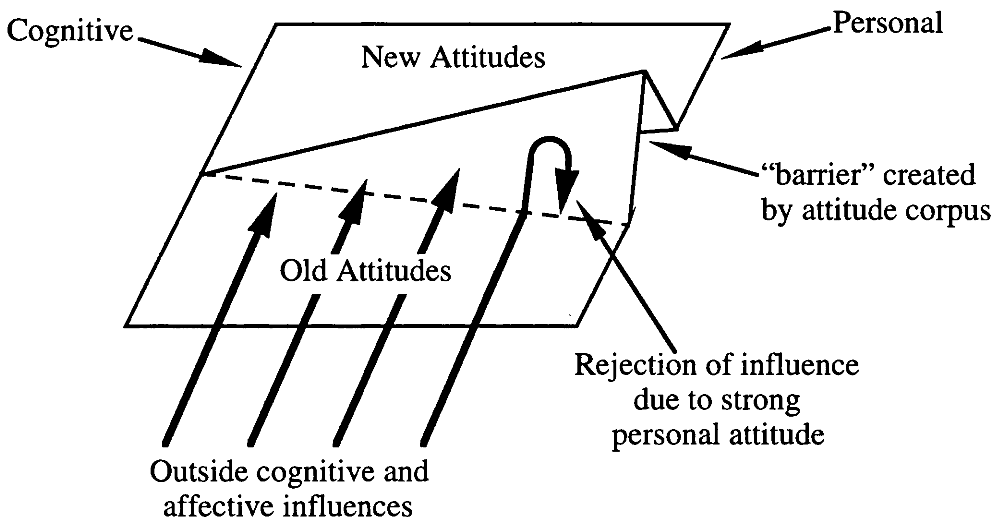
Recognising the lack of available teaching materials for attitudinal development (as opposed to cognitive development), Reid used this model in his work in designing and evaluating such materials for use in Secondary School chemistry courses. He recognised that teachers may feel uncomfortable spending time on non-cognitive outcomes, but pointed out that students will develop attitudes on their own, sometimes from an unsatisfactory cognitive base (Johnstone and Reid, 1981).

Reid (1978) found that the self-contained teaching packages he designed encouraged changes in attitudes that proved stable over time. All the packages used "intra-activity" – that is an activity intended to generate internal processes within a student that went against previously assimilated knowledge and attitudes.

2.6.2 A Model for Attitude Change

From this work, and consideration of the findings of others in the field of attitude study, Johnstone and Reid (1981) proposed a model for attitude change, Figure 2.11.

Figure 2.11 A Model for Attitude Change



(From Byrne and Johnstone, 1988)

This model suggests that everyone possesses a set of attitudes, many of which arise from an individual's upbringing and deep-rooted cultural influences. Such attitudes (as also covered in the Allport definition) may include a person's morality and political viewpoint, for example. These can, then, be regarded as the "Personal" attitudes in Figure 2.11. As Byrne and Johnstone (1988) pointed out, such attitudes may never have been worked out logically but, nevertheless, will be strongly held and so difficult to change (hence the high barrier to change). Such emotive attitudes allow the individual to make sense of the world, producing internal consistency and feelings of security.

Other attitudes, as suggested earlier, originate from more cognitive elements (The "Cognitive" attitudes in Figure 2.11). Cognitive attitudes could be more readily open to change with careful consideration of a superior argument, hence the barrier to change is much lower than for the Personal end of the attitude spectrum. A person could be persuaded that their attitude to pollution was based on poor information and hence change their viewpoint, for example, whereas religious conversion would require very strong cognitive and affective inputs. An alternative outcome from some form of intervention attempting to change attitudes is that the input may be rejected completely or become compartmentalised.

The ideas and kinds of materials developed by Reid have been applied and used in further successful developments by other workers such as Byrne (Byrne and Johnstone, 1988).

2.6.3 Motivation

Another facet of what could be covered by the term of attitude includes the widely used (and generally loosely defined) term "motivation"; an individual's attitude to a subject may well influence his or her motivation towards studying that subject.

The existence of diverse learning styles and motivations has been recognised for some years, and educationalists have argued that these should be taken into account in the design of curricula, courses or lessons. However, logistical problems usually lead to teachers employing methods that treat their pupils as a homogeneous grouping of learners.

Following the introduction of the Standard Grade curricula in Scottish Secondary Schools in the late 1980s, the Centre realised that one solution to this uniform treatment of pupils could be offered via the new chemistry course. Different learning activities, with methods of delivery ranging from group to individual work, were recommended in Standard Grade literature and the Centre felt a blend of methodologies could appeal to different kinds of pupils. One stated aim of the Standard Grade chemistry course on its inception was to introduce problem solving situations at the laboratory bench, although no plans were put forward on how to achieve this at that time. To meet this perceived need, Hadden (1991) produced a large number of workable bench-based problems or mini-projects which were designed to fit into a few minutes of class time. Johnstone and Al-Naeme shadowed this development with a study to determine whether mini-projects did indeed cater for students with different motivational styles.

Al-Naeme used the work of Adar, and Hofstein and Kempa (1985) as a model for categorising pupils by their dominant motivational style. Four such styles were proposed (Johnstone and Al-Naeme, 1995):

- the Achiever enjoyed the challenge of competing with others for top marks; disliked being held back by slower classmates;
- the Conscientious felt secure only when given clear objectives and precise instructions; set out to satisfy the teacher and meet the expectation of home; assiduously prepared for examinations and hard work;
- the Curious preferred freedom in learning and discovering; enjoyed undertaking open-ended tasks and found rigid instructions irksome;

- the Social were very group conscious, preferring study with friends and discussion of problems to lone study; enjoyed social events that could interfere with regular study.

It was felt that the Standard Grade course offered materials and experiences which would suit all the motivational styles, except those who could be classed as Curious: Achievers would strive to achieve in essentially any learning situation presented to them; the Conscientious had worksheets and instructions to follow; and the Social had opportunities to engage in discussion and group activities.

Mini-projects however, it was hypothesised, could be of particular interest to the Curious students and so provide the opportunity of offering a learning experience complementary to a student's dominant motivation factor for each of the groupings.

Al-Naeme (1991) found that this hypothesis was supported, and that although the mini-projects had appealed to all groups of students, it was those of a Curious nature who found them the most agreeable. Al-Naeme showed that a perceived gap in the range of school chemistry curricular activities (in terms of material to interest all) had existed, and had now been filled. However, the finding of this research appeared to require further consideration in the wider context of chemistry curricula at all levels of education.

One other discovery of note in Al-Naeme's work was that students often branded as "uncooperative" or even "unintelligent" by their teachers (who subsequently suggested their removal from the research exercise) were in fact quite the reverse under the experience of mini-projects. Frequently these students displayed the traits of the Curious student. They had found their normal class work dull and stultifying, in some cases becoming rebellious towards the material on offer. Teachers were reportedly amazed to see these "less able" individuals actually blossom when mini-projects were used. Their natural inquisitive instincts suited the learning experience on offer.

Conversely, some of those regarded as "more able" by their teachers virtually crumpled during mini-project lessons, seeing them as a source of insecurity and discomfort due to their creative demands. Frequently these were the Conscientious who appeared to miss their normally safe, instruction led world. The possible implications of this are clear, and perhaps of concern – if the normal thrust of the chemistry teaching had been towards more open, creative learning experiences then the roles of "more able" and "less able" may have be reversed, or at least come closer together.

2.7 General Education and Critical Thinking Skills

Attitude growth as a formal outcome of a science education experience can be seen in the wider context of a general education through the medium of science (or chemistry specifically, as in this case). As far back as the mid 1970s workers in the Centre noticed this (Hadden, Handy and Johnstone, 1974) and considered some of the attitudes put forward as desirable in pupils undertaking science courses in secondary school. They suggested that pupils should acquire attitudes such as:

- *Awareness of the contribution of chemistry to the full development of the individual;*
- *Awareness of the contribution of chemistry to the economic and social welfare of the community;*
- *Interest and enjoyment in chemistry;*
- *Awareness that a number of variables can influence an experimental situation;*
- *Commitment to arriving at conclusions from the information, knowledge and understanding available;*
- *Commitment to apply a scientific approach in other fields of experience.*

(from Hadden, Handy and Johnstone, 1974)

The researchers used a series of tests designed to elicit responses that would allow an assessment of how close science and non-science pupils' attitudes were to those listed above. They concluded that although the science pupils did exhibit more "scientific" attitudes than their non-science counter-parts this did not imply that the courses of study created this difference – such differences may be already inherent in pupils and merely reinforced by their choice of subjects.

Later, Johnstone and Sharp (1979) were to consider attitudinal outcomes of tertiary science education and in particular what skills and attitudes they considered should be present in the chemistry graduate. Whilst they acknowledged that the body of chemical knowledge was an obvious necessity for the chemistry graduate, they pointed out that much of that chemical content would be forgotten or rendered partially or wholly obsolete by future developments within the working lifetime of a practising chemist. They argued that as well as developing the cognitive aspects of a student in his or her subject, other perhaps less cognitive skills and attitudes were just as important. These "Skills of a Chemist" numbered sixteen in total:

Figure 2.12 The Skills of a Chemist

(1) *To argue logically.*
(2) *To see flaws in arguments and hypotheses.*
(3) *To identify problems and devise means for solving them.*
(4) *To make and defend decisions.*
(5) *To make decisions on inadequate information.*
(6) *To appreciate where compromises have to be made in the social and economic implementation of a scientific discovery.*
(7) *To co-operate in discovery.*
(8) *To obtain relevant information.*
(9) *To see interconnections within the subject.*
(10) *To apply chemical knowledge in other disciplines.*
(11) *To apply a precise, scientific approach to problems.*
(12) *To appreciate the limitations of science in solving problems.*
(13) *To write and speak fluently and grammatically.*
(14) *To teach others in public.*
(15) *To design experiments and relate the value of the data to the cost of the experiments.*
(16) *To work to a budget.*

(from Johnstone and Sharp, 1979)

Within the normal undergraduate chemistry course Johnstone and Sharp found little evidence of any formal attempt to inculcate such skills in students. Indeed, even the opportunities of their informal acquisition were few and far between. There seemed to be an assumption made that such ideals would osmose into students naturally as a by-product of their time in a chemistry department.

That skills like those proposed by Johnstone and Sharp are of enormous potential value can hardly be of doubt. The development of "critical skills" are frequently included in a description of the general purpose of an education in science by Higher Education institutions. Similarly the view of "Industry" as an entity, if such a thing exists, clearly demands more of the university graduates it employs than simply a knowledge of a particular subject area. In a study of employer satisfaction in the perceived quality of graduates and graduate skills, as part of the Quality in Higher Education Project, Harvey (with Green, 1994) was able to identify five broad areas of graduate attributes which were of major importance to employers. These areas were:

- knowledge (of the graduate's subject);
- intellectual ability, which encompass the skills of enquiry, innovation, analytical ability, ability to argue logically, numeracy, critical ability, synthesis, creativity and imagination, and adaptability;
- the ability to work within a modern organisation;
- interpersonal skills;
- communication skills.

The overlaps between this list and Johnstone and Sharp's Skills of a Chemist are clear.

Following on from the material Reid developed to encourage attitude development in secondary schools, Johnstone, Percival and Reid (1981) argued that this kind of teaching experience could be incorporated into tertiary chemistry courses and used to encourage the development of some or all of the Skills of a Chemist. Six units developed for small group work were put forward as having the potential as achieving this:

- *The Alkali Problem*: considering the industrial implications of the discovery of a large salt deposit (Easton, Johnstone and Reid, 1978);
- *Amsyn*: a study of the environmental and social effects of a fictitious chemical company's dyestuff plant (Percival and Reid, 1976);
- *Zinc and Lead Extraction*: a design problem requiring students to design an industrial process (Johnstone and Levien, 1978);
- *What Happens when the Gas Runs Out ?*: a thermodynamic / economic study of how artificial gas could be used once natural gas stocks expire (Johnstone and Percival, 1977);
- *Batch or Flow ?*: an investigation of which production method best suits the production of an explosive compound (Reid, 1980);
- *Polywater*: a library exercise to show caution should be exercised when reading the literature (Johnstone and Percival, 1978).

These units encompassed economic, ecological, social and safety considerations for students to deal with, as well as the purely chemical. The concept of utilising learning conditions in such a way as to maximise interactions between the learners and the subject matter, and indeed the learners themselves was seen as crucial to the teaching packages' success: as Byrne and Johnstone stated (1988) "...desired attitude changes are unlikely to be achieved without the use of what have become known as interactive approaches". An assessment of their use showed generally favourable reactions to the materials from students exposed to them.

The development and subsequent assessment of further teaching units was continued in the Centre by the work of Byrne (Byrne and Johnstone, 1983 and 1987a; Byrne, 1985). He was able to show that an experimental group using the sort of materials described appeared to have gained a greater and more effective use of critical skills compared to a control group who simply read relevant papers with no discussion with fellow students (Byrne and Johnstone, 1987a).

2.7.1 Defining Critical Thinking

Although many tertiary education courses in science would claim to develop critical "skills" or "attitudes", such as those in Johnstone and Sharp's Skills of a Chemist, a clear definition of what such terms mean is often lacking as Byrne and Johnstone (1983) point out. Phrases such as "scientific attitudes", "critical attitudes", "critical-mindedness" and "critical thinking" are often used interchangeably to describe these, in some ways elusive, qualities.

Byrne and Johnstone (1987b) reviewed the idea of critical thinking in an attempt to clarify what they meant by the concept, and see if it could be taken further than the initial Skills of a Chemist list.

Gauld and Hukins' (1980) review of the field concluded that the concept of the scientific attitude had been studied from two main standpoints: the scientific and the affective. Those working in the scientific domain had mainly tried to identify the opinions of scientists, with a view to achieving an agreement on what constitutes the scientific attitude.

These components were found to fall into three broad categories:

- general attitudes towards ideas and information;
- attitudes related to the evaluation of ideas and information;
- commitment to particular scientific beliefs.

Research into the affective dimension tended to concentrate on the difference between the ability to do something (i.e. apply scientific attitudes) and the willingness to use that ability.

Clearly the scientific attitude is frequently seen to encompass the notion of having certain critical attributes, which can be termed generally critical-mindedness or more specifically, critical thinking. In examining the status of critical-mindedness in terms of its general applicability, Byrne reports on two schools of thought.

The first, held by workers such as Ennis (1962), suggest that critical thinking is a general skill and ergo can be taught to and practised by an individual independently of a specific subject: someone possessing critical-mindedness has the ability to use it in any situation.

However Byrne reported, others including Martin, Passmore and McPeck, held the view that critical-mindedness will be subject dependent. For example, McPeck argues critical thinking cannot be in the abstract; it has to involve critical thinking about something and an individual must have some experience, knowledge or skills about that something to be able to engage in critical thinking about it.

This gives rise to the important implication that someone with the ability to apply critical thinking in one subject may not be able (or willing) to apply it in another.

Byrne and Johnstone (1987b) reached a number of conclusions about critical thinking, from their consideration of the literature and their own research experience:

(i) Critical thinking requires more than possessing and applying a set of general skills. An individual must have knowledge and understanding of the subject under consideration. Therefore, critical thinking is a subject dependent skill.

(ii) As well as the ability to think critically, an individual should display a tendency to employ these skills widely, i.e. there is an affective side to critical thinking.

(iii) By giving students the opportunity to study science through other contexts they may be able to develop broader critical thinking skills.

They then proposed that scientific critical-mindedness could be defined as:

(1) The possession of certain cognitive skills in relation to evidence and the way it is obtained, regarded and used.

(2) The propensity to exercise these skills both in scientific and science related contexts.

(3) Recognition of the nature of scientific inquiry and evidence and how this relates to, and differs from other forms of knowledge.

(from Byrne and Johnstone, 1987b)

2.7.2 Developing Critical Thinking

As Byrne and Johnstone (1987b) state "...critical-mindedness involves critical thinking and that critical thinking is an aspect of thinking". Although this in itself may seem rather obvious, they make the connection to highlight that cognitive psychology may have an input into any understanding of the processes involved in and development required to perform critical thinking. However, as they lament, most psychological research into cognition focuses on very task specific thinking, rendering that area of literature somewhat barren in this instance.

However, one piece of research of particular note was found in the work of Perry whose study of the cognitive development of American college students led to a Scheme of Intellectual and Ethical Development.

2.7.2.1 Perry's Scheme of Intellectual and Ethical Development

Perry's scheme (Perry, 1981) arose from his work as a student counsellor, in the 1950s. He and a group of his colleagues began to look into student's learning experiences, at Harvard and Radcliffe Universities, in an attempt to understand why students held a variety of perceptions about their teachers and the teaching they received.

The sample of students used in this work consisted of volunteers at the end of their freshman year, who were interviewed to determine what had been the most outstanding feature of the year for them. Perry and his fellow counsellors initially assumed the wide variety of responses the students provided them with were due to differences in each individual's personality.

However, they were surprised to find on re-interviewing the same students in subsequent years that the students had engaged in "reinterpreting" their experiences and that these reinterpretations appeared to follow a logical progression. Each step along that progression represented a challenge to a student's world view and how they had responded to it.

From the interviews the kinds of challenges which had precipitated the changes in the students were identified and a description of the nature of each of the reinterpretations distilled, ultimately forming a "map" of development (Figure 2.14).

A panel of raters verified the map by examining the transcripts of interviews and attempting to match the interviewee with a stage of development on it. This process proved very successful in terms of achieving a very high level of rater agreement. This gave Perry more confidence that the developmental trend he (and his team) had observed was genuine and observable by others. The map of students' sequential interpretations of the world formed the origins of the scheme of development.

Nine interpretations, or Positions as they were called, were identified on the map, with each characterising a meaningful way of looking at the world of knowledge, education, values and self. The Positions are hierarchical, each subsuming the one(s) before it and so represents a true movement or development as opposed to simply phases.

Perry (1981) describes his positions in the following way:

Figure 2.13 Perry 's Scheme of Cognitive and Ethical Development

Position 1	Authorities know, and if we work hard, read every word, and learn Right Answers, all will be well.
Transition	But what about those Others I hear about ? And different opinions ? And Uncertainties? Some of our own Authorities disagree with each other or don't seem to know, and some give us problems instead of Answers.
Position 2	True Authorities must be right, and the other are frauds. We remain Right. Others must be different and Wrong. Good Authorities give us problems so we can learn to find the Right Answer by our own independent thought.
Transition	But even Good Authorities admit they don't know all the answers *yet*!
Position 3	Then some uncertainties and different opinions are real and legitimate *temporarily*, even for Authorities. They're working on them to get to the Truth.
Transition	But there are *so many* things they don't know the Answers to And they won't for a long time.
Position 4a	Where Authorities don't know the Right Answers, everyone has a right to his own opinion; no one is wrong!
Transition	But some of my friends ask me to support my opinions with facts and reasons.
(and / or)	
Transition	Then what right have They to grade us ? About what ?
Position 4b	In certain courses Authorities are not asking us for a Right Answer; they want us to *think* about things in a certain way, *supporting* opinion with data. That's what they grade us on.
Transition	But this "way" seems to *work* in most courses, and even outside them.
Position 5	Then *all* thinking must be like this, even for Them. Everything is relative but not equally valid. You have to understand how each context works. Theories are not Truth but metaphors to interpret data with. You have to think about your thinking.

Figure 2.13 Perry's Scheme of Intellectual and Ethical Development, cont.

Transition	But if everything is relative, am I relative too ? How can I know I'm making the Right Choice ?
Position 6	I see I'm going to have to make my own decisions in an uncertain world with no one to tell me I'm Right.
Transition	I'm lost if I don't. When I decide on my career (or marriage or values) everything will straighten out.
Position 7	Well, I've made my first Commitment!
Transition	Why didn't that settle everything?
Position 8	I've made several commitments. I've got to balance them – how many, how deep ? How certain, how tentative ?
Transition	Things are getting contradictory. I can't make logical sense out of life's dilemmas.
Position 9	This is how life will be. I must be wholehearted while tentative, fight for my values yet respect others, believe my deepest values right yet be ready to learn. I see that I shall be retracing this whole journey over and over – but, I hope, more wisely.

(From Perry, 1981)

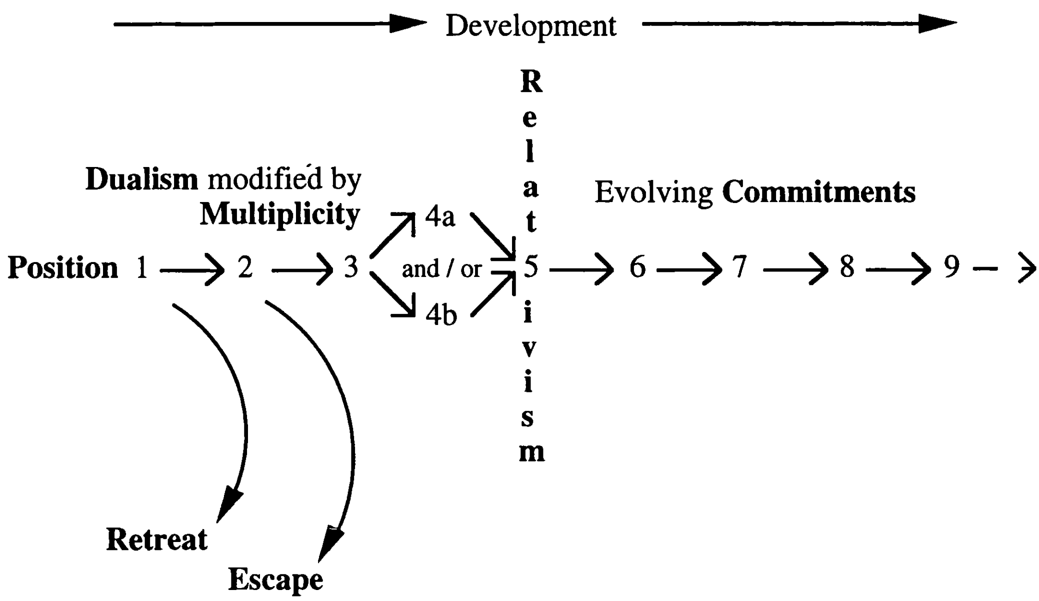
The nine Perry Positions are covered by four broader "super-categories": Duality (Position 1), Multiplicity (Positions 2, 3 and 4a), Relativism (Positions 4b and 5) and, finally, Commitment (to Relativism) (Positions 6, 7, 8 and 9). The super-categories encompass the key point(s) of an individual's stage of development, or world view. They can be described thus:

- Duality (or Dualism, as it has also been termed) consists of a simplistic Right / Wrong or Black / White world view. Correct answers always exist, and learning them is paramount – the more of this knowledge which is ingested, the better the student.
- Multiplicity (also called Multiplism) acknowledges that not all answers are known and so different opinions are valid in such "grey areas".
- Relativism views the source of opinions and judgements (i.e. evidence, logic, analysis) as important. The individual is now a maker of meaning, rather than a receptacle for meaning to be poured into from outside.
- Commitment involves the individual making a choice or decision in the full awareness of Relativism.

Perry's map also includes mechanisms of Retreat (where students return to a more comfortable Dualistic standpoint in the face of Multiplism) and of Escape (where students avoid responsibility and commitment by exploiting the variety of opinions in Multiplism) which he observed some students to take.

Perry's map of development then becomes:

Figure 2.14 A Map of Progression Through Perry's Scheme of Development



(From Perry, 1981)

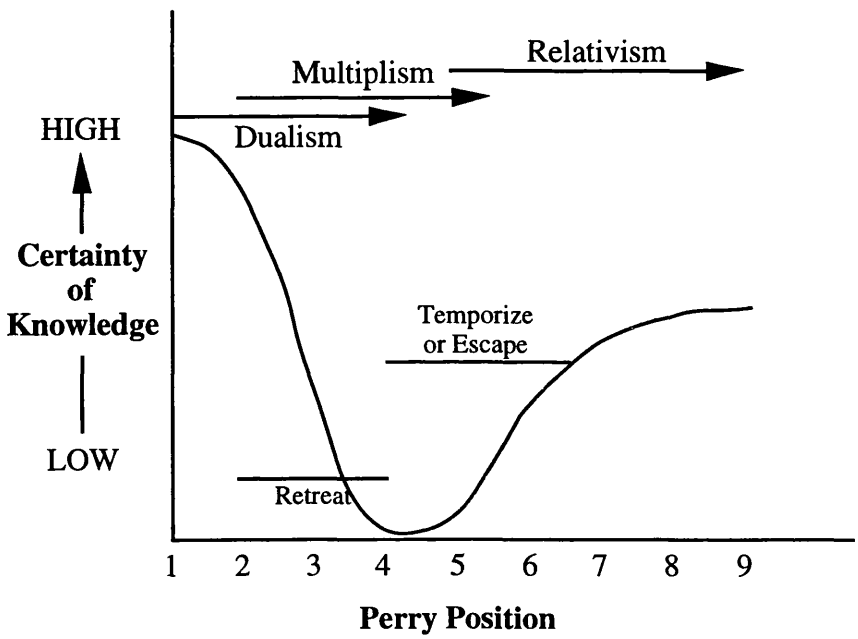
It is easy to envisage situations where this sort of development is applicable in science. For example, a student may be familiar with the concept of electrons being particles, travelling around the nucleus of the atom in fixed orbits – these are "facts" and the student is comfortable in knowing them. However, on being introduced to quantum mechanics and the wave-like behaviour of electrons a problem is caused. The student is confused by these two seemingly different approaches and will still search for the "right" one – they can't both be right. In trying to come to a decision about the two the student may try to go with the one the lecturer appears to be favouring, or the one he/she believes to be worth more in the examination – perhaps one explanation is right for some people and the other for different people. From this position of uncertainty a student can retreat to a single model, or compartmentalise the two giving different responses as they perceive the situation warrants. Alternatively, a student can move forward to a greater appreciation of the situation and hence understanding of the wave / particle duality of the electron.

2.7.2.2 The Centre's Adaptation of Perry's Scheme

In the late 1980s, when the Centre turned its attention to Perry's Scheme, they were strongly influenced by Finster's (1989 and 1991) review of it and the role he perceived for it in chemistry teaching. Finster examined the key positions of the scheme in terms of the students' perceptions of different factors which combined to define a student's Perry

Position (Finster 1991). Finster also diagramatically represented student's confidence in knowledge as a function of their progression through the scheme, indicating the position corresponding to Perry's super-categories and the positions at which Retreat and Escape mechanisms were most likely.

Figure 2.15 The Change in Certainty of Knowledge as Students Progress Through Perry's Scheme



(from Finster, 1989)

Finster concluded that most first year students think Dualistically and that chemistry is usually viewed (and taught) Dualistically. He argued that a program of challenging students' perceptions allied to a support system which allowed them to deal with such challenges represented the best way to encourage development through the Scheme.

The Centre adapted some of Finster's ideas (in particular his use of student perceptions of factors which would help define a student's Perry Position) to produce a simplified version of Perry's Scheme, based on the super-categories of Dualism, Multiplism and Relativism which became Perry A, B and C respectively in this adaptation (Wood, 1993). Figure 2.16 below summarises the Centre's adaptation. This version of the scheme was employed by Harvey (1994) working out of Napier University and by the author of this research, in an earlier work (Gray, 1993).

It can clearly be seen that there is much common ground between Johnstone and Sharp's Skills of a Chemist (Figure 2.12, above) and the later Positions of the Scheme. Similarly, Byrne and Johnstone (1987b) comment that what they term critical-mindedness would require a highly developed style of thinking similar to that encompassed in the later Perry Positions.

Figure 2.16 The Centre's Adaptation of Perry's Scheme: Students' Perceptions of Learning

	STUDENT A	STUDENT B	STUDENT C
STUDENT ROLE	Passive acceptor of knowledge	Realises that some responsibility rests with self: But what ? And How ?	Sees self as source of knowledge, or is confident of finding it Debater, making own decisions
TEACHER ROLE	Authority giving facts and know-how	Authority Where there are controversies, wants guidance as to which Authority favours	An authority among other authorities Values views of peers Teacher as a facilitator
VIEW OF KNOWLEDGE	Factual; Black and white; clear objectives Non-controversial, exceptions unwelcome	Admits no longer black and white Feels insecure in this	Wants to explore contexts; seeks interconnections Enjoys creativity and scholarly work
VIEW OF EXAMS	Regurgitation of facts Objective Hard work rewarded	Quantity better than Quality to demonstrate maximum knowledge	Quality is better than Quantity Wants room for expression

(adapted from Gray, 1993)

Finster (1989) notes that there is evidence that individuals do not approach all aspects of their life from the same Position, and the same is (of course) true of an individual's approach to academic work. Perry (1981) himself illustrates this point clearly in quoting the example of a professor who found himself working outwith his own specialist area. The professor had been employing high level critical thinking skills in his own area for many years, but when faced with a new situation had to struggle to avoid slipping back to a more simplistic "...impulse to dutifully examine and finish anything that was recommended to me whether it seemed fruitful or even bore on my problem or not". Such observations match the view of critical thinking as being a subject dependent entity described earlier.

Perry's Scheme also articulates well with the model for attitude change put forward by Johnstone and Reid (2.6.2, above). Although the model indicates that cognitively based attitudes are likely to be relatively easy to change, Johnstone and Reid suggest that compartmentalisation of an attitude can occur. This is a similar idea to that in Perry's Scheme, whereby individuals at the Multiplist (Perry B) stage can hold different or even conflicting views separately for different subjects. Continuing the example of earlier, a student may be content to consider the electron as a wave in physics classes and examinations, but as a particle in chemistry.

Similarly, the later Commitment to Relativism Positions, which deal more with an individual's ethical development and the development of the self, are likely to be closely liked to the Personal attitudes and the high barrier to change associated with them in Johnstone and Reid's model.

2.7.2.3 Potential Criticisms of the Perry Scheme

As Finster (1989) and Harvey (1994) report, other researchers have successfully used the Perry Scheme as a basis for their work and confirmed Perry's observations (For example Baxter-Magolda and Porterfield, 1985). Despite this, there are some elements of the Scheme's development which have attracted criticism.

Perry's initial work was carried out, almost exclusively with male students, drawn from what can only be described as the crème de la crème of American college students. This raises the obvious questions: a) is the scheme appropriate to female students; and b) is the scheme appropriate to "lesser mortals" than those of Harvard and Radcliffe ?

The question of gender bias is not easily answered, with some work finding no gender differences (Kitchener and King, 1990) whilst others have (Belenky *et al.*, 1986). The Scheme's applicability to students from other learning institutions would seem more robust, however, as already mentioned the Scheme has been used by other researchers.

The age and cultural setting of the Perry Scheme may give rise to other possible problems. Unquestionably students today (regardless of their institution or gender) are different to their late 1950s / early 1960s American counterparts. Reading some of the responses given by students quoted by Perry (1981) it is difficult to imagine most of today's students, living in the Global Village of satellite television and the Internet, as being quite as parochial or (perhaps) innocent in their world view and development as those in his original sample.

At the heart of all of these potential problems is the paradox that whilst the level of detail the Scheme offers is attractive, it is that very feature which may also be its weakest. The detailed descriptions of the nine Positions Perry (1981) gives may not transcend all the potential barriers of gender, culture or institution without alteration (although such alterations could be very minor).

However, even if the high level of detail in Perry's work is not always applicable, his (more general) super-categories, on which the Centre's modified Scheme is based, are likely to be more robust to such factors. Indeed, there are other models of students' approaches to learning which have been shown to be stable in the face of sample changes that are very similar in nature to the Perry Scheme's super-categories in nature. Principal among these are the concepts of Deep and Shallow (or Surface) Learning Approaches (e.g. Biggs, 1985) which are widely recognised within the higher education teaching community.

However, Perry's efforts may prove to be ultimately a more useful approach to examining students development than Deep / Shallow processing ideas, as it describes a continuum rather than simply extremes in approach. Although containing positions akin to these extremes (i.e. Deep can be equated with Relativism and Shallow with Dualism) it is in his portrayal of interconnected intermediate stages that Perry most appeals. There is no indication of how (or indeed if) Deep and Shallow thought processes are connected. It is unlikely all students operate solely at one of the extremes offered by the Deep / Shallow model however Perry's observations give rise to a much more subtle breakdown of students. Perhaps one of the most useful features of Perry's scheme is in clearly defining a stage (Multiplicity) somewhere between (and linked to) the two clear opposites - Duality and Relativism.

Perry not only offers a description of how students move from one extreme to the other, but also shows an intermediate stage at which a combination of external factors, i.e. a course's demands on a student, together with internal feelings of insecurity can not only hamper progression to Relativism, but positively effect a retreat from any progress already made.

2.8 Forming the Ten Commandments

This review of some of the work of the Centre for Science Education was intended to give a fuller appreciation of The Ten Commandments the General Chemistry-1 Design Team used in their work. The research and theory described previously will now be linked to individual Commandments to show why that principle was chosen among the ten. As the Commandments do not appear in any special order, they will be reviewed in the same order as the areas of research they rest on.

2.8.1 Information Processing and The Ten Commandments

The Centre moved towards using a model of information processing following initial work on concept formation – attempting to explore reasons for reported student difficulties – which led to seminal work (in terms of the Centre's other studies) on the role of Working Memory (W.M.) in learning situations.

The key finding of their study into W.M. capacity was that student performance (in laboratories, class room teaching or examinations) decreased as the information load placed a student increased.

Research into actively reducing the load in laboratory situations showed an accompanying increase in performance with students able to focus more on the task at hand.
This gives rise to the fourth Commandment:

4. The amount of material to be processed in unit time is limited

The Centre's model of information processing comprises of a perception filter (through which some external stimuli can be admitted), the Working Memory (where external inputs can be processed alone or allowed to interact with existing knowledge) and the Long Term Memory (LTM).

In order to act effectively in a formal education setting the filter requires guidance as to which stimuli to accept and which to ignore. This guidance is provided by material already stored in the LTM, hence the first Commandment:

1. What you learn is controlled by what you already know and understand

The LTM can have a simple linear structure, with some ideas not connected to any other, or a complex, branched network structure, where relevant concepts are linked together. Ausubel ascribes linear, ill-understood structures to rote-learning – not fully developed and easily forgotten – whereas meaningful learning comes from actively establishing and expanding a branched mental network.

Thus the third Commandment is, then:

3. If learning is to be meaningful it has to link on to existing knowledge and skills, enriching both

To encourage such a development students should be allowed to approach the material to be assimilated from different angles and standpoints. The eighth and ninth Commandments state:

> 8. *There should be room for problem solving in its fullest sense*
> 9. *There should be room to create, defend, try-out , hypothesise*

They should also be encouraged to actively consider their LTMs and thought processes. This "thinking about thinking" process is usually termed "metacognition". The seventh Commandment:

> 7. *Students should consolidate their learning by asking themselves about what goes on in their own heads – metacognition*

2.8.2 Assessment and The Ten Commandments

Given the Centre's attitude to Multiple Choice items, it successfully campaigned for the removal of this method of testing from all chemistry classes at Glasgow a number of years ago. Hence, Multiple Choice testing would not appear in General Chemistry-1, despite the large numbers of students in first year in total.

A generally perceived view at Glasgow was that students did not study appropriately for their class exams, of which there were usually two (pre-1995/96). Students left their study until nearer the degree exam.

This was due to two factors:

i) as the class exams did not (usually) contribute to their final gradings, students did not always appreciate their partially diagnostic function and give them the importance due to them and failed to gain the habit of regular study.
ii) students employed the same study patterns they had found successful at school – a final "burst" of study to pass exams.

This second point was acknowledged in the second commandment:

> 2. *How you learn is controlled by how you have learned successfully in the past (related to learning style, but also to your interpretation of the "rules")*

To combat this it was decided that both class exams would contribute to a student's final grade in General Chemistry-1.

Even if the students did use class exam results as a guide to progress, their timing (January and April) made remedial work difficult. The January exam would cover the work of term 1 hence a poor showing would mean a student had to revise term 1 work whilst trying to cope with term 2 material. If diagnostic testing was used earlier to aid students in their studies then it may help overcome problems earlier.

The fifth Commandment became:

> *5. Feedback and reassurance are necessary for comfortable learning and assessment should be humane*

2.8.3 Attitude Development and The Ten Commandments

The majority of the intended clientele of the General Chemistry-1 course would be unlikely to continue in their chemistry studies beyond its successful completion. Hence, attempting to engender other, attitudinal, outcomes in the course may be possible, and desirable to the students' general appreciation of chemistry and science (rather than giving them more facts and information to forget at the end of the course).

Research had shown that different teaching strategies had appealed to different motivational styles within a class. The sixth Commandment stated:

> *6. Cognisance should be taken of learning styles and motivation*

The proposed model of attribute change and Finster's recommendations for altering student perceptions both called for material which would challenge a student's position and support them in that challenge.

To develop Relativistic, critical thinking approaches and the Skills of a Chemist would require students to meet material in new contexts and in new ways. This supported the eighth, ninth and tenth Commandments:

> *8. There should be room for problem solving in its fullest sense*
> *9. There should be room to create, defend, try-out, hypothesise*
> *10. There should be opportunity given to teach (you don't really learn until you teach)*

Perry (1981) himself comments on the importance of metathought to allow the progression of an individual towards Relativism therefore this process should be encouraged – the seventh Commandment:

> *7. Students should consolidate their learning by asking themselves about what goes on in their own heads – metacognition*

His Scheme also indicates that students will change only if they perceive a need to – the second Commandment:

> *2. How you learn is controlled by how you have learned successfully in the past (related to learning style, but also to your interpretation of the "rules")*

2.8.4 Conclusion

Having identified The Ten Commandments (and the work which lead to those particular statements) the Design Team used them, tempered by practical considerations, to create the details of the new chemistry course. Their design will be described in Chapter Three.

Chapter Three

General Chemistry–1: Year One

3.1 Introduction

Every research project has its own peculiarities – its own individual challenges and problems for the researcher to overcome or, at the very least, learn to work within. This research project is no different.

Frequently in "traditional", "Scientific" research one tries to change a single variable whilst holding all the others constant. One creates a "control group" against which any changes in a test groups' behaviour can be evaluated. Examples of such work, in general research as well as specifically within the field of educational research, are rife. Indeed, one particularly notable example, mentioned in Chapter Two as it impinges on this research, was the work of Vianna (Johnstone, Sleet and Vianna, 1994).

Vianna used the Information Processing Model to modify systematically a Level-1 inorganic chemistry teaching laboratory. Three interlinked strategies, in line with the model, were designed to improve the student's lab experience, namely:

(i) reducing irrelevant information and noise from the laboratory manual;
(ii) the development of pre-laboratory exercises to alert students to relevant material they would meet and allow a "priming" of the mind to better prepare them;
(iii) devising mini-projects which would allow consolidation of knowledge and link it to new material to encourage the development of a richer Long Term Memory network.

Students were allocated to one three-hour lab session per week, with one lab session required each day of the week to accommodate all of the (then) first year students. Students were therefore unable to "drift" from one lab day during one week to another the following week. This allowed Vianna to establish a very traditional approach, summarised in Table 3.1, to study the effects of the last two strategies:

Table 3.1 Vianna's Research Design

	MON	TUES	WED	THUR	FRI
PRE-LAB	no	yes	no	yes	no
MINI-PROJECTS	no	no	yes	yes	no
LABEL	control	Pre-Lab	mini-projects	Pre-Lab + mini-projects	control

(adapted from Johnstone, Sleet and Vianna, 1994)

As can clearly be seen this afforded Vianna the opportunity to study the impact of each variable both individually and in combination. The population of each day was constant over the period of the study, and the compositions of each lab day (in terms of factors such as gender and previous qualifications) would be essentially the same. With this design, Vianna was able to identify that the Pre-Lab exercises were the single biggest factor in improving the laboratory experience, of the modifications proposed.

Not all research, however, uses such an approach, either by choice or necessity. Other strategies of research exist (Robson, 1994a). The project described in this thesis was one which, whilst to some extent building on Vianna's, was unable to follow his research methodology for a number of reasons.

General Chemistry-1 (Gen Chem) would be taught in the same way as its sister class Chemistry-1 (Chem-1) in as far as time-tabling was concerned, i.e. approximately half of the class would attend a lecture given in the morning and the other half would attend a repeat of that lecture in the afternoon. This would give only two potential test groups – one incorporating all of the new features and a control group with none of them. Such an arrangement would make it impossible to identify the effectiveness of any one of the modifications in isolation. However, there were other considerations to be taken into account arising from such a research strategy.

Firstly the composition of each lecture grouping would not necessarily be constant – although students were assigned to one of the two sessions it was common for some of them to drift from morning to afternoon (and vice versa). Students generally appeared to favour morning sessions which had a higher attendance than those in the afternoon.

If the course changes were made in only one session (say, the morning) then there existed the real possibility that students could "vote with their feet" and move to or from that session. If the modifications were viewed as of benefit to – and enjoyed by – the students, then this could drive them into that half of the class. Whilst this would be a very gratifying thought and would suggest that the changes to the course were a positive success, this is not the only possible outcome.

If students disliked the changes and felt they derived little educational benefit from them, then they would drift away from that session. Similarly a drift away from the modified session could be caused by the view that it required more work on the part of the students, regardless of whether that work appeared to be of benefit or not – i.e. the students were likely to follow the path of (perceived) "least resistance" through the course.

A second point to consider, and perhaps the more important, would be the ethics of such a situation. If the innovations did effect the education of the students, either for good or for ill, then this would have to be taken into account in their final assessment. Robson (1994a) includes "withholding benefits from some participants" in a list of questionable practices in social research. In Vianna's study this problem was diminished by the relative size of the lab course compared to the course as a whole. The inorganic lab was only one third of the total laboratory course which contributed only 10 % of the students' final grade. Even the most extreme possible effects of Vianna's research would not cause a great difference to the students' ultimate fate in the class. However, a research project concerning the vast bulk of the course, such as this one, could have much more profound effects.

With all the changes being introduced in Gen Chem in one move, then this would mean the only control groups would be Chem-1 (which would contain students with generally superior entrance qualifications) and the previous year's Chem-1.

With this in mind it was decided to focus on three main design and research areas:

- Creation of the Support Materials the Design Team envisaged as central to the requirements of the course;
- Use of questionnaires, direct observation and interviews to build up a "students' eye view" of General Chemistry and its innovations from the inside;
- Consideration of the examination results to determine if General Chemistry–1 did indeed offer a realisable goal for students of varied chemistry and mathematics backgrounds.

3.2 The Design Team's Innovations

The Ten Commandments described earlier were used to form the innovations of the new General Chemistry course, with other often practical considerations taken into account.

As an addendum to the Ten Commandments, the Design Team drew up four statements to help put "flesh" on the proposals. These statements were:

- It is not enough to tell students how to learn – "Wise saws and modern instances";
- It is not enough to tell teachers how to teach – reactionary and home-spun, everybody knows how;
- To achieve changes the whole structure and ethos of the course must be designed as to change the rules of the game so that both teachers and students learn the new rules and are convinced of their rightness.
- There is no use hoping to change students from Perry A to Perry C without providing the structure, the incentives and the satisfactions to match.

The Design Team intended to promote change via the course, rather than by directly advocating to students what study habits to adopt as is common in study guide documents and some material the Centre For Science Education had previously been involved with (Johnstone and MacGuire, 1990).

3.2.1 Course Content

As indicated in Chapter One, the class would be aimed at those with less than "standard" entry qualifications (i.e. less than Scottish Higher Grade Chemistry and / or Mathematics at grade B) and those who felt their future did not lie with chemistry, requiring only one year of the subject. However, the Chemistry Department wished that students who found they had a flair for the subject or changed their mind about future studies should not be disadvantaged and a mechanism to allow them to transfer from Gen Chem to Chemistry-2 should be incorporated into the design. This constrained the course content to some extent in so far as it could not be allowed to vary too much from that of Chem-1 or else such transfers would not be possible.

Originally there was a feeling that essentially anyone who wished to join the class should be allowed to do so irrespective of their entrance qualifications. It was hoped that courses could be developed which, although covering what was familiar chemistry to the most experienced members of the class, would present it in such a way as to give it a very different approach. For example, some of the early suggested course ideas included "Chemistry and Scenery" (linking to geological aspects of chemistry) and "Living in an Aqueous Environment" which would have covered a range of traditional Level-1 physical chemistry topics such as solubility, pH, equilibrium and electrochemistry but with a biological slant. This approach may also be useful for the less qualified students – generally they would have a stronger background in biology than chemistry so highlighting any links to their preferred subject may appeal to them and impress on them the importance of chemistry study.

In practice, however, the courses which would constitute Gen Chem would end up much closer in appearance to those of Chem-1.

Seven different lecturers worked on Gen Chem, delivering courses on inorganic, physical and organic chemistry. The course documentation described the aims of each course:

(1) *Periodic Table I* – Reviews the elements and their compounds, their occurrence and importance. Uses the Periodic Table to look for generalisations of chemical behaviour and properties of the elements. Discusses ionic and covalent compounds, co-ordination of ligands to metal ions and redox reactions. Illustrates how these ideas relate to everyday experience.

(2) *Periodic Table II* – Considers the chemistry of some of the metallic elements with an emphasis on their structures including defects, relationships between properties and structures, and corrosion. Studies co-ordination chemistry to understand the diverse behaviour of metal ions and their complexes in living systems.

(3) *States Of Matter* – Explores the states of matter (gas, liquid and solid) as well as the intermediate states of colloid and liquid crystal. Rationalises the behaviour of these states on the basis of the particulate nature of matter and in terms of polarity, intermolecular attractions and molecular structure. The discussion encompasses macrophenomena familiar to students and relates chemical concepts to biology and geology.

All of these courses ran during the Martinmas term (October to December).

(4) *How Far and How Fast ?: Chemical Kinetics and Equilibrium* – considers the factors that determine how fast and how far chemical reactions may go – basic kinetics and equilibrium thermodynamics and their applications.

(5) *Aqueous Solutions* – Highlights the unique nature of water as a solvent and considers some of the special properties of aqueous solutions and their significance in nature. Introduces ideas relating to electrolytes in solution, membranes and osmotic pressure, acid-base properties and solubility of substances in water.

(6) *Carbon Compounds I* – Discusses the distinctive characteristics, structures, shapes, names, reactions, applications and natural occurrence of organic molecules and interprets their reactions and bonding using general principles.

These courses made up the Candlemas term (January to March).

(7) *Carbon Compounds II* – Considers the chemistry of some more complex organic molecules and polymers and their uses. Examines how the properties of such compounds depend on their structures and electron distributions.

This course was taught in the Whitsun term (April to June).

The main differences between these courses and those offered in Chemistry-1 lay in the removal of courses on electrochemistry and bonding theory, and a reduction of the depth of some of the coverage of material (e.g. curly-arrow mechanisms were omitted from the organic chemistry).

3.2.2 Pre-Lecture Exercises

The work of Su (1991) carried out during his time with the Centre, had identified student problems in lectures and note-taking skills, and studied their effects on examination results. His work showed that students could have problems in lectures when lecturers assumed the presence of a prior knowledge which was either absent or had been forgotten. This would undoubtedly lead to inefficient processing of the lecture material when the student was note-taking. For example, to a student with poor mathematical skills the terms "log x" or "e^x" would be a mystery and they may loose sight of the chemistry under the onslaught of unfamiliar maths.

Essentially Su's findings, and those of another worker (Percival) can be seen in the context of the Centre's study of Working Memory – students required more processing of unfamiliar material which may actually be in vain. Percival (Johnstone and Percival, 1976) proposed what were termed "micro-sleeps" when students' attention appeared to wander and they suffered measurable learning losses during these periods – the over-loaded Working Memory "shutting down" to flush itself out and prepare for the next input. Whilst some of the effects observed were characteristic of the individual lecturer involved, it was hypothesised that others could be altered by an external influence.

Vianna's work had highlighted the importance of the Pre-Lab exercise as a way to prepare students to navigate their way through a lab session and this finding was reflected in the Ten Commandments (Commandment 1). It was hypothesised that as Pre-Lab exercises had proven to be so successful then perhaps Pre-Lecture sessions could be equally so.

A Pre-Lecture (Pre-Lect), then, would replace a lecture and occur at the beginning of a block of lectures. The material which the lecturer would assume the class had prior knowledge of would be covered in a short test to allow the students to evaluate themselves and prime their minds as to what was ahead of them in the lectures. If on completing the test and checking their own performance, a student felt that they had performed adequately and were comfortable with the material covered then they could leave and return for the next scheduled lecture.

However, if they felt they had problems with the topic then the students were asked to remain behind and tutors would be on hand to help. Those who had successfully coped with the Pre-Lect were also invited to stay and help their less experienced classmates on the grounds that:

(i) they were all in this (i.e. Gen Chem and university in general) together and might as well get to know each other;

(ii) although they may be familiar with this section of the course they may meet a section where they would need help rather than be in a position to offer it, and;

(iii) you don't really understand a topic until you try to teach it (one of the Commandments).

This was a deliberate attempt to encourage an atmosphere of camaraderie in the class as well as informally foster group work and discussion skills.

The remainder of the time would be devoted to trying to solve student problems and recommend any relevant reading.

Kristine (1985) reported a similar system of Pre-Lecture assignments, involving preview reading and review questions, at Pennsylvania State University to encourage study skills development.

Naturally, no material specifically designated as Pre-Lecture material existed in the department prior to the development of General Chemistry-1. It was decided to create two Pre-Lect exercises each for *Periodic Table I*, *States of Matter* and the mathematical content required for *How Far & How Fast ?*. The other courses generally followed on from these and so would not require a separate special preparatory session. The organic component of the syllabus would begin from a position of no prior assumptions about the students' level of knowledge in this field, and so required no Pre-Lects.

The author's role here was to ascertain what each of the lecturers involved would assume their class was already familiar with when their courses began. Having settled this, the worksheets were then written, in conjunction with the lecturers, to cover the relevant topics. Examples of the text of the Pre-Lects used are given in Appendix A.

3.2.3 Support Packages

As an addition to any help offered to students during Pre-Lect sessions, the Design Team felt it would be useful to produce support material covering traditionally difficult areas of the syllabus. Such packages could also be used before a Pre-Lect to give students some preparation for them.

It was hoped that the packages could help students with common problems without requiring extra staff time in tutorials whilst encouraging them to become more independent (of staff) in their study habits.

The key areas of difficulty in the syllabus (from previous experience and research) were clearly the concept of the mole and the mathematical skills required in the course.

The researcher produced two small packages *The Bluffer's Guide To The Mole* (which covered defining the mole, balancing equations and using them in calculations, and the mole in solution) and *Improve Your Basic Mathematics Skills* (covering solving equations, graph work, and logarithms and exponentials).

The text of the first of these booklets is included as an example (Appendix B).

3.2.4 Problem Solving Workshops

The Chemistry Department successfully introduced Problem Solving Workshops in place of lectures in many of its other courses a number of years ago, and such Workshops would be included in Gen Chem.

Workshops usually replaced one lecture a week and consisted of a worksheet of problems based on material recently covered in lectures. Students would be invited to attempt these problems, with assistance available from staff tutors on hand and their peers. These sessions allowed reinforcement of ideas, gave students the opportunity to discuss concepts with staff, and hoped to encourage the development of a more enriched mental network.

The sessions were also designed to introduce general problem solving strategies and arithmetic algorithms (e.g. use of the Gas Laws) giving students the chance to practise them.

3.2.4.1 Quality of Problem Solving

Although Chemistry-1 Workshop material existed and had been used for a number of years, there were some concerns about its use in General Chemistry.

Obviously there was some course content and difficulty level difference between the two Level-1 classes which would need to be reflected in the material the Workshops covered.

Frequently the Chem-1 Workshops did not offer questions in a logical, progressive sequence and it was not unusual to find the most challenging question near the beginning of the worksheet. It was also common for questions to offer potential Working Memory overload (a factor already clearly shown to hamper student learning) via problems with the langauge, mathematical skills or number of steps required to find an answer. Some of the problems required skills additional to those the Workshop was aimed at teaching to solve them (e.g. predicting the products of an unfamiliar reaction before being able to carry out a calculation).

A gradual increase in demand (in every sense of the word – i.e. language, maths and thought steps) would seem more conducive to learning and so it was intended that this should be incorporated where possible, bearing in mind the work of Kellett and the "Concorde" diagram (Figure 2.1).

Another cause for concern was in the perceived quality of the questions asked in the worksheets. Johnstone (1993b) argued that a problem could be broken down and described in terms of three components: the information given; the method required to produce a solution and; the goal or outcome required. He identified eight types of problem, depending on the status of these factors (Table 3.2).

Table 3.2 Types of Problems by Classification

Type	Data	Method	Goal	Skills Bonus
1	Given	Familiar	Given	Recall of algorithms.
2	Given	Unfamiliar	Given	Looking for parallels to known methods.
3	Incomplete	Familiar	Given	Analysis of problem to decide what further data are required. Data seeking.
4	Incomplete	Unfamiliar	Given	Weighing up possible methods and then deciding on data required.
5	Given	Familiar	Open	Decision making about appropriate goals. Exploration of knowledge networks.
6	Given	Unfamiliar	Open	Decisions about goals and choice of appropriate methods. Exploration of knowledge and technique networks.
7	Incomplete	Familiar	Open	Once goals have been specified by the student, data are seen to be incomplete.
8	Incomplete	Unfamiliar	Open	Suggestions of goals and method to get there; consequent need for additional data. All the above skills.

(from Johnstone, with Akhtar, Gray and Pollock, 1993)

Problem Types 1 and 2 were identified as being the most prevalent in education (e.g. "how many grams of X will react with N grams of Y?"). Problems such as these allow students to master the application of algorithms and produce unique answers – indeed once a Type 2 problem is encountered and a method of solution found, it immediately becomes a Type 1. Whilst the role of these problems were not in question, their dominance was.

The remaining Types begin to mirror real-life situations, where some level of judgement and / or creativity is required to find a (not always unique) answer. There was a feeling that students should be confronted with problems drawn from the latter Types to help them realise the nature of their thinking and to challenge that thinking (in line with the movement towards Perry C status discussed in Chapter Two). Indeed, there are clear links between the skill bonuses offered by certain Types of problem and the higher stages of Perry's Scheme.

Wood (1993) produced a book of problems, based on these ideas, and it was felt that material of this nature should be included in Gen Chem Workshops.

Again the researcher's role here was one of developing new and editing existing Workshops. Questions were rejected on the basis of being inappropriate for the course content or modified to improve their relevance or introduce more realism.

The Workshops for *Periodic Table I*, covering the use of the unit cancellation method for calculations (e.g. Brown and LeMay, Jr., 1988; Holtzclaw, Jr., Robinson and Odom, 1991), balancing redox equations, and predicting reaction products were adapted from Chemistry-1 material by the lecturer delivering that course. All the others, however, were devised by the author in collaboration with the other lecturers.

Samples of some of the Workshop exercises used in the course are given in Appendix C.

3.2.5 Diagnostic Tests

As mentioned at the end of Chapter Two, the Design Team believed that Diagnostic Testing materials would be of great potential benefit to the students in General Chemistry.

With the Class examination results contributing towards the students' final grades, regular Diagnostic Testing would allow them the opportunity to obtain an indication of their progress in the course and hopefully allow them adequate time to seek any remedial help they may require before these exams.

Some of the ideas discussed in Chapter Two's review of Assessment research (Section 2.5) would be incorporated into the design of the testing materials. Although most, if not all, of the techniques proposed would readily lend themselves to computer-based testing (as suggested by Johnstone, McAlpine and MacGuire, 1986) which could have many benefits in terms of data processing and use of staff time, this option proved not to be viable.

Given the large number of students that would be involved, the Chemistry department's (then) computer provision would never have coped with the through-put of students at such a rate as to make computer testing a realistic proposition. It was decided then, that pencil-and-paper tests, which would be marked by class tutors would be used for diagnosis.

Each of the lecturers involved in Gen Chem had a group of students assigned to them as a tutorial group. The lecturer would mark the tests, completed by the students in place of a lecture, and arrange with his group a suitable time to collect and discuss the test. Beyond this arrangement, no formal tutorials would be scheduled for General Chemistry-1, leaving any additional sessions to be agreed between tutor and students as to the best time, topic to be covered, etc.

The researcher co-devised the tests for the courses covered in the second and final Terms, again with the respective lecturers involved. Examples of the Diagnostic Tests used are reprinted in Appendix D.

3.2.6 Examinations (Class and Degree)

Although both Chemistry-1 and General Chemistry-1 students had the same examination load, i.e. two Class exams (January and April) and a final Degree exam in June, the treatment of the results of these exams were quite different.

Chem-1 operated an exemption system in common with most Level-1 science courses. Students who achieved a high standard in both Class exams were granted an exemption from the June Degree exam and were taken to have passed the course. The remainder of the class would have to sit the Degree exam. These students were awarded a final grade calculated on the basis of a 90 % contribution from the June exam and the other 10 % from laboratory grades.

Each of the three exams given over the year had a consistent format. A single paper (of two hours duration for the Class exams and three hours for the Degree) would offer students a (partially constrained) choice of questions. Generally one question was available for each of the courses comprising the Chemistry-1 syllabus.

The Design Team decided on a different structure to the assessment procedures of General Chemistry. To ensure strict comparability of the exam results, and keep the format in line with that used in the Scottish Examination Board's papers and SCOTVEC modular assessments, it was decided to remove the element of choice from all the papers. Each paper would be split into two sections each worth 50 % of the total. The first section would comprise short-response questions covering basic knowledge and understanding, whereas the latter section would require longer written answers for students to calculate, explain, define, apply and connect ideas.

The Class exams would contribute 20 % each to a student's final grade and there would be no system of exemptions on offer. It was hoped this (together with the regular Diagnostic Tests) would encourage students to develop more consistent, and hence effective, study habits rather than the "last minute dash" many of them relied on to pass the Degree exam. The remaining 60 % of the assessment would come from the Degree exam (50 %) and lab grades (10 %).

Class exams would cover the material from the courses of the preceding term, giving each of them equal weighting (of course, this necessitated that there be a slight bias towards *Carbon Compounds II* in the Degree exam to make up for it not appearing in a Class exam).

For students of both Chem-1 and Gen Chem who did not pass by June there was a second chance in the shape of a resit Degree exam in late August or early September. Anyone facing this prospect was assessed by the same formulae as before, with the September exam mark replacing that of June.

3.2.7 Other Features

General Chemistry-1 teaching would be delivered by 83 traditional "chalk 'n' talk" lectures over a period of 25 academic weeks. Each week would comprise five lecture slots, or more appropriately "teaching times" as the time could be filled by a Pre-Lecture, a Lecture, a Workshop or a Diagnostic Test.

The laboratory course comprised 17 three hour sessions, covering inorganic, physical and organic chemistry. All of these sessions were revisions of the existing Chem-1 lab sessions. The revisions, in the main, involved reducing the workload of the individual experiments. All of the lab courses incorporated some of the feature from Vianna's work (e.g. Pre-Labs and mini-projects) and so will not be considered further in this thesis.

3.3 Breakdown of Class Composition

Before beginning their studies at Glasgow each new student in the Faculty of Science has a meeting with a member of staff who is designated as an Advisor of Studies. The Advisor's role is to help guide the new students in the construction of their Level-1 timetable of subjects, although in some cases, depending on an individual's intended Honours subject, there may be few or no options.

Generally students are free to choose from the wide range of Level-1 subjects in the Faculty (depending on entry qualifications) and even (time-tabling permitting) from other Faculties. Indeed, under the proposed arrangements for the revised three-year Degree at Glasgow described in Chapter One, this cross-Faculty range offered is a practice that is likely to be encouraged further in the future.

As General Chemistry-1 was a new course, there was a concern that the message of what it was and who it was designed for may not be given consistently across the range of Advisors, under the pressure of so many students to see. This is a point, as will be seen later, the researcher would attempt to probe.

In the opening weeks of the first Term it is common for a few students to switch from subject to subject as they try to settle in to their studies, although this practice is not widely encouraged. This was certainly true of Gen Chem where 15 students (of the 145 who enrolled) decided that it was not the course they wanted and moved to another or otherwise withdrew from the class. There was also a (natural) confusion between the two chemistry courses offered by the Department and some students were advised to transfer from one to the other (2 students moved to Chem-1). In fact, the opportunity to transfer from Chemistry-1 to General Chemistry-1 was open to students, albeit at the Head of Department's discretion, until the end of the Term.

By June, 121 students were left in the class, following some withdrawals from university over the year. Four of these 121 did not provide full information on themselves and so all the percentages presented are in terms of this revised June figure of 117 students unless otherwise stated.

The class was made up of 51 male students and 66 female students, with the wide range of chemistry and mathematics qualifications expected by the Gen Chem Design Team being represented. These qualifications included modules (SCOTVEC), Scottish Examination Board Standard and Higher Grade, Certificate of Sixth Year Studies (CSYS), Access courses and those with no formal qualifications in chemistry or maths. There was also a small group of students with Irish and other foreign qualifications which were classed as "other". As this group was of such a disparate nature their examination results will not be discussed in any detail later in the chapter.

Table 3.3 Breakdown of General Chemistry-1 (1993-94) Entrance Qualifications by Class and Gender

Chem Qual.	Class (% of 117)	Male (% of 51)	Female (% of 66)	Maths Qual.	Class (% of 117)	Male (% of 51)	Female (% of 66)
modules	16 (13.7)	10 (19.6)	6 (9.1)	modules	15 (12.8)	11 (21.6)	4 (6.1)
S Grade	21 (17.9)	9 (17.6)	12 (18.2)	S Grade	27 (23.1)	13 (25.5)	14 (21.2)
H Grade	54 (46.2)	17 (33.3)	37 (56.1)	H Grade	58 (49.6)	18 (35.3)	40 (60.6)
CSYS	4 (3.4)	3 (5.9)	1 (1.5)	CSYS	3 (2.6)	0	3 (4.5)
other	8 (6.8)	7 (13.7)	1 (1.5)	other	8 (6.8)	6 (11.8)	2 (3.0)
none	10 (8.5)	3 (5.9)	7 (10.6)	none	3 (2.6)	2 (3.9)	1 (1.5)
access	4 (3.4)	2 (3.9)	2 (3.0)	access	3 (2.6)	1 (2.0)	2 (3.0)

The students with CSYS Chemistry had obtained a low grade at this level, but (of course) did have a Higher Grade in the subject. Those with Higher Grade were mostly at C Grade (77.8 % of those with Higher Chemistry) with the rest being made up of B and D Grades. None of those in the class had Higher Grade Chemistry at A. For the purposes of further analysis "Standard Entry Qualification" will be assumed to be a Higher Grade pass (or better) in a subject (the shaded entries in Table 3.3), whereas "Non-Standard Entry Qualifications" will be assumed to be less than Higher Grade (with "other" omitted).

The class can be divided into those who had Standard Entry Qualifications

- in both chemistry and maths;
- in one of these only;
- in neither of these subjects.

Table 3.4 shows the distribution of students by such sub-division.

It would be reasonable to hypothesise that those with Standard Entry Qualifications in both subjects should be expected to be the highest achievers in the class on the basis of past experience, and conversely Non-Standard Entry for both being the weakest students. This is discussed later in the chapter.

From Table 3.4 an interesting observation can be made. As well as having slightly more female students than male, it is clear that the female students are generally more qualified in chemistry and maths than their male counterparts with more of them having Standard Entry Qualifications in both subjects. This is also shown in the numbers of students who have only Non-Standard Entry Qualifications with males predominating here. This would seem unusual given the traditional view of science subjects (such as chemistry) being more male-dominated than non-science subjects.

Table 3.4 Breakdown of General Chemistry-1 (1993-94) Chemistry and Mathematics Qualifications by Class and Gender

Chemistry Qualification	Mathematics Qualification	Class (% of 117)	Male (% of 51)	Female (% of 66)
Standard Entry	Standard Entry	47 (40.2)	16 (31.4)	31 (47.0)
Standard Entry	Non-Standard Entry	10 (8.5)	4 (7.8)	6 (9.1)
Non-Standard Entry	Standard Entry	13 (11.1)	1 (2.0)	12 (18.2)
Non-Standard Entry	Non-Standard Entry	35 (29.9)	21 (41.2)	14 (21.2)

3.4 Students' Views of General Chemistry-1

To help build up a clear picture of students' experiences of General Chemistry-1 it was decided actively to seek their views. From such an investigation, it was hoped a more accurate picture would be produced of how Gen Chem functioned as a course, highlighting any problem areas or particular successes.

It was also of importance to establish how the "less-qualified" students felt towards the course in terms of bringing the chemistry content to within a level they could more readily deal with, than had been the case in Chemistry-1. This was a key aim of the course.

As much of the support material to be used had been co-designed by the author, and it was through these that Gen Chem hoped to meet its ideals, then monitoring student attitudes towards the material would seem vitally important. If students were unsure or unclear of the purpose of one of the "extra" features of Gen Chem then this attitude may undermine both the individual feature and perhaps the course as a whole.

As mentioned earlier, the novelty of the course may have meant that the advice and information given to students may have left something to be desired. At its worst this may have left students feeling misled about the nature of the class they were enrolling in. There may also be a feeling that Gen Chem was in some way an "easy option" although such a reputation would not be welcome or indeed deserved.

A final, and perhaps more ambitious, question that such an investigation may help shed light on was in trying to establish if any of the ideas embodied in the Ten Commandments had come across to the students. For instance, had their outlook on knowledge and learning in general shown any development along the lines of Perry's Scheme ? Proving a direct connection is, of course, a different matter.

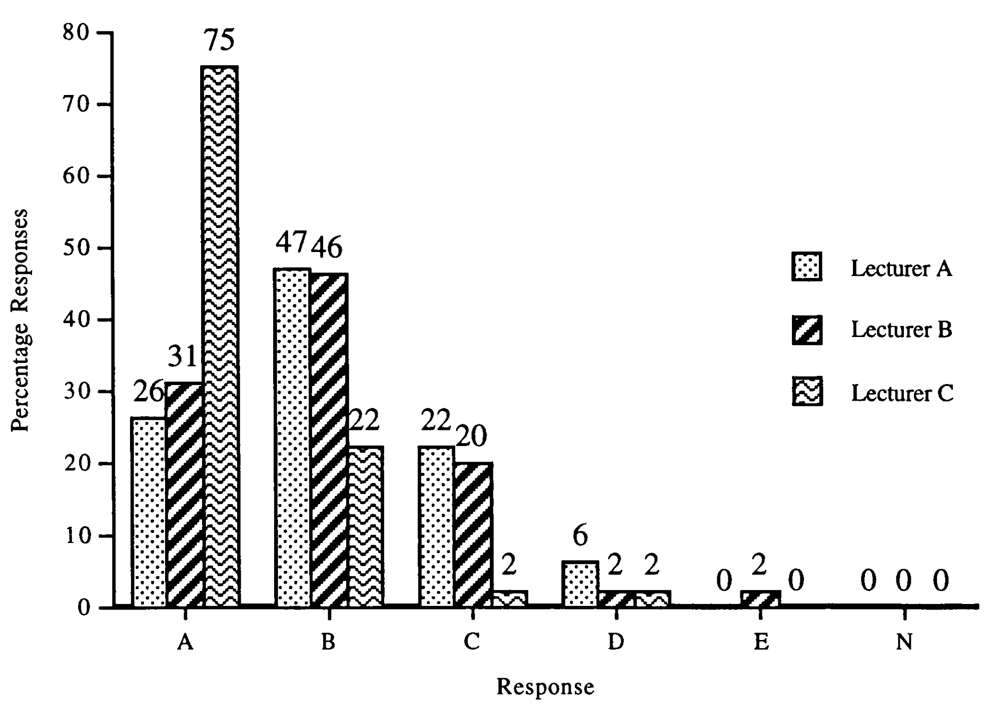
A variety of tools to probe the class were available, these being:

- The Chemistry Department's own course assessment questionnaires;
- Student interviews with a volunteer group;
- The researcher's own questionnaires;

3.4.1 The Chemistry Department's Assessment

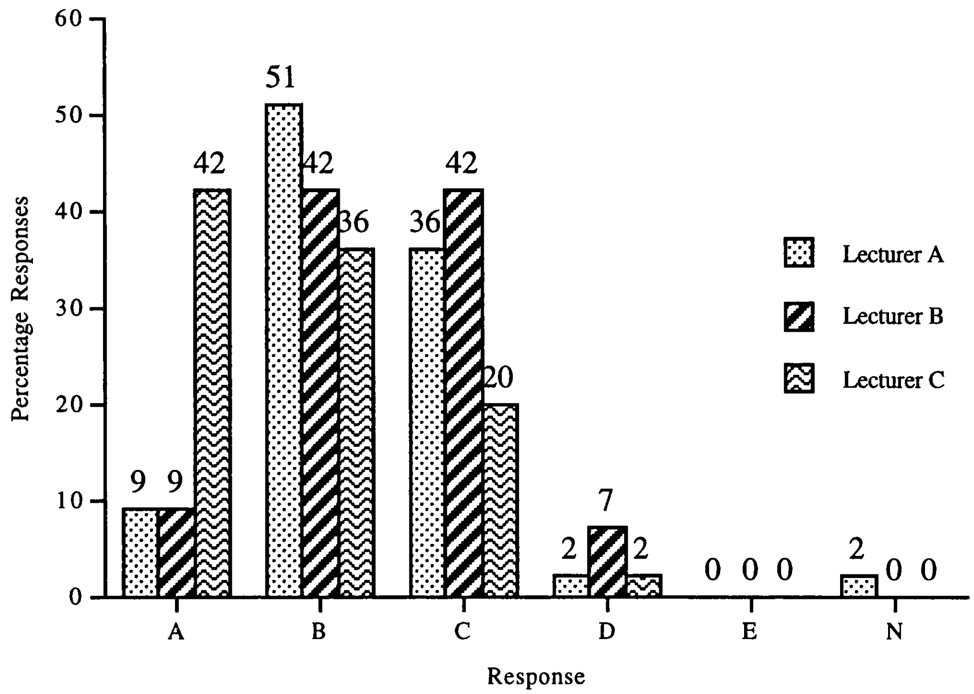
The Chemistry Department introduced an assessment of their teaching by questionnaires in the mid to late 80s. These were developed to draw relevant questions from a bank of available items and the results scanned by an optical mark-sense card reader to speed up (collection and) processing of data. The questionnaires probed students' opinions of the lecturer (in terms of presentation and content) and of specific course features, scored on a five-point Likert scale. Figure 3.1 and 3.2 displays the students' responses to the lecturer for the first term lectures as an illustration:

Figure 3.1 Students' Opinion of Lecturers' Presentation in Term One



A = Excellent, B = Very Good, C = Good, D = Poor, E = Very Poor, N = No Response

Figure 3.2 Students' Opinion of Lecture Content in Term One



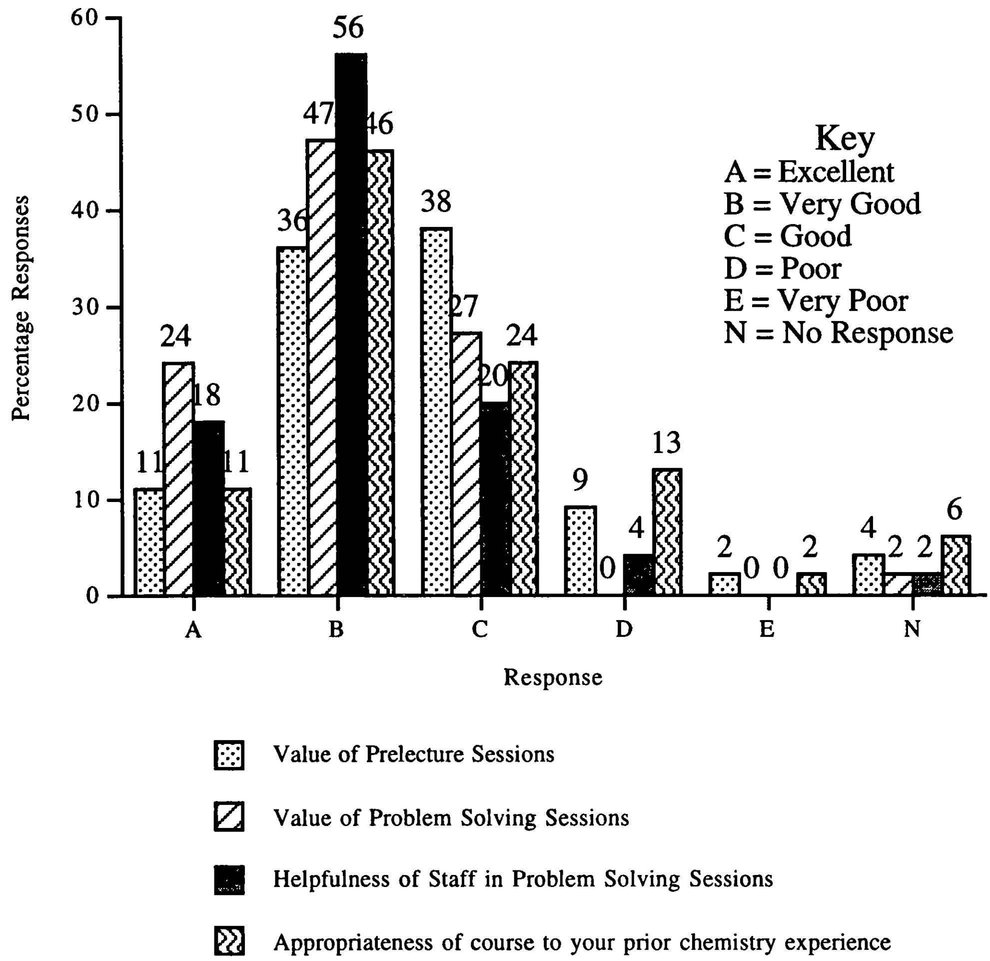
A = Excellent, B = Very Good, C = Good, D = Poor, E = Very Poor, N = No Response

As can be seen all three lecturers scored highly (grades A, B and C). This high appreciation was broadly maintained in Term 2, although the more unpopular mathematical courses suffered a slight dip.

Figure 3.3, overleaf, shows the pattern of student opinion on some of the key questions concerning the course. Again students were asked to give their opinion on the five point scale to several statements. The results for the following areas are shown in Figure 3.3:

- The value of the Pre-Lecture Sessions;
- The value of the Problem Solving Sessions;
- The helpfulness of staff in the Problem Solving Sessions;
- The appropriateness of the course to a student's prior chemistry experience.

Figure 3.3 Students' Opinion of Some Key Features



It is clear from this bar chart that the support materials (Pre-Lects and Problem Solving Sessions) appeared to have found favour among the members of the class.

3.4.2 Student Interviews

In an attempt to build up a more detailed and personal view of Gen Chem it was felt that conducting student interviews could be a useful research method. The advantages of such an approach are numerous and clearly documented (Robson, 1994a):

- The abilities to modify a line of enquiry in the light of an interviewee's response and gain clarification;
- The opportunity to observe the interviewee's behaviour when giving a response.

On the other hand, there are disadvantages to the interview as an enquiry method:

- The process is time consuming, thereby limiting the number of interviews that can realistically be attempted;
- The skill of the interviewer can play a crucial role in the amount and quality of data gathered.

A representative sample of students, in terms of gender, was chosen to reproduce the class as at Week 4 of the first term. By this stage the class had generally settled down and few changes occurred after this. Suitable students, i.e. from those of a particular gender and holding a particular qualification, were chosen randomly and invited to be part of the Interview Group. Those who were asked to participate agreed to co-operate, with only a few exceptions when a replacement had to be sought. A sample of 26 students was felt to strike a realistic balance between having a reasonably sized group to interview whilst not becoming too unwieldy in terms of time.

Figure 3.4 indicates the class and Interview Group breakdown in terms of qualifications.

Figure 3.4 Breakdown of the Composition of the Class and Interview Group by Qualifications

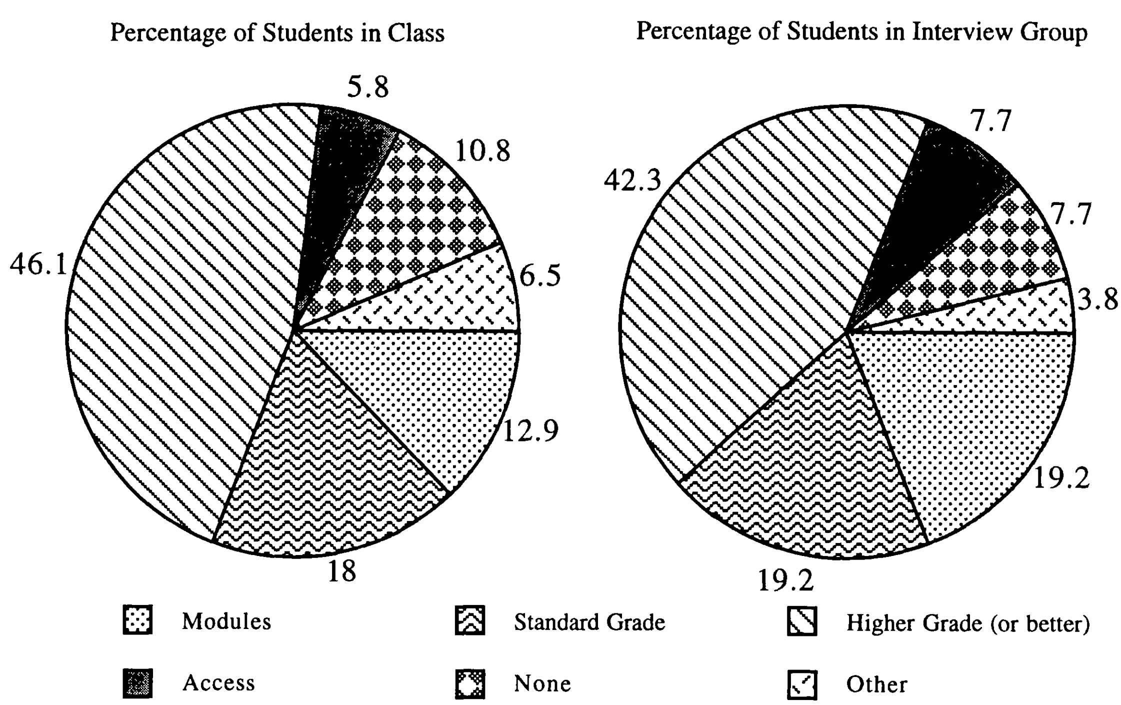
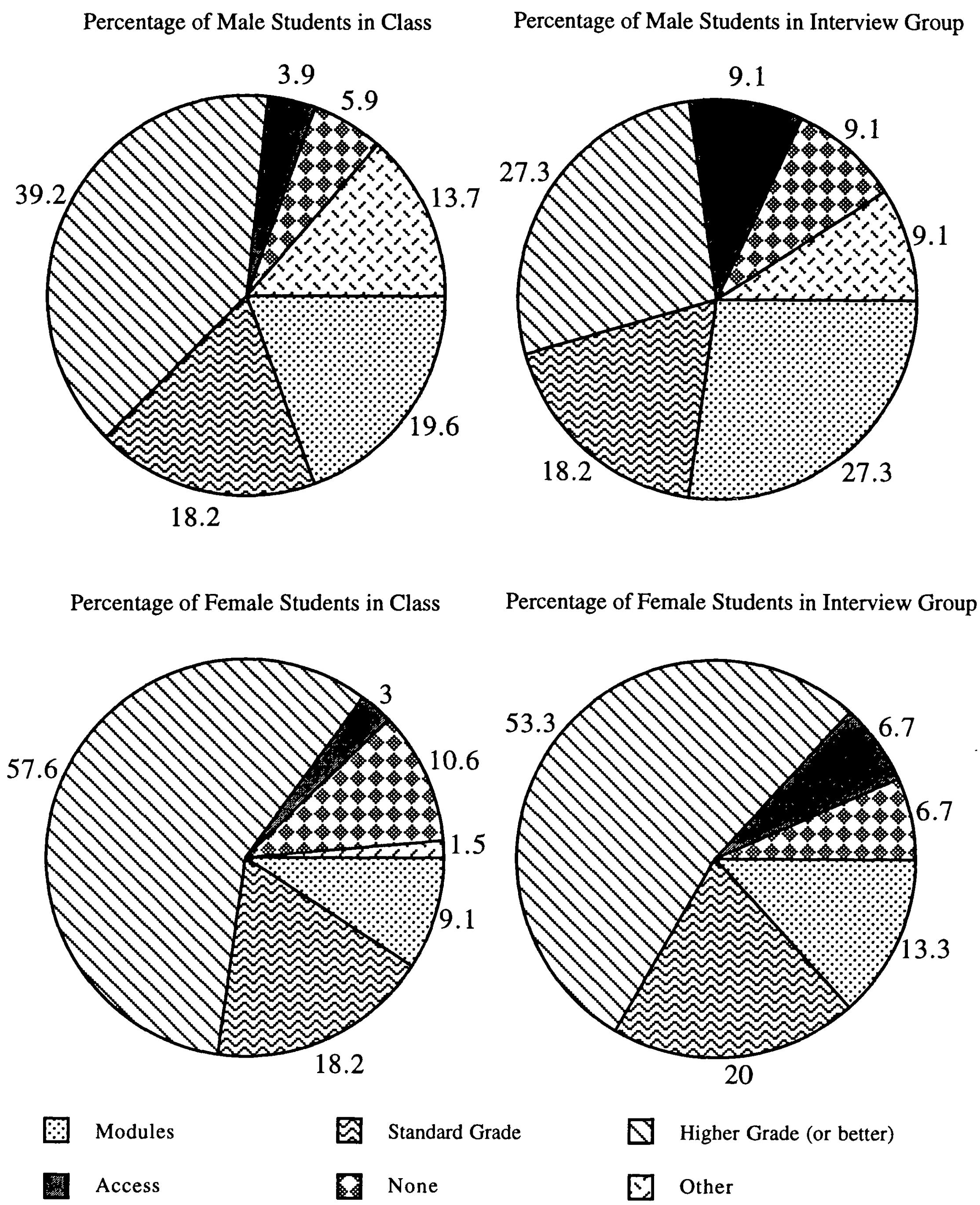


Figure 3.4 Breakdown of the Composition of the Class and Interview Group by Qualifications cont.



3.4.2.1 The First Interview

The initial interview was seen as important – a "getting-to-know-you" process to breakdown any potential barriers between the researcher and the interviewees. For this reason the interview was deliberately short and light, following a semi-structured (Robson, 1994a) protocol as would be adopted for all the interviews.

The majority of the Interview Group attended a first interview during Week 10, the final week of the first term. The timing of this period of interviews clashed with some Class exams, most notably in Psychology, which was a cause for non-attendance. Despite this problem Week 10 was almost certainly the best time to hold the interviews as there were no Gen Chem lectures that week, thereby reducing the students' timetable.

One area in need of clarification in some cases was the information given by the students on their enrolment forms. This form, completed by students on their entry to the class, was effectively the only source of information on an individual's background prior to joining the class. By using the completion or correction of the information held on the student's enrolment form, this offered a straightforward way of easing into the interview.

The students were also asked about the other subjects they had decided to pursue in their first year and as to why they had opted for General Chemistry-1.

Most of the group (23 out of 26) were also studying Biology-1, which was as the Design Team had envisaged. The second most common subject was Psychology-1, taken by 12 students. The remainder consisted of Mathematics, Archaeology, Geology, Geography and Environmental Science.

General Chemistry-1 was generally taken since students cited the study of chemistry as a fairly natural accompaniment to their study of biological sciences. This choice of subjects offered them a wide variety of potential future studies. On the advice of the Advisors of Study students with less than Higher Grade, or a Higher at a low grade, were directed to Gen Chem entry rather than Chemistry-1. However, one or two students commented that either they had to ask about the course and its suitability to them or felt that they weren't entirely clear about the difference between the two courses on offer following their meeting with an Advisor. Only one of the Interview Group was openly "anti-chemistry", having been forced to continue his study of the subject for a year at university in order to conform to the requirements of his intended honours course.

The semi-structured format used allowed some natural variation of the interview depending on students' responses, but, in each case, information was sought on:

- Pre-lects, Tests, Workshops and Tutorials;
- Lectures and laboratories;
- how General Chemistry-1 compared with other subjects being studied.

There was a broad consensus on virtually all of these matters from the group.

The nature of the Pre-Lects (students had experienced four of these by the time the interviews occurred) seemed to have made little impression on the group. Whilst only one interviewee thought them a waste of time (better spent on an extra, introductory lecture if that was required in his opinion) the group as a whole did not have strong feelings either way on these exercises.

The Diagnostic Tests did, however, provoke more response. Students had undergone a test covering the content of both *Periodic Table I* and *II* before the interviews. The Group generally agreed that the idea of having a test had given them a focus for study and had made them make at least some effort for it. It was commented that as the test did not "count for anything" (in their eyes) the incentive to study was less than it would be for a class exam, although this attitude was more prevalent in those with a stronger background in the subject.

Those studying maths courses had experienced an early class exam and cited this as having led them to prioritise their study and spend less time on the chemistry Test. This was really the only problem associated with the Tests identified – clashes of timing with certain demands from other subjects. It would seem fair to argue then that students were perhaps failing to organise their time efficiently.

However, it is entirely understandable, of course, if students avoided spending what they viewed as inordinate amounts of time on subjects of little future importance to them. This is a general problem that would affect any subsidiary subject such as General Chemistry – it is unlikely for students to choose to spend large amounts of time on them.

The problem arising from such a strategy occurs when students either misjudge or deliberately spend insufficient time for their needs on a subject.

The Workshops were given almost universal support by the Interview Group. Students said they enjoyed the opportunity to tackle problems based on recent lectures as it allowed them to ask individual questions that the traditional lecture format precluded. Occasionally students commented that other subject demands meant they had not really looked at recent chemistry material which a Workshop covered. Again this was a manifestation of the same "prioritisation problems" suggested as surfacing in Diagnostic Testing.

The sole, although frequently aired, complaint on the Workshop sessions was a perceived lack of tutors available for consultation. Normally a Workshop had two tutors per session, with half the class envisaged as coming to each. In practice, most students attended the Workshops in the morning, making these sessions busier for the tutors.

Whilst more tutors would have been a welcome addition, this was not possible for staffing reasons. Chemistry-1 Workshops occurred at the same time reducing any chance of extra staff being deployed in Gen Chem. In fact, the tutor / student ratio was more favourable in Gen Chem than in Chemistry-1 Workshops.

Some of the students reported that they had not (yet) approached their assigned tutor as they had not felt the need of their help or advice. Many of those who had, reported that the tutor had made an arrangement to be available at a certain day and time regularly, rather than arranging tutorials if and when the tutorial group wanted, as the design Team had originally envisaged.

The lectures were viewed favourably, with *States of Matter* (the course which had just ended) being singled out as particularly popular. This confirmed the Departmental Questionnaire's findings. Students felt generally comfortable with the pace and style of both the lectures and the lecturers, although those with the least chemical experience admitted to feeling apprehensive at times, particularly when the course began.

Again the level of previous experience in the laboratory was another telling factor for some students, with the less qualified feeling the inorganic lab had at times been very demanding. Frequently the purpose of the work was unclear to them. Although an edited version of the Chem-1 course had been prepared for Gen Chem, it would require further work as the comments received were indicative of the sort of problems identified by Johnstone *et al.* in their work of laboratory design (Chapter Two).

Having gone through each component of General Chemistry-1, the members of the Interview Group were then asked to compare the course to their other Level-1 subjects. It was hoped this would give some indication of how the "extra demands" of Gen Chem had been viewed in light of other subject demands. The Group agreed that Gen Chem compared favourably and offered them more support than their other subjects, and that they did not fing this extra support excessive. Some queried if this level of support was simply a temporary measure as the course was as much a novelty to the Department as to the students, and that the Department was going out of its way to be seen to succeed.

Many commented that if Workshops could be incorporated into their other classes then they would welcome them and find them beneficial. Biology-1, for example, was criticised for a dearth of opportunities for students to tackle problems of the sort they were expected to be able to deal with in assessments.

In conclusion, General Chemistry-1 had been generally well received – although with the Class Exam looming after the Christmas break some were a little wary as to how they may find it. Despite its role of a subsidiary subject, the Group largely enjoyed their experiences of the course and found it less arduous than some of them had originally expected.

3.4.2.2 The Second Interview

The majority of the Interview Group returned for a second session after the publication of the class examination results (mid-Term 2).

The positive feelings expressed about Term 1 seemed to extend to the new term, perhaps bolstered by results which most students were quite pleased with. The more mathematical nature of the lecture content was cited as causing more problems than the course had in Term 1, but most students felt that with the help of the Workshops they were coming to terms with the material.

The Class Examination was met with less trepidation than some had expected, being regarded as a fair (although some felt, easy) test of their learning.

One clear outcome from this second round of interviews was a generally positive and favourable consensus view of the course had formed. The Group has been chosen specifically to mirror the class, in terms of different qualifications, but no pattern of differing opinions corresponding to those qualifications was observed. In other words, the generally positive, favourable feelings towards the course were held by students regardless of what background they had entered the class with.

3.4.2.3 The Third Interview

A third Interview was scheduled late in the year (Term 3) to look at the Perry Scheme and how the students would react to it. It had been decided to show the students the grid containing the Centre for Science Education's modification of the Perry Scheme (Figure 2.16). The researcher wondered if students would recognise the three Types of Student described, either in themselves or in their classmates.

Due to the late timing of these interviews, the number of interviewees willing to contribute was only around half of the sample, although a spread of qualifications were represented. It was also decided to conduct the discussions with several groups of students rather than individually as had been the case previously. It was felt that this may give the opportunity for discussion and debate between the students, and that this interaction may give insights into how they thought.

Unfortunately (perhaps) the Group was as united in their views of the modified Scheme as they were in their views of General Chemistry. They recognised the Student Types – A, B and C – although, perhaps, not as simplistic as A (B or C). The progression formed from Student A to C was also recognised. It was felt that students may, for example, hold Student C's opinion of their Role as a Student, but believe examinations were more like Student A's viewpoint. It became obvious that the Group felt students could and did change their stance on the four aspects contributing to a Student Type, if they perceived a need for change, and not necessarily at the same rate for each dimension.

There was unanimous agreement that Student C represented the student best suited to university life – C was felt to have the level of independence and qualities of an "all-rounder" required to succeed. However, the Group was quick to point out that the other Types, particularly Student A, was not therefore unsuited to university. They felt that Student A could also succeed at university – this position represented a "learn-what-you-need", "do-what-you're-told" approach which would get an individual through their course.

A similar view of the Student Types was held by the Group on the specific subject of examinations. One group expressed a concern that Student C may have problems in remaining relevant to the demands of a question. However, both Students A and C were seen as potentially well suited to exams.

The Groups did feel that there were certain subjects which particular Student Types would gravitate towards. When asked for examples all said Student A would be naturally suited to maths, whereas C would be more of an Arts student. It was clear that they recognised certain subjects as requiring certain demands.

Student B was regarded as basically indecisive and not specifically suited to anything. This Type of student could be studying any subject and may do well. The group members made no atempt to solve this apparent conflict.

When asked which of the Types the Group members felt most like, they tended to place themselves somewhere between B and C. The three types were viewed as extreme positions which none of the Group felt represented them entirely. No one placed themselves close to Student A. The students said their positions had changed very little over their first year at university. They reported that they had expected university to tend towards what they could now describe as requiring Type C behaviour. This was the same sort of initial viewpoint that Harvey (1994) found in her study of biology-based students. She observed far stronger Type C tendencies than she had expected in those just entering a course; students appeared to enter university with particular expectations of what would lie ahead.

In conclusion the Group were asked to rate their experience of General Chemistry-1 and indicate whether they would recommend the course to prospective new students.

The Group stated they had largely enjoyed, or at least not found unpleasant, their year of study. Gen Chem was regarded as a fair course, which did give the less experienced more support. The students felt they would recommend it.

3.4.3 The Researcher's Own Questionnaire

To supplement the information given by the Interview Group it was decided to use a specially written questionnaire which would focus on the support materials. The questionnaire developed (a copy of which appear in Appendix E) was given to the class midway through Term 2. A total of 72 students (61.5 %) responded. Table 3.5 gives the pattern of replies to some of the key questions in Section A of the Questionnaire.

Table 3.5 A Selection of Responses to General Chemistry-1 Questionnaire

	Better than expected	As expected	Worse than expected	No reply
Lecture Course:				
i) Rate of work	18	45	6	3
ii) Subject matter	19	44	7	2
iii) Help from staff members	23	46	0	3
In the inorganic lab:				
iv) Nature of the practical work	8	43	17	4
v) Help from the demonstrators	28	25	13	6
vi) Support of Pre-lab exercises	13	37	16	6
In the physical lab:				
vii) Nature of the practical work	19	37	12	4
viii) Help from the demonstrators	23	31	12	6
ix) Support of Pre-lab exercises	16	39	12	5

Table 3.5 A Selection of Responses to General Chemistry-1 Questionnaire cont.

	Better than expected	As expected	Worse than expected	No reply
In general:				
x) Support material, like Workshops and Pre-lects	33	30	7	2
xi) Class Tests	15	44	13	0
xii) The 1st Class exam	37	25	8	2
xiii) The picture of the course painted by your advisor	12	45	7	8

As can be seen from the students' replies on the Lecture Course segment the course scored well on Rate of work and Subject matter, just as the Interview Group had indicated. Similarly, the level of assistance offered by staff and laboratory demonstrators is very favourably commented on.

Question x) gives a particularly gratifying response, clearly showing the students felt better supported by the course than they had expected.

The remaining sections of the Questionnaire covered each of the individual support materials. The respondents indicated that they were mostly regular attendees at Workshops (90.3 % in Term 1; 75.0 % in Term 2). Comments given as to why students did not regularly attend consisted of complaints about the more mathematical exercises used in Term 2. However, the majority (75.0 %) of those students attending reported that they found the Workshops helpful.

The most common improvement to the Workshops which was called for was to increase the help available, which as explained earlier was not possible. However, adding more background information to help explain the relevant theory was a popular realistic change that could be made.

Diagnostic tests also scored highly on attendance and helpfulness (72.2 and 69.4 % respectively). Criticisms of the Tests concentrated on clashes with the demands of other subjects and hence lack of time to prepare for chemistry.

Tutorials were not as popular a support method – 52.8 % did not see their tutor regularly, with unsuitable times and lack of problems identified as the two main reasons for this.

The majority (77.8 %) felt they had received "sufficient" advice at the start of the year concerning General Chemistry-1. Only 11.1 % of the students felt they had been actually "misled" about the course and its aims.

From this questionnaire it is clear that the responses given by the Interview Group were indeed representative of the class as a whole.

3.4.4 Conclusions

One obvious problem with the questionnaires used (or the interviews for that matter) is that only those present responded. Whilst this constituted the majority of the class – a strong core of regular attendees who clearly had a very positive attitude to the class – one question is "what were the views of those who did not regularly attend". Was non-attendance caused by a dislike of the course and its unusual structure or was it simply apathy and lack of interest on the part of the students ?

Questions such as these cannot, of course, be answered by any research of this nature. To find out why students are not attending, they have to attend to ask them – but if they did attend one would not be asking them why they didn't attend !

It is clear, however, that those who did attend General Chemistry-1 (regardless of entry qualifications) found it to be a course which was enjoyable, offered support to those who needed it and gave them a positive chemistry experience.

The aims of the Design Team (in so far as student opinion was concerned) appeared to have been met, with their innovations proving very successful. The problems identified by this enquiry were either minor or beyond the control of the class (e.g. the number of tutors in Workshops).

3.5 Examination Results

Although student views and opinions of General Chemistry-1 were very clear, the other measure of the course of concern to the researcher in this initial year was the examination success achieved by students.

University does offer and deliver more to an individual than simple exam results. As ideas like Perry's Scheme make clear, the development of the individual and his attitudes are just as much part of the university experience as learning the content of a specific subject. However, the gaining of (in this case) chemical knowledge and understanding is of paramount importance and, considering measurements of this would form the final major strand of the year's research.

One factor of particular interest was the relationship between entrance qualifications and ultimate success in Gen Chem's assessment procedures. The Design Team had always intended that Gen Chem should offer a realistic goal achievable by anyone in the class regardless of entrance qualifications – it was one of the key reasons for creating the course. It was intended that enough support should exist within the course to accommodate those of the weakest background, without any additional burden on staff time. By examining the spread of examination results achieved by each qualification cohort it would become clear if there was any significant difference in the patterns observed due to past experience.

Although simple inspection of suitable distribution graphs may suffice in some cases, the *chi*-square (χ^2) test (Clegg, 1994; Robson 1994a and 1994b) would seem to be the ideal statistic to compare the distributions in unclear or borderline instances. Using *chi*-square, the alternative hypothesis, that there existed a difference between distributions of exam results of students of different qualifications, could be tested.

Although this method would allow examination of different categories of students there are potential problems. As Robson (1994b) reports, there are frequent inappropriate uses of *chi*-square. If a population can be divided into three or more categories (say, HIGH, MEDIUM and LOW) then all categories must be included in the contingency table used in the calculation of the *chi*-square statistic, i.e. HIGH and LOW cannot be used alone. Although combining, or collapsing, categories can be used as a way of solving this problem, the technique is not always feasible. Another problem with collapsing categories is that distributions will naturally lose detail and this may affect the result of the test in extreme cases.

One other possible method of examining the data would be to use a statistic involving a measure of central tendency, such as the *t* test (Clegg, 1994; Robson, 1994b) which compares means. However, the *t* test is a parametric test, i.e. it uses underlying assumptions of normality and same variance for sets of data. Such tests are generally reported to be fairly robust with regard to these assumptions but the data arising from this investigation may well break or at least strain them on one or more grounds. The Mann-Whitney test is an appropriate non-parametric equivalent of the *t* test, but is typically less powerful. Another advantage of Mann-Whitney is that it can be used with small sample sizes, and some of the sub-groupings in this investigation may be small. Hence this second statistic would also be employed.

3.5.1 Examination Results Distribution Graphs

The exam results for the January and April Class exams are contained in Appendices F and G respectively. The same format has been adopted for these and subsequent examination results discussed in later chapters.

Each Appendix shows (where available) the general distribution graph for an exam and the same distribution in terms of z scores, where:

$$z = \frac{(raw\ score) - (mean\ score)}{standard\ deviation}$$

Using z scores gives any distribution a mean of zero and standard deviation of 1, allowing an accurate comparison between examinations.

The general distribution graph incorporates a line indicating the mean for that data (as do all the sub-groupings' graphs). This first graph also includes a plot of the normal distribution curve corresponding to a sample of that size, with the same mean and standard deviation. This allows a quick, pictorial check on how close to the theoretical normal distribution the results are.

Distribution graphs are also given for Standard (Higher Grade or better) and Non-Standard (less than Higher) Entry students in both chemistry and mathematics. The Non-Standard distributions have been broken down further into the major contributing qualifications (i.e. Standard Grade, modular and no qualifications).

3.5.2 January 1994 Class Examination

As described previously, the January Class Exam set in early Term 2, covered the material taught in the first Term. The exam offered candidates short-response type questions as well as those requiring more length answers.

Graph F1 (Appendix F) shows the distribution of scores on this Class Exam. It is clear by inspection that the results are reasonably close to a normal distribution.

Graphs F3 and F4 detail the results for students with Standard and Non-Standard Entry chemistry qualifications respectively. Although slightly flatter and broader, the Non-Standard results cover the same range of marks generally, as do the Standard ones. A *chi*-square test confirms that the null hypothesis (that there is no difference between the two distributions) cannot be rejected ($\chi^2 = 2.64$; 6 d.f.) i.e. there is no significant difference in the performance of the two groups.

By examining the further sub-divisions of the Non-Standard Entry chemistry students (i.e. Standard Grade in Graph F5, Modules in F6 and No chemistry qualification in F7) using the Mann-Whitney test it is clear that there is no significant difference between these groupings in terms of results achieved in the exam.

Table 3.6 Results of Analysis of Difference in January 1994 Class Examination Performance Based on Chemistry Qualifications

	Standard Grade (N = 21)	**No Qualification**	**Modules**
Standard Entry (N = 58)	Non-sig.	Non-sig.	Non-sig.
Modules (N = 14)	Non-sig.	Non-sig.	
No Qualification (N = 10)	Non-sig.		

This can also be observed by inspection of the graphs.

The same process was applied to the corresponding mathematics qualifications.

Although noticeably flatter and broader, the results achieved by those entering the class with Non-Standard Entry mathematics qualifications was not significantly different from those with Standard Entry by a *chi*-square test ($\chi^2 = 3.85$; 5 d.f.). However, it was clear by inspection that the means of both distributions were not very close (55.1 for Standard Entry and 49.2 for Non-Standard Entry). This was an example of a *chi*-square calculation where the given distributions had to be collapsed quite considerably to fit the test's criteria of generating expected values of greater than 5 in the contingency table (Robson, 1994b). A Mann-Whitney test did allow perhaps a better comparison of the two distributions in this case. When this was performed the test result was found to just fall outside the 5 % level of significance ($p \leq 0.054$).

Further examination of the mathematical sub-groupings by Mann-Whitney indicated that it was the difference in performance between those of Standard Entry and Modular mathematics qualifications that had contributed to this result.

Inspection of the relevant graphs (F11 in particular) shows that those with a modular qualification performed rather poorly compared to their classmates.

Table 3.7 Results of Analysis of Difference in January 1994 Class Examination Performance Based on Mathematics Qualifications

	Standard Grade (N = 26)	**No Qualification**	**Modules**
Standard Entry (N = 60)	Non-sig.	Non-sig.	$p \leq 0.070$
Modules (N = 15)	Non-sig.	Non-sig.	
No Qualification (N - 6)	Non-sig.		

Why this should be the case is not entirely clear. Term 1 is not the most mathematically demanding of the three, hence any difference which may exist between maths backgrounds would be expected to be of less importance here than in Term 2.

As hypothesised earlier, it would seem reasonable on the basis of past experience for there to be differences in the achievements of those entering the class with Standard Entry chemistry and mathematics qualifications, and those with Non-Standard Entry qualifications in both subjects – see Graphs F12 to F15. Each distribution covers broadly the same range, although F12 and F13 are slightly lower than F14 and F15.

However, as Table 3.8 shows the null hypothesis could not be rejected in any case.

It is clear that (with the exception of two results) there was no difference in examination performance in the January 1994 class exam between the sub-groupings investigated that can be assigned to differences in entrance qualifications.

Table 3.8 Results of Analysis of Difference in January 1994 Class Examination Performance Based on Chemistry and Mathematics Qualifications

	Non-Stand. Ent. Both Subjects (N = 34)	Stand. Ent. Both Subjects	Stand. Ent. Chem.; Non-Stand. Ent. Maths
Non-Stand. Ent. Chem.; Stand. Ent. Maths (N = 12)	Non-sig.	Non-sig.	Non-sig.
Stand. Ent. Chem.; Non-Stand. Ent. Maths (N = 10)	Non-sig.	Non-sig.	
Stand. Ent. Both Subjects (N = 47)	Non-sig.		

3.5.3 April 1994 Class Examination

This second class examination, set during the start of Term 3, had the same format as the first. It was clear that there may be more of an effect from mathematics qualifications in this exam, as the bulk of the material covered was drawn from the physical chemistry courses.

Again, similar to January's results, those of the April exam were reasonably close to normal. Comparison of graphs F2 and G2 show that there was no significant difference in the distributions of the results between each of the two class exams (χ^2 = 2.05; 12 d.f.). Despite covering quite different aspects of the course the general standards achieved in the January exam were maintained in April.

Students with Standard Entry and Non-Standard Entry chemistry qualifications showed the same general pattern in their April results as they had previously. Again there was no significant difference between these two categories (χ^2 = 2.16; 6 d.f.). It is perhaps worth mentioning that in both examinations the highest individual mark was achieved by a student with Non-Standard (in fact Scottish Standard Grade) qualifications.

The analysis carried out for January using Mann-Whitney was repeated for April, looking first at the Non-Standard Entry chemistry cohort; then the mathematics qualifications; and finally the combined qualifications.

The relevant graphs are contained in Appendix G, G3 to G15. The results are summarised in the following set of tables:

Table 3.9 Results of Analysis of Difference in April 1994 Class Examination Performance Based on Chemistry Qualifications

	Standard Grade (N = 21)	No Qualification	Modules
Standard Entry (N = 58)	Non-sig.	Non-sig.	Non-sig.
Modules (N = 15)	Non-sig.	Non-sig.	
No Qualification (N = 10)	Non-sig.		

Table 3.10 Results of Analysis of Difference in April 1994 Class Examination Performance Based on Mathematics Qualifications

	Standard Grade (N = 27)	No Qualification	Modules
Standard Entry (N = 60)	Non-sig.	Non-sig.	Non-sig.
Modules (N = 15)	Non-sig.	Non-sig.	
No Qualification (N = 6)	Non-sig.		

Table 3.11 Results of Analysis of Difference in April 1994 Class Examination Performance Based on Chemistry and Mathematics Qualifications

	Non-Stand. Ent. Both Subjects (N = 35)	Stand. Ent. Both Subjects	Stand. Ent. Chem.; Non-Stand. Ent. Maths
Non-Stand. Ent. Chem.; Stand. Ent. Maths (N = 12)	Non-sig.	Non-sig.	Non-sig.
Stand. Ent. Chem.; Non-Stand. Ent. Maths (N = 10)	Non-sig.	Non-sig.	
Stand. Ent. Both Subjects (N = 47)	Non-sig.		

To say the results are clear is something of an understatement. There was no significant difference in performance in the April exam attributable to entry qualification for either chemistry or mathematics qualifications. Even this most mathematical section of the course had proven to be "resistant to" or "independent of" the mathematical qualifications of the students.

3.5.4 June 1994 Degree Examination

The data presented for this examination is somewhat different from that of the Class exams. The students' individual marks, either for the Degree exam itself or the corresponding composite Class / Degree / Lab mark, were not publicly available and so were not available for this thesis. However, final grades achieved by individuals, based on the composite mark, were published and are displayed in Table 3.12 (by Chemistry Qualification).

At the University of Glasgow students are awarded a pass on four grades (A to D) or a fail on two (F and G). There is no E grading. Other "grades" which students may be awarded are EX (an exemption from the Degree exam and hence a pass grade); X, meaning the student was absent from the exam; or NT meaning the student was not awarded a Class Ticket. To be allowed to sit a Degree exam a student must "perform the work of the class" and so earn a notional Class Ticket. Usually students are called upon to meet the criteria of having regular attendance in labs and tutorials, and achieve some minimum standard in the

Class exams. In practice, however, it is the former criterion which has the greatest effect in the determination of an individual's suitability to be awarded a Ticket. An NT grading is, therefore, essential a fail grade.

General Chemistry students operated under the same general system, although there were no exemptions as this feature was not part of the course.

Table 3.12 Final Grades Achieved in General Chemistry-1 1993-94 According to Chemistry Entrance Qualification

	General Chemistry-1 Grade						
Entrance Qual.	**A**	**B**	**C**	**D**	**F**	**G**	**NT**
CSYS	1	1	1	1	0	0	0
Higher Grade	4	10	12	10	11	5	2
Standard Grade	2	4	6	4	2	2	0
Access	0	0	1	1	0	1	0
None	0	0	4	2	2	2	0

Although the distribution of grades achieved for students of different backgrounds are given in Table 3.12, it is only for completeness. In essence the important distinction for any student in the class was whether they had passed or failed – the exact grade achieved would make no difference in terms of progression to second year. Indeed, it is likely that, as Gen Chem was a subsidiary subject, a pass was all that was of interest to the students, with a good grade being nothing more than a pleasant bonus.

The only exception to this viewpoint, would be held by anyone wishing to continue the study of chemistry into Chemistry-2. As stated to the class, anyone who wished to progress to a second year of chemistry study could do so provided they had done "well enough" in Gen Chem. Following the publication of the results, "well enough" was defined as any student who had achieved a minimum of a B grade pass. Only two students (both with A grades) opted to continue their studies and were admitted to Chemistry-2 the following academic year.

With the examination data presented as grades rather than individual marks and with pass / fail being (essentially) the only results, the researcher decided to use *chi*-square to analyse them.

On this basis, comparison of Standard Entry and Non-Standard Entry chemistry qualifications showed no significant difference in the number of students passing / failing ($\chi^2 = 0.064$; 1 d.f.). The nature of the data precluded an examination of sub-groupings, as in the Class exams.

3.6 Conclusions

In its initial year General Chemistry-1 had much to achieve. The course, carefully planned by the Design Team, had to become a reality (involving writing and re-writing of new and existing materials) and begin to meet its aims of offering a quality chemistry course which was accessible to students regardless of their background in the subject.

This research project played a considerable integral part in the development of the course by providing most of the support material required and attempting to assess the course in terms of student opinion and study of examination results.

Pre-Lectures, Workshops, Diagnostic Tests and information booklets were produced (Appendices A to D) and used throughout the lecture courses comprising the Gen Chem syllabus. These items were assessed by a variety of means, and found to be generally popular and well thought of by the students making use of them. The course in general also proved popular and was compared favourably to other subjects studied by members of the class.

Neither of the Class exams showed any educationally significant link between entrance qualifications held by students and their examination results. Only two comparisons came close to the traditionally taken benchmark of statistical significance of 5 %, those being the comparison of January Class exam results achieved by students with Standard Entry vs. Non-Standard Entry mathematics qualifications and Standard Entry vs. modular maths qualifications. Both were significant at the 10 % level. There was no clear reason why this apparent difference in ability should be the case. The exam in question did not cover the most mathematically oriented segments of the course. One possibility is that students of a particular experience found the moles calculations which were present of particular difficulty relative to the level of calculations presented in the second class exam. If this was the case, then it would fit with what the Centre for Science Education identified as areas of specific difficulty in chemistry courses (section 2.3.2.2 The Mole).

From this evidence, then, it appears that much of the Design Team's goals were realised. They produced a popular course, which supported its students by its own structure and internal mechanisms, requiring no extra time commitments from the staff.

General Chemistry-1 also proved to be "qualification-proof" to a large extent – some of those enrolling with the "strongest" entrance qualifications passed, and some failed; equally some of those with the "weakest" entrance qualifications passed, and some failed. The patterns of exam result distributions observed were not characteristic of the entrance qualification held by the students. In other words, a student's ultimate fate in the class could not be predicted on the basis of their entrance qualifications alone.

Chapter Four

Literature Review II

4.1 Introduction

Having shown that the correlation between a student's entrance qualification and his/her ultimate success in General Chemistry-1 examinations was effectively nil and that there was no real educationally significant link between the two, then one obvious research question presents itself:
Can other factors which may better predict student success in the course be identified ?
This has the equally obvious corollary question:
If such factors can be identified, can the strength of the link between them and examination success be determined ?

If such factors could be found then their potential value is obvious. The factors could be used by universities in their selection of students to greater effect than previous qualifications only. However, perhaps more in keeping with the traditions and ethos of the Centre for Science Education, identification of such factors could lead to a greater understanding of how students learn and ultimately be used to predict or diagnose potential learning difficulties and begin to allow development of pedagogy to deal with them.

It is to the investigation of the existence of these "other factors" that the main research effort was turned in the second year of research.

In this chapter the potential factors to be explored will be discussed – what they were and why they were placed under scrutiny. The methods of measuring these factors employed will also be discussed, where relevant.

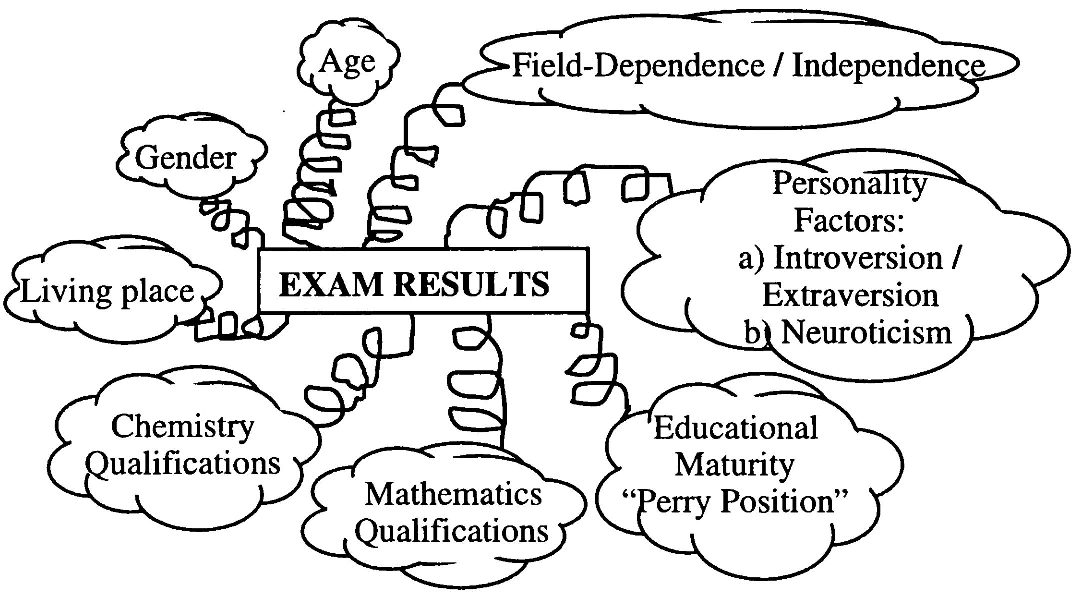
4.2 Choice of Factors

Having made the decision to pursue such a course of research, a judgement had to be made as to which factors should be examined and measured. Again, as mentioned at the beginning of Chapter Three, constraints will exist to limit what can and cannot be measured or considered. Obviously any measure has to be observable within the time scale available to the researcher. Similarly this, together with potential fatigue factors on the part of both the General Chemistry students and lecturers, will limit the number of factors which can be investigated. Any such research survives only on the goodwill and willing participation of both the chemistry staff and students whose roles are to provide and receive an education in chemistry, respectively – not supply endless data for educational research projects.

The factors chosen must also make some kind of sense in the context of the course and the work in general. On the basis of previous research, the hypotheses uder consideration, and the advice of experienced colleagues, many spurious and less likely potential factors can be rejected. Ultimately, the judgement made at this stage will shape the subsequent research in how it will be carried out and what its final conclusions will be.

With all this in mind, the following factors and their link to examination success (using the examination results as the independent variable for comparison purposes) were decided upon as the ones to probe:

Figure 4.1 Potential Factors Affecting Student Success in General Chemistry-1



Some of these factors are obvious; characteristics of the student – e.g. gender, age, etc. come "with" the student and need no special effort to collect.

The other factors are more specialised and would require measurement of some kind to be applied to the class. First, however, the reasoning behind the choice of these factors must be explained.

4.3 Gender, Age, Living Place and Entrance Qualifications

These factors were included for obvious reasons – the data is easily obtainable, for one thing, and to ignore such "gifts" would seem churlish. More importantly, all of these factors seemed worthwhile investigating.

The choice of Gender hardly seems to need any justification in such a study. Attempts to determine Gender effects in educational contexts are a traditional and universal pastime of researchers over the years, with literally volumes of material being produced. Indeed such is the wealth of literature examining this factor that it hardly needs discussion in depth.

That male and female students can behave and learn differently has been shown in a variety of work in numerous areas. Gender effects, however, may be of particular relevance in General Chemistry-1, where somewhat unusually, the majority of the class had been female. As indicated in Chapter Three, these female members of the class had generally superior entrance qualifications than their male counterparts.

The effects of Age on learning is another commonly examined factor in research. As the number of mature students has increased, with older people returning to education, so has interest in their achievements. At Glasgow, a mature student is defined as being of age 23 years or older on entry to the course of study. As most of these students did not possess Standard Entry Qualifications; had been out of formal education for some time; or had lower grades for Scottish Higher Grade Mathematics or Chemistry, many of them opting to study chemistry had been directed towards Gen Chem. Many studies (e.g. Richardson, 1994) have shown that mature students can adopt learning strategies which would be more in the spirit of those which Gen Chem attempted to foster.

The term "Living Place" almost certainly needs some further explanation. Unlike many universities (particularly those in England) the traditional student at Glasgow attends what is actually his or her "local" university, opting to live at home during term time. Despite this the student population can, obviously, be divided into those who live at Home during term time and those who live in a Flat. A Flat, then, would be any living place other than the normal home – a hall of residence, accommodation with other students, some form of lodging, etc. By looking at this factor, it was hoped any effect on exam results caused by living in the normal or an unusual environment for the individual would be detected.

Although the effects of either chemistry or mathematics qualifications had been shown to be almost non-existent in the first year of General Chemistry-1, it was worth retaining both factors in further study. It was possible that (although at best, very weak) the influence of qualifications may well be the strongest single factor to govern success. Taken in combination with some other factor (e.g. Gender) qualifications might prove more significant. It was also valuable to maintain a check on whether Gen Chem was still as "qualification proof" as it had first appeared as this was an important feature of the course.

The other potential influencing factors from Figure 4.1, however, require more detailed explanations.

4.4 Educational Maturity – "Perry Position"

The role of Critical Thinking skills and their development in students as perceived by the Centre for Science Education was fully discussed in Chapter Two (section 2.7). Clearly as Perry's work in this area had been part of the Design Team's thinking, an attempt at establishing the effect of an individual's Perry Position on examination success would seem logical.

To achieve this, however, a method of assessing where on Perry's Scheme, or the Centre's modification of it, a student fell was required. The more "Educationally Mature" an individual was, the more highly developed their level of Critical Thinking and the further along Perry's Scheme they would be. Perry's Scheme had been successfully used in other research work, as mentioned in Chapter Two, giving rise to a range of different methods of measuring intellectual development on the Scheme.

4.4.1 Measurement of Perry Position

Perry's original work was conducted by interview, as previously described. Whilst such a method can obtain large amounts of quality data for the skilled interviewer, it is slow, cumbersome and difficult to ensure reproducibility of conditions from interviewee to interviewee. In short, for a large scale investigation, such as was envisaged here, this kind of interview would prove impractical to use. The problem of finding a method of assessing Perry Position may be one reason why the Scheme has not found wider use in research when compared to, say, the similar ideas of Deep and Shallow processing.

However, others have developed alternative measuring techniques for assessing students successfully – for example, Baxter-Magolda and Porterfield (1985) used the Measure of Epistemological Reflection, which sought justification to specific stimuli; Widick (1977) used essay type materials.

Harvey's work (1994) concerned a study of the development of biology students' higher level cognitive skills via a group poster exercise. One factor which had been observed in affecting the standard of the posters produced was in the different ways students appeared to regard knowledge itself and their approach to it. Harvey drew parallels between the observed behaviour and stages in Perry's Scheme. One key aspect of Harvey's research became the development of a method of identifying an individual's stage of intellectual development, based on the Centre for Science Education's adaptation of Perry's work.

Based on the Centre's descriptions of Student Types A, B and C (figure 2.16), Harvey drew up a set of statements that each specific type would agree with based on the rationale "what would a person of this Type be like, if I met one of them". These statements were validated by a panel of experts who gave a high level of agreement as to which Types would agree / disagree with each statement.

Following Pilot studies, Harvey produced 18 statements (6 for each Type) which students were asked to indicate a level of agreement with on a 6-point Likert style scale (6 - "Strongly Agree"; 5 - "Agree"; 4 - "Probably Agree"; 3 - "Probably Disagree"; 2 - "Disagree"; 1 - "Strongly Disagree"). In an attempt to ellicit more detailed information, a second section asked students to agree or disagree with 6 statements and then give a written explanation as to their decision. It was hoped this would aid in the selection of students for interview in the project.

Harvey assessed her 18 statements by counting the number of "Agree" (an aggregate of 4, 5 and 6) responses only. This would give each student a "score" ranging from 0 (meaning the student did not Agree with any statement) to 6 (meaning Agreement with all the statements) for each of the three Types. From these scores the percentage response Types and C/A, B/A ratios were produced as measures of intellectual development.

At the Centre for Science Education, Hadden and MacGuire (unpublished) worked on Harvey's materials, using them to look at Chemistry-1 students in 1993, to develop them further and to find ways of using the data collected. Students can respond to Harvey's statements on the given six point scale, or choose not to respond at all to a particular item (given a value of 0). This data for Chemistry-1 1993 was entered into a database designed by MacGuire to allow easy manipulation and display. The database was programmed to classify replies of 0, 3 or 4 as "Neutral"; 1 or 2 as "Disagree"; and 5 or 6 as "Agree". This differed from Harvey's analysis in that she considered 4 – "Probably Agree" – as a legitimate positive response. She argued that due to sample size, not including this response meant she was only considering extremist viewpoints. Clearly the decision as to whether the "Probably Agree" replies be used in this way in the analysis of the data or not, is likely to make a great difference to the results produced.

The author of this work felt it was inappropriate to use Harvey's argument, on the grounds that "Probably Agree" (and the corresponding "Probably Disagree") could just as easily be termed "Grudgingly Agree / Disagree". It is not an unequivocal, definite response to a statement and, in the author's opinion, would not necessarily be replicated by the same student when asked on a different day.

Another potentially contentious issue in the Harvey analysis was in her use of Agree statements only. Harvey concluded that her panel of experts had been in broad agreement as to which Type of student – A, B or C – would Agree with a given statement, but that there was not as good a consensus on which Type would Disagree with a statement. Students, she argued, may Disagree with a statement for totally different reasons. On this basis she chose to ignore Disagree replies. However, on re-examining copies of the results from her experts held by Hadden and MacGuire, this decision seems, at least, harsh. It is entirely possible for students to Agree with some of the statements for very different reasons. For example, the statement "I am uncomfortable when I am left to make up my own mind about a subject and I don't know how the lecturer feels", is intended as a B Type statement. However, an A Type student may very well Agree with this viewpoint – A Type Students are "teacher-centred" in much the same way as B students are and would prefer precise instructions. There are other examples.

More noticeable, though, is that when the panel of experts did differ most it was in the classification of statements which B Type students should respond positively to. There is very little dissent regarding Agreement and Disagreement of A and C Type statements.

It would seem logical that a strongly C Type student should not only Agree with C statements, but should actively Disagree with A statements (and vice versa). Given the nature of the test instrument – based on a simplified version of Perry's Scheme – it would seem that it is the Perry Position of the more extreme students which will be most readily detected. There is an obvious recognition of A and C Types as representing contrasting positions on a continuum, but it is the consideration of B Types that seems to cause any real problems in analysis as this position lies somewhere between the two.

With Harvey essentially treating Disagrees in the same way as a Neutral or non-response would seem to incorporate a risk of creating bias or ignoring potentially important information. The researcher believes, as did MacGuire in his database construction, that a definite response must be taken into account, rather than cobbled together with a non-response or non-commitment when attempting to assess a student. A Disagree is a definite, clear reply to a statement – not a "don't know / care" reply as Neutral can frequently be.

Considering both Agrees and Disagrees also offers a check on the validity of a student's questionnaire replies. A consistent pattern of Agrees and Disagrees would suggest the student had given proper consideration to the statements, whereas an essentially random scattering could call into question that individual's attitude to the questionnaire.

In an attempt to recognise Disagree responses, and incorporate some system of weighting, MacGuire devised a measure of students' Perry Position based on the actual numbers used in the questionnaire. He used a system derived in part from current Scottish Examination Board practice regarding the assessment of Certificate of Sixth Year Studies physics projects.

His method took the raw number supplied by the student's response for each statement and subtracted 1 from it, essentially turning the original 0 - 6 scale into a 0 - 5 scale. A Tally of the 0 - 5 scale for each Type was produced and used to calculate a so called "Success Index" (SI):

$$\text{Success Index 1} = \frac{\text{Tally C} + \text{Tally B} - \text{Tally A}}{\text{Tally C} + \text{Tally B} + \text{Tally A}}$$

Another source of inspiration for this analysis appears to have been the work of Entwistle and Ramsden, in particular their Approaches to Studying Questionnaire. Using a similar battery of statements to those generated independently by Harvey, students using Entwistle and Ramsden's material are asked to indicate their level of agreement or disagreement on a 5-point scale, which is scored as 0 - 4. These values are then totalled for each of three sub-scales called Achieving Orientation, Reproducing Orientation and Meaning Orientation. These sub-scales are then combined, in a similar way to the Success Index, to produce Predictor of Success:

$$\text{Predictor of Success} = \text{Achieving} + \text{Meaning} - \text{Reproducing}$$

Taking on board comments from other workers in the Centre, MacGuire produced two other variants of his Success Index to investigate the effect of giving different relative weightings to each Type:

$$\text{Success Index 2} = \frac{2 \times \text{Tally C} + \text{Tally B} - 2 \times \text{Tally A}}{2 \times \text{Tally C} + \text{Tally B} + 2 \times \text{Tally A}}$$

and

$$\text{Success Index 3} = \frac{3 \times \text{Tally C} + \text{Tally B} - 2 \times \text{Tally A}}{3 \times \text{Tally C} + \text{Tally B} + 2 \times \text{Tally A}}$$

MacGuire investigated the correlation between his three Success Indices using Spearman's *rho* (ρ). Table 4.1 give the values of ρ, whilst Figure 4.2 shows the scattergram of SI1 vs. SI2 as a typical case, for the sample of Chemistry-1 replying to the 18 statements in December 1992 and again in May 1993.

Figure 4.2 SI1 vs SI2 for 126 Chemistry-1 Students in December 1992

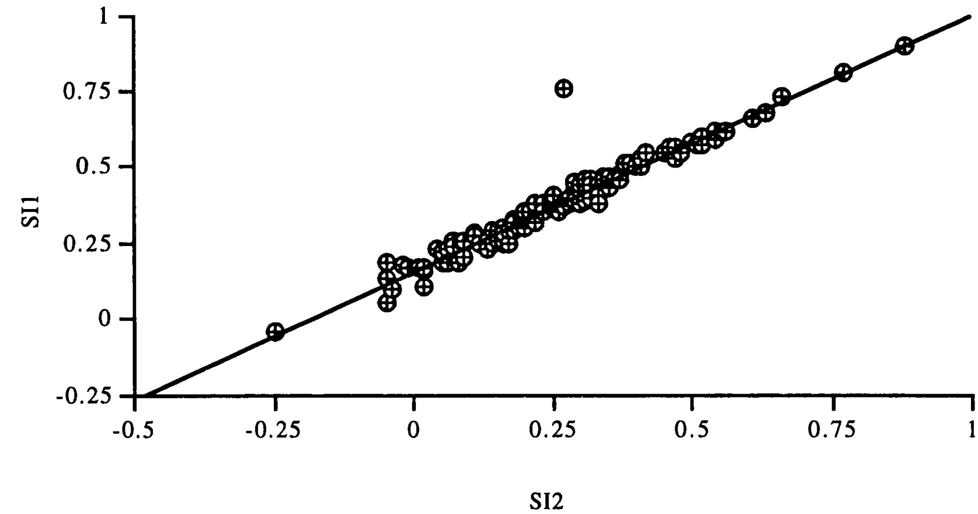


Table 4.1 Values of Spearman's Rho (ρ) for SI1, SI2 and SI3 for 126 Chemistry-1 Students in December 1992 and May 1993

December		
	SI1	SI2
SI3	0.974	0.970
SI2	0.966	
May		
	SI1	SI2
SI3	0.958	0.996
SI2	0.976	

From these results MacGuire concluded that whatever each of his Success Index values actually measured was essentially the same thing – the different weighting given to each different response Types did not appear to matter.

Any analysis based on the Success Indices raises two important points. Firstly, there is the question of how valid the treatment of the data actually is. The Perry Questionnaire used, as with any Likert scale, produces data which is ordinal in nature and hence, strictly speaking arithmetical operation cannot be carried out on this type of data meaningfully (Clegg, 1994). The assumption that the difference between any two consecutive points on the scale are the same (i.e. that the data is interval) must be made to allow the use of the sort of analysis described. However, in defence of this analysis is the fact that this assumption is made (consciously or not) by many researchers and is common in the literature – e.g. Entwistle and Ramsden's Approaches to Studying Questionnaire is a prime example.

If this assumption is accepted, and arithmetic operation on the data treated as valid, then a second point raised is that of subtracting 1 from the raw response. Using this system appears to offer no benefits to the analysis, indeed it reduces both a non-response and a Strongly Disagree response to a numerical value of 0 – treating them the same despite these replies meaning very different things.

For this reason parallel versions of the three Success Indices (SI1', SI2' and SI3') using the raw numbers (0 - 6) given by the questionnaire, were created by the researcher to check if there was any difference between the two methods of calculating the Indices.

The researcher created a further measure based on the frequency of Agree and Disagree replies. Further, this measure did not include a contribution from the B Type statements on the grounds that:
a) any real discrepancies in the experts' ratings were found mainly in these statements, and
b) the measure is more likely to identify those at the extremes more clearly than those in some intermediate stage.

Using these considerations Agree statements were classed as +1, Neutral as 0 and Disagree as -1. The total for each Type of statement (A & C) was then calculated and used to produce the Perry Index (PI):

$$\text{Perry Index} = \frac{\text{Tally C} - \text{Tally A}}{\text{Tally C} + \text{Tally A}}$$

The central assumption in this measure (which also underpins the SIs) is that each statement carries equal weighting when combined. As the statements in the questionnaire are derived from the four factors (from Figure 2.16) contributing to an overall Perry Position in the Centre's modified Scheme, the assumption is made that each of the four contribute equally in defining a Type of student.

Data arising from measurements made on General Chemistry-1 were examined using each of the scoring systems described (see Chapter Five). The Perry Questionnaire used is reprinted in Appendix H.

4.5 Personality Factors

One of major areas of interest in the field of psychology is in the study of an individual's personality. Indeed, descriptions of personality or temperaments stretch as far back as Hippocrates and the ancient Greeks. However the major work and research into personality has been carried out since the 1800s.

Hampson and Colman (1995) describe the term Personality as referring to the "internal properties of a person that lead to characteristic patterns of behaviour". Eysenck and Eysenck (1985) give a fuller definition of Personality thus:

> *a more or less stable and enduring organisation of a person's character, temperament, intellect and physique, which determines his unique adjustment to the environment.* Character *donotes a person's more or less stable and enduring system of conative behaviour (*will*);* temperament, *his more or less stable and enduring system of affective behaviour (*emotion*);* intellect, *his more or less stable and enduring system of cognitive behaviour (*intelligence*);* physique, *his more or less stable and enduring system of bodily configuration and neuroendocrine endowment.*

They go further to point out that a "a remarkable degree of *consistency*" can be observed in human behaviour, particularly in the main personality variables, hence allowing coherent study of the topic.

Many modern Personality theories are grounded in the work of clinical psychology and involve the existence and identification of Traits. Such Traits may not be directly observable, but can be inferred from the repetition of actions – a predisposition to similar behaviour that displays consistency in a variety of situations (Eysenck, 1995).

Traits, however, as the underlying drive to a particular response are not the same as States which are, in contrast, short lived expressions of a particular behaviour caused by the interactions of Traits and situation. For example, a person with a particular Trait will not always display that state of behaviour, and conversely, it is possible for an individual to be in a particular state not common to them.

Most of the modern theories based on the concept of Traits also give rise to over-arching "Super-factors" or Types. These super-factors are made up of a collection of correlated Traits, usually identified by carrying out factor analysis. This, of course, requires the existence of reliable and valid measures of the individual Traits, upon the development of which the whole Trait theory depends.

Super-factors identify the major dimensions of an individual's personality, accounting for the greatest variations in individual differences.

However, the number and naming of super-factors found by different researchers differs. Eysenck (1995) argues that three super-factors – Extraversion, Neuroticism and Psychoticism – exist and account for the greatest variations in Personality whereas the work of Cattell insisted upon the need for 16 factors (Kline, 1994). A more modern view (Hampson, 1995) gives a consensus for 5 major factors: Factor I, Extraversion; Factor II, Agreeableness; Factor III, Conscientiousness; Factor IV, Neuroticism; Factor V, Openness to Experience. As it is clear that Eysenck's Extraversion and Neuroticism factors seem common to systems other than his own, a closer examination of them is warranted.

4.5.1 Eysenck's Theories of Personality

Eysenck and Eysenck (1987) point out that reviewing the literature in the field of personality work gives support to two super-factors which can be traced back to the earliest notions of temperaments. These super-factors were identified via factor analysis of a number of questions designed to identify individual Traits. These factors were called Extraversion – Introversion (E) and Neuroticism – Stability (N).

The super-factors were defined in terms of the Traits which intercorrelated to produce them (Eysenck and Eysenck, 1985):

Extraversion	–	*Sociable; Lively; Active; Assertive; Sensation-seeking; Carefree; Dominant; Surgent; Venturesome*
Neuroticism	–	*Anxious; Depressed; Guilt feelings; Low self-esteem; Tense; Irrational; Shy; Moody; Emotional*

A third major factor, named Psychoticism (P), was added to Eysenck's Theory at a later stage and characterised by the following Traits:

Psychoticism – *Aggressive; Cold; Egocentric; Impersonal; Impulsive; Antisocial; Unempathic; Creative; Tough-minded*

(Psychoticism is described as a combination of Agreeableness and Conscientiousness from the five major factors Hampson describes.)

Eysenck and Eysenck (1985) review the other major Trait-based theories in the literature, such as Cattell's 16 Personality Factors, the Guilford-Zimmerman Factors, The NEO (Neuroticism, Extraversion, Openness) Model of Personality and the Minnesota Multiphasic Personality Inventory. They concluded that virtually every system described produced super-factors analogous to their three factors of P, E and N; although Psychoticism was acknowledged as being the least readily discernible of the three from the other systems.

Similarly in a review, Kline (1995) points out that most major systems in use give rise to factors akin to those of Eysenck. He concludes "these factors, especially those of Eysenck... should form the basis of any theory of Personality".

4.5.2 Personality Factors and General Chemistry-1

The use of Eysenck's Personality Factors in exploring links between Personality and academic success is common. The role Personality may play in education is, of course, likely to be dependant on a number of factors about the particular education experience under consideration; e.g. the nature of the subject being studied, the teaching methods employed, etc. However, there seem to be some generally robust findings common to several investigations in the field.

As Kline (1995) reports, Extraversion's effect on academic performance appears to depend on what stage of education is being considered. Under the conditions of primary school education Extraverts tend to be the best performers (presumably due to the nature of organisation); at the more advanced levels of education Introverts begin to take the lead in secondary and maintain it in university (Furneaux, 1957; Lynn, 1959). The reasons behind these observations are not clearly understood with several researchers having explored different possibilities. These have included Extraverts having an inability to maintain concentration during periods of study and Introverts having greater commitment to study tasks.

Neuroticism has shown a range of different relationships to academic achievement being found variously to be positively, negatively and curvilinearly related to success ! Eysenck (1971) noticed that rather like E, the nature of the relationship depended on at what stage of education the study focused. He noted that where a selection procedure of some kind (e.g. entry into Higher Education) had been encountered positive correlations were observed (Furneaux, 1957; Lynn, 1959) whereas N had an adverse effect in situations where such procedures had not occurred (e.g. at school).

More general work on Neuroticism (or anxiety) suggests it can have two effects: a) improve motivation towards a task, and b) interfere with performance by increasing task-irrelevant thoughts. Educational selection procedures may actually have been separating out those Neurotics for whom effect b) is greater than effect a). Another consideration when evaluating effect on performance is the nature of the task itself, and an individual's approach to it. Weiner and Schneider (1971), for example, suggest the efficiency of a highly anxious student's learning can be affected by the success or failure that student experiences as a result of their efforts.

It is worth noting that some of these general finding come from work carried out many years ago – as documented previously the world of Higher Education is very different to that of the past. As Gen Chem was created to meet new considerations in education, then investigating how Personality factors interact with success may be of interest.

If, as has been suggested, selection procedures have helped to choose certain Personality characteristics conducive to academic success, then how today's more open procedures and wider range of students fare, could be worthy of study.

It is possible (and indeed personal observation of the first year of Gen Chem suggested) that some of the less qualified students may be open to anxiety towards the task of learning so much chemistry in a short period of time, for example.

4.5.3 Measuring Personality

Using Eysenck's Theory in a study of Gen Chem students' Personalities would be of great advantage. There is wide agreement that two, if not all three, of his super-factors can be shown to exist and give consistency of measurement. The seemingly universal nature of E and N, as well as the extensive literature covering them add to their attractiveness. Although P is regarded as one of the major factors determining variation in behaviour, its nature (and previous work carried out with it) would suggest that its role in educational research is limited. For this reason it was omitted from this study.

The importance of reliable and valid test instruments to the field of Trait-based Personality study has already been mentioned. As Kline describes, a test must not only be reliable – able to give replicable results – but, obviously, be valid – it must measure what it purports to measure. The construction of such tests is not simple and are major research exercises in themselves. Any attempt to construct such a test, therefore, lies outwith the scope of a project such as this. For these reasons the only sensible course of action was to adopt Eysenck's testing materials (Eysenck and Eysenck, 1987).

Eysenck's factors can be measured via two different tests, or inventories, the Eysenck Personality Inventory (EPI) and the Eysenck Personality Questionnaire (EPQ). The EPI was developed from the Maudsley Personality Inventory, an earlier instrument, and measures Extraversion and Neuroticism. The later EPQ incorporated the Psychoticism scale. Both EPI and EPQ added a Lie scale (L) to help determine the truthfulness of the responses.

One of the potential disadvantages of paper-and-pencil Personality tests is the effect of particular response sets being given by test subjects. As well as deliberately giving false replies, respondents can complete questionnaires in such a way as to put themselves in the best possible light – giving what Kline refers to as a "socially desirable" response. Eysenck and Eysenck (1987) report that this response set is really only of concern in the EPI in situations where respondents are aware that the test results will be used for selection purposes. However, the Lie scale incorporated into the Eysencks' tests allow a modicum of judgement about how much faith an investigator can place in an individual's test.

A second common response set, acquiescence (Kline, 1995) the tendency for individuals to agree with a statement regardless of its content, is also reported to show little effect on the EPI.

For these reasons, and as Psychoticism was not of interest to this project, the EPI was chosen over the EPQ as the best inventory to use.

The Eysenck Personality Inventory, used since the 1960s, is available in two forms (A and B) both of which contain 24 items on the Extraversion and Neuroticism scales respectively and 9 items on the Lie scale. Test subjects are asked to decide whether "Yes" or "No" represents the way they would normally feel or act to each of the given questions. Using an overlay key, the researcher simply totals up the number of responses shown through holes in the key for each of the three scales.

Data on the reliability and independence of the scales was readily available (Eysenck and Eysenck, 1987), showing high reproducibility and results consistent with the hypothesis that E and N are uncorrelated. As Personality factors have proven to be stable over time, and only one measurement of the relative E and N scores for each student in Gen Chem would be required, it was decided to use one form of the EPI only.

4.6 Field Dependency

The final factor considered in this investigation of examination success was a cognitive style which the Centre for Science Education had found useful in the past. As already indicated (Chapter 2.4.2.1) the work of Witkin had produced the cognitive styles of Field Dependent / Independent.

Hampson and Colman (1995) define Field Dependency thus:

> *A personality trait and cognitive style associated with the extent to which a person is influenced by the perceptual and social environment (the field) in making judgements, forming opinions, etc.*

Stated more practically, this factor considered whether an individual was able to extract relevant material from a confusing background, hence its use on the Centre's work on problem solving ability. Those students who were poor at distinguishing what was required in a learning or problem solving situation (Field Dependent) were, it was hypothesised, not likely to perform as well as those who could (Field Independent).

A number of studies carried out by those in the Centre, such as the work of Al-Naeme (1991, Chapter 2.4.2.1) and MacNab, Hansell and Johnstone (1991), has confirmed this hypothesis in a variety of situations.

Al-Naeme's research suggested that Field Dependency could be used almost as a measure of mental processing "efficiency", acting as a limiting factor on how well a student could use their Working Memory capacity. As the role and relative importance of Working Memory in learning had already been recognised by other workers (Chapter 2) it was felt that some consideration of any effects on performance in Gen Chem arising from such factors was a necessary part of this study.

Although measures of Working Memory capacity which would be suitable for large scale investigations exist, it was decided not to look at raw capacity directly, but rather, it was argued, that how efficiently an individual was able to use that capacity was crucial.

Therefore it was decided to take measures of the Field Dependency of Gen Chem's students rather than their Working Memory capacities.

4.6.1 Measuring Field Dependency

Witkin *et al.* (1971) developed a simple paper-and-pencil test to determine an individual's Field Dependency. This test required subjects to identify a given target shape from within a more complex pattern in which it was hidden. The number of correctly identified target shapes within a given time limit was used as an individual's score from which their status of their Field Dependency could be determined.

The Centre for Science Education developed its own version of this test through the work of El-Banna (1987). The El-Banna test paralleled the basic style of the Witkin original, but (as it was initially intended for senior school and university students) used much more complicated complex patterns. Again participants were scored on the number of correctly identified target shapes. El-Banna extensively trialled this test, producing an accepted final version of it which has been used in several research projects in the Centre.

Concern was expressed, however, about the visual quality of the test materials in recent years by members of the Centre. The test figures were produced by hand and there was a feeling that the master copies available were no longer suitable due to repeated use. In particular it was felt that distortions in the masters meant that the target shape, which must be found in the correct orientation and with exactly the same dimensions, was not strictly speaking present in the complex figures. There existed the possibility that those who were particularly Field Independent would spot this in the worst cases, assume the target shape to be absent and not indicate the shape closest to the target (i.e. the distorted target). As this would result in such individuals being awarded a low score then the test would not be discriminating Field Dependent from Field Independent.

In a few cases El-Banna had included more than one correct target shape in a complex figure. This was a definite change from the Witkin test and deemed unfair in hindsight. Curved patterns and target shapes were also used by El-Banna, although the Witkin original used only straight line figures. Again there was an unhappiness about the quality of the figures and the validity of using curves.

It was decided to produce a modified, desktop-published version of El-Banna's test to remove these perceived problems. This would provide researchers with a superior quality master from which to produce test booklets at any time and ensure the consistency of the graphics. As this was done, curved shapes were replaced by new targets and complex figures.

The modified El-Banna test (which forms Appendix I) essentially comes in three sections, although these are not indicated in the booklet. The first four complex figures were intended to be considered as practice items which would not be included in a respondent's total mark. However, the option did remain with the researcher to use these as part of the test if wished. The 8 target shapes were used once in each of the following 8 complex figures and this was intended to be the first "half" of the test. Each target shape then appeared once more in the next 8 complex figures, forming the second half of the test. This construction would allow researchers to perform split-half correlations on the test results, if required.

As before a student's total score (both halves, with or without the practice item) would be used to determine that individual's Field Dependency.

4.7 Conclusion

Having given an indication of the factors selected for study and how they were to be measured, Chapter Five will expand on how these measures were carried out and interpreted in General Chemistry-1's second year of existence.

Chapter Five

General Chemistry–1: Year Two

5.1 Introduction

Following the successful introduction of General Chemistry–1, the course entered its second year of existence in the academic year 1994-95.

Those behind the course were encouraged by the positive feedback and indications they had received from a number of sources.

Reaction from the students who had taken the class was clearly positive and their examination results bore evidence that students could achieve success regardless of their chemistry background, as had been intended. Indeed, a departmental analysis of Gen Chem results concluded that the course offered an attainable goal to students of varied previous experience whilst giving them a respectable chemical basis for Level-2 subjects. It was noted that as those who failed or dropped out of the course had come from all the constituent groups that those at risk could not have been identified by their entry qualifications alone. The department felt "the major factor in determining success has (naturally) been *motivation*, irrespective of prior knowledge". This comment was given to Advisors of Study in a statement sent to them before the beginning of the '94-'95 academic year to aid them in their discussions with prospective first year chemistry students.

The department offered the following recommendations on entry to each of the chemistry classes:

Students should be directed at Chemistry-1 who come with

Higher B (or better) in Chemistry
Higher C and CSYS in Chemistry
Higher C and Higher Maths
GCE D in Chemistry
and those who intended to take Honours in Chemistry, Biochemistry or Pharmacology

Students should be directed to General Chemistry-1 who come with

National Diploma
Standard Grade or GCSE in Chemistry
Access courses (or similar schemes)
Modular Chemistry Qualifications
Higher C (even after resit) in Chemistry

Students offering Higher Grade C (in Chemistry) without Maths or Higher C but not intending Honours in any of the subjects mentioned fell into a grey area where an individual's preferences and the Advisor's assessment of his or her motivation would guide the final decision.

5.2 Changes in the Course

Due to the success of General Chemistry's initial year, there was a desire to keep changes to the course to a minimum (to maintain that success). However, as with any educational situation, other external pressures may (and in this case did) bring changes – although the greatest of these were limited to Term 1 only.

5.2.1 Lecturers and Course Content

The retirement and promotion respectively of two members of the original design and lecture team forced the biggest alterations to the course. Two new lecturers stepped in to fill the vacant slots, namely the sections on *Periodic Table II* and *States of Matter*. Whilst these lecturers would undoubtedly bring their own ideas, style and experience to bear on adapting the content of these lecture blocks, further change was necessitated by time-tabling commitments which required *States of Matter* to become the first (rather than third) section.

In fact this revised order had, at one time, been considered as the original one when General Chemistry was first being discussed. Some of the material used in Year One's *States of Matter* would now be unsuitable (e.g. discussions of chemical properties based on structure before more basic concepts had been introduced). However, some of the introductory material from *Periodic Table I* became part of the new revised *States of Matter*.

The remainder of the lecturers made very few alterations to their courses that were presented in the same order as in the first year.

5.2.2 Support Materials

One consequence of the reorganisation of Term 1's time-table was the loss of two of the Pre-Lecture sessions intended for *Periodic Table I*. Some of the material from these, together with some from the original *States of Matter* Pre-Lects, were combined to produce new Pre-Lects for the revised *States of Matter*.

As described in Chapter Three, the concept of the Pre-Lecture sessions did not provoke particularly strong reactions either way from the students in the interview group, hence this reduction in number was unlikely to be crucial. Indeed, as these sessions were the first thing the new students encountered it is not surprising that, with no prior experience to guide them, the novel nature of the Pre-Lect was lost on them. Another potential problem of the Pre-Lect was a lack of focus in the priming of students' minds for what was to come in a lecture block. The Pre-Laboratory exercises, from which the Pre-Lects drew their inspiration, prepared students for a single three-hour session of work on a particular topic – the Pre-Lects, however, had to prepare students for material which may be spread out over several days of lectures.

The Problem Solving Workshops underwent minor revisions, with a summary of the relevant theory being added to those concerning material in *How Far and How Fast ?*, as the students had requested (Chapter 3.4.3). The Workshops had occurred exclusively on a Friday during Year One (one potential reason for the observed dip in attendance during these events). This arrangement also had constraints on lecturers as the required material had to be taught before being used in a Friday Workshop. For these reasons Year Two would see the time-tabling of Workshops become more open, with sessions being placed on different days of the week depending on the lecturers' requirements. Although such an arrangement could cause problems in terms of staffing Workshops (due to other commitments) these did not materialise in practice.

The other design features used (i.e. Diagnostic Tests, the Support Packages and the format of the examination system) were unchanged from the first year. As before, the course would be delivered by lecturers over a 25 week teaching year, with each week containing five "teaching times" filled by a Pre-Lect, Lecturers, a Workshop or a Diagnostic Test as appropriate. The laboratory component of Gen Chem remained largely as before with further revisions made to the inorganic course following student comments on it.

5.3 Breakdown of Class Composition

For this second year of Gen Chem, the Chemistry Department decided to increase the number of students admitted to the course, with the size of the available lecture theatre accommodation becoming the only real constraint on the growth of the class

As in Year One the initial enrolment of around 220 students fell to 200 following transfers and withdrawals. Of these, 6 provided no background data, with the rest giving at least partial information on their qualifications. Of the 200, 118 (59.0 %) were female which compared to 56.4 % in Year One. All percentages quoted in the tables below are in terms of the total number of students giving information about themselves.

Table 5.1 gives the distribution of chemistry and mathematics qualifications in the same manner as Table 3.3 did previously.

Table 5.1 Breakdown of General Chemistry–1 (1994-95) Entrance Qualifications by Class and Gender

Chem Qual.	Class (% of 194)	Male (% of 79)	Female (% of 115)	Maths Qual.	Class (% of 185)	Male (% of 75)	Female (% of 110)
modules	13 (6.7)	3 (3.8)	10 (8.7)	modules	17 (9.2)	8 (10.7)	9 (8.2)
S Grade	28 (14.4)	18 (22.8)	10 (8.7)	S Grade	26 (14.1)	13 (17.3)	13 (11.8)
H Grade	93 (47.9)	27 (34.2)	66 (57.4)	H Grade	96 (51.9)	31 (41.3)	65 (59.1)
CSYS	1 (0.5)	0	1 (0.9)	CSYS	10 (5.4)	4 (5.3)	6 (5.5)
other	15 (7.7)	7 (8.9)	8 (7.0)	other	16 (8.6)	8 (10.7)	8 (7.3)
none	23 (11.9)	10 (12.7)	13 (11.3)	none	1 (0.5)	0	1 (0.9)
access	21 (10.8)	14 (17.7)	7 (6.1)	access	19 (10.3)	11 (14.7)	8 (7.3)

Comparison of Tables 5.1 and 3.3 shows that whilst the proportion of the class with modular and Standard Grade Chemistry qualifications had decreased, the other Non-Standard Entry Chemistry qualifications (None and Access) showed an increase. A similar pattern can be observed in the maths qualifications, although there is also an increase in the percentage of students offering Standard Entry qualifications (the shaded section).

Dividing the class into those who had Standard Entry Qualifications in (a) both chemistry and maths, (b) only one of these subjects and (c) neither of them gives the distribution shown in Table 5.2.

The same general pattern observed in Year One (Table 3.4) recurs – i.e. that the female students have generally more experience in chemistry and maths than the males. Yet again this, together with the majority of the class being female, challenges the traditional view of science subjects as being a male province.

Table 5.2 Breakdown of General Chemistry-1 (1994-95) Chemistry and Mathematics Qualifications by Class and Gender

Chemistry Qualification	Mathematics Qualification	Class (% of 163)	Male (% of 64)	Female (% of 99)
Standard Entry	Standard Entry	70 (42.9)	20 (31.3)	50 (50.5)
Standard Entry	Non-Standard Entry	20 (12.3)	7 (10.9)	13 (13.1)
Non-Standard Entry	Standard Entry	35 (21.5)	15 (23.4)	20 (20.2)
Non-Standard Entry	Non-Standard Entry	38 (23.3)	22 (34.4)	16 (16.2)

5.4 Year Two Research Aims

The author's work during Year Two of Gen Chem shifted emphasis and moved on from that described in Chapter Three. With only minor modifications required to the Support Materials devised in Year One, the design side of the project was greatly diminished. Similarly the attempts to establish a detailed view of the course from the students was dropped, partially because of the consistency positive response to the course achieved in Year One and partially to allow time for new investigations to be carried out.

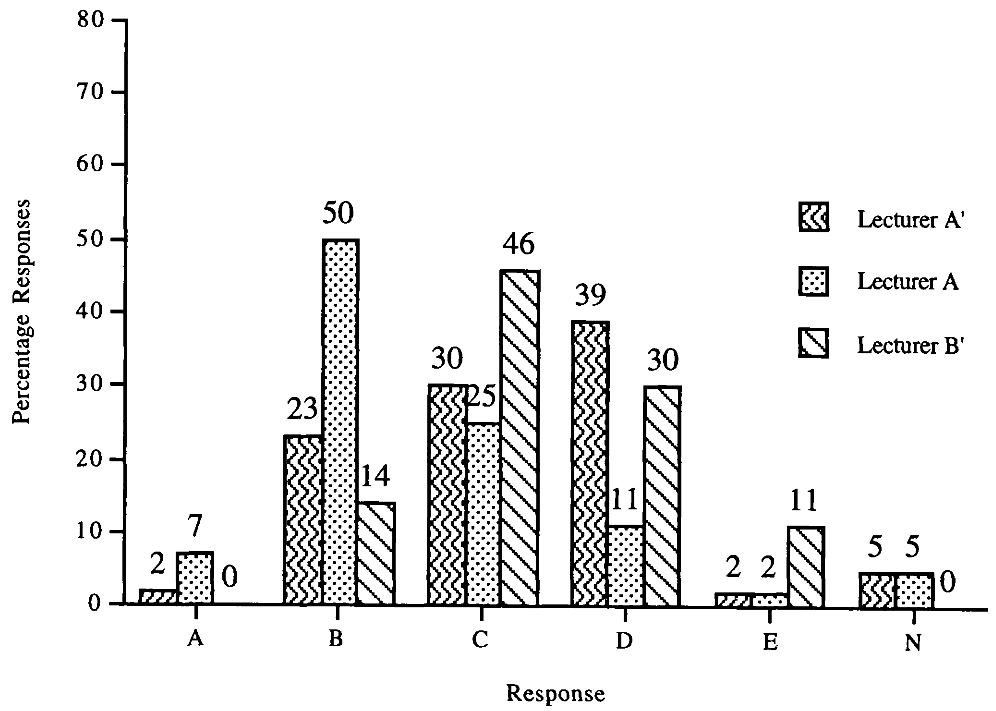
The examination results produced would continue to be studied in the same way as before to ensure that the course retained its ability to offer success to those with all entrance qualifications. Added to this the researcher would probe the other factors which it was felt may influence student success that were outlined in Chapter Four – namely Gender, Age, Living Place, Perry Position, Field Dependency and Personality (Extraversion / Introversion and Neuroticism / Stability).

5.5 Students' Views of General Chemistry–1

Although the researcher did not intend to repeat any of the assessments of students views, the Chemistry Department continued to use its own, internal questionnaire (Chapter 3.4.1).

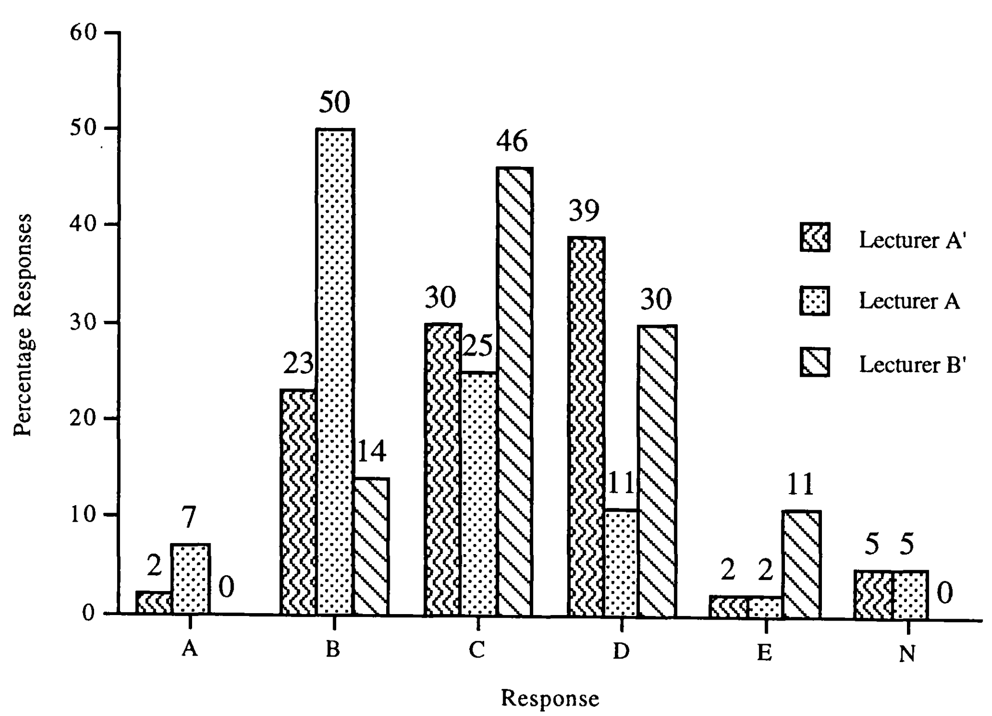
The results from the assessment of Term 1 are given below for some of the key questions. As before, students were asked to state their strength of feeling about the lecturers (and their courses) in terms of Presentation and Content on a 5-point scale.
Figure 5.1 and 5.2 show the students' responses.

Figure 5.1 Students' Opinion of Lecturers' Presentation in Term One



A = Excellent, B = Very Good, C = Good, D = Poor, E = Very Poor, N = No Response

Figure 5.2 Students' Opinion of Lecture Content in Term One



A = Excellent, B = Very Good, C = Good, D = Poor, E = Very Poor, N = No Response

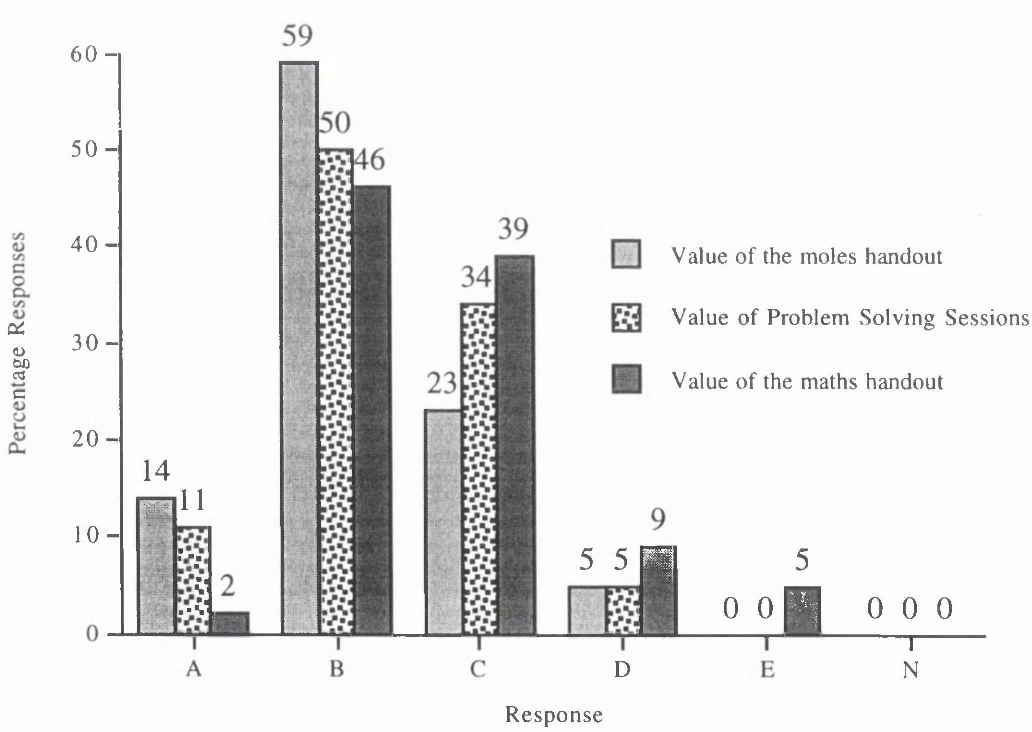
Lecturer A is the same as in Figure 3.1, whereas Lecturer A' and B' were the two who were new to General Chemistry-1. In both Presentation and Content the new lecturers didn't appear to find as much favour with the students as their Year One counterparts. Lecturer A, on the other hand, maintained the high scores achieved previously.

As before, students were also asked their opinion on a number of other matters relating to the course, such as lab experiences and the quality of the recommended text. Unfortunately some of the statements used were not the same as those in Year One and there were some changes in which features were probed. Figure 5.3 shows the results for the following areas:

- The value of the moles handout
- The value of the Problem Solving Workshops
- The value of the maths handout

As can be seen, all three of these support systems received overwhelming backing from the class. As in the year before (Figure 3.3) the Workshops scored highly in student appreciation.

Figure 5.3 Students' Opinion of Some Key Features



A = Excellent, B = Very Good, C = Good, D = Poor, E = Very Poor, N = No Response

Student opinion of the rest of Gen Chem was very similar to that mentioned previously in Chapter Two.

5.6 Examination Results

Given the findings of the first year of research into Gen Chem with regard to examination results and entrance qualifications, it was felt important to repeat the analysis for Year Two's exams.

As previously, *chi*-square and the Mann-Whitney test would be used to assess if there was a statistically significant difference in the pattern of examination results achieved by the various qualification cohorts. Appendices J, K and L give the results achieved in the Class and Degree exams.

5.6.1 January 1995 Class Examination

The format and style of the Class exams remained the same as had been established in Year One.

Appendix J contains the January results. Graph J1 shows the results to be reasonably close to a normal distribution, but with a slight bimodality, similar in appearance to the corresponding Year One results (Graph F1). Comparison of January 1994 results with those of January 1995 (Graphs F2 and J2, respectively) indicate there was no significant difference between the two (χ^2 = 7.82; 13 d.f.). This result shows the general standard of achievement was maintained over the two years.

Those with Standard Entry Qualifications (i.e. Higher Grade or better) in chemistry achieved the results displayed in Graph J3, with Non-Standard Entry (less than Higher Grade) results in J4. Graph J4 is of a noticeably slightly broader distribution than that in J3 and indeed this was reflected in the *chi*-square result (χ^2 = 17.11; 10 d.f.) giving a statistically significant difference between the two at 10 % level. However, this result appears to have been caused by the requirement of *chi*-square i.e. by producing a contingency table with expected values of 5 or greater. Using the Mann-Whitney statistic indicates there is no significant difference between Standard and Non-Standard results.

The Mann-Whitney test allowed the results of those with Standard Grade (Graph J5), Modules (J6), Access (J8) and no chemistry qualifications (J7) to be examined. Table 5.3 summarises these results.

Table 5.3 Results of Analysis of Difference in January 1995 Class Examination Performance Based on Chemistry Qualifications

	Standard Grade (N = 28)	**No Qualifications**	**Modules**	**Access**
Standard Entry (N = 85)	Non-sig.	Non-sig.	Non-sig.	Non-sig.
Access (N = 21)	Non-sig	Non-sig.	Non-sig	
Modules (N = 13)	Non-sig.	Non-sig.		
No Qualifications (N = 23)	Non-sig.			

It is clear that the same pattern observed in the first year's results (Table 3.6) is repeated here.

The Non-Standard Entry Maths students' results distribution (Graph J10) was slightly broader than that of those with Standard Entry Maths (J9). The *chi*-square test shows that there was no significant difference between the two patterns ($\chi^2 = 8.64$; 8 d.f.).

Table 5.4 gives the results of applying the Mann-Whitney test to the sub-groupings comprising the Non-Standard Entry group.

Yet again, a similar pattern to that of Year One is observed.

As with the chemistry qualifications, virtually the same pattern as the year before is observed in the analysis based on maths qualifications (Table 3.7). In both cases there was a relatively poor performance from those with modular mathematics qualifications.

Table 5.4 Results Analysis of Difference in January 1995 Class Examination Performance Based on Mathematics Qualifications

	Standard Grade (N = 24)	Modules	Access
Standard Entry (N = 103)	Non-sig.	$p \leq 0.014$	Non-sig.
Access (N = 18)	Non-sig.	$p \leq 0.013$	
Modules (N = 17)	Non-sig.		

Why this result should have been observed in the January exam is still not clear – Term 1 was not considered the most mathematically demanding and problems requiring numeracy skills were in the minority.

Analysis of the results in terms of combined chemistry and maths entry qualifications failed to support the hypothesis that those with Standard Entry in both subjects would perform better than those with Non-Standard Entry for both, as had been the case in Year One. Table 5.5 gives the details of this analysis on the distributions in Graphs J14 to J17.

Table 5.5 Results of Analysis of Difference in January 1995 Class Examination Performance Based on Chemistry and Mathematics Qualifications

	Non-Stand. Ent. Both Subjects (N = 38)	Stand. Ent. Both Subjects	Stand. Ent. Chem.; Non-Stand. Ent. Maths
Non-Stand. Ent. Chem.; Stand Ent. Maths (N = 35)	Non-sig.	$p \leq 0.065$	Non-sig.
Stand. Ent. Chem.; Non-Stand. Ent. Maths (N = 19)	Non-sig.	Non-sig.	
Stand. Ent. Both Subjects (N = 67)	Non-sig.		

The poorer performance of those with Standard Entry in Maths and Non-Standard Entry in Chemistry when compared to those with Standard Entry in both subjects (significant at the 10 %) level is the only comparison showing any degree of statistical significance. In general, however, the pattern observed in 1994's January exam resurfaced in 1995.

5.6.2 April 1995 Class Examination

The second Class Exam remained identical in style to that of Year One, covering Term 2's material – *How Far and How Fast ?*, *Aqueous Solution* and *Carbon Compounds I*.

The relevant distribution graphs are contained in Appendix K. Graph K1, giving the pattern of results achieved by the class was more clearly bimodal than that of the previous year (G1). However, there was no significant difference between the two graphs (G2 and K2) using *chi*-square (χ^2 = 14.57; 12 d.f.). Similarly there was no significant difference between the results of the two 1995 Class Exams (χ^2 = 21.30; 16 d.f.).

This indicates again that the standards achieved by both the 1994/95 and the 1993/94 classes were maintained exam to exam, year to year.

The comparison of Standard Entry Chemistry (Graph K3) to Non-Standard Entry (Graph K4) gave a statistically significant difference in the distributions at the 5 % level (χ^2 = 18.50; 10 d.f.) and inspection of these graphs shows this was due to the number of students with Non-Standard Entry Chemistry achieving low scores in the exam. It must be noted, though that conversely some of these students performed very well (as in 1994 the highest mark comes from this group).

Breaking down the Non-Standard Entry chemists (Graph K5 to K8) gives the results indicated in Table 5.6.

Inspection of the results indicates the students who undertook an Access course performed exceptionally well compared to their classmates, and this is borne out by the results above. Due to the small number of students offering an Access qualification in Year One (only four students) this was a group not included in the analysis before as it was too small a sample from which to draw any conclusions.

Table 5.6 Results of Analysis of Difference in April 1995 Class Examination Performance Based on Chemistry Qualifications

	Standard Grade (N = 28)	No Qualifications	Modules	Access
Standard Grade (N = 92)	Non-sig.	Non-sig.	Non-sig.	$p \leq 0.091$
Access (N = 19)	$p \leq 0.029$	$p \leq 0.045$	Non-sig.	
Modules (N = 11)	Non-sig.	Non-sig.		
No Qualifications (N = 23)	Non-sig.			

The relatively poor performance of those with modular chemistry experience and the good performance of those who took an Access course shows up again in the investigation of the results based on maths qualifications (Graphs K9 to K13). With this in mind it is no surprise that the difference between these two sub-groupings was highly significant at the 0.1 % level.

Table 5.7 Results of Analysis of Difference in April 1995 Class Examination Performance Based on Mathematics Qualifications

	Standard Grade (N = 24)	Modules	Access
Standard Entry (N = 104)	Non-sig.	$p \leq 0.016$	$p \leq 0.002$
Access (N=17)	$p \leq 0.003$	$p \leq 0.001$	
Modules (N = 16)	Non-sig.		

Indeed, it is worth noting that Access students out-perform those with Standard Entry qualifications (significant difference between the two groups at the 5 % level).

Consideration of the combined maths and chemistry qualifications (Graphs K14 to K17) gives the following results.

Table 5.8 Results of Analysis of Difference in April 1995 Class Examination Performance Based on Chemistry and Mathematics Qualifications

	Non-Stand. Ent. Both Subjects (N = 34)	Stand. Ent. Both Subjects	Stand. Ent. Chem.; Non-Stand. Ent. Maths
Non-Stand. Ent. Chem.; Stand. Ent. Maths (N = 35)	Non-sig.	Non-sig.	Non-sig.
Stand. Ent. Chem.; Non-Stand. Ent. Maths (N = 19)	Non-sig.	Non-sig.	
Stand. Ent. Both Subjects (N = 69)	Non-sig		

As in Year One the combined qualifications groupings show no significant difference in exam performance.

5.6.3 June 1995 Degree Examination

Unlike the previous year's Degree Examination results, actual marks scored by students were made available to the researcher in Year Two. This allowed a similar analysis to that employed in the Class Exams to be used with the Degree Exam. Appendix L contains the relevant histograms in the usual format.

Graph L1 shows that the distribution pattern for this exam had a slight negative skew. Comparison of these results with those of January shows no significant difference (χ^2 = 21.65; 17 d.f.), whereas there is a significant difference in the distribution of Degree Exam results and April's Class Exam at the 10 % level (χ^2 = 26.71; 18 d.f.).

No significant difference was observed in the performances of students with Standard Entry Chemistry Qualifications and those without them (χ^2 = 9.43; 9 d.f.). Similarly, there was no significant difference in the marks of those with Standard Entry and Non-Standard Entry Mathematics (χ^2 = 4.34; 8 d.f.). Tables 5.9, 5.10 and 5.11 give the results of a Mann-Whitney analysis of the individual sub-groupings.

Table 5.9 Results of Analysis of Difference in June 1995 Degree Examination Performance Based on Chemistry Qualifications

	Standard Grade (N = 23)	No Qualifications	Modules	Access
Standard Entry (N = 88)	Non-sig.	Non-sig.	Non-sig.	Non-sig.
Access (N = 18)	Non-sig.	Non-sig.	Non-sig.	
Modules (N = 10)	Non-sig.	Non-sig.		
No Qualifications (N = 20)	Non-sig.			

Table 5.10 Results of Analysis of Difference in June 1995 Degree Examination Performance Based on Mathematics Qualifications

	Standard Grade (N = 23)	Modules	Access
Standard Entry (N = 98)	Non-sig.	$p \leq 0.098$	$p \leq 0.042$
Access (N = 17)	$p \leq 0.011$	$p \leq 0.010$	
Modules (N = 11)	Non-sig.		

The results in Table 5.9 are very clear and continue the trend displayed in all previous General Chemistry exams.

As with the April 1995 exam, a poor performance by those with Modular mathematics experience and a relatively good performance by those who undertook an Access course, give rise to some statistically significant results in Table 5.10. Again the Access group have produced better results than those with Standard Entry Mathematics.

Table 5.11 Results of Analysis of Difference in June 1995 Degree Examination Performance Based on Chemistry and Mathematics Qualifications

	Non-Stand. Ent. Both Subjects (N = 29)	**Stand. Ent. Both Subjects**	**Stand. Ent. Chem.; Non-Stand. Ent. Maths**
Non-Stand. Ent. Chem.; Stand. Ent. Maths (N = 31)	Non-sig.	Non-sig.	Non-sig.
Stand. Ent. Chem.; Non-Stand. Ent. Maths (N = 18)	$p \leq 0.042$	$p \leq 0.050$	
Stand. Ent. Both Subjects (N = 66)	Non-sig.		

5.7 Chemistry-1 1994/95 Examination Results

Following the clear results obtained from the analysis of General Chemistry Year One examinations, it was decided to study this year's Chemistry-1 results to see if that course was also "qualification resistant".

The examination system for Chem-1 followed the more traditional Science Faculty model shunned by Gen Chem (Chapter 3.2.6). Although Chem-1 students undertook two Class Exams, these did not contribute to the final overall assessment. However, if a student performed "well enough" in these exams he or she would win an exemption from the final Degree Exam and be assumed to have passed the course. For those who did not achieve this (but had fulfilled the conditions to be awarded a Class Ticket) the Degree Exam would form 90 % of their final grade, with the remaining 10 % coming from lab. grades.

All of Chem-1's exams offered some (constrained) choice of questions to be attempted.

As in Year One, Chemistry-1 1994/95 was by far the largest of the two chemistry classes with 540 students (54.6 % of which were female).

Table 5.12 Breakdown of Chemistry-1 in Terms of Entrance Qualifications in Chemistry

Chemistry Qualifications	Higher Grade	CSYS	A Level	Modules	other
Class (% of 540)	252 (46.7)	187 (34.6)	48 (8.9)	5 (0.9)	48 (8.9)

The variety of qualifications was (obviously) smaller than that of Gen Chem – removal of the wide experience range in Chem-1 was one of the reasons for establishing Gen Chem after all.

The examination results discussed in this section are limited to considering those with Scottish Higher Grade and Certificate of Sixth Year Studies (CSYS) only, as:

i) this comprised the overwhelming bulk of the class, and;
ii) these were very much the qualifications that the education system was designed for, rather than A Levels.

Graphs of the relevant data are contained in Appendix M. Both January (M2) and April (M13) results show a quite pronounced positive skew, and, indeed, these sets of data show no significance difference between them (χ^2 = 22.94; 21 d.f.). This positive skew is also evident in the underlying results of those with Higher Grade in both January (M4) and April (M15), but much less so in those with CSYS (Graphs M3 and M14). *Chi*-square calculations confirm that there is a significant difference between the results of the CSYS cohort and those of the Higher Grade in both January (χ^2 = 40.14; 13 d.f.), at the 0.1 % level, and in April at the 1 % level (χ^2 = 32.45; 13 d.f.).

Unlike Gen Chem, the numbers of students involved in Chem-1 make an analysis of the exam results according to the different grades of entrance qualifications feasible. Table 5.13 gives the results of the Mann-Whitney analysis of these sub-groups for January, Table 5.14 for April.

Table 5.13 Results of Analysis of Difference in Chemistry-1 January 1995 Class Examination Performance Based on Chemistry Qualifications

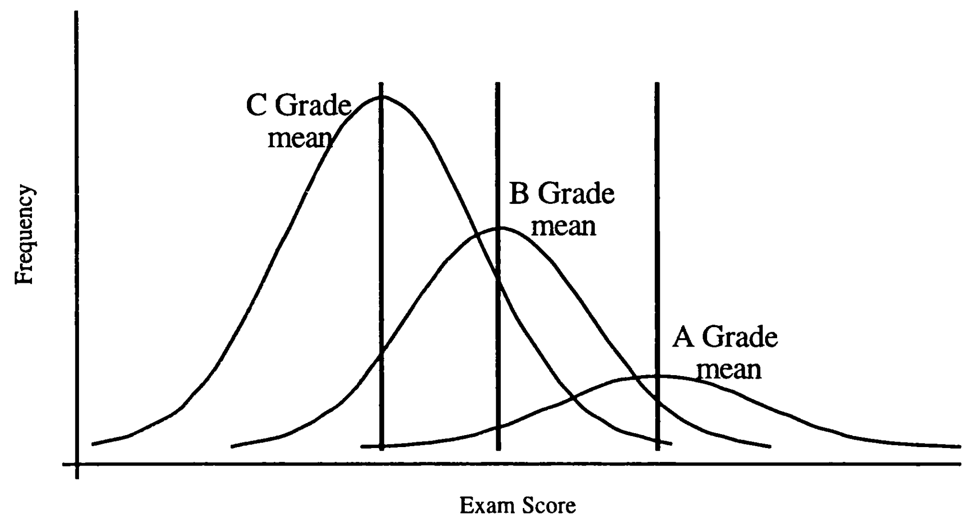
	Higher C (N = 39)	Higher B	Higher A	CSYS D	CSYS C	CSYS B
CSYS A (N = 18)	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$
CSYS B (N = 49)	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.081$	$p \leq 0.0001$	$p \leq 0.0001$	
CSYS C (N = 83)	$p \leq 0.0001$	$p \leq 0.0003$	$p \leq 0.0014$	$p \leq 0.0004$		
CSYS D (N = 31)	$p \leq 0.046$	Non-sig.	$p \leq 0.0001$			
Higher A (N = 56)	$p \leq 0.0001$	$p \leq 0.0001$				
Higher B (N = 149)	$p \leq 0.0007$					

Table 5.14 Results of Analysis of Difference in Chemistry-1 April 1995 Class Examination Performance Based on Chemistry Qualifications

	Higher C (N = 39)	Higher B	Higher A	CSYS D	CSYS C	CSYS B
CSYS A (N = 18)	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$
CSYS B (N = 49)	$p \leq 0.0001$	$p \leq 0.0001$	Non-sig.	$p \leq 0.0001$	$p \leq 0.0001$	
CSYS C (N = 82)	$p \leq 0.0001$	Non-sig.	$p \leq 0.0001$	$p \leq 0.0125$		
CSYS D (N = 30)	$p \leq 0.0694$	$p \leq 0.0611$	$p \leq 0.0001$			
Higher A (N = 56)	$p \leq 0.0001$	$p \leq 0.0001$				
Higher B (N = 149)	$p \leq 0.0001$					

The results are as striking as their General Chemistry-1 counterparts, but for very different reasons. Simple inspection of the relevant graphs (M5 to 11 and M16 to 22) shows the clear trend of results, not just from one qualification to another (CSYS to Higher), but also within the different grades of each qualification. Rather than a series of (largely) overlapping distributions as was observed in all five Gen Chem exams detailed so far, Chem-1 produced a range of distribution patterns, the central tendencies of which decreased with the grade of that particular grouping.

Figure 5.4 Representation of the General Trend Found in Chemistry-1 Examination Results



The evidence from these two class exams clearly support the hypothesis that exam success in Chem-1 is linked to the standard of a student's entrance qualifications – completely the opposite of the findings from the work on Gen Chem results. Another equally striking feature is the very high levels of statistical significance indicated by the Mann-Whitney test. In work such as this it is important to draw the distinction between *statistical* significance and *educational* significance – although something may be statistically significant, it does not automatically follow that it will be of any significance in practical education terms. However, the results of these examinations would appear to have been unquestionably directly influenced by entrance qualifications given the levels of significance observed, whereas frequently the few statistically significant results in Gen Chem analyses were only at the 10 % or 5 % level.

It would also appear that a good Higher pass (Grade A or B) is more conducive to success in Chem-1 than a poor (Grade C or D) pass at CSYS level, as indicated in Table 5.15. This has clear implications for an entrance policy based on previous qualifications and the amount of support offered to students in Chemistry-1.

Table 5.15 Mean Class Examination Marks of Each Qualification Cohort in Order

January							
Cohort (Mean Score)	CSYS A (77.4)	CSYS B (54.9)	Higher A (49.6)	CSYS C (38.2)	Higher B (31.2)	CSYS D (28.1)	Higher C (22.5)
April							
Cohort (Mean Score)	CSYS A (77.4)	CSYS B (55.1)	Higher A (53.3)	CSYS C (40.2)	Higher B (38.2)	CSYS D (33.2)	Higher C (28.1)

One reason often cited as a cause of poor exam results in both of the Class Exams is apathy towards them on the part of the students. As these exams did not contribute to the students' final assessment they were often seen, it was claimed, as not of any great value and hence they did not study regularly or consistently for them. Indeed, this was one of the reasons the Gen Chem examination system was developed as it was.

Whilst apathy towards the exams almost certainly did exist and may very well have been a contributing factor towards the results observed, it cannot possibly be the only, or even (perhaps) the most important. If it was then one clear, broad interpretation from the results described above would be that apathy was inversely proportional to entrance qualification grade! It would seem very strange indeed if this was indeed the case. However, it is logical to hypothesise that many of those with good CSYS results could find much of Chem-1's content overlapped with the CSYS syllabus and hence become apathetic towards material they felt they already knew, which may give rise to poor study habits. However, the examination results do not appear to support this, unless (in an even more worrying conclusion) **Chem-1 is not really teaching students very much and it is their previous schooling that is being tested by the exams**, rather than any understanding of Chem-1! One possible effect of having a year of chemistry which contained much of the same material as CSYS, is that well qualified students may find Chem-2 a much greater challenge.

On the basis of these examinations some 57 students were granted exemptions (EX) and so did not require to sit the Degree Exam, a further 14 were not awarded Class Tickets (NT). The remainder of the groups achieved results summarised in Graphs M23 to 32. The class distribution (M23) is noticeably closer to the normal distribution than those of the two Class Exams. Indeed, this time there is a significant difference between January and June at the 0.5 % level ($\chi^2 = 56.11$; 21 d.f.) and between April and June at the same level ($\chi^2 = 44.22$; 21 d.f.). This was undoubtedly caused by the loss of the highest achievers (who

gained exemptions) and extra motivation for study as students knew their ultimate fate in the class depended on this exam, so improving their scores.
The results of those with CSYS differ significantly from those with Higher at the 10 % level ($\chi^2 = 18.01$; 10 d.f.). Table 5.16 breaks down the qualifications further.

Table 5.16 Results of Analysis of Difference in Chemistry-1 June 1995 Degree Examination Performance Based on Chemistry Qualifications

	Higher C (N = 36)	Higher B	Higher A	CSYS D	CSYS C
CSYS B (N = 36)	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.002$	$p \leq 0.0001$	$p \leq 0.0001$
CSYS C (N = 77)	$p \leq 0.0001$	$p \leq 0.058$	Non-sig.	$p \leq 0.023$	
CSYS D (N = 30)	$p \leq 0.064$	Non-sig.	$p \leq 0.016$		
Higher A (N = 37)	$p \leq 0.0002$	$p \leq 0.047$			
Higher B (N = 133)	$p \leq 0.002$				

Once more the (now) familiar Chem-1 pattern emerges, with (generally) the similarly high levels of significance to those reported earlier.

Table 5.17 gives the number of students in each sub-grouping achieving each final grade in Chem-1. Just as the analysis of Gen Chem's Year One and Two exam results gave a clear and consistent pattern, so did those of 1994/95's Chemistry-1 class, although the pattern observed was very different to that in Gen Chem. It can be seen that an extra year of secondary school chemistry (in the shape of CSYS) essentially guarantees a good pass in Chemistry-1, **as long as the student achieved a good pass at CSYS**. Conversely, a poor CSYS performance does not really offer any advantage over those students who only have a Higher Grade pass. This would perhaps suggest that those who achieve a C pass in Higher Grade in S5 might more profitably spend a sixth year at secondary school resitting Higher to increase their grade, rather than attempting CSYS.

Table 5.17 Final Grades Achieved in Chemistry-1 1994/95 by Entrance Qualifications

	Chemistry-1 Grade							
Entrance Qual.	EX	A	B	C	D	F	G	NT
CSYS A	16	1	0	1	0	0	0	0
CSYS B	13	8	14	10	3	1	0	0
CSYS C	5	3	18	19	11	16	10	1
CSYS D	0	0	1	11	3	8	7	1
Higher A	18	2	11	8	4	7	5	2
Higher B	5	6	13	42	14	36	22	7
Higher C	0	0	1	12	0	9	14	3

5.8 Other Factors Influencing General Chemistry-1 Success

As discussed in Chapter Four, having found that there was essentially no link between entrance qualification and exam results in Year One of Gen Chem, it was decided to consider the effects of other factors which may influence success.

The effects of these factors – namely Age, Gender, Living Place, Perry Position, Extraversion, Neuroticism and Field Dependency – were analysed in the same way as the qualification sub-groupings; i.e. by use of the Mann-Whitney test. This was chosen over the *chi*-square test as the numbers involved meant having to collapse most of the distributions of results (in some cases quite considerably) to meet the criteria of the test. Factor analysis, frequently used to investigate relationships between data, was also deemed inappropriate in this case for two reasons – firstly, the method is complicated and potentially time consuming. The second point of concern was the data itself, much of which was categorical in nature and so unlikely to meet the requirements of factor analysis.

5.8.1 Gender, Age and Living Place

The three factors were the easiest to define and use in sub-dividing the class.

Dividing the class by Gender gave no significant difference in the results of each group in any of the three exams under consideration (January and April Class Exams and June Degree Exam). Similarly Age (dividing the class into those who were 23 year of age and older – "mature students" – and those who were under 23) did not show any significant difference in January or June. However, there was a significant difference at the 10 % level between the Age groups in the April exam, with the over 23s showing the better performance.

The students' Living Place (normal Home or a Flat) did not show any significant difference in January or April, but was significant in the Degree Exam at the 10 % level. In this case the students living in a Flat were generally more successful than their Home based counterparts.

5.8.2 Perry Position

As described in Chapter Four, several formulae were proposed to generate a score for each student based on their responses to Part One of the Perry Questionnaire (Appendix I). Work on these formulae by MacGuire had shown that his three Success Indices (SIs) were essentially measuring the same thing (Figure 4.2 and Table 4.1). These, together with the modified versions of the Success Indices and the Perry Index (PI) the author described earlier, were used in an attempt to give each student a measure of their Perry Position. Success Index 1 used the actual numbers indicated on the Likert response scale minus one, as did SI2 and SI3 (which also altered the weighting of A and C statements); SI1', 2' and 3' were exactly the same except they used the Likert response only and the PI used only the A and C statements scoring +1 for and Agree and -1 for a Disagree.

The Perry Questionnaire was completed by 134 students in total towards the end of the first term. As before, the correlations of the scores generated by the replies were investigated using Spearman's *rho* (Table 5.18).

Table 5.18 Values of Spearman's Rho (ρ) for SI1, SI2, SI3, SI1', SI2', SI3' and PI for 134 General Chemistry-1 Students

	PI	SI3'	SI2'	SI1'	SI3	SI2
SI1	0.839	0.974	0.986	0.998	0.975	0.986
SI2	0.892	0.996	0.998	0.983	0.997	
SI3	0.907	0.998	0.995	0.971		
SI1'	0.834	0.973	0.986			
SI2'	0.890	0.997				
SI3'	0.906					

The results show the same pattern as in MacGuire's investigations – all versions of the SIs and the PI would appear to measure the same thing, suggesting that any one of them could be used. As the modifications put forward by the author did not appear to make any real difference to the rank order of the scores it was decided to use SI1 to assign a student's Perry Position.

As with the work discussed earlier it was decided to omit those with qualifications classed as "other" from the analysis, leaving some 114 (of a possible 178) students who had completed the questionnaires.

Using the generated SI1 to put the students into rank order it was decided to split the class up into three groups – top third, middle third and bottom third. The sub-groups were then termed "Perry C", "Perry mid A/C" and "Perry A" respectively. These labels were adopted for convenience sake and did not imply that the top third were wholly Perry C (or similarly that the bottom third wholly Perry A) as outlined by the definition of these positions in Chapter Two. These measures gave relative positions of the students only: the Perry A group would more accurately, if somewhat clumsily, be called "the group showing stronger Perry A / weaker Perry C tendencies relative to their classmates", and vice versa for the Perry C group. For this reason the middle group could not truly be called Perry B, hence the Perry mid A/C label.

The decision to divide the group into thirds, as opposed to (say) top and bottom quarters as the extreme groups, was (largely) arbitrary – although such a division had to balance two different considerations. First of all, the grey area between the two extreme groups would need to be sufficiently large to ensure these groups were genuinely different with regard to the measure under consideration. However, if this mid-group was too large then the extreme groups may too small to analyse meaningfully by statistics.

This same rationale – splitting the class into thirds and labelling method employed – was used in dividing up the respondents to the other questionnaires used (see below).

Applying this system, 38 students fell into the Perry A category, with 39 in Perry mid A/C and 37 in Perry C. In each of the exams there was no significant difference in performance between any pairing of the three sub-groups, using the Mann-Whitney Test.

5.8.3 Personality Factors

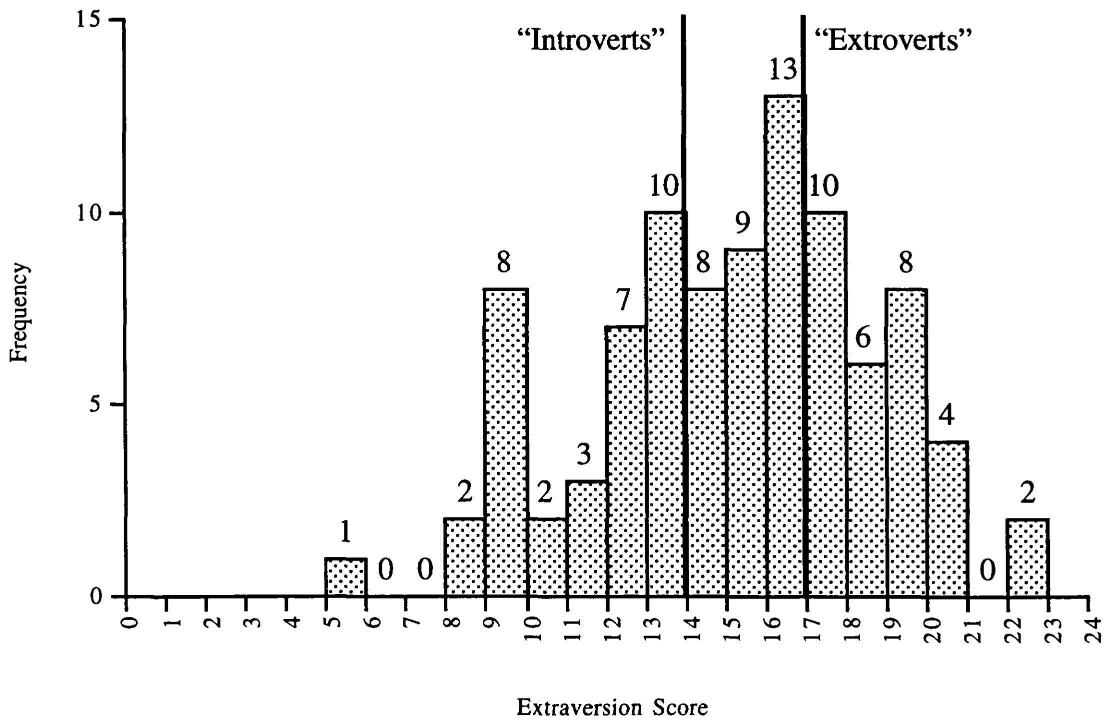
As outlined in Chapter Four, two of the major super-factors in Eysenck's theory of Personality were to be included in the analysis. Form A of Eysenck's EPI (Eysenck Personality Inventory) was given to students in the early part of Term Two.

Following the advice given in the instruction manual (Eysenck and Eysenck, 1987) anyone scoring on more than half of the Lie scale was considered to have given responses which may have been an attempt at giving a socially desirable response set, and so were rejected on these grounds. Only 8 students failed this Lie test by scoring 5 or more out of 9 and were omitted from the analysis. The remaining 93 were divided as described earlier to give three groups for each of the two factors, Extraversion and Neuroticism.

5.8.3.1 Extraversion

Figure 5.5 shows the distributions of Extraversion scores which were divided into Extraverts (i.e. "the group showing strongest Extravert / weakest Introvert tendencies relative to their classmates"), mid I/E, and Introverts.

Figure 5.5 Distribution of Extraversion Scores on EPI For 93 General Chemistry Students



January's exam showed a significant difference in results between the Introverts and the mid I/E group and between Introverts and Extraverts, at the 10 % level in both cases. There was no difference between mid I/E and Extraverts.

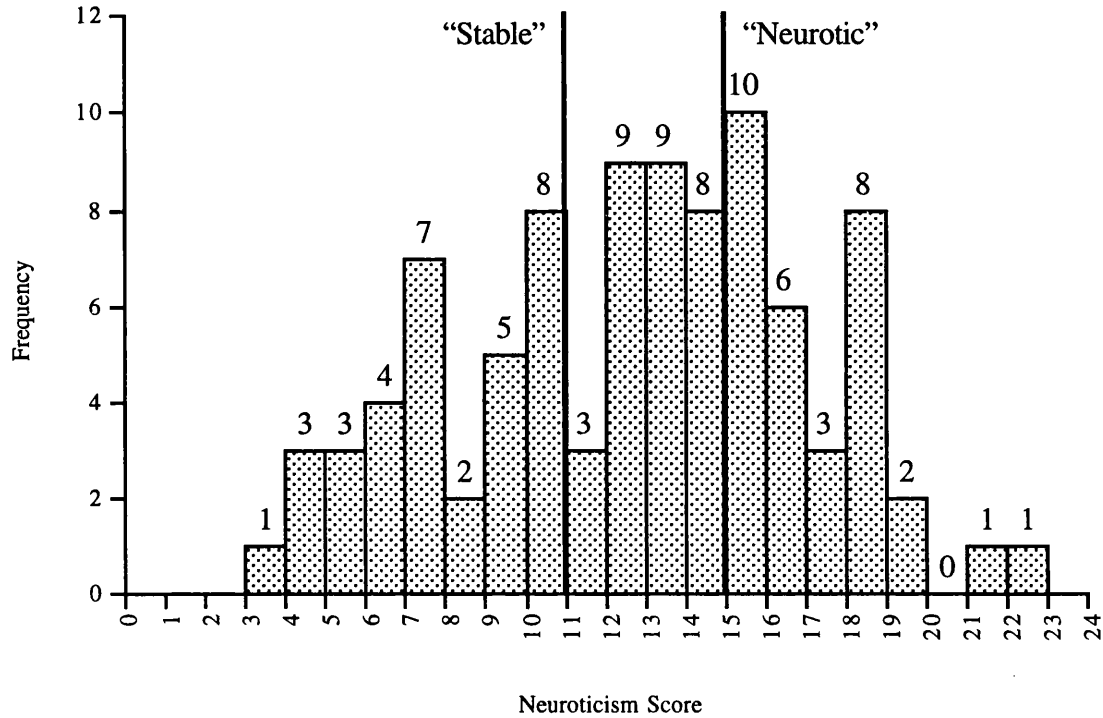
Neither of the other exams showed any difference in the results achieved by each group.

5.8.3.2 Neuroticism

Figure 5.6 shows the distribution of Neuroticism scores, which were divided into Stable, mid S/N and Neurotics.

Again none of the three exams showed a significant difference between any pairing of the groups.

Figure 5.6 Distribution of Neuroticism Scores on EPI For 93 General Chemistry Students



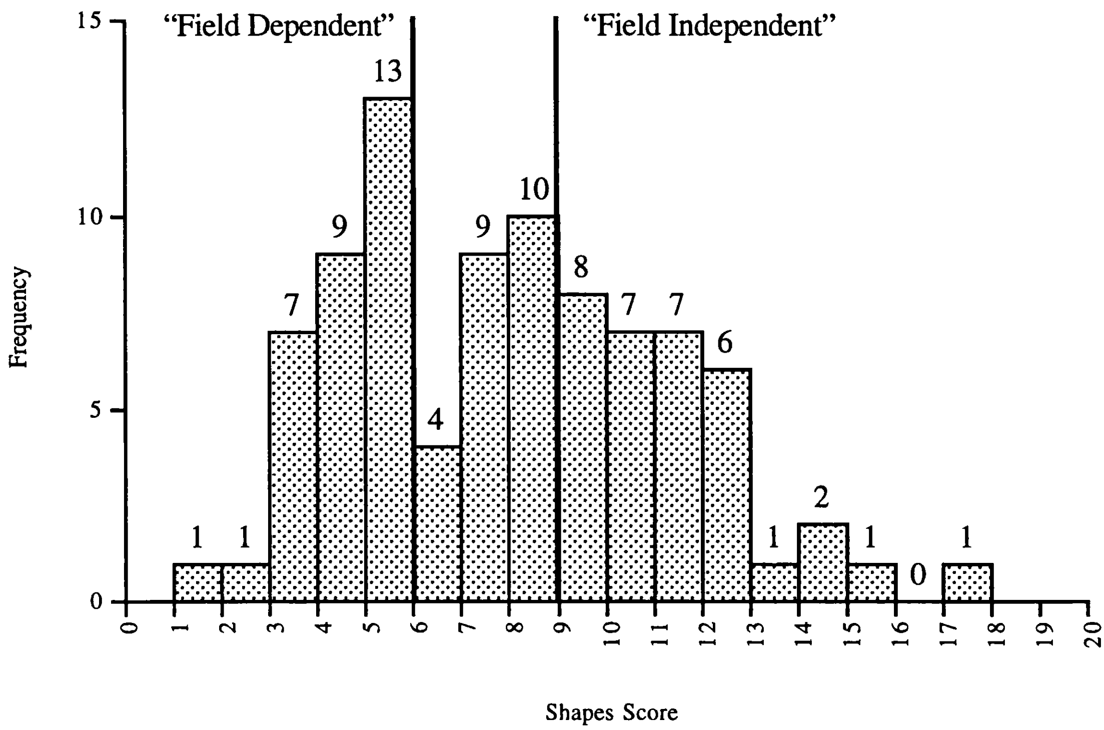
5.8.4 Field Dependency

The modified El-Banna test (Appendix I) was given out to 87 students in the latter half of the second term. The four practice items were included in scoring, giving the distribution in Figure 5.7.

This was split into Field Dependent, mid FD/FI and Field Independent.

In the January exam there was no difference in the performance of the three groups. However, both April and June showed a difference at the 5 % and 10 % levels respectively in the results of those who were Field Dependent compared to those in the mid FD/FI group, with the Field Dependent students outperforming the other group. There was no difference between the Field Independent group and any of the others.

Figure 5.7 Distribution of Shapes Scores For 87 General Chemistry Students



5.9 Combining Factors

So far the factors under consideration have been looked at in isolation: this was an attempt to look for the gross effects of each variable. Another way of considering the data is to study the cumulative effects of two or more factors.

Whilst combining factors is possible, there are obvious limitations to this. The more constraints put on each variable the smaller that sub-group of students will be and hence any generalisations arising would be questionable.

Another consideration is in the practicality of combining multiple factors – what is the likely pedagogical benefits of discovering that (say) male, Stable, Extroverted, Field Dependent, Perry mid A/C students with standard entrance qualifications significantly out-performed some other equally obscure group ?

For these reasons combining more than two factors would seem rather fruitless. To maximise the numbers in each grouping it was decided to combine Gender with the other factors. From exam to exam the numbers in each sub-grouping generally changed by a small amount due to absenteeism, however this did not affect the statistical analysis greatly.

One thing that can be investigated by combining these factors is whether there is any link between Gender and the other factor. A difference between the distribution of male and female students were found in the following factors (Table 5.19):

Table 5.19 Difference in Male and Female Distributions for Each Factor Investigated

Factor	Level of Significance
Chemistry Qualification	Jan: 0.5 % ($\chi^2 = 9.34$; 1 d.f.) Apr: 0.5 % ($\chi^2 = 9.51$) Jun: 0.5 % ($\chi^2 = 12.25$)
Extraversion	Non- sig.
Neuroticism	Jan: 5 % ($\chi^2 = 7.01$; 2 d.f.) Apr: 5 % ($\chi^2 = 6.75$) Jun: 5 % ($\chi^2 = 7.47$)
Field Dependency	Non-sig.
Perry Position	Jan: 10 % ($\chi^2 = 4.81$; 2 d.f.) Apr: 10 % ($\chi^2 = 5.58$) Jun: 10 % ($\chi^2 = 5.25$)
Maths Qualification	Jan: 5 % ($\chi^2 = 4.30$; 1 d.f.) Apr: 10 % ($\chi^2 = 3.40$) Jun: Non-sig.

It is clear from this table that some of the factors did appear to be Gender related in terms of how the students were distributed across the different categories involved.

By combining Gender with each of the factors, the resulting sub-groups were examined using Mann-Whitney as before, for each of the exams.

Although there was a significant difference in the distribution of Standard and Non-Standard chemistry qualification by Gender, there was no significant difference between any of the sub-groups in any exam, except at the 10 % level between Females with Standard and Non-Standard Entry in the January exam. This may be due to the Non-

Standard students experiencing a little difficulty with the weight of new material presented in Term 1.

Male Introverts performed significantly differently from Male Extraverts, Female Extraverts and the Female mid I/E group at the 5 % level, and Female Introverts at the 10 % level in the January exam. This is broadly in line with the general findings discussed in Chapter Four. No other exam shows any difference with these factors.

Female Neurotics differed from the Female mid S/N group at the 10 % level in the April exam, the only result for this Personality Type.

Field Dependency, however, shows much more consistent differences between sub-groups over all of the exams. In January, Male Field Independents show a difference in results when compared to both Male mid FD/FI and Female Field Independent students, at the 5 % level in each case. These same pairings occur again in April (at the 1 % and 10 % level respectively) and in June (at 5 % for both). Inspection of the data shows the Male Field Independents as being the better performers in each case.

The Female Field Dependents differed from the Male mid FD/FI (1 % level), the Female mid FD/FI (10 % level) and the Female Field Independents (5 % level) in April. In June two of these results, Female Field Dependents compared to Male mid FD/FI and compared to Female Field Independents were significant at the 5 % and 1 % respectively. In each case, inspection revealed the Female Field Dependents to be the better performers, which seemed unusual in light of previous work (Chapter Two).

The general indication from the analysis is that Field Independence is slightly more conducive to better exam results in Males, whereas Field Dependence has a similar effect in Females.

Neither Perry Position nor Maths Qualification showed any significant differences between their relative sub-groups in any of the exams.

5.10 Conclusions

Having established a successful course in Year One, which met all of the demands made of it, General Chemistry-1 Year Two was very much a consolidatory year with little having been changed. The numbers of students allowed into the class was increased; the composition of the class changed slightly with an increase in Non-Standard Entry Students.

Only minor modifications of the support material devised for the course were required, which meant that the design side of the researcher's work was dramatically reduced. Similarly, the researcher's own investigations into students' attitudes towards the course was dropped, as Year One attitudes had been so universal and strong. The departmental student questionnaires showed responses clearly in line with those from the initial year, with the support materials used scoring highly in appreciation. In this respect Year Two would seem to have maintained the successes of Year One.

The key finding of Year One's work had been that the course was (largely) "qualification-proof" with respect to an individual's chemistry and maths entrance qualifications. It was important to continue to monitor this during Year Two to see if this trend was continued or simply a one-off event.

Both Class Exams generally showed the patterns established in the previous year. The January exam showed a few significant results in maths qualifications, as in Year One (i.e. differences in comparisons involving the Modular students – different to both Standard Entry and Access groups at the 5 % level in each case). It is still not clear why this should be the case, as the level of maths content of the first Class Exam is not particularly high, unless as proposed in Chapter Three it is the moles calculations which cause this problem. As in Year One, the chemistry qualifications showed no differences between the sub-groups. It is worth noting that the change of lecture staff in this term did not appear to affect results, suggesting the course did have a degree of independence from the staff teaching it.

April's exam showed a number of significant results, but most of these involved students with an Access background – a group excluded from last year's analysis due to the small number of students. In Year Two, Access chemists had results that differed from those with Standard Entry, Standard Grade and those with no qualifications at the 10 %, 5 % and 5 % levels respectively. This is likely to have contributed to the difference between Standard Entry and Non-Standard Entry being significant at the 5 % level, which was not the case in Year One. Similarly, Access mathematicians were significantly different from modular students (0.1 %), Standard Entry (1 %) and Standard Grade (1 %). Modular students also differed from Standard Entry at the 5 % level. These results were undoubtedly due to the higher maths demands of the physical chemistry material examined in April.

Unlike Year One, results for June's Degree Exam were available and the analysis repeated. Yet again the same trends emerged: chemistry qualifications showed no differences and maths qualifications showed the same significant results as April, but at lower levels of significance (the modular group different to Standard Entry [10 %]; Access different to modules [1 %], Standard Entry [5 %] and Standard Grade [5 %]). This is probably due to the maths content which would cover similar topics to the second Class Exam, but take up less of the paper.

Although there are clear, significant results (in particular involving the Access students and the very high performances they achieved), the trends of Year One generally resurface. As before some of those enrolling with the "strongest" entrance qualifications passed, and some failed; equally some of those with the "weakest" entrance qualifications passed, and some failed. As before, a student's ultimate fate in the class could not be predicted on the basis of their entrance qualifications alone. Again Year Two maintains the standards set by Year One.

This year Chemistry-1 exam results were investigated to ascertain if the results in that course followed the same, or similar, pattern to that of its sister class. All of the exams, both Class and Degree, showed very strong results for each of the qualification sub-group. Virtually every comparison made showed a statistically significant difference between the results involved, frequently at the 0.01 % level – very highly significant indeed.

The analysis clearly supports the hypothesis that the standard of a student's entrance qualification influences that individual's exam success in Chemistry-1. This is the converse of the findings for Gen Chem. The pattern observed is quite clear and very different to that in Gen Chem.

In an attempt to discover any other influences which may effect student performance in Gen Chem, the researcher investigated a variety of factors. No single factor consistently emerged in each exam (except the difference between Field Dependent and the mid FD/FI group in two exams). Figure 4.1 can be redrawn for each of the exams (Figures 5.8, 5.9 and 5.10), where the thickness of the line connecting the factor to exam results is related to its level of statistical significance:

Figure 5.8 Individual Factors Influencing January 1995 Class Exam

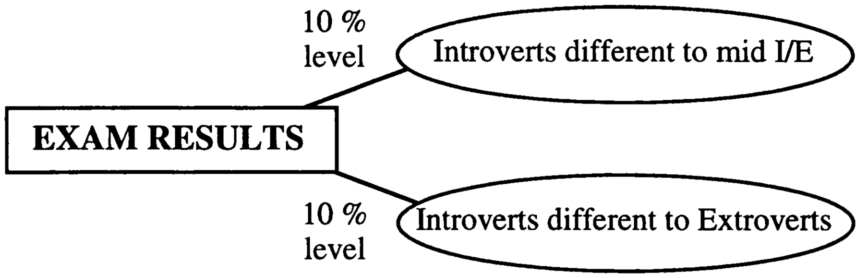


Figure 5.9 Individual Factors Influencing April 1995 Class Exam

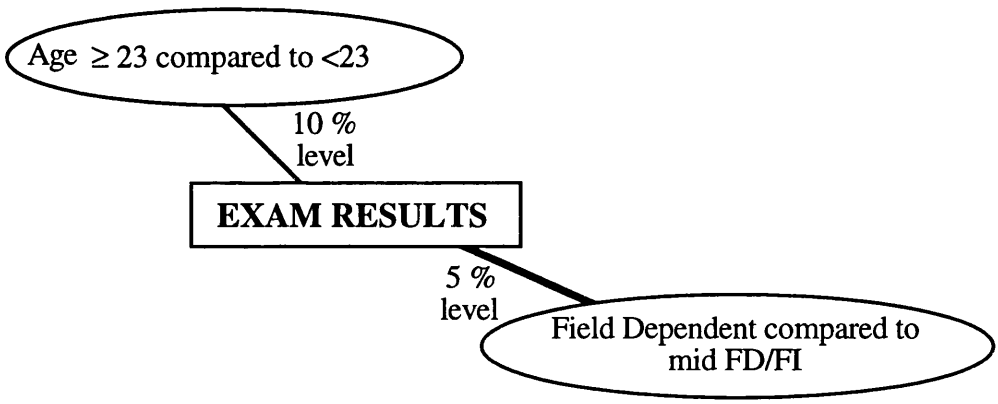
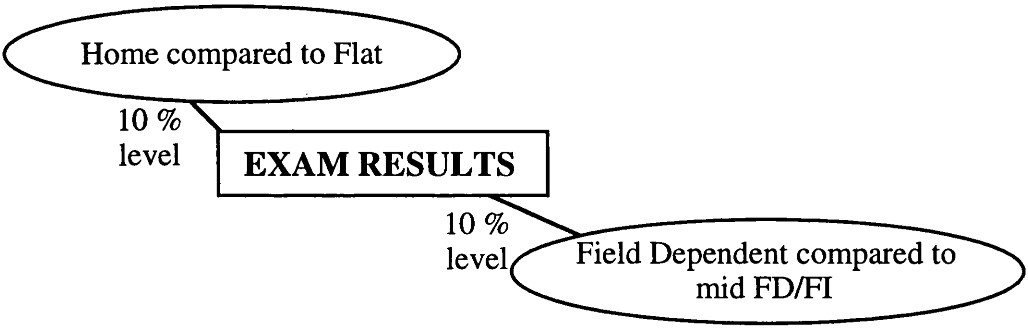


Figure 5.10 Individual Factors Influencing June 1995 Degree Exam



The apparent "lack of consistency" of factors from exam to exam is perhaps not too surprising, if a little disappointing. Different parts of the curriculum, which may well require different skills and hence be influenced by different factors, were examined in each Class Exam. However, the appearance of a Field Dependency difference in both exams with maths content is consistent with previous work (Chapter Two) which linked this factor to such problem solving material. The levels of significance observed were also perhaps disappointing, being similar in magnitude to the those observed for differences in exam results due to different qualifications.

Combing Gender with the other factors showed that there was a link between it and the distribution of the students over the various sub-groups of most of the factors. It was already noted that Female students were generally better qualified than their Male counterparts on entrance to the class and this is reflected in the results. Similarly the difference in Neuroticism is unsurprising given previous research into Personality (Eysenck and Eysenck, 1987). The link between Gender and Perry Position, although only at the 10 % level, is interesting and would suggest that this may be worthy of further research in its own right.

Results from combining the factors could be summarised thus (Figures 5.11, 5.12, 5.13):

Figure 5.11 Combined Factors Influencing January 1995 Class Exam

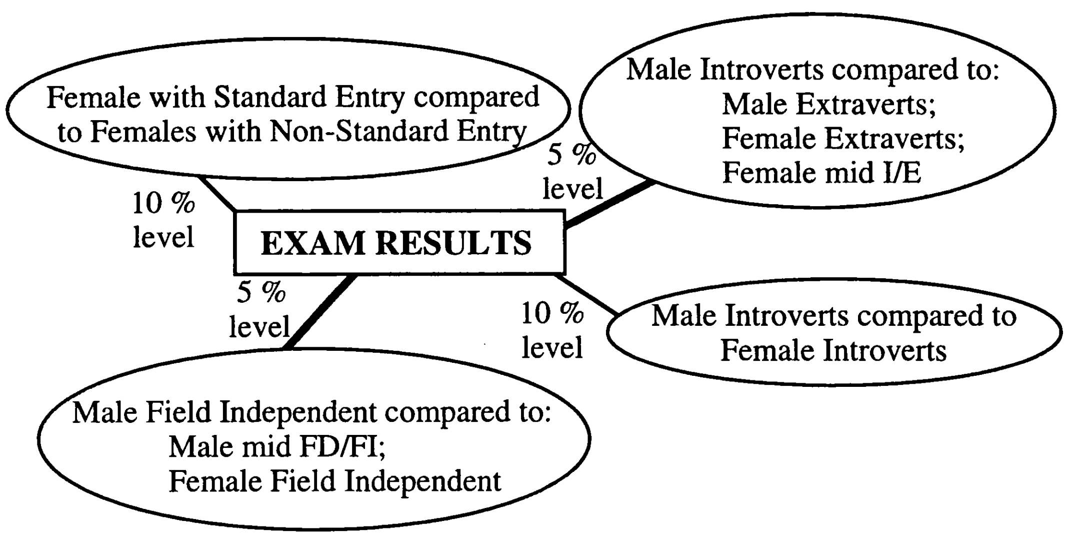


Figure 5.12 Combined Factors Influencing April 1995 Class Exam

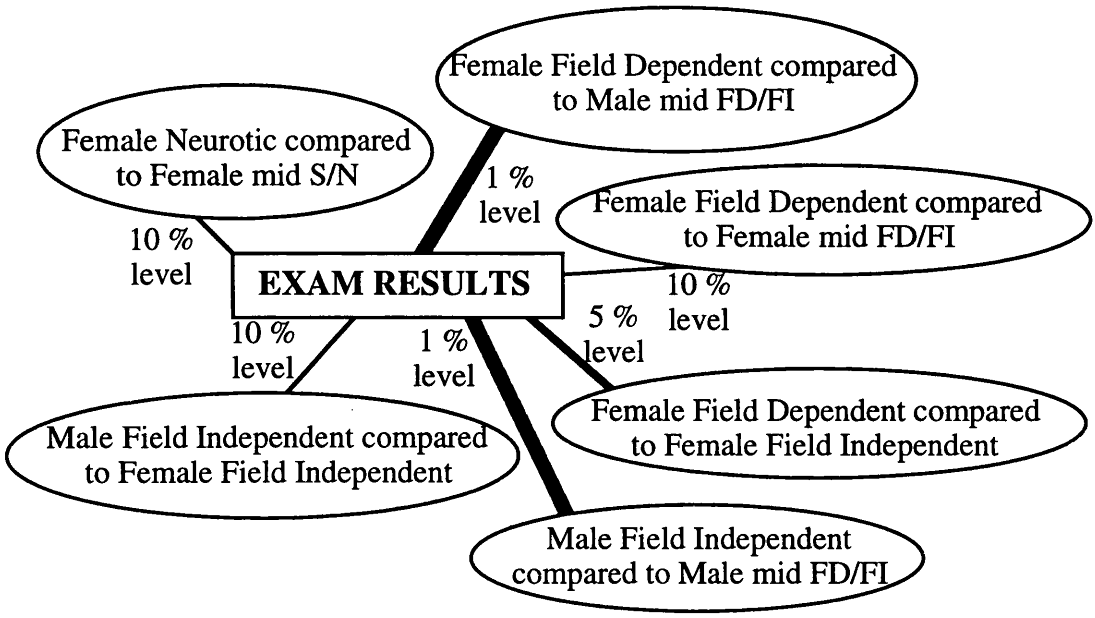
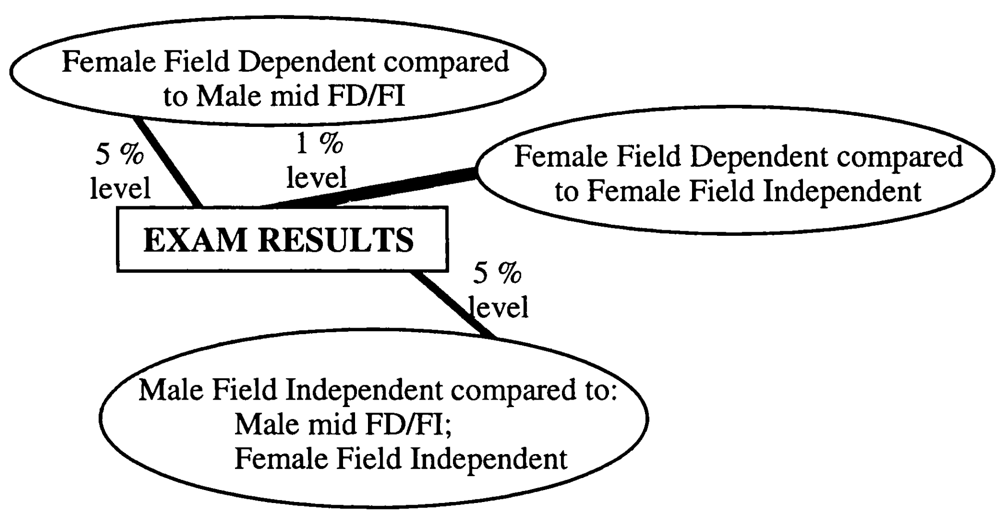


Figure 5.13 Combined Factors Influencing June 1995 Degree Exam



Only Field Dependency occurs from exam to exam again, whilst other factors vary. Given the Gender differences in Qualification it is understandable that there is an appearance of Chemistry Qualifications in January, when the less experienced students would be faced with a wave of new material to be assimilated (and later built on).

Chapter Six

General Chemistry-1: Year Three

6.1 Introduction

No educational course exists in reality in quite the way its designer(s) intended. "Real life" will undoubtedly intrude to a greater or lesser degree. In this regard General Chemistry-1 was no different.

Following on from a year of (relative) stability, Year Three of the course's existence (academic year 1995-96) was to be a year of change which would affect the whole Faculty of Science. A Faculty Working Party recommended the adoption of a system of sub-dividing Level-1 and -2 courses into a number of "units" with related "Student Learning Hours" (SLH). The Working Perty also recommended that the number of Class Examinations reduced from two to one.

The key effects of these proposals would be to:

- reduce the number of contact hours between staff and students
- reduce exam marking work load
- move towards a model of "continuous" assessment – i.e. one in which the class exams and diagnostic tests would contribute towards the final grading
- lead to the loss of the Exemption system
- shift the emphasis of responsibility for study further towards the students

It is interesting to note how some of these proposals (i.e. the model of assessment, the loss of the exemption system, and an attempt to make students more autonomous) are in spirit to those that formed Gen Chem-1.

6.2 Details of Course Changes

Level-1 courses, such as Chem-1 and Gen Chem, would be made up of some 400 Student Learning Hours where one lecture (workshop or tutorial) would be worth 4 SLH, as would one 3 hour laboratory session. The SLH would include the private study required by a lecture, such as preparation for a topic and revision. It was suggested that testing material could be employed to evaluate such pre-reading.

Again the Pre-Lecture concept originated for Gen Chem appeared to be mirrored, albeit less formally, in the thinking of others. Ironically, Year Three would see Pre-Lects dropped from Gen Chem as part of the squeeze on lectures (see below).

6.2.1 Assessment Procedures

One problem faced Faculty wide was that of Class Exam time-tabling. The Mathematics Department, for example, tended to have its first Class Exam just after mid-way through Term 1, whereas the Chemistry Department waited until early in Term 2. In large Level-1 Classes (Maths, Chemistry, Biology, Psychology) this had a knock-on effect of high absenteeism from one course when the Class Exam of another occurred.

To combat this it was proposed to move all Class Exams to a one or two week period during Term 2, at the end of a 12 week "teaching block" which would consist of Term 1 and the first 2 weeks of the second term.

Chem-1 intended to meet the changes in assessment by introducing regular tests into the course. The results of these tests would form part of a continuous assessment procedure which would generate a final grade for each student made up of 10 % from Laboratory work, 30 % from the Class Exam, 10 % from the tests and the remaining 50 % from the June Degree Exam. The content of the Degree Exam would be adjusted to take into consideration the contribution of Term 1 material in the Class Exam, ensuring parity of coverage of all aspects of the course.

Again these were key ideas from Gen Chem being transferred to another course. It appeared that one of the statements used by the Design Team to facilitate the Ten Commandments had been realised (Chapter 3.2):

> To achieve changes the whole structure and ethos of the course must be designed as to change the rules of the game so that... teachers... learn the new rules and are convinced of their rightness.

General Chemistry-1 would also move to this model of assessment, with what had been until then intentionally optional diagnostic tests becoming compulsory. It was hoped such a move would encourage better attendance of the tests and foster study habits, as poor performance in tests may adversely effect a student's final grading. A poor performance in the original diagnostic tests could allow a student to uncover and remedy weaknesses without penalty, however the new arrangements would remove that safety net.

6.2.2 Lectures and Workshops

Both Chemistry classes would adopt a "four-day week" essentially – three lectures plus a workshop, as opposed to four lectures and a workshop. Naturally this loss of lecture time would mean a loss of content. This was more severe in Chem-1 than Gen Chem, which was already a slimmer course. However, one of the casualties of the cuts, as mentioned earlier, was the loss of the Pre-Lect sessions.

The Pre-Lects had generally been found to be liked by students, but their lack of frequency, coupled with their tendency to come early in the course undoubtedly led to most students did not understand the special purpose of them. As the students involved are new to university they cannot identify Pre-Lects as novel and unusual as they have no previous experience allowing them to realise this. Although only anecdotal, the author was of the opinion that Pre-Lects in practice tried to be the proverbial "all things to all men". The gulf between most and least experienced in Gen Chem was, of course, quite wide meaning that in some cases Pre-Lects would identify many gaps in knowledge. Having identified these gaps, there was little time left in a Pre-Lect session and no formal extra material to help bridge them. The author feels that Pre-Lects may be more successful in courses where the students are from a similar background (e.g. Chem-1, Chem-2 or above) and/or support material designed to address problems identified is available. Another potential problem, which may have been solved by careful writing, was a lack of focus in the Pre-Lects when compared to Vianna's Pre-Labs. A Pre-Lab has the aim of preparing a student for a single 3 hour lab, whereas a Pre-Lect may cover material that will be delivered in several lectures, spread over a number of days. All of the problems described would seem worthy of attention in future years.

6.2.3 Entrance Policy

The Chemistry Department proposals for Gen Chem retained the central tenet that the course should be "...both *demanding* and *achievable* for all students, including those with a poor, or non-existent, chemical background". Indeed, departmental recommendations on entry became more vague – simply stating the course was intended "for students having a range of previous knowledge of chemistry, from... no.. previous experience, to... some Higher Grade...".

Chemistry-1 was now intended for those with Higher Grade B or better, as the department felt there had been poor performance from Higher Grade C students in previous years (as shown in Table 5.17). The Higher C group would now be directed towards Gen Chem, unless they expressed a strong desire to continue with chemistry, or one of the few subjects which did not accept Gen Chem in lieu of Chem-1. It would still be possible, of course, for those who did well enough (and wished to do so) to move to Chem-2 from Gen Chem.

6.3 Year Three Research Aims

This year it was decided to continue to probe the examination results of both chemistry classes to check if the observed patterns were repeated.

Chemistry-1's results would be of particular interest to see if the "Gen Chem style" alterations made to the course would change the clear link between entrance qualifications and exam success established previously (Table 5.17).

6.4 Breakdown of Class Compositions

Unlike the previous years, the researcher was only supplied with the numbers and entry qualifications of each group of students at the time of the final Degree Exam rather than for the start of the year. Another difference from earlier work was the lack of information on Maths qualifications.

Table 6.1 Breakdown of General Chemistry-1 (1995-96) Chemistry Entrance Qualifications as of June 1996

Chemistry Qualification	CSYS	Higher Grade	Standard Grade	Modules	Access	None	other
Class (% of 144)	5 (3.5)	67 (46.5)	32 (22.2)	3 (2.1)	15 (10.4)	14 (9.7)	8 (5.6)

From comparison with the previous two classes (Tables 3.3 and 5.1) it is clear that the most noticeable change is that the numbers of students with modular qualifications has decreased, while the numbers with Standard Grade has increased.

Table 6.2 Breakdown of Chemistry-1 (1995-96) Chemistry Entrance Qualifications as of June 1996

Chemistry Qualification	Higher Grade	CSYS	A Level	other
Class (% of 490)	197 (40.2)	207 (42.2)	62 (12.7)	24 (4.9)

This year's Chem-1 saw a reduction in those with Higher Grade and other qualifications, due to many of the Higher Grade Cs being moved into Gen Chem (see Table 5.12)

6.5 Examination Results

Unlike previous years it was not possible to access the required data, hence restricted results are discussed in this section.

6.5.1 General Chemistry-1 Exam Results

Data to allow a repeat of the analyses carried out in Chapters Three and Five were not available – namely the entrance qualifications of each student to allow histograms for each cohort to be plotted.

The only comparison to previous years' Class Exams possible, was to compare the general distribution of the Year Three Class with those of before. In this case there was no significant difference when compared to Year Two (χ^2 = 18.34; 16 d.f.) or Year One (χ^2 = 16.59; 14 d.f.), indicating that the general distribution of the class had been maintained.

The final grades awarded to students, broken down by entrance qualification were available:

Table 6.3 Final Grades Achieved in General Chemistry-1 1995/96 According to Chemistry Entrance Qualifications

	General Chemistry-1 Grade						
Entrance Qual.	**A**	**B**	**C**	**D**	**F**	**G**	**NT**
CSYS	0	0	3	0	1	1	0
Higher Grade	6	12	28	6	7	6	2
Standard Grade	1	4	7	6	4	10	0
Access	0	1	5	1	2	6	0
None	0	1	3	3	3	3	1
other	0	0	1	1	2	2	2

By grouping the students into Standard and Non-Standard Entry Qualifications, and Pass (A, B, C, D) and Fail (F, G, NT) Grades, it was possible to use *chi*-square to analyse the results. In this case there was a significant difference between the Qualification groups at the 0.5 % level (χ^2 = 10.78; 1 d.f.). This would appear to have been caused by a particularly good performance by the Standard Entry group (of which less than a quarter failed) and a mediocre one from those with Non-Standard Entry (half of which failed).

Although this was the only comparison possible, given the data, it is worrying that the proportion of Non-Standard Entry students failing increased, considering the results of previous work. For example, in Year One (1993-94) a third of the Non-Standard Entry failed, with just under a third of the Standard Entry failed.

It seemed unlikely that the loss of the Pre-Lects had been the sole cause of this. Two potential influences which may have been the more probable causes were the use of test scores in creating a final grade, and the reduction in the number of lectures.

The Non-Standard Entry students were likely to perform badly in tests at the start of the course (compared to Standard Entry students) and this would be seen in the final assessment In the previous two years poor test performance did not affect the final grade. Without information on the students' entrance qualifications it is impossible to investigate how much of an effect test scores had on grades. As mentioned earlier, poor performance in tests (by the least experienced) may discriminate against this group, although test scores accounted for only up to 10 % of the final grade.

The reduction in the number of lectures may well have had the bigger effect, however. In documentation describing the changes made to the course, the Chemistry Department claimed that there was a "...significant feeling amongst the lecturing staff that we presently 'over lecture' to the class; hence such a proposal [reducing the number of lectures] would be of some pedagogical benefit". Why this should be the case is not clear – a reduction in lecture time would undoubtedly lead to a "speeding-up" of delivery of the material, even in an already lighter course such as Gen Chem. This increased rate of delivery of material may mean the less experienced students did not have sufficient time to assimilate the course (which may in turn lead to poor test performances and hence effect the final grade).

6.5.2 Chemistry-1 Exam Results

In contrast, a full analysis of Chem-1's Class Exam was possible and the exam scores of each qualification grouping are displayed in a series of histograms in Appendix N.

Inspection of graphs M2 and N2 shows the distribution has shifted to the right, and indeed this caused a difference at the 5 % level between the two (χ^2 = 32.85; 20 d.f.). This was probably due to two factors which were different in the '95-'96 class to the '94-'95 class. Firstly the composition of the class had changed with an increase in the number of CSYS students and a decrease in the number of Higher students. Since the standard of entry qualification is related to exam success, removing less qualified students, who are likely to be the weaker performers, will change the appearance of the distribution observed. A second, more subtle change was in the material covered in the class exam, which had traditionally been inorganic and physical chemistry topics. In an effort to give students a positive feeling towards the Class Exam, some of the organic chemistry (which was felt to be seen as generally more popular and approachable by students) was moved into Term 1, and hence covered in the exam. If students did indeed find organic material easier then this may also contribute to the changed distribution.

As there had been a difference in the general distribution, the underlying distributions of each grouping were examined using the Mann-Whitney test as before. Again the hypothesis being tested was that the standard of entry qualification was linked to exam success. There was a difference at the 0.01 % level between those with CSYS and those with Higher (Graphs N3 and N4), as there had been the year before. Table 6.4 contains the results of the other analyses (see Graphs N5 to N10).

The results were as striking as (indeed, virtually identical to) those described in Chapter Five – there was clear (general) support for the hypothesis that the standard of entrance qualification is linked to a student's exam success in Chemistry-1. Just as General Chemistry-1 showed strong trends over Year One and Year Two, so does Chemistry-1 in 1995 and 1996's Class Exam: The pattern of results for the 1995 class Exam (see Figure 5.4) could equally well apply the 1996 Class Exam results.

Table 6.4 Results of Analysis of Difference in Chemistry-1 1996 Class Examination Performance Based on Chemistry Qualification

	Higher B (N = 144)	Higher A	CSYS D	CSYS C	CSYS B
CSYS A (N = 28)	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$
CSYS B (N = 43)	$p \leq 0.0001$	$p \leq 0.045$	$p \leq 0.0001$	$p \leq 0.0002$	
CSYS C (N = 99)	$p \leq 0.0001$	Non-sig.	$p \leq 0.0001$		
CSYS D (N = 27)	Non-sig.	$p \leq 0.0001$			
Higher A (N = 51)	$p \leq 0.0001$				

The changes made to Chemistry-1 may have raised the general standard of the exam's results compared to the previous year, but in terms of ranking the groups of students and discriminating between them there was no difference (comparing Table 6.5 and 5.15).

Table 6.5 Mean Class Examination Marks of Each Qualification Cohort in Order

Cohort (Mean score)	CSYS A (80.9)	CSYS B (68.7)	Higher A (61.5)	CSYS C (58.6)	Higher B (46.3)	CSYS D (45.2)

Unlike Gen Chem, examination results in the revised version of Chem-1 had not become independent of entry qualification. Obviously the author does not lament the fact that very few of those with CSYS failed the course, but it would have been encouraging to see exam performance not being so strongly linked to entrance qualification.

6.6 Conclusions

This year of upheaval in both chemistry classes was, from a researcher's point of view, somewhat disappointing.

As it was not possible to continue to monitor General Chemistry-1 in the manner established earlier, the effects of the alterations made to the course could not be properly evaluated in terms of examination results. One comparison which was made, however, showed a worrying decrease in performance of the Non-Standard Entry students, in relation to previous years.

Despite changes made to Chemistry-1, which it would appear were designed to mimic some of the features of General Chemistry, the patterns described in Chapter Five reappeared this year. Once again there was a very strong link between entrance qualification and exam success.

Chapter Seven

General Conclusions

7.1 Introduction

In this chapter, the work described in this thesis is evaluated in terms of the researcher's role and relevance of the General Chemistry-1 course set out in Chapter One. The key findings of the investigation are restated and considered for potential future work or implications arising. The author also suggests possible reasons behind some of the results.

7.2 A New Kind of Chemistry Course

General Chemistry-1 was conceived against a backdrop of change to both senior secondary schooling in Scotland and the tertiary education sector as a whole.

Higher education has become the destination for an ever increasing number of young people leaving school, as well as adults returning to formal education following (in some cases) years away from it. Glasgow, just like every other university in Britain, has had to accommodate this rise in student numbers in the face of increasing pressure on funding and calls for increased quality in education generally.

With this rise in the number of students has come a change in the qualifications and experience those entrants have. The days of a Glasgow lecturer (in, say, chemistry) facing a class made up solely of those with good Scottish Higher Grade and Certificate of Sixth Year Studies passes are over, and, it would seem, are unlikly to return.

The creation of Access courses and SCOTVEC modules, amongst others, have produced tertiary students with widely varying educational backgrounds and academic achievements. This variety must be offered a tertiary education system which can accommodate it. This problem will become even more of a consideration in the light of the impending changes facing secondary schools under the Higher Still proposals.

Another problem, shared by chemistry and a few other subjects, is its dual role as a central support to other fields of study as well as a popular subject in its own right. Indeed, chemistry was one of the largest Level-1 classes at the University of Glasgow, and physical constraints (the size of lecture theatres and laboratories!) were beginning to become too restrictive on the "public demand" that existed for the subject.

Despite being a prerequisite for many other courses, chemistry may not be the major strength of those intending to follow such courses. Some students may not have studied chemistry before.

It became clear to members of the staff in Glasgow's Chemistry Department that the current Chemistry-1 may not be the ideal vehicle to take its teaching into the 21st Century. There was some concern that the students from "non-traditional" backgrounds were being somewhat unfairly treated by Chemistry-1's content and approach, as well as concern at the increasing staff time that was required in extra tutorials to compensate for its shortfalls.

The solution, as these lecturers saw it, lay in a second chemistry course – General Chemistry-1 – which would:

- reduce student numbers in Chemistry-1;
- give a realistic, achievable goal for the less qualified students to aim for;
- not lower academic standards too far and so compromise the integrity of the course.

In an unusual step, a team of lecturers designed the course together. The team was guided in their task by a set of educational principles (later christened The Ten Commandments), as well as their by own experiences.

The Ten Commandments were based on the research of Glasgow's Centre for Science Education and other related research. The Centre's long history covered research in many aspects of science education in general, as well as many projects focusing on chemistry alone. In many ways, The Ten Commandments and General Chemistry-1 are a pooling of sound theoretical ideas and good practical teaching arising from this body of work.

Using the Commandments the team also hoped to affect the attitudes of both staff and students towards their respective roles. From the ten principles came:

- a system of continuous assessment;
- diagnostic testing;
- Pre-Lecture sessions;
- Revised Workshop exercises;
- Support material handouts covering areas of traditional problems.

7.3 General Chemistry-1 in Practice

Beginning in 1993, General Chemistry-1 had much to prove in terms of student attitudes towards it and its applicability for the wide ability range it aimed to cater for.

This research project, running over the first three years of Gen Chem's existence, would initially form an integral part of the production and later evaluation of support materials called upon by the Design Team's specifications. By allowing a researcher to essentially "sit inside" the course it was felt a clearer picture of how the students dealt with it would be revealed. This would form the second strand of the author's work, using specially devised, as well as internal Chemistry Department, surveys.

Studying the relationship between the students' entry qualifications and their examination results was another key area of interest. This was expanded to cover an investigation into other possible factors which might influence exam success in some way.

7.3.1 General Chemistry and Student Attitudes

The Chemistry Department, like many others within the University of Glasgow, used internal questionnaires to ascertain student opinion of its courses. Usually information on students' opinion of a lecturer's performance, or a laboratory course was sought as a feedback mechanism for refining Departmental policy.

The results of the questionnaires were displayed publicly, and hence were readily available to the author. Responses from the first two years of the course showed very strong, positive opinions towards it across most of the areas polled. There was also good general agreement between both years.

In Year One, Departmental investigation was supplemented by the researcher's own questionnaire, and a series of interviews with a representative sample of students. Yet again there was strong agreement both within each method and in relation to the other questionnaires, giving positive opinions almost universally.

It was clear that students found the support systems that were integral to the course helpful and welcomed their inclusion. Several students expressed a wish that some of the innovations of Gen Chem could be transferred to their other subjects (e.g. calls for Gen Chem-style Workshops in Biology-1).

7.3.2 General Chemistry and Examination Results

Examinations, sir, are pure humbug from beginning to end. If a man is a gentleman, he knows quite enough, and if he is not a gentleman, whatever he knows is bad for him.

Lord Henry Wotton's uncle, Lord Fermor, from *The Picture of Dorian Gray*, by Oscar Wilde

Although not quite as unequivocal as one of Wilde's characters, the researcher feels there may be a grain of truth in his claim, particularly in so far as the role of the exams by which the students their entrance qualifications to the Gen Chem course. Another set of exams which required some scrutiny was those of the new chemistry course itself. This was especially true given Gen Chem's target market. If the course failed to offer a quality chemistry course in which students from a variety of previous experiences could succeed, then it could be seen to have failed in one of its core objectives.

Over the first two years, examination results from five exams (four Class and one Degree) were analysed in detail to determine if there was any support for the hypothesis that the quality of a student's entrance qualification was directly related to that student's exam performance in the class.

In each of the five cases there was very little evidence to support such a hypothesis, with the vast majority of the comparisons made between the exam results of groups with different entry qualifications showing no significant difference. That this pattern was essentially repeated over two separate year groups gives the researcher confidence that the results represented a genuine feature of the course, rather than some isolated statistical occurence.

The few comparisons over all the exams that did give significant differences between groups were frequently at the 10 % level (i.e. outwith the standard 5 % level traditionally taken as the level of statistical significance), and usually occurred when maths qualifications, rather than chemistry qualifications were considered.

The only results to show a consistent series of much more significant differences involved those who undertook an Access course, prior to university entry. Indeed, this group were seen to outperform those with Standard Entry Qualifications.

Whilst this is probably very gratifying to those who provide Access courses, it is perhaps not too surprising. University entrance and the preparation of people to become students are among the specific aims of Access courses, whereas public, Scottish Examination Board examinations are not designed with this sole consideration.

It was also noticeable that, particularly in Year Two, students with modular qualifications did not perform quite as well as their classmates. This could suggest that such a background can leave students ill-prepared for university.

One possible interpretation of the results that show no difference between those with only Standard Grade and those with Higher Grade, is that Higher Grade has taught these students nothing they did already know at Standard Grade! However, it is perhaps more likely that Gen Chem's content is the cause of such results. It could be that Higher Grade (and Standard Grade) contains an over emphasis on topics which are either omitted or reduced in Gen Chem. This is one possible explanation as to why the extra year of school chemistry does not give those who studied it an advantage over those who didn't.

Unfortunately, Year Three could not be analysed in the same way as the previous two. As this was a year of change it could have been very interesting to ascertain if the class had retained its "qualification-proof" credentials. Worryingly, the one comparison made indicated this was not the case. The researcher believes it is very important that monitoring of Gen Chem's results should be carried out each year to ensure it continues to meet the aims it was designed to meet.

If the changes made in Year Three do mark a change of emphasis in the class, then efforts should be made to identify the cause(s) of the change and, where possible, these causes should be investigated.

7.3.3 General Chemistry, Examination Results and Other Factors

As exam results had proved to be largely independent of entrance qualifications, the search for other factors which may have an effect was instigated. Having decided on the seven other factors which would be tested (Age, Gender, Living Place, Perry Position, Extraversion, Neuroticism and Field Dependency) the collection of student data was carried out during Year Two.

No clear single factor emerged in any of the exams as being linked to a significant difference in results, that was more significant than the few qualification based results. However, Introverts did outperform Extroverts in the January exam, much in line with the general findings for that factor discussed in Chapter Four.

The Field Dependency factor influenced two exams, with good performances by the Field Dependent students being recorded. This would reinforce its place as a key factor established in the work of other researchers as the Centre for Science Education. Whilst it may be slightly surprising that Field Dependents performed better than Field Independents given (for example) the work of Al-Naeme (1991), the actual nature of the exam questions involved probably explains this result. The suggestion that Field Dependency may have different effects depending on Gender is interesting and perhaps worthy of further investigation. Indeed, in combining factors with Gender, Field Dependency appears in each exam.

Although Perry Position did not show any clear link to exam results it remains a useful concept, and the Centre's adaptation of the Perry Scheme lies at the heart of other work currently ongoing. This thesis, together with that other work may lead to refinements of the Centre's model, and improvements in assessing Perry Position. Future research would appear to be required to address such questions as what (if any) limits may exist to impede a student's progress towards Perry C ? Another question of interest, given the Perry Position of students entering university (from work by Gray (1993), Harvey (1994), Hadden and MacGuire (Chapter Four), and this research) would be to explore the changes occurring at the school level, as students entering university appear to be closer to Perry C than might be expected.

One obvious factor (likely to play a part in student success) overlooked by this project, was that of motivation. It sometimes appears that this is a word bandied about frequently as a catch-all term to explain differences in student performances. Whilst that may well be true, it remains an elusive concept to pin down and (more importantly) measure. Whilst schemes of motivation do exist (e.g. Al-Naeme, 1991), the motivation required here is, perhaps, more fundamental – "why are you attending university ?"; "what do you see as your long term goals ?". Such an approach seems almost impossible to "measure" and categorise, and so motivation was not included in the analysis.

7.4 Chemistry-1 and Exam Results

In Gen Chem's second year, the investigation of exam results was extended to Chemistry-1. Once again, the hypothesis under consideration was that the quality of a student's entry qualification was linked to that student's exam performance.

The results of that year's work were quite different to those of Gen Chem, and supported the hypothesis.

The clear link between entrance qualifications and exam results was repeated in 1995-96, despite changes made which appeared to be intended to bring the course closer to Gen Chem in style. This indicated that, just as with the first two years of Gen Chem, the results in Chemistry-1 were sustained and not just a statistical randon event. Whilst it might seem disappointing that when some of Gen Chem's novel features were transferred to Chem-1 there was no measurable change made to the students' exam performances, it is the author's belief that this may have been caused by the changes not going far enough. The changes to Chem-1 seemed largely cosmetic rather than directly affecting the philosophy of the course. For example, by transferring some of the organic chemistry content to Term 1 the Class Exam did not contain inorganic and physical topics only. Students generally regard organic material as a whole more approachable than the other two and so this seemed to have the effect of raising the general standard of marks compared to the previous year. However, the underlying trends of achievement by the various sub-groups remained the same – nothing (except a general improvement of the marks) had changed over the two years.

One possible reason for these results, as mentioned earlier, is that previous schooling was being tested by the exams rather than an understanding of Chem-1. It is perhaps, however, unsurprising that this may be so. Chemistry-1 builds on from school courses and (as the course for "real" chemists) would naturally require a good understanding of early material – hence the better qualified, more experienced student does best.

Again, motivation could be an important part of such a study. Apart from the fundamental questions which were mentioned for Gen Chem, there exists the possibility of a resentment from the students who may be in Chem-1, when they feel Gen Chem is more appropriate for their aspirations. Good school qualifications in a subject do not necessarily equate with high motivation to study that subject further. Perhaps some of the students in Chem-1, most of whom have no intention of continuing with chemistry beyond Level-1, would feel more inclined towards Gen Chem's objectives. This would move Gen Chem entrance policy closer to that originally envisaged by its designers, i.e. open to anyone who wanted it. This would undoubtedly make Gen Chem the larger of the two classes.

An (understandable) concern that the Department appears to have in this regard would be a situation where highly qualified students opt for Gen Chem in the hope of an "easy year", and then transfer to Chem-2. This would seem an unlikely situation, however, as such students should be aware that transferred into Chem-2 from Gen Chem would require some extra work from them to cover necessary material. Another point to consider is that well qualified students appear to be having a fairly "easy" time of it already in Chem-1, without opting for its sister class!

The results suggest more work is required to give less qualified students a more even playing field in Chem-1. Pre-Lectures, with relevant support material to help those with problems, may be more successful than they were in Gen Chem, given the smaller range of qualifications involved.

Another point to consider in light of these results is in future Departmental entrance policy. The changes Higher Still will bring to those entering universities must be evaluated and any problems found addressed. If the new Advanced Higher can maintain the standards of the outgoing CSYS, then results such as those described here would lend weight to the suggestion that those holding such qualifications should be considered for direct entry to Level-2 courses. CSYS Grade A and B do not appear to be really challenged by the Chem-1 course, but to raise its standards any further would unquestionably put the course beyond the scope of many of those with Higher Grade.

7.5 Final Conclusions

General Chemistry-1 achieved all of the goals set for it by its designers in its first two years of existence:

- it was a popular course;
- it did not lower the tandard of the chemistry standards unacceptable (and so was accepted in place of Chemistry-1 for most Level-2 subjects);
- it did offer a realistic goal for students to achieve, regardless of their entrance qualifications

It gives a model which could be used to deal with the problem of students with less than standard entry qualifications and, indeed, calls into question the reliance on school qualifications as a predictor of future university success.

The Ten Commandments and Design Team approach created a quality course, and such an approach could be replicated in other courses in the University of Glasgow and beyond.

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Appendix A

Examples of Pre-Lecture Exercises

General Chemistry 1
Periodic Table, Pre-lecture 1

States of Matter

1) What physical properties would you use to define:
   a) a solid b) a liquid c) a gas

Mixtures, Pure Substances, Compounds and Elements. Homogeneous or Heterogeneous?

2) How would you explain the difference between elements and compounds ?
3) Arrange the following under the headings "elements", "compounds" and "mixtures":

ink	mercury	air	battery acid
ice	carbon	fruit cake	sugar
lithium metal	vodka	table salt	gold

4) In your own words, explain the terms *homogeneous* and *heterogeneous.* Go through the substances in 3), above, and decided which mixtures are homogeneous and which are heterogeneous.

Physical and Chemical Changes

5) Which of the following are *chemical changes* and which are *physical changes*?

rusting of iron	melting of aluminium	cooking a steak
digesting sugar	crushing rocks	burning a cigarette
evaporation of water	souring of milk	

Symbols for the Elements

6) Give the chemical symbol for each of the following elements:
   a) carbon c) bromine e) copper g) iron
   b) oxygen d) magnesium f) sodium h) tin
7) Name of the elements represented by the following symbols:
   a) H c) Si e) Zn g) Pb
   b) P d) Co f) K h) Hg

General Chemistry 1
States Of Matter, Pre-lecture 1

A Model Of Matter

1) The eminent Professor of Chemistry at the University Of Gallifrey is examining gases. To this end he has filled a balloon with hydrogen and another with air.
He observes that both balloons deflate over a period of time, but that the hydrogen filled balloon goes down faster.
Explain why:
   a) the hydrogen filled balloon goes down faster
   b) both balloons go down
Do you think the Professor's observations would be the same for a balloon of H_2 in a room with an atmosphere of H_2 ?
2) What is the relative spacing of the particles in a solid, a liquid and a gas ?
   A. 1:2:7   B. 1:2:10   C. 1:1:10   D. none of these
3) It has been decided that a scale model of a gas will be built to show the public what a gas looks like at the molecular level. You have been given this task and have decided to use snooker balls to represent the particles in the gas. If you place the first ball on the bench at the front on the lecture theatre, where would you place the *next* ball (approximately) ?
4) Explain what is meant by the *pressure* of a gas.

Units and Unit Cancellation

5) Which SI (i.e. metric) units (e.g. km, mm, µm, etc.) would be appropriate to use in the following measurements ?
   a) distance between Glasgow and London   b) the length of an ant
   c) the thickness of a hair   d) your height
   e) the length of the lecture theatre
   f) the distance between two nitrogen atoms in N_2.
6) Given the data on the back page, work out conversion factors for the following units:
   a) days to seconds   b) atomic mass units (amu) to kilograms
   c) inches^3 to litres   d) km to miles
7) Use your answers from 6) in the following problems:
   a) The mass of a carbon atom is 12.00 amu. What is this in kilograms ?
   b) You are driving down a stretch of American highway and spot a sign

indicating a speed limit of 40 km/hr. Unfortunately your car's speedometer only gives readings in miles/hr! You are travelling at 30 miles/hr - should you watch out for speed cops ?

The Mole Revisited!

8) Consider 1 mole of Na_2SO_4.
   a) How many moles of sodium *ions* are present ?
   b) How many moles of sulphate *ions* are present ?
   c) What is the mass of one mole ?

9) As an expert in environmental chemistry you have been asked to examine the work of Grayco™ Chemicals Ltd.
One of the industrial processes carried out at this plant is the thermal decomposition of sodium bicarbonate to give sodium carbonate:

$$2\ NaHCO_3 \dashrightarrow Na_2CO_3 + H_2O + CO_2$$

New Governmental guidelines insist that emissions of "Green-house Gases", such as CO_2, must not exceed 15 tonnes per month. Grayco™ figures show they produce 21 tonnes of Na_2CO_3 per month.
Are their CO_2 emissions within the guidelines ?

Conversion Factor Data:

1 hour	**=**	**3600 seconds (s)**
1 atomic mass unit (amu)	**=**	**1.66054 x 10^{-24} grams (g)**
1 litre (L)	**=**	**10^{-3} metres^3 (m^3)**
1 inch^3 (in.^{3})	**=**	**16.4 centimetres^3 (cm^3)**
1 metre (m)	**=**	**1.0936 yards (yd)**
1 mile	**=**	**1760.04 yards (yd)**
1 centimetre^3 (cm^3)	**=**	**1 millilitre (mL)**

Relative Atomic Masses

carbon	**=**	**12**
hydrogen	**=**	**1**
oxygen	**=**	**16**
sodium	**=**	**23**
sulphur	**=**	**32**

General Chemistry-1
Chemical Kinetics & Equilibrium, Prelect Test

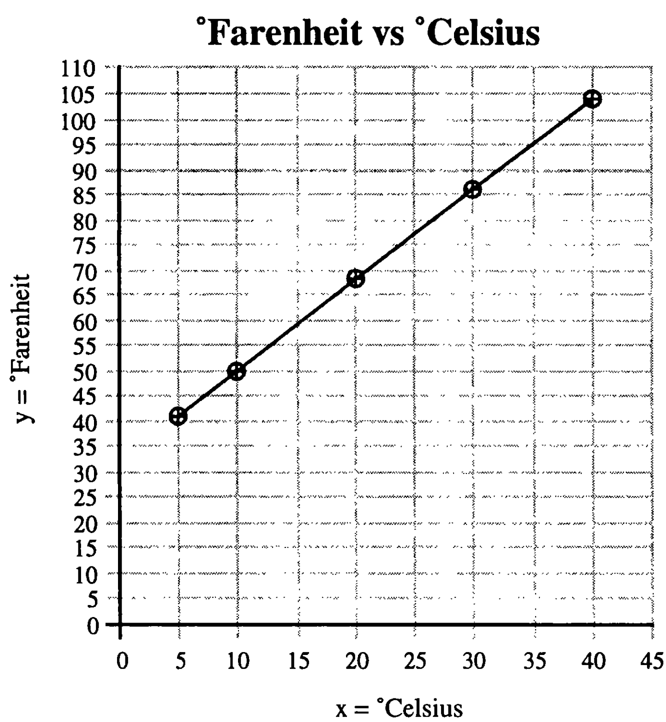
Part One – Graphs

1) Temperatures can be measured in °Celsius (°C) or °Fahrenheit (°F). You could explore the relationship between these two units experimentally using differently calibrated thermometers. You might obtain the following data:

Fahrenheit (°F)	41	50	68	86	104
Celsius (°C)	5	10	20	30	40

You would then be able to convert between the two either **graphically** or **numerically**.

Plotted on a graph, the linear relationship between °C and °F can be seen:



Use the graph above for the following questions

a) Interpolation: from the graph what is
   i) 25 °C in °F ?
   ii) 80 °F in °C ?
b) Extrapolation: What is 0 °C in °F ?

If you know the equation of this line, $y = mx + c$, then you could use this to convert from °C to °F.

c) From the data provided, calculate the gradient, m, of the line

d) Work out the value of c. What is the equation of this line ?

e) Using this equation find out what the temperature in °F will be at:

i) 62 °C ?

ii) 25 °C ?

iii) –35 °C ?

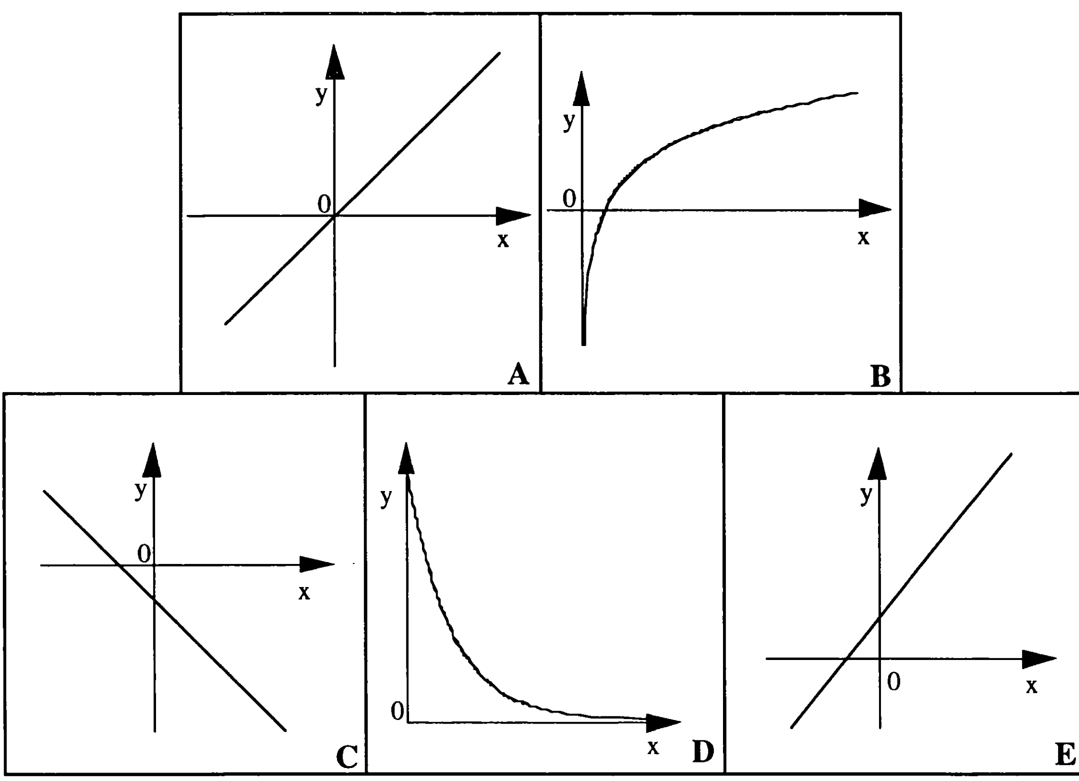
f) Rearrange the equation to make °C the subject. What will the temperature be, in °C at:

i) 0 °F ?

ii) 80 °F ?

Compare you answers in e) ii) and f) ii) with those you obtained directly from the graph in a) above.

2) The grid below shows sketches of various different graph shapes. Using the equations listed, match the equation to its graph shape. Note: there may be more than one possible answer !



a) $y = mx + c$ b) $y = e^{-x}$ c) $y = mx$ d) $y = \ln x$

Part Two – Using Calculators & Logarithms

3) Use your calculator to work out the following:

a) $3.6 \times 10^5 + 7.9 \times 10^8 = ?$

b) $5.22 \times 10^4 - 3.21 \times 10^{-2} = ?$

c) $(5.4 \times 10^2) \times (2.1 \times 10^3) = ?$

d) $(1.2 \times 10^5) \times (3.22 \times 10^{-3}) = ?$

e) $(1.2 \times 10^5) \div (3.22 \times 10^{-3}) = ?$

f) $(1.2 \times 10^{-5})^3 = ?$

g) $\sqrt[3]{2.5 \times 10^6} = ?$

4) In "Improve Your Basic Mathematics", you were told that (in general) if $x^n = a$, then the logarithm of a (to the base x) equals n. (i.e. $\log_x a = n$)

For natural logarithms the base is e ($e = 2.7183$), so, if $e^n = a$, then $\ln a = n$.

Using your calculator, work out the natural logarithm (ln) of the following:

a) 1

b) 16

c) 1×10^5

d) 6.3×10^{-2}

Using your calculator, work out the *anti*log (e^x) of the following:

a) 1

b) 10

c) 11.513

d) –5.9

5) In this term you will meet equations involving ln and e. You must be able to rearrange these equations. Here are two examples:

a) if $A = -BC \ln D$, rearrange this to give "D = "

b) if $A = B\, e^{-C/X}$, rearrange this to give "C ="

You will need these skills to rearrange $\Delta G° = -RT \ln K$ and $k = A\, e^{-Ea/RT}$, two of the equations you will meet later in this course.

Appendix B
Example of Support Material

BLUFFER'S GUIDE TO THE MOLE

Bluff your way in labs and problem sessions*

Sound like you really know what you're talking about*

Pretend you understood that last lecture*

Maybe even pass General Chemistry-1 exams*

* these claims are made without guarantee of their truthfulness, and may, indeed, be false

Unit 1 – What is the Mole ?

We often use **collective words** for things rather than an actual number. For example, we talk about:

- a **dozen** eggs (12 eggs)
- a **score** of oranges (20 oranges)
- a **gross** of pencils (144 pencils)

In Chemistry, we are dealing with **very** small particles, and so with very large numbers of them. In one teaspoonful of water, for example, there are more than one hundred million, million, million particles (molecules) !

To handle these big numbers we use a collective word, the **mole** (equal to about 6×10^{23} particles) that is about 600, 000,000,000,000, 000,000, 000 (that's six hundred thousand million, million, million) ! To avoid such a big mouthful each time, we call this number a **mole**.

The mole is seen to be a counting unit as in a dozen, a score, or a gross. But it differs from the other units because of its sheer size. ***Remember:*** *1 mole = 6×10^{23} particles*

You are no doubt wondering why we would use such a strange number as 6×10^{23} - no it wasn't chosen out of a hat !

6×10^{23} - "I am not a number - I am a free mole"

If you pay some coins into a **bank**, you will find the bank staff don't **count** the coins but **weigh** them instead. This is because they know the weight of a single coin. For example, if you paid in 140 g of 50 pence pieces (one coin weighs 14 g), how many coins would you have ? To count the coins you would have to divide the **total weight** (140 g) by the **weight of a single coin** (14 g).

i.e. $$\text{Number of coins} = \frac{140}{14} = 10 \text{ coins}$$

We can calculate the number of **particles** in any weight of any **element**, if we know the weight of **one atom** of this element.

e.g.

To calculate how many **hydrogen atoms** are in **1 gram of hydrogen**, you would have to divide 1 gram by the weight of one hydrogen atom. If you know that the weight of a hydrogen atom is 1.67×10^{-24} grams, then:-

Number of hydrogen atoms in 1 gram of hydrogen (its Atomic Mass in grams) is:

$$\frac{1\ \text{g}}{1.67 \times 10^{-24}\ \text{g}} = 6 \times 10^{23}\ \text{atoms}$$

i.e. 1 mole of atoms

Consider another element:-

An atom of sodium weighs 3.8×10^{-23} g. How many sodium atoms are in 23 g of sodium (its Atomic Mass in grams) ? So:-

Number of sodium atoms in 23 g of sodium is:

$$\frac{23\ \text{g}}{3.8 \times 10^{-23}\ \text{g}} = 6 \times 10^{23}\ \text{atoms}$$

i.e. 1 mole of atoms

In general:

*If we weigh out a number of **grams** of **any** element, **numerically equal** to its **atomic mass** we would have a **mole of atoms** of that element.*

e.g.

Relative atomic mass of lithium is 7

Relative atomic mass of aluminium is 27

Relative atomic mass of calcium is 40

So:-

7 g of lithium contains **1 mole** of lithium atoms
27 g of aluminium contains **1 mole** of aluminium atoms
40 g of calcium contains **1 mole** of calcium atoms

Compounds and the Mole

A chemical **compound** is a substance which contains **more than one** element chemically bound together. The idea of a mole **can** be extended to chemical compounds.

*To weigh out one mole of any **chemical compound**, we would have to calculate the **gram formula mass** (GFM) of that compound.*
*This is done by **adding** the **relative atomic masses** of all the atoms in the formula expressed in **grams**.*
i.e. 1 mole of any compound = GFM of that compound

Here are some examples:

1) One mole of sodium chloride, NaCl, would be:

formula:			NaCl
relative atomic mass Na:			23
relative atomic mass Cl:			35.5
hence GFM =	23 + 35.5	=	58.5 g

So, **one mole** of **NaCl** weighs **58.5 g.**

Let's think about this a bit further:
58.5 g of NaCl will contain one mole of sodium ions and one mole of chloride ions. So, 58.5 g of NaCl contains **two** moles of ions in total.

Imagine you were asked how many moles of NaCl were in a sample weighing x g. How could this be calculated ?
For example, how many moles of NaCl are in 117 g of sodium chloride ?

To answer this, simply divide the mass present, by the mass of one mole.

i.e.

$$\text{number of moles} = \frac{117\ \text{g}}{58.5\ \text{g}} = 2 \text{ moles NaCl}$$

In general:

$$\text{number of moles} = \frac{\text{mass present}}{\text{mass of one mole}}$$

2) One mole of aluminium oxide, Al_2O_3, would be:

formula:	Al_2O_3
relative atomic mass Al:	27
relative atomic mass O:	16
hence GFM = (2 x 27) + (3 x 16) =	102 g

This means 102 g of Al_2O_3 will contain 2 moles of Al^{3+} (aluminium ion) and 3 moles of O^{2-} (oxygen ion).

Summary

1 mole of aluminium, Al	contains	1 mole of Al atoms, or 6×10^{23} Al atoms, and weighs 27 grams.
1 mole of sodium sulphate, Na_2SO_4	contains	2 moles of Na^+ ions and 1 mole of SO_4^{2-} ions, a total of 3 moles of ions per mole of Na_2SO_4, and weighs 142 grams.
1 mole of chlorine gas, Cl_2	contains	2 moles of Cl atoms, 1 mole of Cl_2 molecules, and weighs 71 grams.

Molar Mass

Molar mass means "**mass per mole**". It is another way of saying GFM of a compound or the atomic weight of an element.

For example:

1) Atomic mass of Al = 27
   $\therefore$ Molar mass of Al = 27 g/mole

2) Formula mass of Na_2SO_4 = 142
   $\therefore$ Molar mass of Na_2SO_4 = 142 g/mole

Unit 2 – Chemical Equations and the Mole

You may already have seen the practice of writing a **chemical equation** as a way of **summarising** a chemical reaction. In an equation the mole is used to **unify** the reactants and products.

For example, the equation for the reaction between one mole of hydrogen gas and one mole of chlorine gas to form hydrogen chloride gas is as follows:-

$$H_{2(g)} \quad + \quad Cl_{2(g)} \longrightarrow \quad HCl_{(g)}$$

Let's consider this equation further. The left hand side has **two moles** of hydrogen atoms, and **two moles** of chlorine atoms in total. The right hand side has **one mole** of hydrogen atoms and **one mole** of chlorine atoms in total. It seems we've "lost" one mole of each element somewhere! This cannot be allowed!

One fundamental law of nature is:
*Matter **cannot** be created or destroyed by a chemical reaction*

Since material cannot "disappear" in a reaction it must all be accounted for in a **balanced equation**. In the example above, the total mass of the **reactants** (H_2 and Cl_2) should equal the total mass of the **products** (HCl). However, as has already been pointed out, this isn't the case, for the above "equation".

	$H_{2(g)}$ +	$Cl_{2(g)}$	$\longrightarrow$	$HCl_{(g)}$
mass:	(2 x 1) g	+ (2 x 35.5) g	=	(1 + 35.5) g
	73 g in total			36.5 g in total

The balanced equation would have to include **two moles** of hydrogen chloride on the right hand side:-

	$H_{2(g)}$ +	$Cl_{2(g)}$	$\longrightarrow$	**2** $HCl_{(g)}$
mass:	(2 x 1) g	+ (2 x 35.5) g	=	**2**(1 + 35.5) g
	73 g in total			73 g in total

*A **balanced equation:** an equation in which the number of the different kinds of atom in the reactions must be equal to those which appear in the products, and so*
the mass of reactants = the mass of the products

Calculations from an Equation

1) **Balancing** an equation:
A balanced equation is essential for calculating quantities in a chemical reaction. So, you would have to balance the equation before doing any calculation by the following steps:-
   (i) work out the formulae of the **reactants**
   (ii) write the formulae of the **products**
   (iii) **balance** this equation by "evening up" the mass on each side of the equation.

2) Getting the **mole ratios**:
Having balanced the equation, the numbers **before** each formulae indicate how many moles of that substance are required to react with a given number of moles of another substance.

3) The calculations:
The final step is to do the actual calculation required following this procedure:-
   (i) identify the **known** and **unknown**
   (ii) Carry out the calculation in steps, remembering that
   1 mole = gram formula mass

This method will become clearer by studying its use in the following examples - honestly!

Example 1

How many moles of hydrogen gas (H_2) are required to react completely with 1 mole of nitrogen gas (N_2) to form ammonia (NH_3) ?

From 1) - the balanced equation

i) formulae of reactants:- H_2 and N_2
ii) formula of product:- NH_3
iii) the equation:- $H_{2(g)} + N_{2(g)} \longrightarrow NH_{3(g)}$
iv) balance the equation:-
a) write the unbalanced equation:

$$H_2 \quad + \quad N_2 \quad \longrightarrow \quad NH_3$$

mass: $(2 \times 1)\ g \quad + \quad (2 \times 14)\ g \quad = \quad 14+(3 \times 1)\ g$

30 g in total   17 g in total

b) *if we add 1 mole of NH_3 on the right hand side:*

	H_2	+	N_2	$\longrightarrow$	**2** NH_3
mass:	(2 x 1) g	+	(2 x 14) g	=	**2**(14+3) g
	30 g in total				34 g in total

c) *another 2 moles of H_2 are required on the left hand side:*

	3 H_2	+	N_2	$\longrightarrow$	2 NH_3
mass:	**3**(2 x 1) g	+	(2 x 14) g	=	2(14+3) g
	34 g in total				34 g in total

i.e. the balanced equation is:

$$3\,H_2 + N_2 \longrightarrow 2\,NH_3$$

From 3) - the calculation:-

i) **known** is: 1 mole of N_2

unknown is: moles of H_2

ii) from the balanced equation:-

3 moles of H_2 are required to react with 1 mole N_2

Example 2

What mass of magnesium would react completely with 32 g of oxygen ?

From 1) - the balanced equation

(i) formula of reactants:- Mg and O_2

(ii) formula of product:- MgO

(iii) the equation:- $Mg + O_2 \longrightarrow MgO$

(iv) balance the equation:-

a) *write the unbalanced equation:*

	Mg	+	O_2	$\longrightarrow$	MgO
mass:	24 g	+	(2 x 16) g	=	(24 + 16) g
	56 g in total				40 g in total

b) *by adding 1 mole of MgO to the right hand side:*

	Mg	+	O_2	$\longrightarrow$	**2** MgO
mass:	24 g	+	(2 x 16) g	=	**2**(24 + 16) g
	56 g in total				80 g in total

c) *another mole of Mg is required in the left hand side:*

$$\begin{array}{lcccc} & 2\ Mg & + & O_2 & \longrightarrow\ 2\ MgO \\ \text{mass:} & (2 \times 24)\ g & + & (2 \times 16)\ g & = 2(24+16)\ g \\ & & 80\ g \text{ in total} & & 80\ g \text{ in total} \end{array}$$

i.e. the balanced equation is:-

$$2\,Mg + O_2 \longrightarrow 2\,MgO$$

From 2) - the Mole Ratios

2 moles of Mg + 1 mole of O_2 ---> 2 moles of MgO

From 3) - the calculation

i) **known** is: mass of O_2

unknown is: mass of Mg

ii) From 2):-

2 moles of Mg react with 1 mole of O_2

but 1 mole = 1 GFM (or atomic weight)

32 g of O_2 = 1 mole of O_2

1 mole of O_2 = 2 moles of Mg

1 mole of Mg = 24 g of Mg

$\therefore$ 2 moles of Mg = 2(24) g of Mg = 48 g of Mg

Now try to solve these problems yourself:

1) Calculate the weight of sodium required to react completely with 106.5 grams of chlorine gas to form solid sodium chloride.

2) What weight of hydrogen gas is produced when 7.8 grams of potassium reacts completely with water ?

Summary

Three main steps are required to do any calculation from the chemical equations. These steps are:

1) **Balancing an equation**:-

by: writing the formula of the reactants
writing the formula of the products
balancing this equation.

2) **Getting the Mole Ratios**:-

From the balanced equation, the numbers before each formula indicate how many moles of this substance are required to react with another substance.

3) **The Calculation**:-

by: identifying the known and unknown substances

doing the calculation in steps remembering

1 mole = GFM of a compound, or atomic mass of an element.

Unit 3 - The Mole in Solution

Suppose you wanted to obtain **one hundredth** of a mole of sodium chloride, NaCl. With a good balance, this could be weighed out accurately, and would weigh 0.585 g.

If, however, we needed **one thousandth** of a mole of NaCl, weighing could be more difficult now. How then, can we handle such small quantities accurately ? Here is a clever idea:

Suppose we weigh out accurately 58.5 g NaCl, and dissolve it in water, and make it up to exactly 1 litre and mix the **solution** thoroughly.

Each **millilitre** (mL, a thousandth of a litre) of this solution will now contain one thousandth of a mole of NaCl. We could do even better if we weigh out one tenth of a mole accurately, dissolve it in some water and make it up to a litre with water; each millilitre will now contain **one ten thousandth** of a mole or 0.00585 g NaCl.

If you know that a drop of this solution has a volume of one twentieth of a mL, and each mL contains 0.00585 g NaCl, how much does a drop contain ?

Simply:

$$1 \text{ mL of solution} = 0.00585 \text{ g of NaCl}$$

$$1 \text{ drop} = \tfrac{1}{20} \text{ mL of solution} = \frac{0.00585}{20} \text{ g} = 0.000295 \text{ g NaCl}$$

By using solutions we have invented a means of handling very small amounts of material.

Since most chemical reactions occur in solution, this is very convenient.

Concentration

A solution which contains 1 mole of a substance (its GFM) in 1 litre of solution is said to have a **concentration** of **1 mole per litre** (or **1 $molL^{-1}$** for short).
A mole of sodium chloride weighs 58.5 g. If you dissolve 58.5 g of sodium chloride in some water then make it up to exactly one litre, you would have a 1 $molL^{-1}$ solution of NaCl.

Sometimes a solution of concentration 1 $molL^{-1}$ is called a **molar** solution. In some books its concentration would be written as 1M, where the symbol M = $molL^{-1}$. We will not be using this notation, but you may come across it in older textbooks.

Now:- if you have -
1 mole of substance dissolved in 1 L solution - the concentration is 1 $molL^{-1}$
2 moles of substance dissolved in 1 L solution - the concentration is 2 $molL^{-1}$
8 moles of substance dissolved in 2 L solution - the concentration is 4 $molL^{-1}$

In general:-
The concentration of the solution is the number of moles of dissolved material (solute) per litre of solution

$$\text{concentration} = \frac{\text{no. of moles}}{\text{volume (in litres)}}$$

or

$$\text{volume (in litres)} \times \text{concentration} = \text{no. of moles}$$

Example 1

How many moles of potassium hydroxide (KOH) are there in 0.2 L of 2 $molL^{-1}$ potassium hydroxide solution ?

1 L of solution = 2 moles of KOH
0.2 L of solution = 0.2(2) moles = 0.4 moles of KOH

Example 2

How many moles of sodium chloride (NaCl) are dissolved in 500 mL of 1 $molL^{-1}$ NaCl solution ?

1 L of solution = 1000 mL of solution = 1 mole of NaCl
1 mL of solution = $\frac{1}{1000}$ moles of NaCl
500 mL of solution = $\frac{500}{1000}$ moles = 0.5 moles of NaCl

Sometimes you might have be asked to calculate the number of grams of substance dissolved in the solution.

Example 3

How many grams of sodium sulphate (Na_2SO_4) are there in 0.5 L of 2 $molL^{-1}$ sodium sulphate solution ?
(Atomic masses: Na = 23, O = 16, S = 32)

$$1 \text{ L of solution} = 2 \text{ moles of } Na_2SO_4$$
$$0.5 \text{ L of solution} = 1 \text{ mole of } Na_2SO_4$$
$$1 \text{ mole of } = (2 \times 23) + 16 + (4 \times 16) \text{ g} = 142 \text{ g of } Na_2SO_4$$

Counting Ions in Solution

You already have methods for finding the number of moles of materials (or the number of grams) dissolved in solution. The question here is about the number of **ions** in that solution.

Suppose that the above beaker contains 0.5 L of hydrochloric acid solution; if you know the concentration of this solution is 4 $molL^{-1}$, it is possible to find the number of moles of HCl, where:-

$$1 \text{ L of solution} = 4 \text{ moles of HCl}$$
$$0.5 \text{ L of solution} = 2 \text{ moles of HCl}$$

To find the number of moles of H^+ in this beaker, you would have to know how many H^+ ions are in each mole of hydrochloric acid (HCl), and multiply it by the number of moles of HCl present in the beaker:

$$1 \text{ mole of HCl} = 1 \text{ mole of } H^+$$
$$2 \text{ moles of HCl} = 2 \text{ moles of } H^+$$

Example 1

How many moles of H^+ ions are there in 200 mL of 2 $molL^{-1}$ sulphuric acid (H_2SO_4) solution ?

$$1 \text{ L of solution} = 2 \text{ moles of } H_2SO_4$$
$$1 \text{ mL of solution} = \frac{2}{1000} \text{ moles of } H_2SO_4$$

$$200 \text{ mL of solution} = \frac{2(200)}{1000} \text{ moles} = 0.4 \text{ moles of } H_2SO_4$$

$$1 \text{ mole } H_2SO_4 = 2 \text{ moles } H^+$$

$$0.4 \text{ moles of } H_2SO_4 = 0.8 \text{ moles of } H^+$$

Example 2

How many moles of OH^- ions are there in 1 litre of 3 $molL^{-1}$ sodium hydroxide (NaOH) solution ?

$$1 \text{ L of solution} = 3 \text{ moles of NaOH}$$

$$1 \text{ mole of NaOH} = 1 \text{ mole of } OH^-$$

$$3 \text{ moles of NaOH} = 3 \text{ moles of } OH^-$$

Summary

New concepts you have met in this unit are:

1) A solution which contains 1 mole of substance in 1 L of solution has a concentration of 1 $molL^{-1}$

2) Concentration of a solution can be quoted as its molarity, i.e. the number of moles of dissolved material per litre

i.e. $\text{molarity} = \dfrac{\text{no. of moles}}{\text{volume (in L)}}$

Appendix C
Examples of Workshop Exercises

General Chemistry 1
States of Matter, Workshop 2

Gas Law Calculations

Ideal Gas Equation exercises

The ideal gas equation, PV=nRT, can be rearranged to make any one of the four variables the subject and you should be able to do this.

e.g. $V = \frac{nRT}{P}$ $T = \frac{PV}{nR}$

> Remember: as there are several different units in use for pressure and volume, you must be careful about which value of R, the gas constant you can use. The units of R (and therefore the numerial value) must correlate with the units of P, V and T being used. T is always given in K and the amount (n) of gas given in moles

For example:

Verify that 1.00 mole of an ideal gas at s.t.p. (0°C and 760 torr) has a volume of 22.4 litres.

i) *Since V is the "unknown" here the ideal gas equation must be rearranged to make V the subject:*

$$V = \frac{nRT}{P}$$

ii) *Choose the value of R to suit the units of pressure and volume involved. As the units are litres (L) and torr then the appropriate value of R is:*

$R = 62.4\ \mathrm{L\ torr\ K^{-1}mol^{-1}}$ - N.B. they all have $\mathrm{K^{-1}mol^{-1}}$

iii) *Substitute the numbers into the equation, converting the temperature to K:*

$$V = \frac{1(62.4)(273+0)}{760} = 22.4\ \mathrm{L}$$

1) Select the correct value of R for the following problems, **but do not do the calculations!**

i) Using the ideal gas equation, calculate the volume, in litres, of exactly 1 mol of gas at 0°C and exactly 1 atm pressure.

ii) What would be the pressure, in atmospheres, of 11.0 g of carbon dioxide in a 20.0 cm^3 vessel at 403 K ?

iii) How many moles of nitrogen are present in a sample which has a pressure of 2.5 x 10^5 Pa at 20°C in a volume of 1.00 m^3 ?

Use the ideal gas equation in the following problems:

2) Calculate the volume of exactly 1 mole of gas at 0 ^{o}C, and exactly 1 atm pressure.

3) A flashbulb of volume 2.6 cm^3 contains O_2 gas at a pressure of 2.3 atm and a temperature of 26^{o}C. How many moles of O_2 does the flashbulb contain ?

4) The Main Lecture Theatre in the Chemistry Department is 16.0 m x 15.0 m and has an average height of 5.50 m. Make a **guess** at the mass of air contained in the room.

Using the ideal gas equation, the number of moles of a gas and subsequently the mass of gas present can be calculated (assuming the mass of one mole of the gas is known). This will also hold true for a *mixtures* of gases, as is the case for air.

Given that the average molar mass of the gases which make up the atmosphere is 29.0 g mol^{-1}, and assuming the temperature in the room is 15^{o}C and the air pressure is 745 torr, **now** calculate the mass of air in the room.

How close is your guess ?

5) The eminent Professor of Chemistry at the University Of Gallifrey is now working on compounds formed by the element xenon. He has managed to produce a gas containing only xenon and fluorine, and believes it to have the formula XeF_x. This gas has a measured density of 10.93 gL^{-1} at s.t.p.

Work out the weight of one mole and hence deduce the molecular formula of the gas.

6) In an experiment recently reported in the scientific literature, male cockroaches were made to run at different speeds on a miniature treadmill while their oxygen consumption was measured. This incredibly important research found that the average cockroach running at 0.08 km/hr consumed 0.8 mL of O_2 at 1 atm pressure and 24^{o}C, per gram of insect weight per hour. On this basis, how many moles of O_2 would be consumed in one hour by a 5.2 g cockroach moving at this speed ?

Ideal Gases - Change of P,V or T with a fixed amount of Gas

If you have a fixed amount of gas, the ideal gas equation can be used to predict the result of changes to the conditions of the gas.

i.e. if a fixed amount of gas (n moles) at a certain pressure(P_1), volume (V_1) and temperature (T_1) experiences a change in one (or more) of these factors, then the other(s) will change to obey the ideal gas equation.

$$\frac{P_1V_1}{nT_1} = \frac{P_2V_2}{nT_2} = R$$

Since n is a constant, appearing on both sides of the equation it can be cancelled out, giving:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

For example:

> *A sample of nitrogen at 750 torr and 5°C has a volume of 753 cm^3. What will be its volume at 785 torr and 25°C ?*

Using equation 2, where P_1 = 75 torr, V_1 = 753 cm^3, T_1 = 5°C, P_2 = 785 torr and T_2 = 25°C

$\boxed{\text{Remember: always convert from }^{o}\text{C to K}}$

$$\frac{(750)(753)}{(273+5)} = \frac{(785)V_2}{(273+25)}$$

$$\therefore\ V_2 = \frac{(750)(753)(273+25)}{(273+5)(785)} = 771\ \text{cm}^3$$

However, often one of the three factors will remain constant.

Repeat the above calculation for yourself, only this time hold the temperature constant at 5°C.

Try the following examples:

7) A sample of hydrogen occupied a container of volume 2.50 litres at 20°C, and exerted a pressure of 235 torr. What pressure would it exert if the temperature were increased to 750°C ?

8) At 743 torr and 15°C a sample of helium occupied a volume of 965 cm^3. What would be its volume at 810 torr and 29°C ?

Gas Constant, R, in various units:

0.0624	**m^3 torr $K^{-1}mol^{-1}$**
0.0821	**L atm $K^{-1}mol^{-1}$**
82.06	**cm^3 atm $K^{-1}mol^{-1}$**
8.21×10^{-5}	**m^3 atm $K^{-1}mol^{-1}$**
62.4	**L torr $K^{-1}mol^{-1}$**
8.31×10^{6}	**cm^3 Pa $K^{-1}mol^{-1}$**
8.31	**m^3 Pa $K^{-1}mol^{-1}$**

Relative Atomic Masses:

xenon	**=**	**131**
fluorine	**=**	**19**

General Chemistry 1
Chemical Kinetics & Equilibrium, Workshop 1

Chemical Kinetics

1) The following kinetic data were obtained at 67°C for the reaction

$$2\,N_2O_{5(g)} \longrightarrow 4\,NO_{2(g)} + O_{2(g)}$$

time (s)	0	60	120	180	240
$[NO_2]$ (mol L^{-1})	0	0.590	1.006	1.302	1.508
$[N_2O_5]$ (mol L^{-1})	1.000	0.705	0.497	0.349	0.246

i) Plot a graph of $[N_2O_5]$ vs. time. On the **same** graph, plot $[NO_2]$ vs. time.

ii) What is meant by the **half-life** of a reaction ? What is the half-life of this reaction ?

iii) Write expressions comparing the rate of disappearance of N_2O_5 to the rate of appearance of each product.

Information:

For a general reaction,

$$A + B \longrightarrow C + D$$

the rate is, $\text{rate} = -\dfrac{\Delta[A]}{\Delta t} = -\dfrac{\Delta[B]}{\Delta t} = \dfrac{\Delta[C]}{\Delta t} = \dfrac{\Delta[D]}{\Delta t}$

The rate law for this reaction would be,

$$\text{rate} = k\,[A]^m[B]^n$$

where k is the rate constant, m is the reaction order with respect to reactant A,

n is the reaction order with respect to reactant B.

Values for m and n can be worked out from experimental data – by inspection of a table of initial concentration and corresponding rates.

For example, the reaction:

$$NH_4^+{}_{(aq)} + NO_2^-{}_{(aq)} \longrightarrow N_{2(g)} + 2\,H_2O_{(l)}$$

gives the following data:

EXPERIMENT	$[NO_2^-]$ (mol L^{-1})	$[NH_4^+]$ (mol L^{-1})	$\frac{-\Delta[NH_4^+]}{\Delta t}$ (mol $L^{-1}s^{-1}$)
1	0.0100	0.200	5.4×10^{-7}
2	0.0200	0.200	10.8×10^{-7}
3	0.200	0.0202	10.8×10^{-7}
4	0.200	0.0404	21.6×10^{-7}

Consider expt 1 and 2:

$[NH_4^+]$ is constant, $[NO_2^-]$ doubles and the rate doubles

so reaction is 1st order with respect to NO_2^-

(if $[NO_2^-]$ had doubled and the rate of reaction had quadrupled, then the reaction would be 2nd order with respect to NO_2^-)

Consider expt 3 & 4:

$[NO_2^-]$ is constant, $[NH_4^+]$ doubles and the rate doubles

so reaction is 1st order with respect to NH_4^+

So the rate law is:

$$-\frac{\Delta[NH_4^+]}{\Delta t} = k[NH_4^+][NO_2^-]$$

Using any set of figures from the table a value for k can be calculated:

$$k = \frac{\frac{-\Delta[NH_4^+]}{\Delta t}}{[NH_4^+][NO_2^-]} = \frac{5.4 \times 10^{-7}}{(0.200)(0.0100)} = 2.7 \times 10^{-4}\ \text{mol}^{-1}\ \text{L}^{-1}\ \text{s}$$

Now try question 2.

Questions:

2) The initial rate of disappearance of $S_2O_8^{2-}$ in the reaction

$$S_2O_8^{2-}{}_{(aq)} + 3\ I^-{}_{(aq)} \longrightarrow 2\ SO_4^{2-}{}_{(aq)} + I_3^-{}_{(aq)}$$

was measured at a fixed temperature, using reaction mixtures with different initial concentrations of $S_2O_8^{2-}{}_{(aq)}$ and $I^-{}_{(aq)}$. The following results were obtained:

EXPERIMENT	$[S_2O_8^{2-}]$ (mol L^{-1})	$[I^-]$ (mol L^{-1})	$\frac{-\Delta[S_2O_8^{2-}]}{\Delta t}$ (mol $L^{-1}s^{-1}$)
1	0.038	0.060	1.4×10^{-5}
2	0.076	0.060	2.8×10^{-5}
3	0.076	0.030	1.4×10^{-5}

4	0.044		3.2×10^{-5}
5	0.025	0.100	

i) Find the order of the reaction with respect to $S_2O_8^{2-}$, and to I^-, and the overall order.

ii) Write the rate law for the rate of disappearance of $S_2O_8^{2-}$.

iii) Calculate the rate constant, k, for this reaction, using the data from experiment 1. Repeat for experiments 2 and 3. Consider your value for k, and the concentration of the reactants and the initial rate of each reaction for the first three experiments. Can you see any patterns ?

iv) Complete the entries in the table for experiment 4 and 5.

v) What is the rate of **appearance** of SO_4^{2-}, when $[S_2O_8^{2-}] = 0.025$ molL^{-1} and $[I^-] = 0.050$ molL^{-1} ?

3) Is your scalp a busy place at the molecular level ?
Or, to put it another way, how fast does your hair grow ?
Estimate the **approximate** rate of growth of your hair in ms^{-1}. How might you get information on this ? Discuss this problem with your colleagues - two heads can grow more hair than one!
Let's turn this into a chemistry question. Hair growing is a chemical reaction! Hair can be considered as a long "chain" made up of molecules called amino acids. Amino acids have the general structure: H_2N-CHX-CO_2H, where X can be different things - giving different amino acids.
The average amino acid has a length of about 5×10^{-10} m. How many of these molecules will join a single chain in 1 second ?
A single hair will be made up of several "chains" of molecules "bundled" together. A reasonable guess for the cross section of a hair is about 10^{-11} m^2. The cross section of the average amino acid is about 10^{-19} m^2. How many amino acids join a single hair each second ?
With the figure you calculate in mind, is your scalp a busy place at the molecular level ?

General Chemistry-1
Carbon Compounds, Workshop 2

1) Draw the structures of the products you expect to get from reaction of 2,3-dimethylbut-2-ene with:

   a) hydrogen (and Pd catalyst)
   b) bromine
   c) water (and acid catalyst)

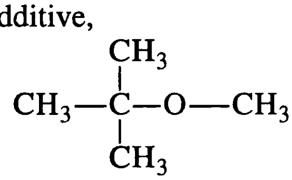
   If these products were mixed and the mixture passed through a gas chromatograph column packed with the polymer $(CH_2CH_2\text{-}O\text{-})_x$, at 150 °C, in what order would they come out ?

2) Draw the structure of a hydrochlorofluorocarbon, C_2HClF_4,which is a **chiral** molecule.

3) Draw the product you expect to get by oxidising the following alcohols with Cr (VI):

   propan-1-ol butan-2-ol methanol

4) The antiknock fuel additive,



   is a low boiling liquid. It is made by addition of methanol to an alkene, C_4H_8. Suggest:

   i) a structure for this alkene.
   ii) a way of catalysing the addition.
   iii) how a mixture of the alkene, the methanol and the product could be separated.

5) Molecules with lone pairs or with π bonding pairs sometimes react by donating these pairs to form new bonds (i.e. they act as nucleophiles). Which of the reagents in each of the reactions below is acting in this way ?

   i) $NH_3 + H^+ \longrightarrow NH_4^+$
   ii) $CH_2{=}CH_2 + H^+ \longrightarrow {}^+CH_2\text{-}CH_3$
   iii) $CH_3\text{-}CH_2^+ + Br^- \longrightarrow CH_3\text{-}CH_2\text{-}Br$

6) Among the products from a petrochemical plant are five isomers with the formula C_4H_8. All have similar boiling points.
   Three of them react with water and acid to give butan-2-ol.
   The fourth one is the one in question 4), above.
   The fifth one does not react with water/H^+ or Br_2.
   Draw all of these isomers.

Appendix D
Examples of Diagnostic Tests

Diagnostic Test 2 (Kinetics and Equilibrium)

Name:____________________________ **Matric.No.:**____________
Tutor's Name:____________________________

Answer all of the following questions

1. Consider each of the factors listed in the grid below. Decide which of these factors would, in general, have the effect of **increasing the rate of a reaction,** if they were applied to that reaction.
Enter the number(s) of any box containing a factor that would do this in the spaces provided below the grid.

INCREASE TEMPERATURE **1**	STIR THE MIXTURE **2**	ADD A CATALYST **3**
DECREASE THE PRESSURE OF GASEOUS REACTANTS **4**	INCREASE THE CONCENTRATION OF REACTANTS **5**	INCREASE THE PRESSURE OF GASEOUS REACTANTS **6**
DECREASE THE CONCENTRATION OF REACTANTS **7**	DECREASE TEMPERATURE **8**	LEAVE REACTION RUNNING FOR A LONG TIME **9**

Factor(s) increasing rate:

2. Consider the reaction:

$$NH_4NO_{2(s)} \longrightarrow N_{2(g)} + 2\ H_2O_{(g)}$$

i) Write expressions comparing the rate of disappearance of NH_4NO_2 to the rate of appearance of each of the products.
State in words what these expressions mean.

ii) Write the equilibrium constant expressions for the reaction

a) in terms of concentration b) in terms of partial pressures

a)	b)

3) Urea, NH_2CONH_2, is the end product of protein metabolism in animals. Urea decomposes in aqueous acid by a reaction which is first order in urea.

i) Write the rate law for this reaction.

When [urea] = 0.200 mol L^{-1}, the rate, at a particular temperature is found to be 8.56×10^{-5} mol L^{-1} s^{-1}.

ii) What is the value of the rate constant for the reaction ?

iii) What is the concentration of urea after 1.5 hours under these conditions if the starting concentration of urea in this reaction is 0.500 mol L^{-1}.

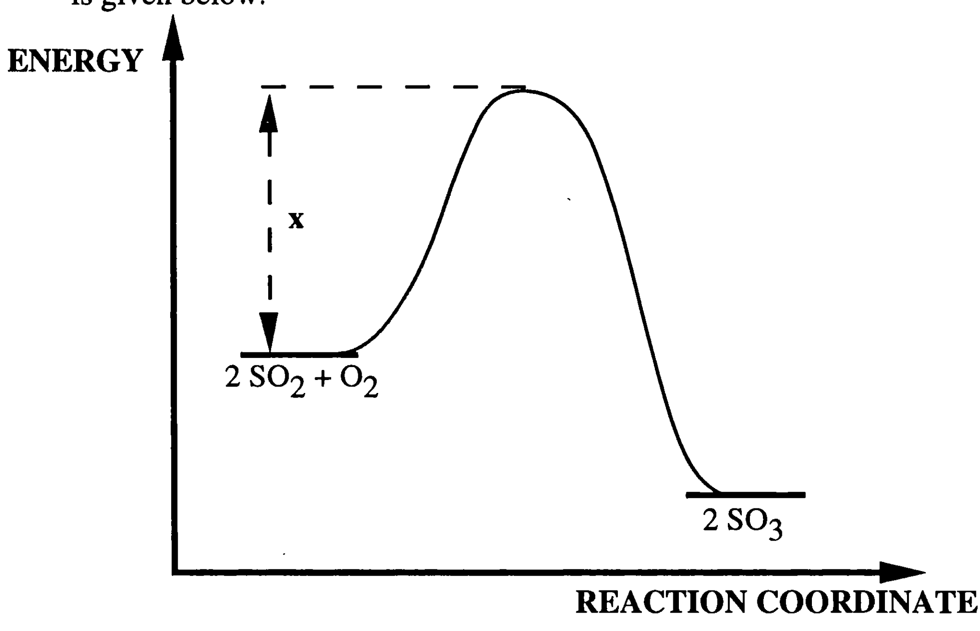
iv) What is meant by the half-life, $t_{1/2}$, of a reaction ?

v) Calculate the $t_{1/2}$ for this reaction:

4) The energy profile for the reaction

$$2\,SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\,SO_{3(g)}$$

is given below.



i) Is this reaction **endothermic** or **exothermic** ? Give a reason for your answer.

ii) What is the name of the quantity labelled **x** on the diagram ?
What is the significance of this quantity ?

iii) At **equilibrium** which is the **faster** reaction - **forwards** (to give SO_3) or **backwards** (to give SO_2 and O_2) ? Explain your answer.

iv) The position of equilibrium can be altered by changes in pressure, volume or temperature.

Consider each of the following changes and state how they would shift the equilibrium - towards SO_3, or towards SO_2 and O_2 ?

a) Increase pressure

b) Increase volume

c) Increase temperature

v) SO_2 is produced in car engines due to sulphur impurities in petrol. The catalytic converters now fitted to cars can promote convertion of SO_2 to SO_3 by this reaction.

Using a dotted line on the diagram above, sketch what might be a possible energy profile for the catalysed reaction.

How does a catalyst effect the position of the equilibrium ?

vi) Estimate whether the change in entropy, $\Delta S°$, for this reaction is likely to be positive or negative. Justify your decision.

vii) Considering the sign of ΔH° and ΔS°, what predictions would you make about the sign of ΔG° and how it may vary with T ?

5. i) For the reaction

$$2\,NO_2Cl_{(g)} \rightleftharpoons 2\,NO_{2(g)} + Cl_{2(g)}$$

the value of K, the equilibrium constant, is 0.558, at a particular temperature. For each of the experiments below calculate Q, the reaction quotient, and enter the value in the space provided. Use this to decide if the reaction is at equilibrium or not. If the reaction is **not** at equilibrium, indicate the **direction** (towards products or towards reactants) in which it must shift to achieve equilibrium.

Expt.	$[NO_2Cl]$ ($molL^{-1}$)	$[NO_2]$ ($molL^{-1}$)	$[Cl_2]$ ($molL^{-1}$)	Q	At equilibrium ? (**Yes** or **No**)	Direction ? (to **reactants** or to **products**)
a	0.0120	0.0344	0.00452			
b	0.130	0.0280	0.0260			
c	0.00127	0.00162	0.343			

ii) This reaction is actually thought to follow a mechanism involving **two** elementary steps:-

$NO_2Cl \longrightarrow NO_2 + Cl$: **SLOW step**

$NO_2Cl + Cl \longrightarrow NO_2 + Cl_2$: **FAST step**

i) Write down any transient intermediate(s) in this reaction.

ii) The rate law consistent with this mechanism would be (Ring the correct answer) :

A) Rate = $k[NO_2Cl]^2$

B) Rate = $k[NO_2Cl]$
C) Rate = $k[NO_2Cl][Cl]$
D) Rate = $k[NO_2Cl]^2[Cl]$
E) Rate = $k[NO_2Cl][NO_2][Cl]$

6. Deep-sea divers breathe a mixture of gases with a lower proportion of oxygen in order to:-

(Ring correct response)

a) Make their voices less squeaky
b) Reduce the risk of fire
c) Prevent too much oxygen binding to haemoglobin at high pressure
d) Reduce the risk of the "bends"
e) Make them less bouyant underwater
f) Increase oxygenation of the blood.

7. The eminent Professor of Chemistry at the University of Gallifrey has had an idea of how to solve the thinning of the ozone layer, by producing **new** ozone (O_3) by the reaction:

$$3\ O_{2(g)} \rightleftharpoons 2\ O_{3(g)}$$

He has asked you to check the thermodynamics and position of the equilibrium for this reaction.

i) Using the data provided, calculate ΔH° for this reaction at 298 K (25 °C).

ii) Calculate ΔS° for this reaction, at the same temperature.

iii) Calculate ΔG° at 298 K for this reaction.

Will the professor's plan work ? Explain your answer.

iv) Calculate K, the equilibrium constant, for this reaction at 298 K

v) Can you find a temperature at which the Professor's plan will work ?
Explain your answer.

DATA

$R = 8.314\ J\ K^{-1}\ mol^{-1}$

$O_{3(g)}$ $\Delta H_f^\circ = 142.3\ kJ\ mol^{-1}$ $S^\circ = 237.6\ J\ K^{-1}\ mol^{-1}$

$O_{2(g)}$ $\Delta H_f^\circ = 0\ kJ\ mol^{-1}$ $S^\circ = 205.0\ J\ K^{-1}\ mol^{-1}$

Diagnostic Test 4 (Carbon Compounds I)

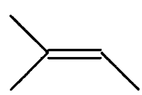
Name:____________________________ **Matric.No.:**__________

Tutor's Name:____________________________

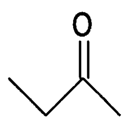
Answer all of the following questions

1. Draw the structure of propene and mark all the bond angles.

2. Name the compounds shown:



a)



b)

a)	
b)	

3. A compound $C_3H_6Cl_2$ exists in two enantiomeric forms. Draw the two forms **clearly**.

   Do you expect their boiling points to be identical or different ? Explain your answer.

4. Explain what is meant by the term **racemic mixture**.

5. Which of the following do you expect to be most soluble in water (ring the correct compound) ?

$CH_3CH_2CH_2OH$	$CH_3CH{=}CH_2$	$CH_3CH_2CH_2\overset{\overset{\large O}{\|}}{C}CH_3$	$CH_3CH_2CH_2Cl$
A	**B**	**C**	**D**

Explain how you made your decision.

6. A compound C_3H_5Cl exists in two geometrically isometric forms. Draw them.

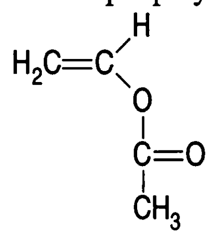
Do you expect their boiling points to be identical or different ? Explain your answer.

7. Fractional distillation of crude oil gives mixtures of different boiling ranges. Suggest:

i) **three** possible uses for a fraction of boiling point $150 - 200\ ^{o}$.

ii) a typical structure for a molecule likely to be found in this mixture.

8. A wood glue is made by the simple polymerisation of:



Draw a representative portion of the polymer.

What functional group is present in the **polymer** ?

Total hydrolysis of the polymer gives a new water soluble polymer. Draw it.

9. Bacon and eggs don't stick to a Teflon coated pan. Why not ?

Bacon and eggs don't stick to paraffin wax either. Why is it not used on pans?

10. Describe **in words** as best you can the structure of a molecule of a vegetable oil, such as olive oil.

11. How could you prepare a soap from such an oil ?

Appendix E

General Chemistry–1 Questionnaire

General Chemistry - 1
Questionnaire

This questionnaire is about Gen Chem-1 and your view of it.
It's anonymous (that means we don't want your name), so please be honest!

A. Consider the following table and put a tick in the box which best expresses your view

	Better than expected	As expected	Worse than expected
Lecture course:			
Rate of work			
Subject matter			
Help from staff members			
In the Inorganic lab:			
Nature of the practical work			
Help from the demonstrators			
Support of Pre-lab excersises			
In the Physical lab:			
Nature of the practical work			
Help from the demonstrators			
Support of Pre-lab excersises			
In general:			
Support material, like Workshops and Prelects			
Class tests			
The 1st Class exam			
The picture of the course painted by your advisor			

B. Workshops

Did you regularly attend workshops in term 1: YES ❑ NO ❑

Did you regularly attend workshops in term 2: YES ❑ NO ❑

If NO, why not:-

If YES, did you find them helpful ? YES ❑ NO ❑

Would it be helpful if a summary of the theory needed for the workshop was provided at the workshop ? YES ❑ NO ❑

Do you have any suggestions to improve the workshops ?

C. Tests

Do you regularly attend the class tests ? YES ❑ NO ❑

If NO, why not:-

If YES, did you find them helpful ? YES ❑ NO ❑

D. Tutorials

Do you see your tutor regularly ? YES ❑ NO ❑

If NO, why not:-

Do you find the tutorials helpful ? YES ❑ NO ❑

Would fixed tutorials be more useful ? YES ❑ NO ❑

E. Choosing Gen Chem-1

Do you feel the advice given to you at the start of the year was:

sufficient ❑ insufficient ❑ misleading ❑

Do you feel you were mislead about General Chemistry-1 and its aims ?

YES ❑ NO ❑

If **YES**, in what way(s):

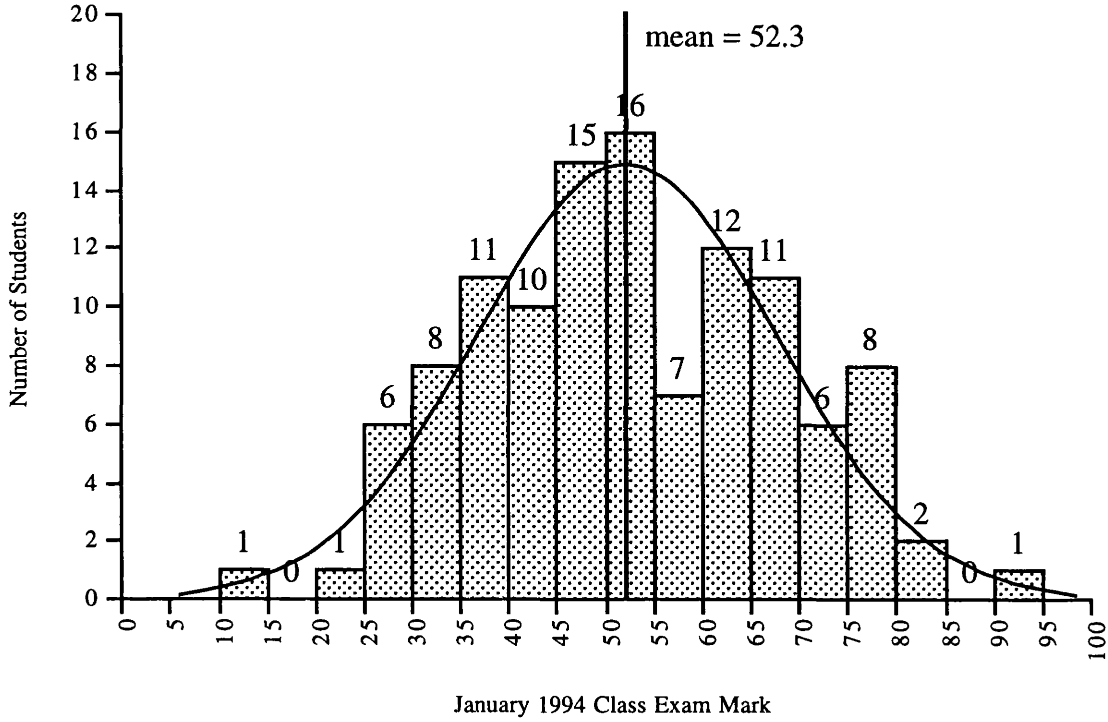
Thank you for your cooperation.

Appendix F

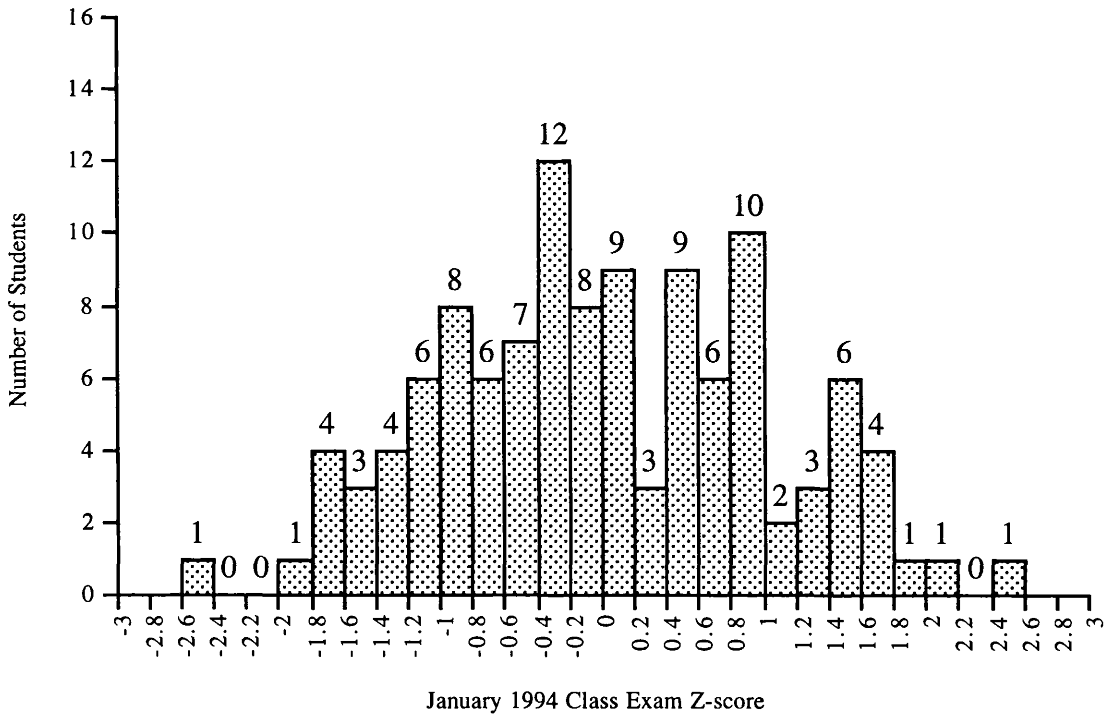
General Chemistry–1, 1993/94

January Exam Marks

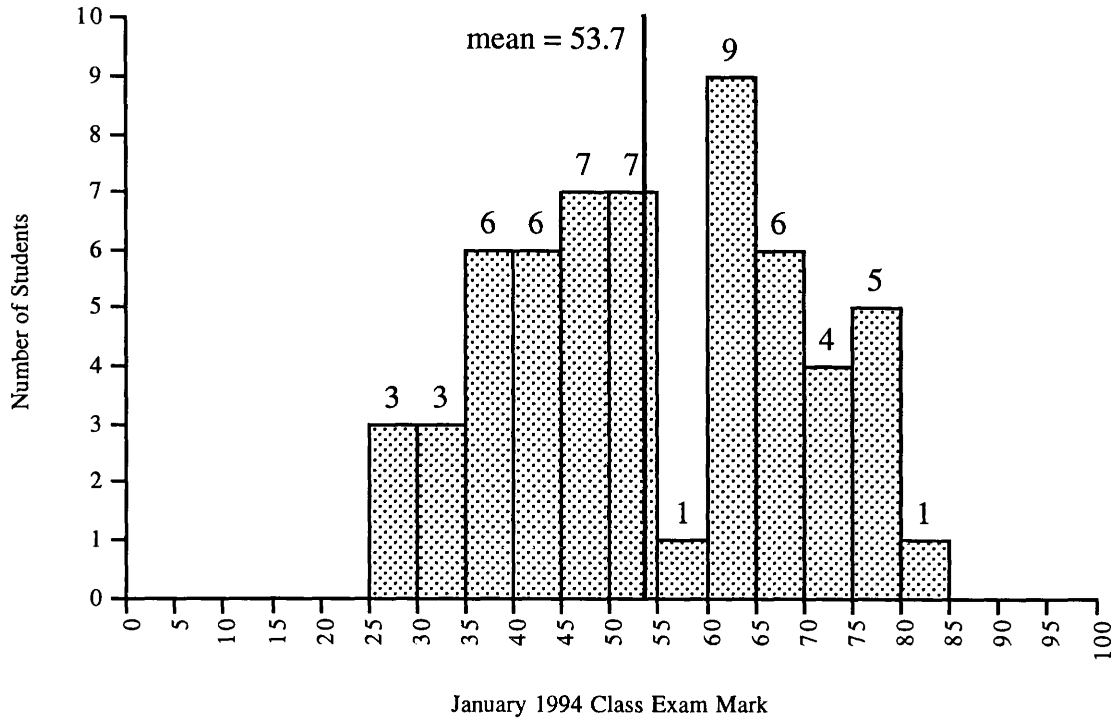
Graph F1 Distribution of General Chemistry–1 1993/94 January Class Exam Marks



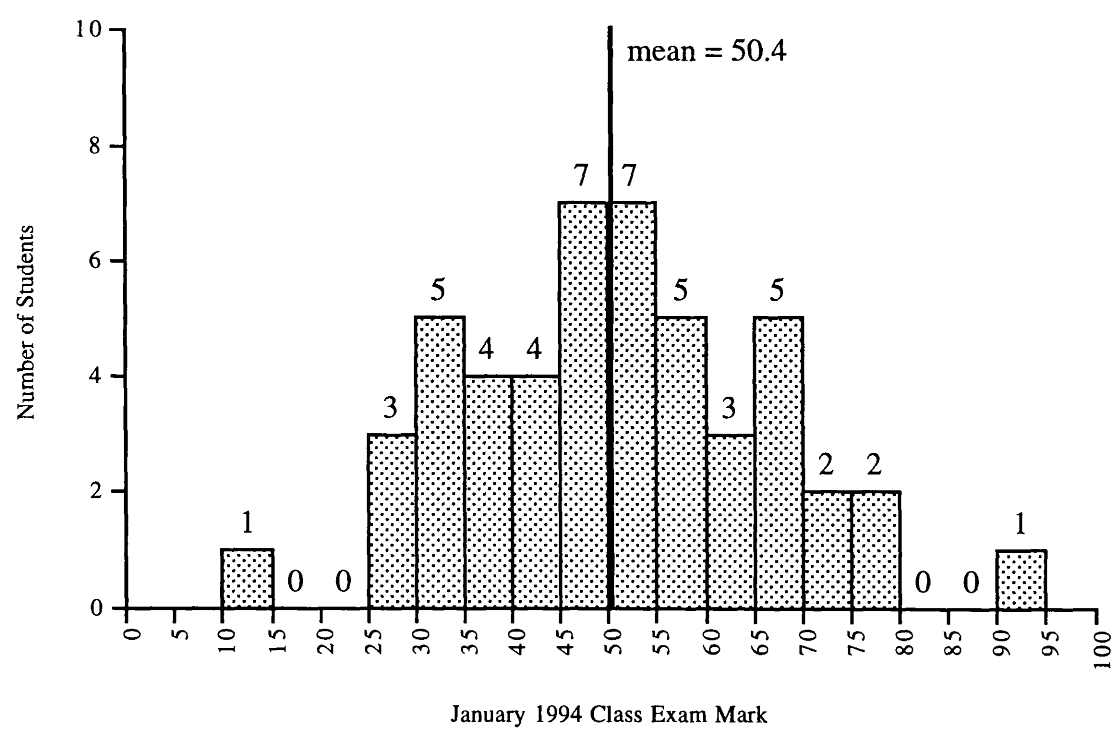
Graph F2 Distribution of General Chemistry–1 1993/94 January Class Exam Marks as Z-scores



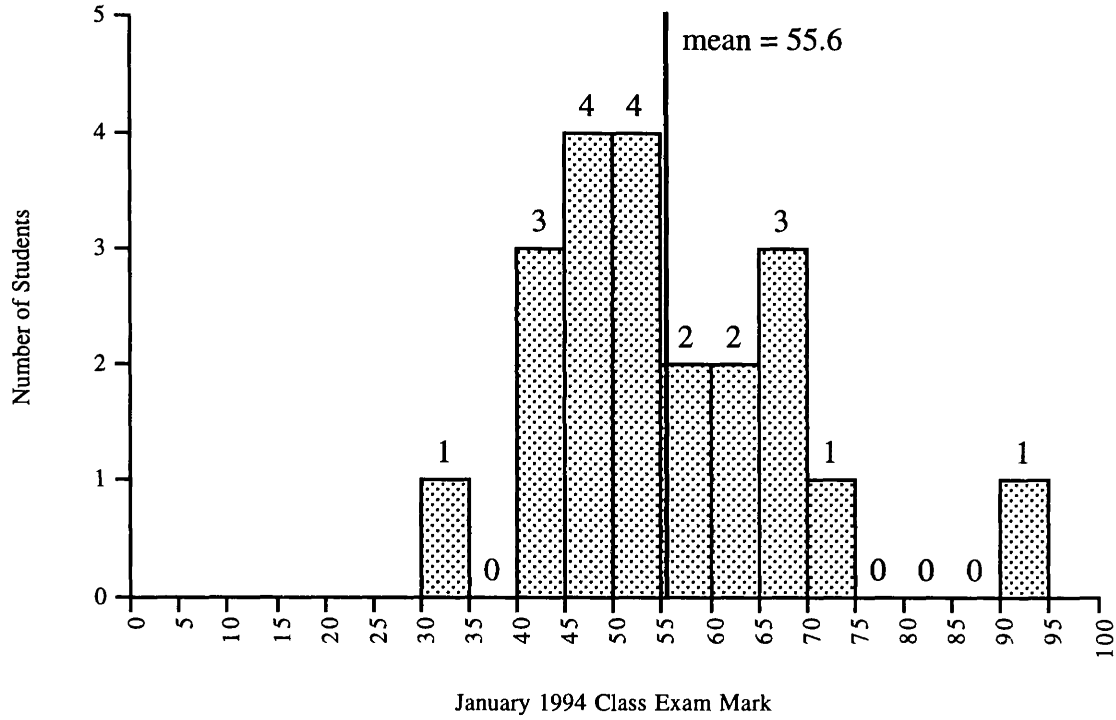
Graph F3 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Standard Entry (Chemistry) Qualifications



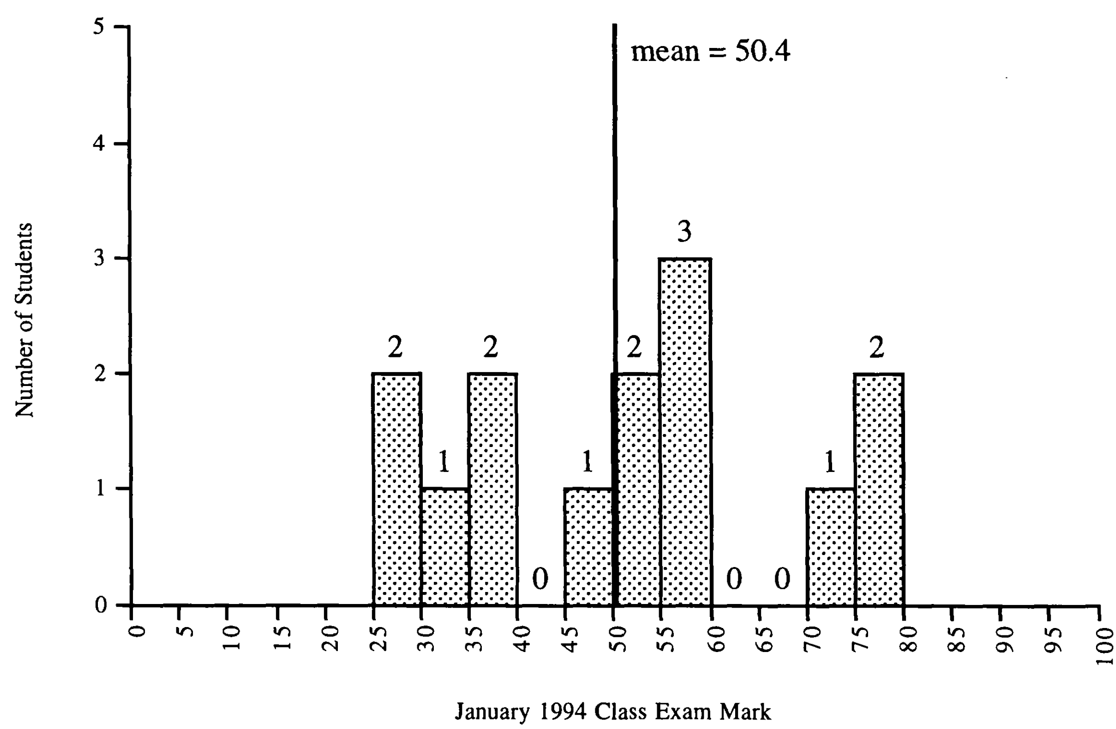
Graph F4 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Non-Standard Entry (Chemistry) Qualifications



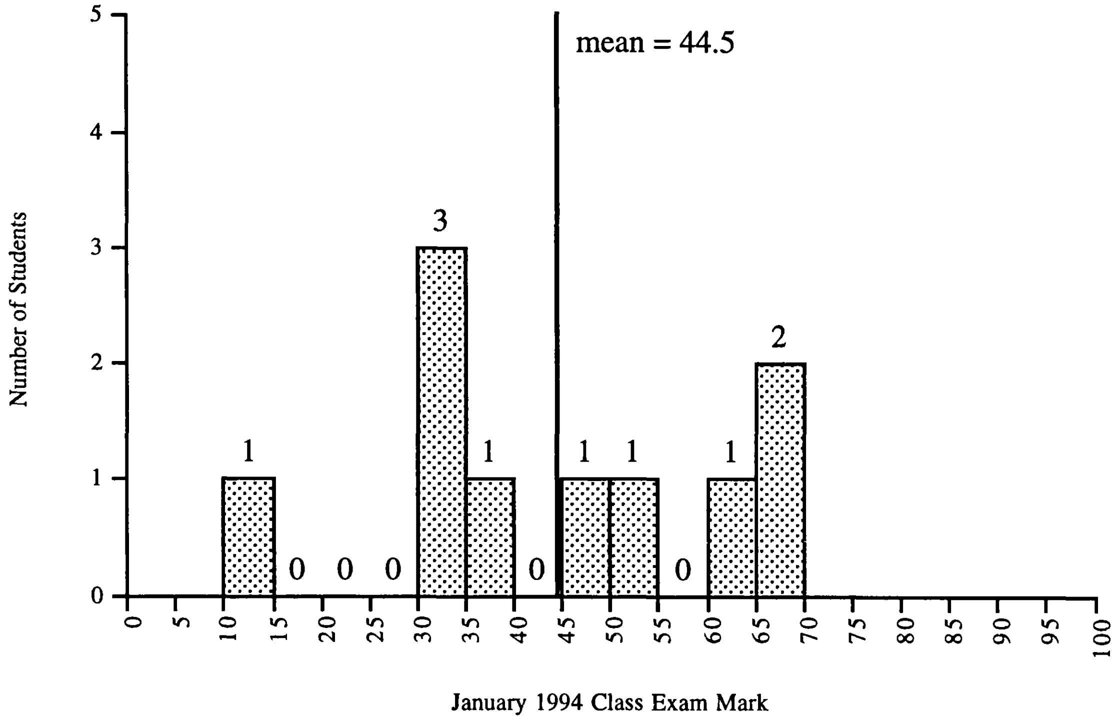
Graph F5 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Scottish Standard Grade Chemistry Qualifications



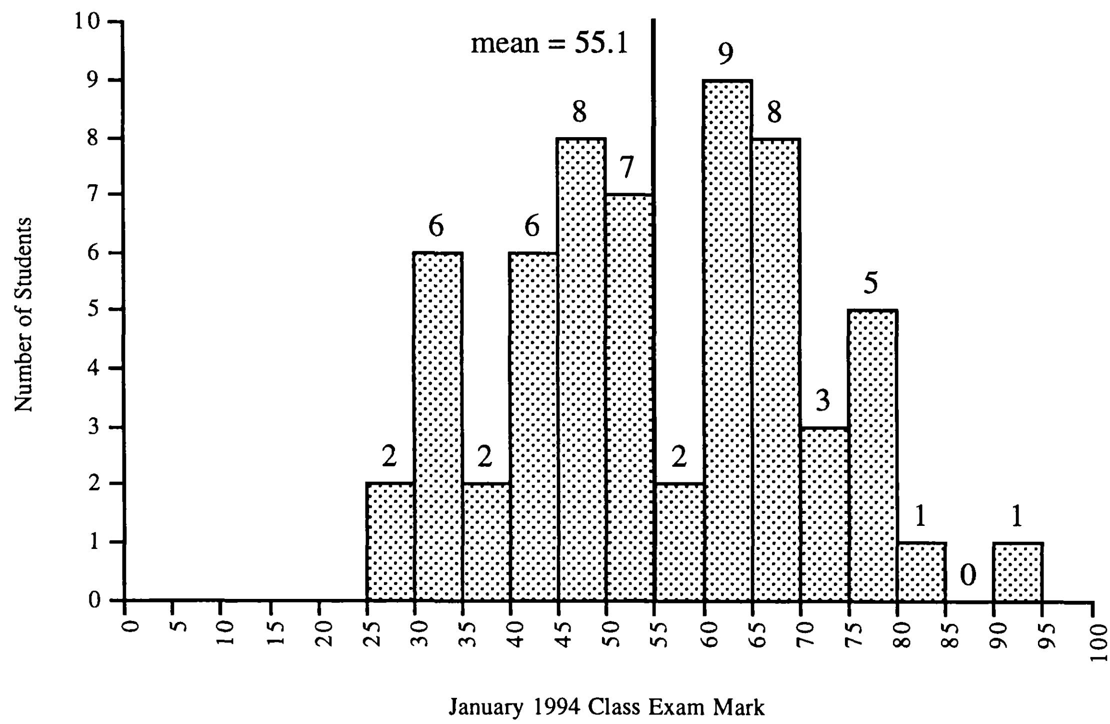
Graph F6 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Modular Chemistry Qualifications



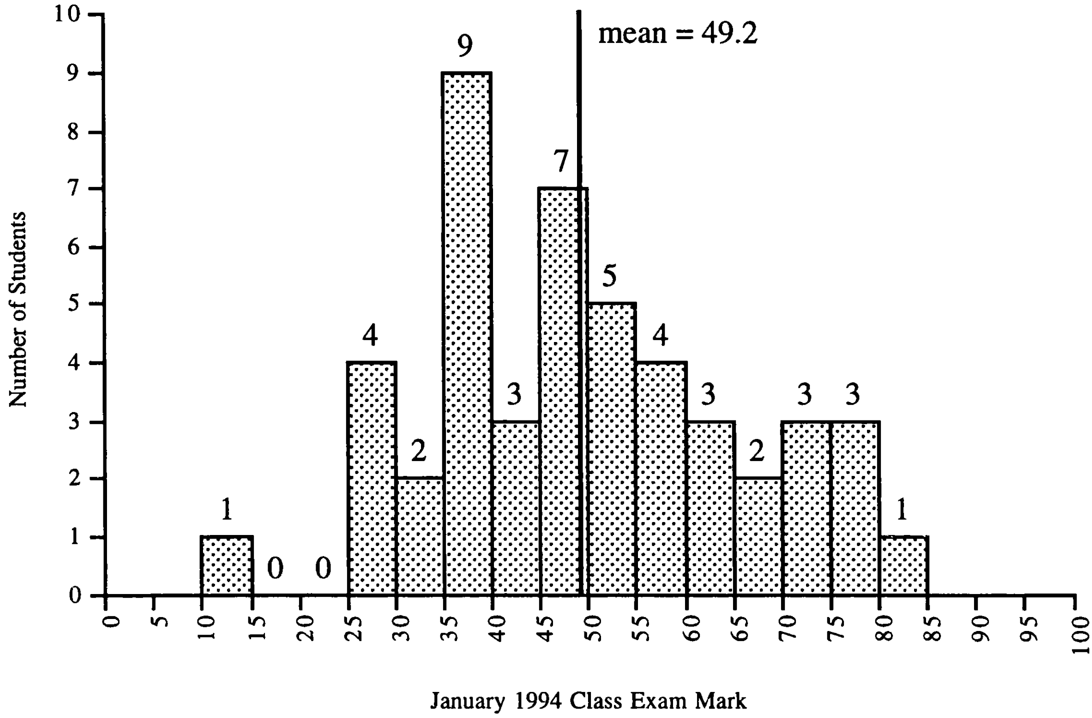
Graph F7 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with No Chemistry Qualification



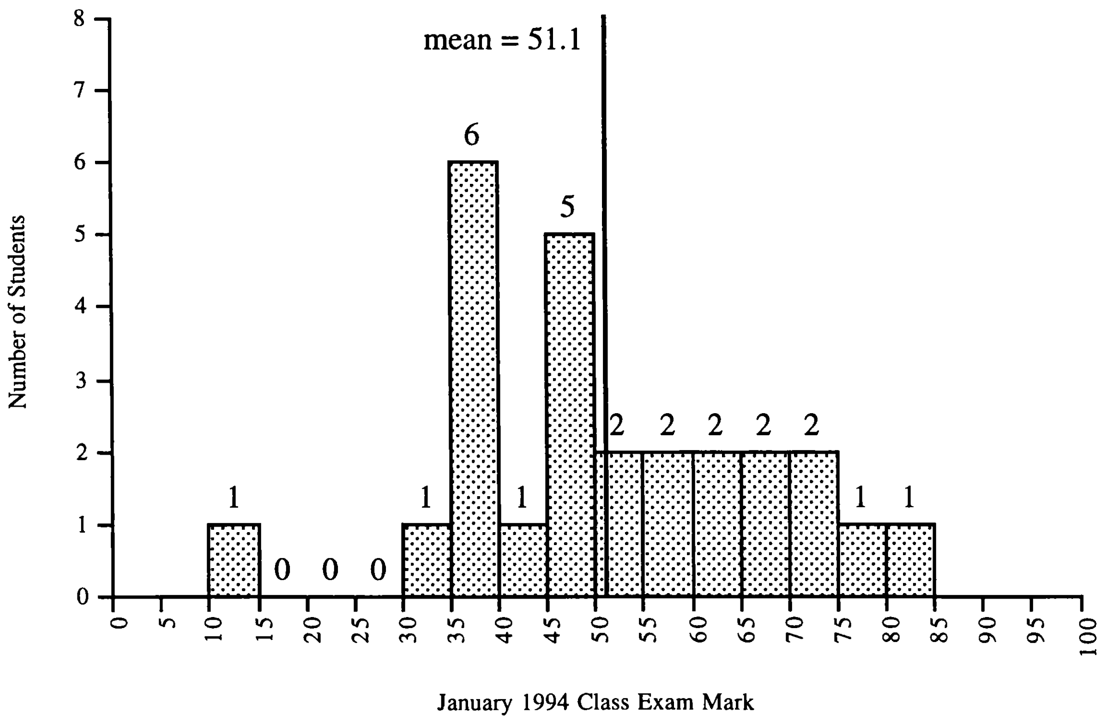
Graph F8 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Standard Entry (Mathematics) Qualifications



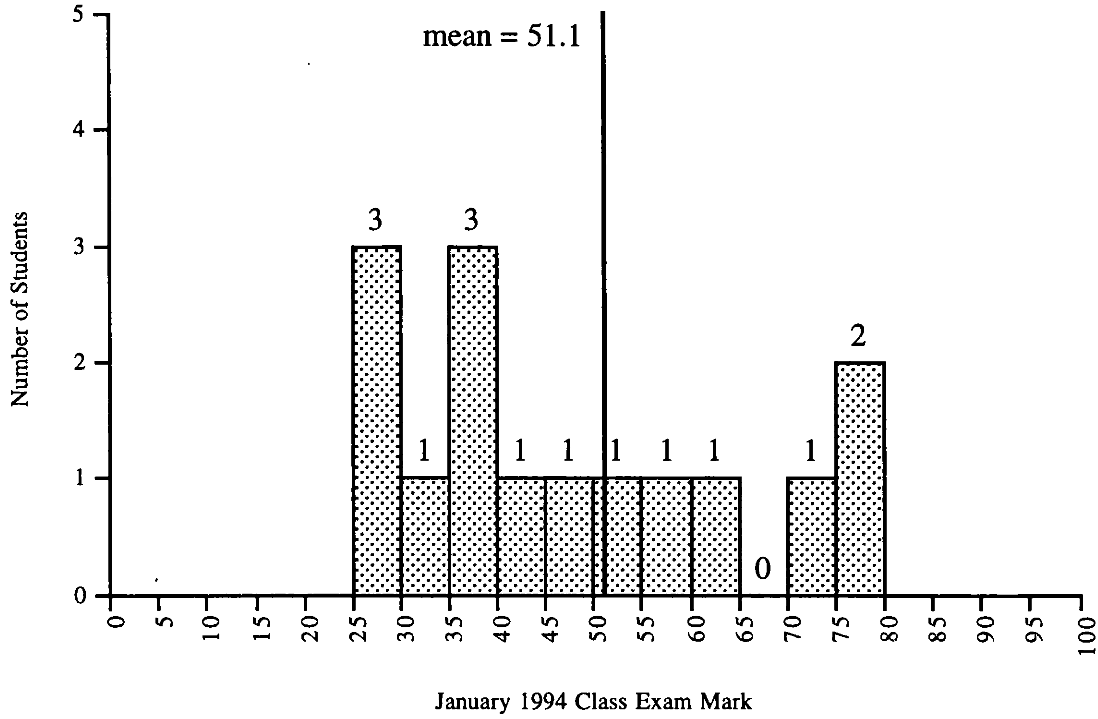
Graph F9 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Non-Standard (Mathematics) Qualifications



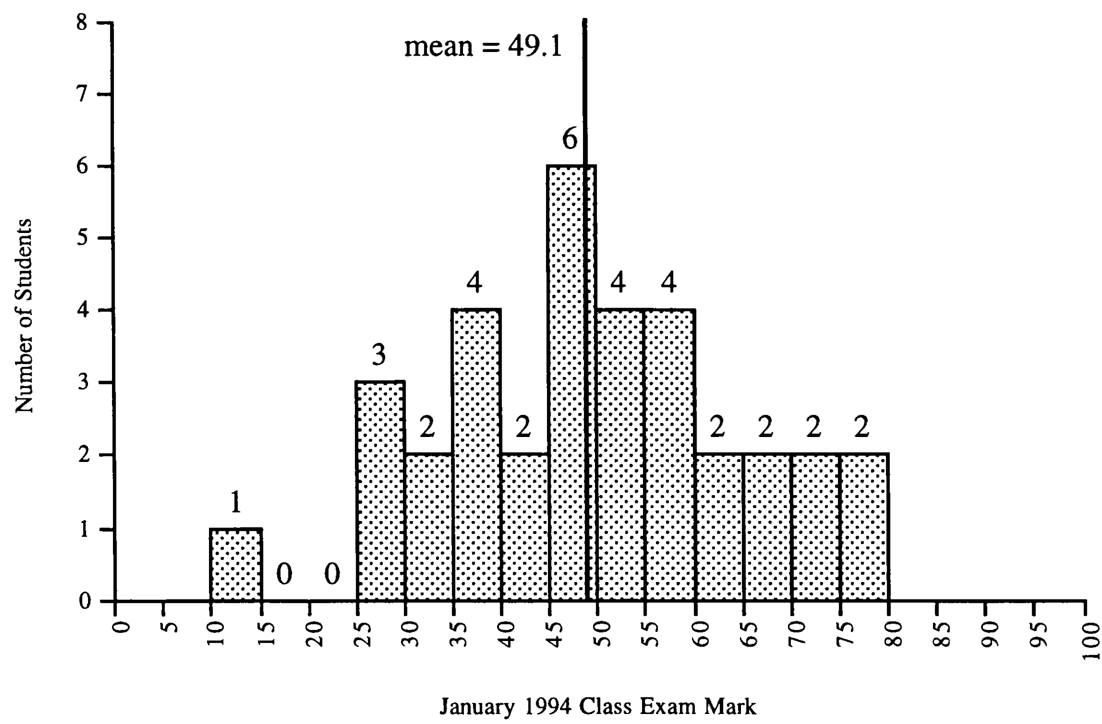
Graph F10 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Scottish Standard Grade Mathematics Qualifications



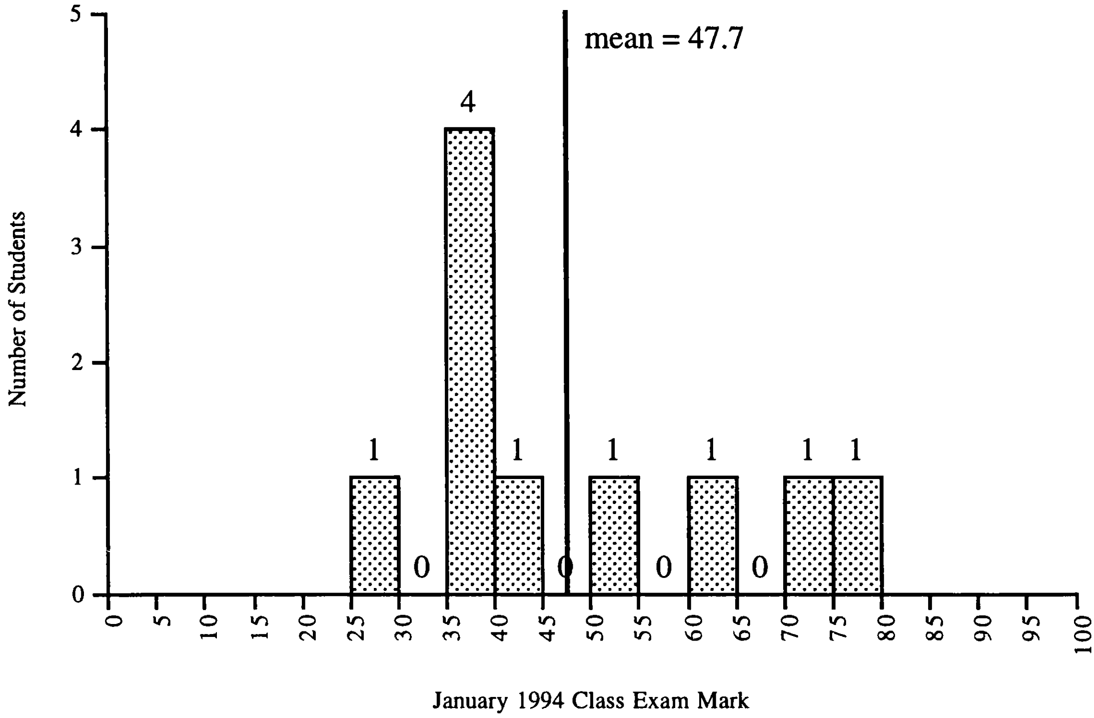
Graph F11 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Modular Mathematics Qualifications



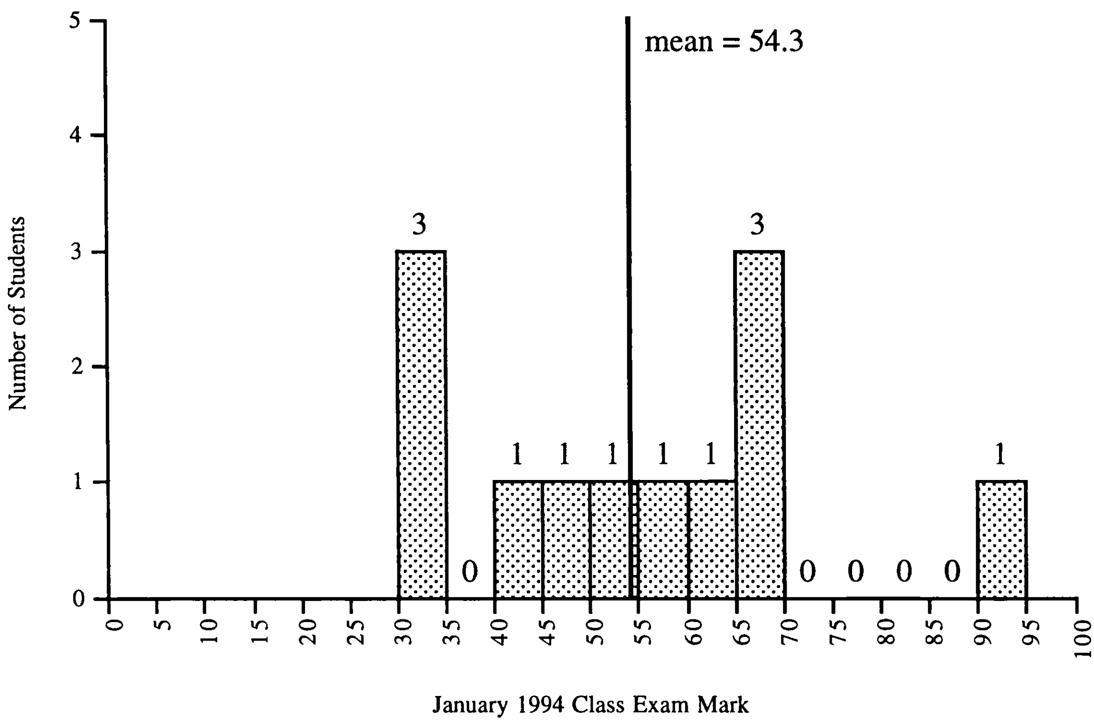
Graph F12 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Non-Standard Entry (Chemistry and Maths) Qualifications



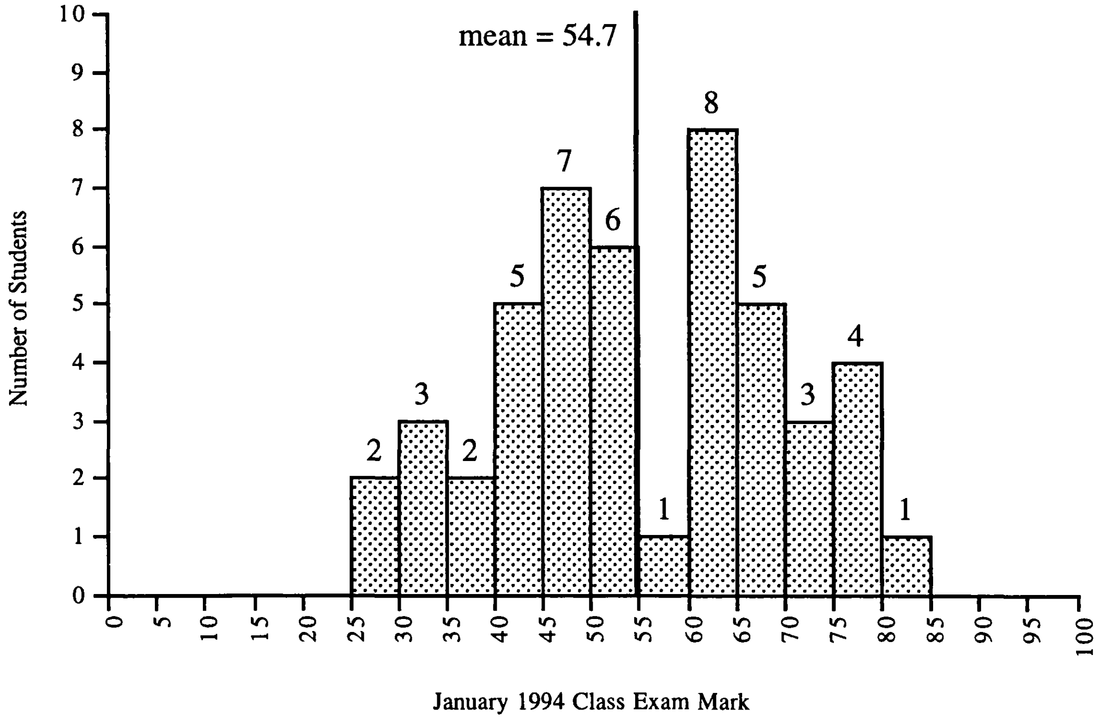
Graph F13 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Non-Standard Mathematics and Standard Chemistry Qualifications



Graph F14 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Standard Mathematics and Non-Standard Chemistry Qualifications

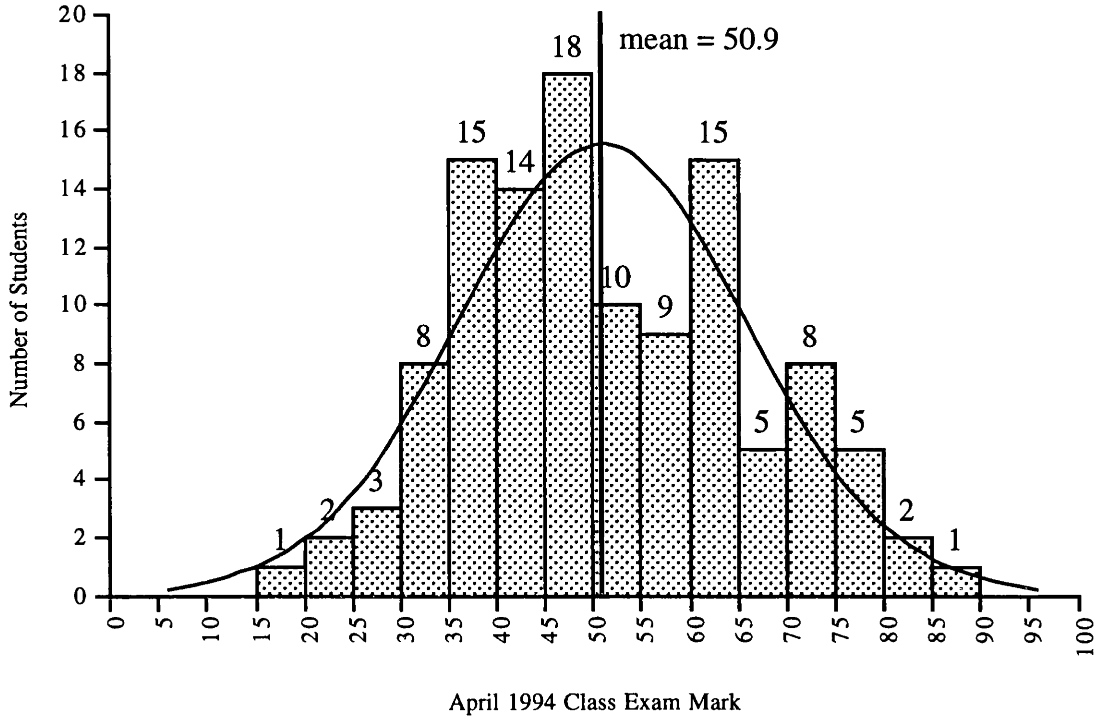


Graph F15 Distribution of General Chemistry–1 1993/94 January Class Exam Marks Students with Standard Entry (Maths and Chemistry) Qualifications

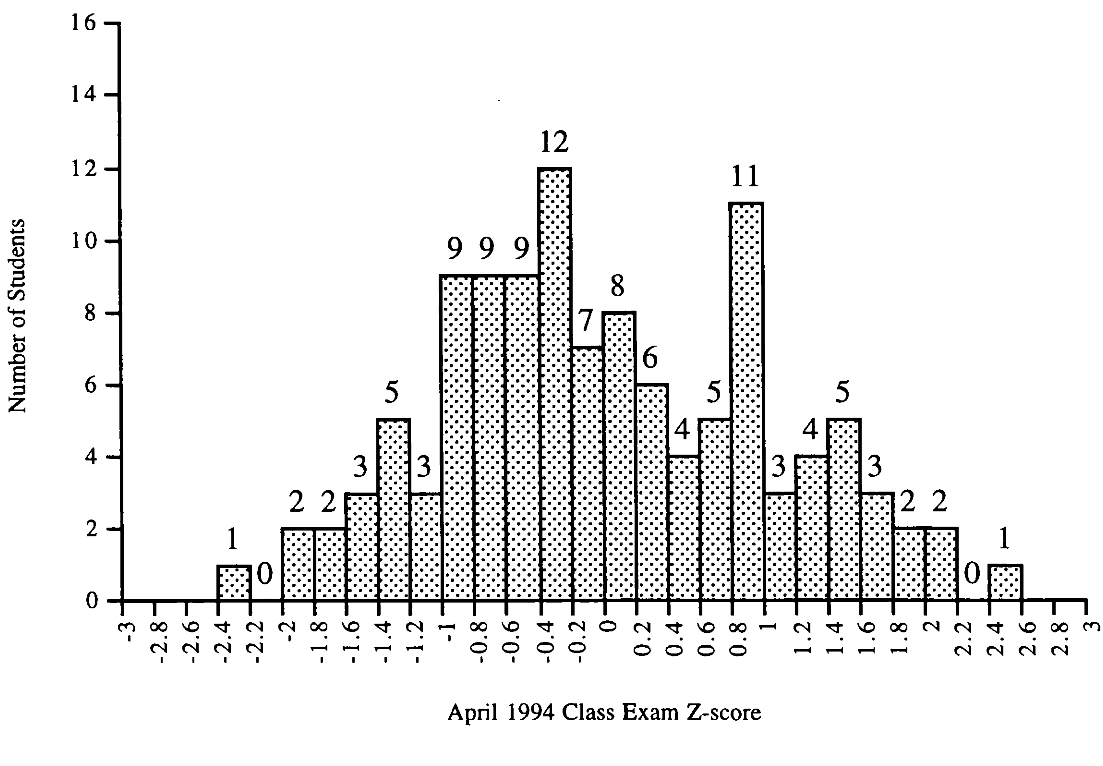


Appendix G
General Chemistry–1, 1993/94
April Class Exam Marks

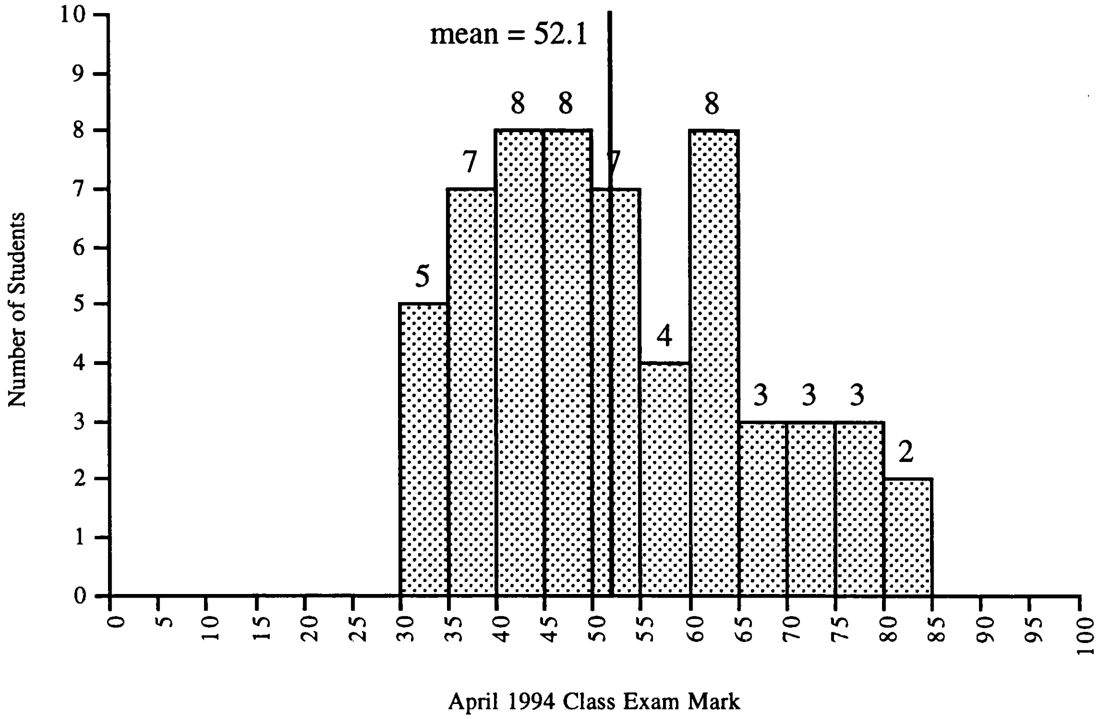
Graph G1 Distribution of General Chemistry–1 1993/94 April Class Exam Marks



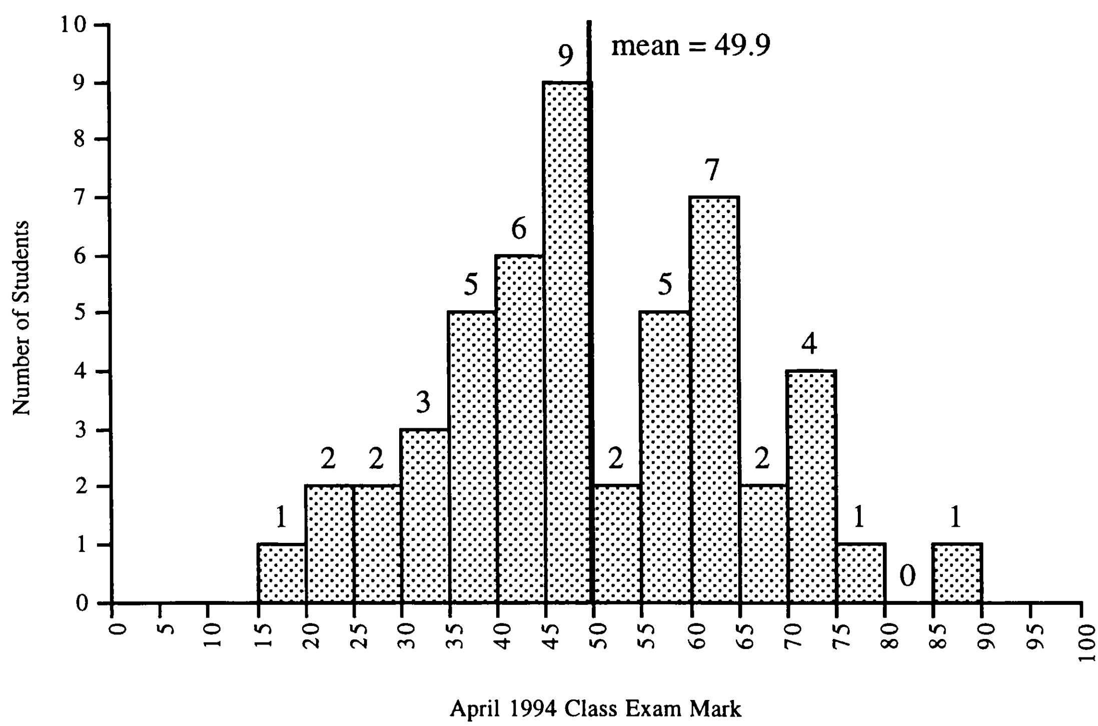
Graph G2 Distribution of General Chemistry–1 1993/94 April Class Exam Marks as Z-scores



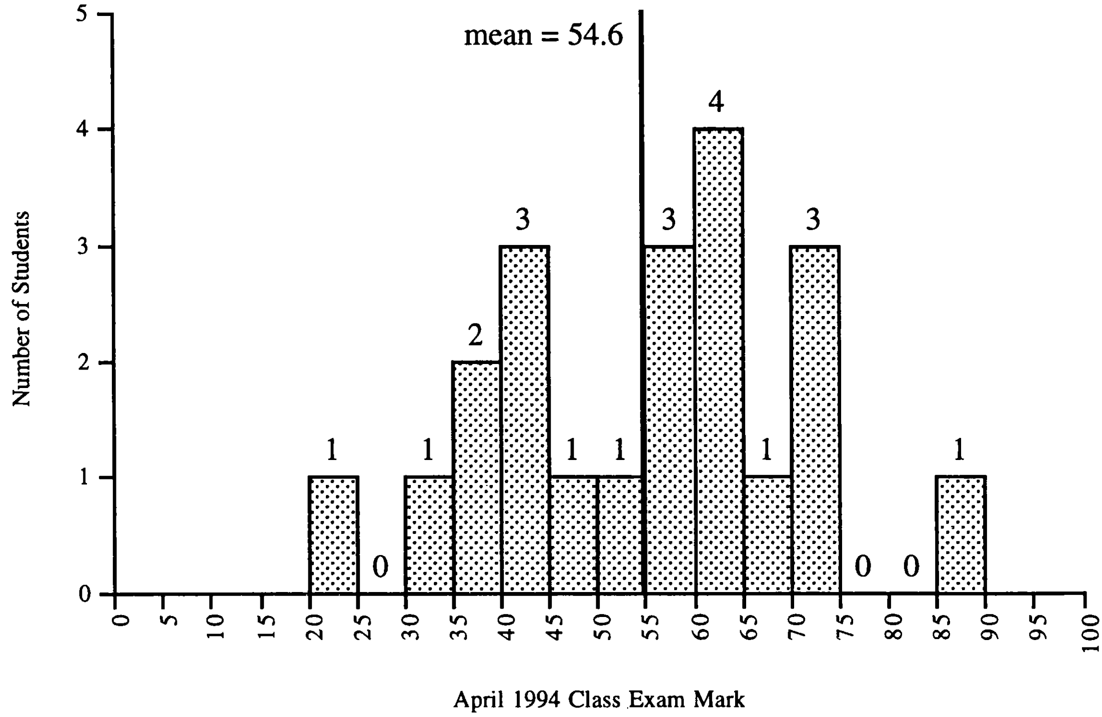
Graph G3 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Standard Entry (Chemistry) Qualifications



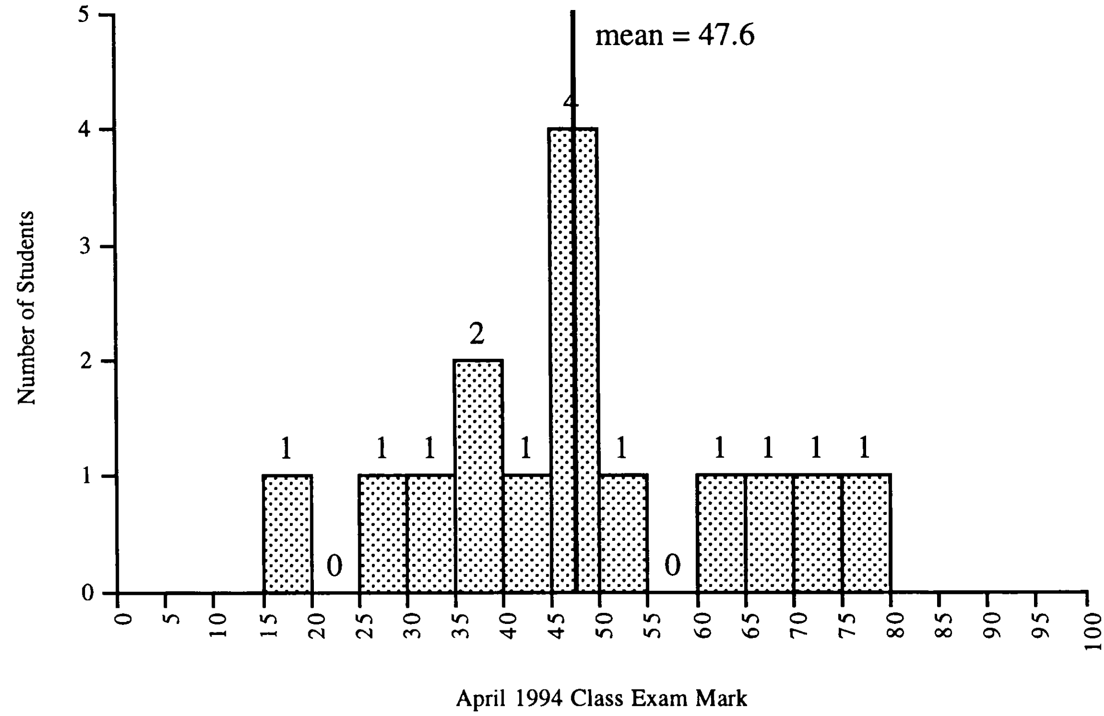
Graph G4 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Non-Standard Entry (Chemistry) Qualifications



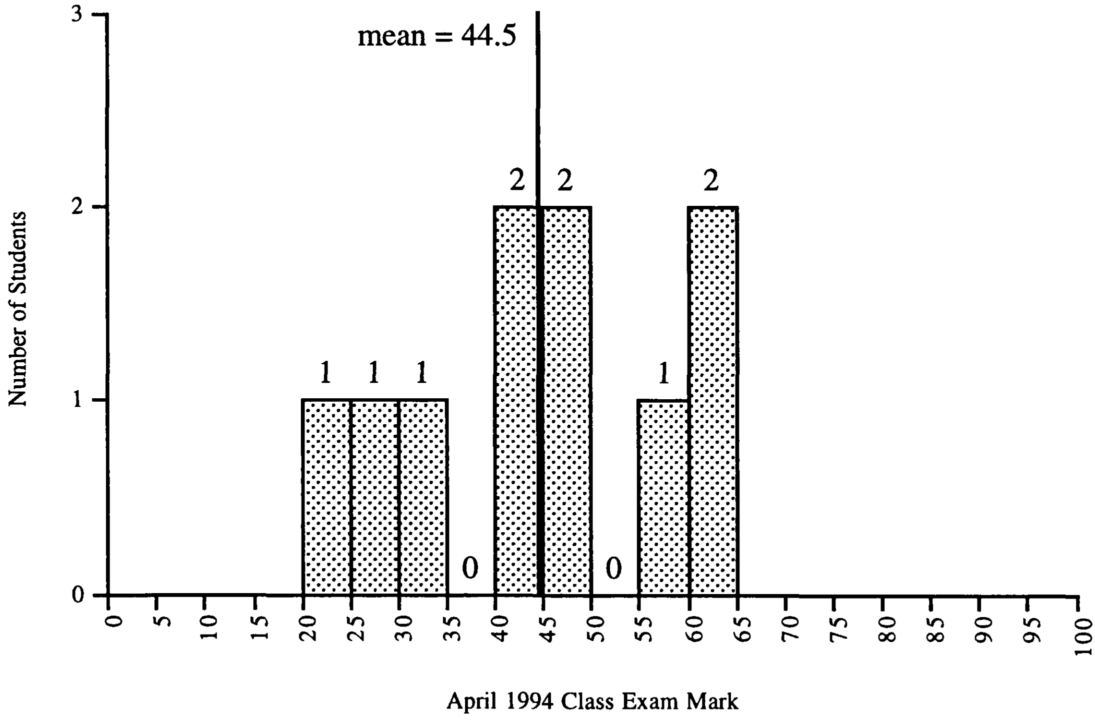
Graph G5 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Scottish Standard Grade Chemistry Qualifications



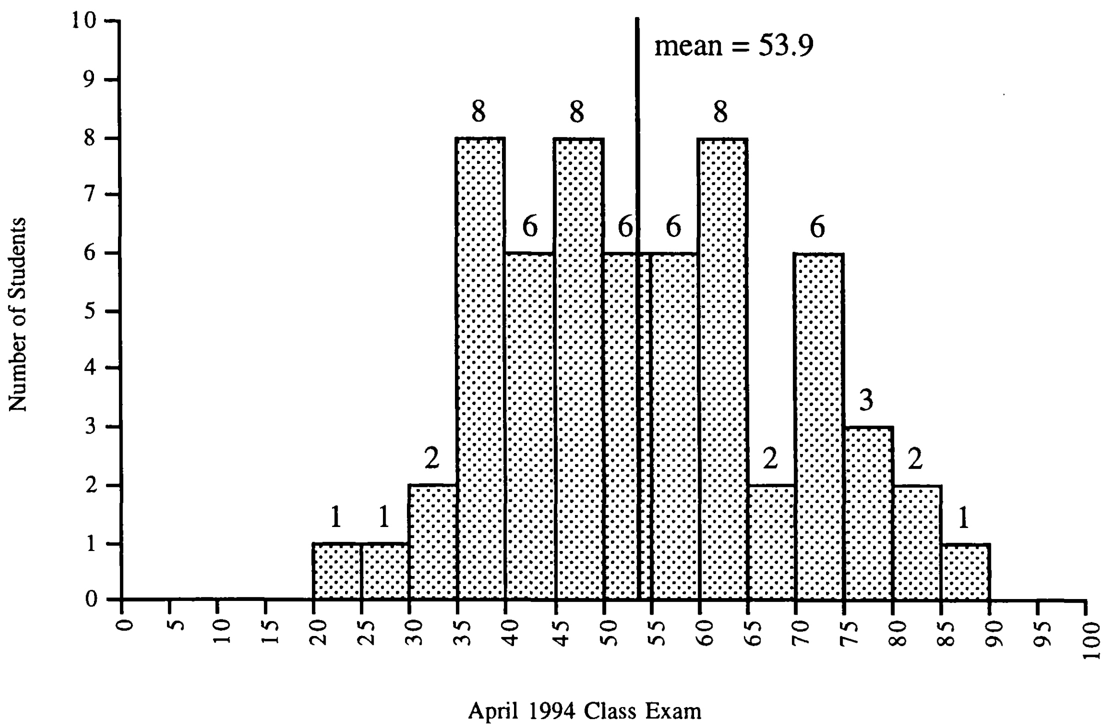
Graph G6 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Modular Chemistry Qualifications



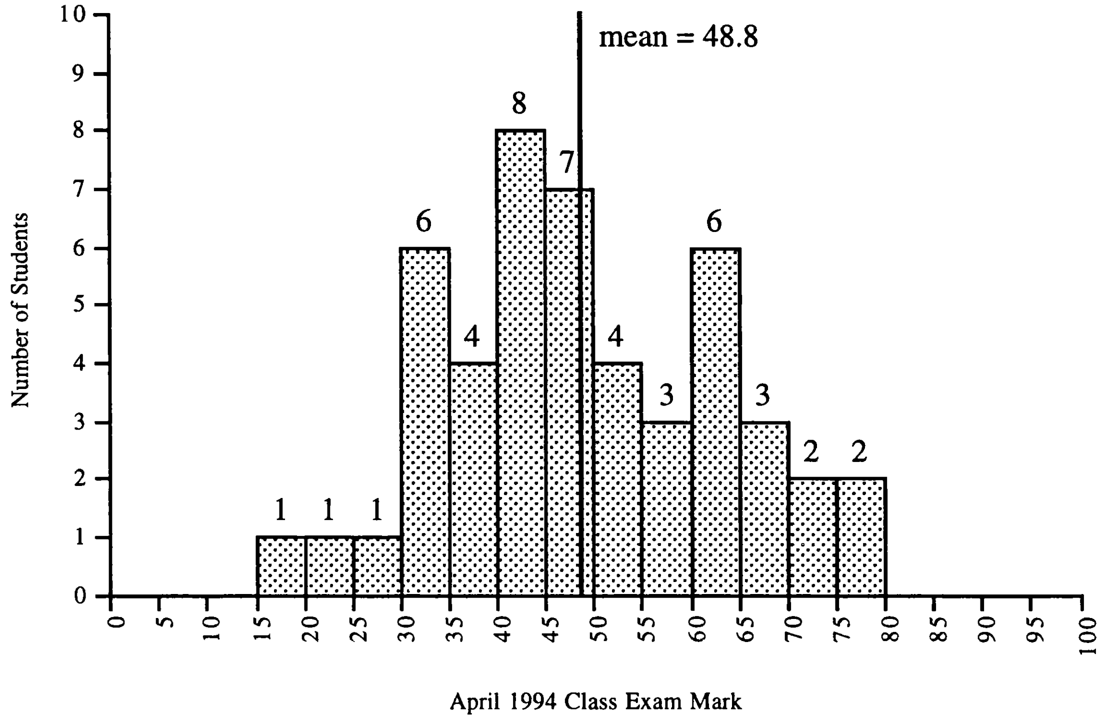
Graph G7 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with No Chemistry Qualifications



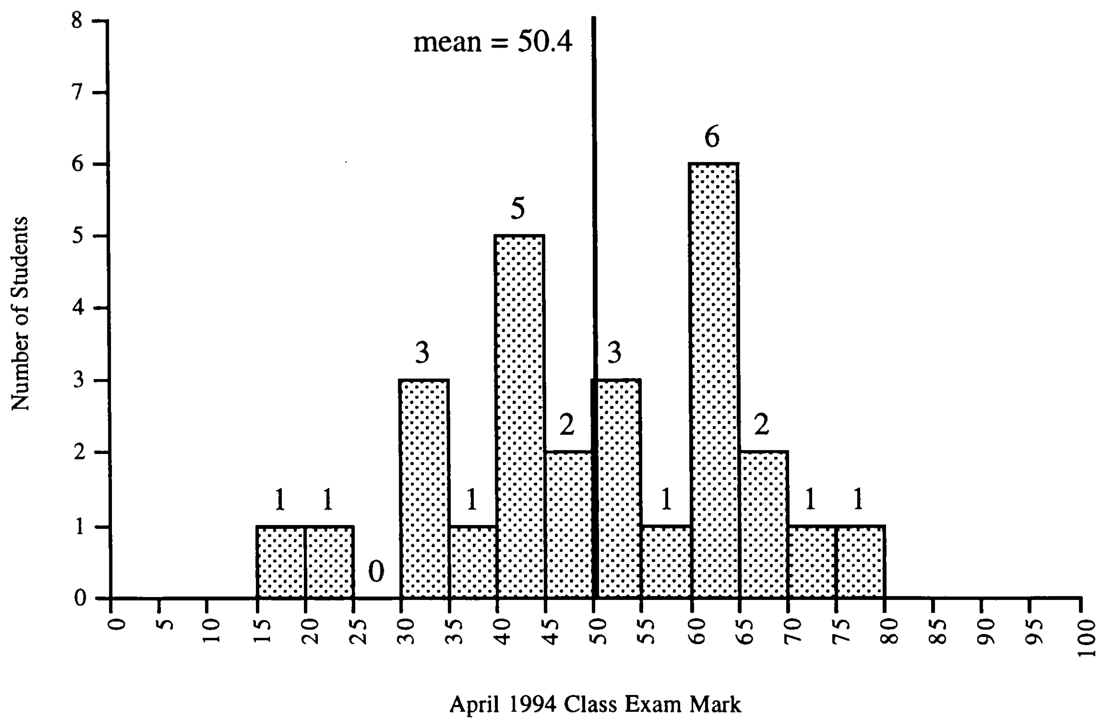
Graph G8 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Standard Entry (Mathematics) Qualifications



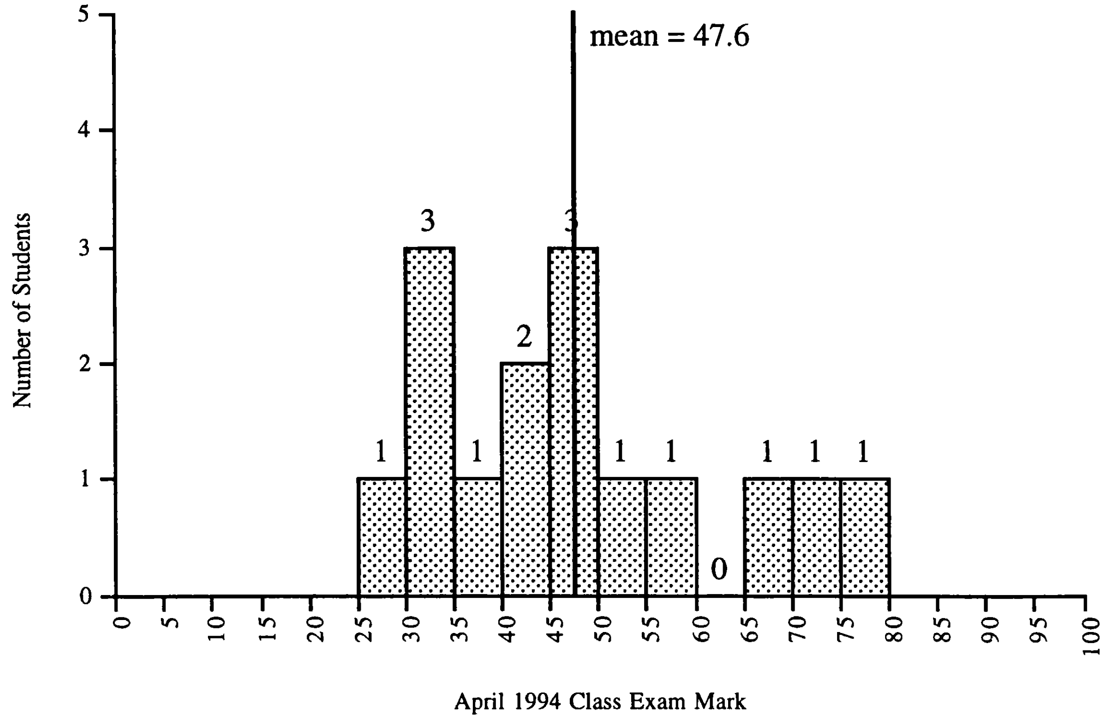
Graph G9 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Non-Standard (Mathematics) Qualifications



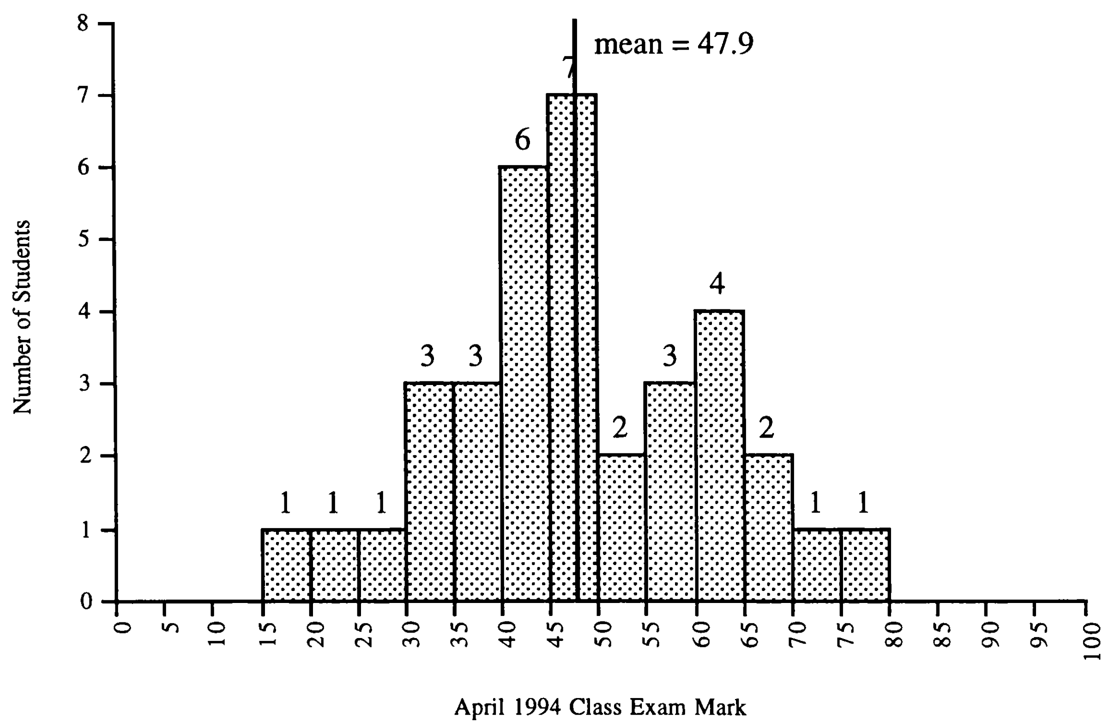
Graph G10 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Scottish Standard Grade Mathematics Qualifications



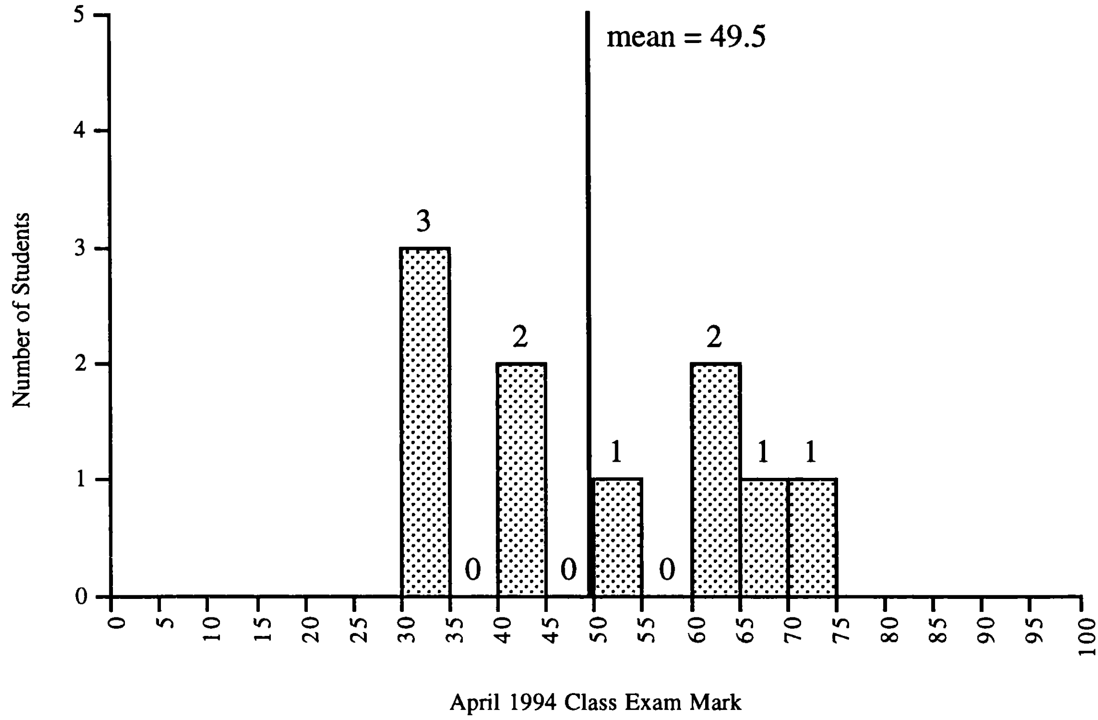
Graph G11 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Modular Mathematics Qualifications



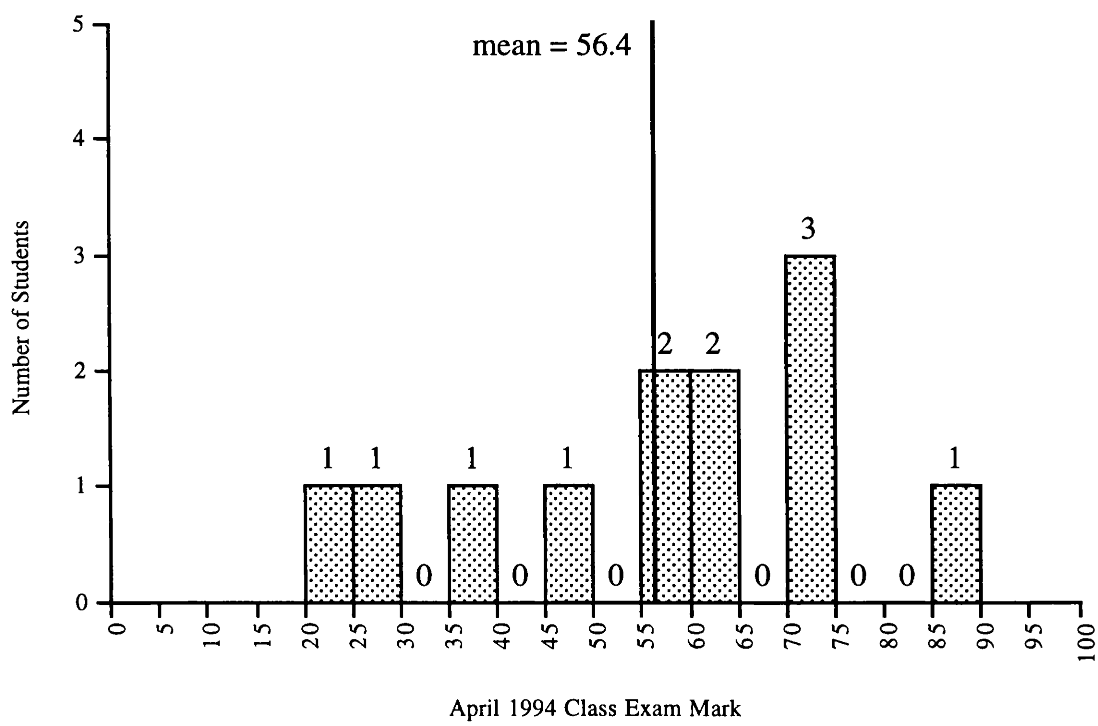
Graph G12 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Non-Standard Entry (Chemistry and Maths) Qualifications



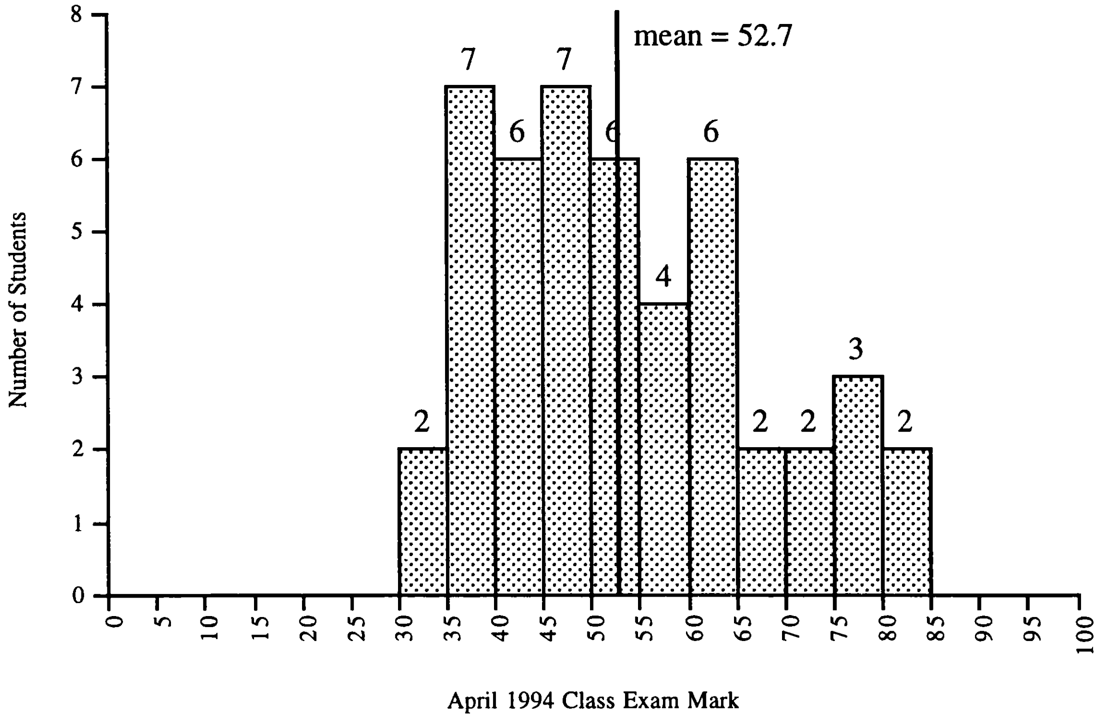
Graph G13 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Non-Standard Mathematics and Standard Chemistry Qualifications



Graph G14 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Standard Mathematics and Non-Standard Chemistry Qualifications



Graph G15 Distribution of General Chemistry–1 1993/94 April Class Exam Marks Students with Standard Entry (Maths and Chemistry) Qualifications



Appendix H

Perry Questionnaire

Notes:

i) The Perry Questionnaire was presented to students as an A5 booklet and is reprinted here at approx. 140 % of actual size.

ii) The 18 statements in Part One appear in the order Perry A, B, C over and over again.

Centre For Science Education

Student Questionnaire

NAME(optional):______________________________

MATRICULATION No:____________________________

Part One

This is a questionnaire about your course and your approach to studying. Go through the following statements and indicate your immediate reaction by circling the appropriate number. Remember, there are no correct answers and your responses to this questionnaire will not affect any other part of your course.

(6 = strongly agree, 5 = agree, 4 = probably agree, 3 = probably disagree, 2 = disagree, 1 = strongly disagree)

1.	I think it is the responsibility of the lecturer to give me all the information I need to pass a course	6 5 4 3 2 1
2.	Sometimes there seem to be so many ways of looking at the course subjects, I feel confused about what is right and wrong	6 5 4 3 2 1
3.	Sometimes, I find that I learn more about a subject by discussing it with other student than I do by sitting and revising at home	6 5 4 3 2 1
4.	There isn't any point in a course including things which will not be included in an exam	6 5 4 3 2 1
5.	If I read something which doesn't agree with I have been told in lectures, I prefer to stick with the lecturer's point of view	6 5 4 3 2 1
6.	If I had the choice of written feedback or a specific mark at the end of a piece of coursework, I would select the feedback	6 5 4 3 2 1
7.	It is a waste of time to work on problems which have no possibility of coming out with a clear-cut, unambiguous answer	6 5 4 3 2 1
8.	I feel uncomfortable when I am left to make up my own mind about a subject and I don't know how the lecturer feels	6 5 4 3 2 1
9.	I enjoy undertaking projects where the lecturer doesn't specify exactly what has to be done and it is left to me to decide	6 5 4 3 2 1

(6 = strongly agree, 5 = agree, 4 = probably agree, 3 = probably disagree, 2 = disagree, 1 = strongly disagree)

10	A good thing about learning science is the fact that everything is so clear cut – either right or wrong	6 5 4 3 2 1
11.	The worst thing about a vague assignment is that you don't know how much the lecturer wants done	6 5 4 3 2 1
12.	I like exams which give me an opportunity to show I have ideas of my own	6 5 4 3 2 1
13.	The only fair problem exercises are those which are exactly like those we have already done in class	6 5 4 3 2 1
14.	I sometimes pick a topic or way of answering an exam question which I know the lecturer likes, in order to get higher marks	6 5 4 3 2 1
15.	It's good when a number of lecturers are teaching a course because you get not just one, but a variety of opinions	6 5 4 3 2 1
16.	I would be surprised, if the lecturer could not answer any questions relating to their courses, I might ask	6 5 4 3 2 1
17.	It is better if a course has only one person lecturing it, so that you don't get any conflicting opinions	6 5 4 3 2 1
18.	I usually find myself thinking about how new topics relate to other parts of the course	6 5 4 3 2 1

Part Two

Do you AGREE or DISAGREE with the following statements ? Justify your answers in 3 or 4 sentences.

Agree	Disagree	
_____	_____	A good thing about learning science is the fact that everything is so clear cut – either right or wrong. **Justify your decision** __________
_____	_____	Scientists will eventually be able to solve every medical problem: it is only a question of time. **Justify your decision** __________
_____	_____	There sometimes seems to be so many ways of looking at scientific subjects, I feel confused about what is right and wrong. **Justify your decision** __________
_____	_____	A scientific idea cannot have meaning own its own; its meaning will depend on the situation in which it is being used. **Justify your decision** __________
_____	_____	You can never be completely sure of any scientific fact: uncertainty will always exist. **Justify your decision** __________
_____	_____	When I meet a new idea in a course I try to relate it to things I have met in other parts of the course. **Justify your decision** __________

Other Information

Information about your background and your university life would be very valuable for research purposes. All responses will be held in strict confidence.

Date of birth ____________________

Entered University from: (tick as appropriate)
____ fifth year at school
____ sixth year at school
____ college
____ other (please specify)__________
____
____
____

Chemistry Qualifications: Tick box(es) of all courses studied, giving grades where appropriate (give both first grade and re-sit grade if applicable)

Course	Studied ?	Grade(s)
Standard / "O" Grade		
Higher Grade		
CSYS		
GCSE		
GCE "A" level		
Modular*		

* Specify which / how many

Other / module* details ____________________
____
____

Highest mathematics qualification (with grade) ____________________
____

Other subjects studied at university this year ____________________
____
____

What is likely to be your intended honours subject ? ____________________
____

Thank you for your co-operation.

Appendix I

Shapes Test for Field Dependency

Notes:

i) The Shapes Test was presented to students as an A5 booklet.

ii) Page I16 formed a flap on the back of the booklet to allow students to see the Target Shapes as they searched the Complex Figures.

iii) The answers to the Shapes Test are included, beginning on page I17

NAME (optional):______________________________
MATRICULATION NO.:____________________________

SHAPES

This is a test of your ability to recognise simple SHAPES, and to pick out and trace HIDDEN SHAPES within complex patterns..

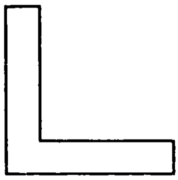
The results will not affect your course assessment in any way.

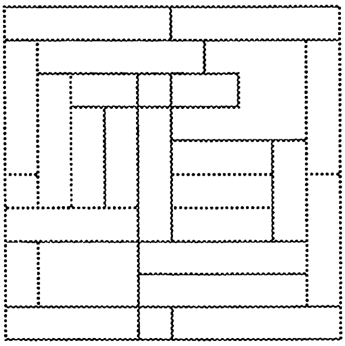
YOU ARE ALLOWED ONLY 20 MINUTES TO ANSWER ALL THE ITEMS.
TRY TO ANSWER EVERY ITEM, BUT DON'T WORRY IF YOU CAN'T.
DO AS MUCH AS YOU CAN IN THE TIME ALLOWED.
DON'T SPEND TOO MUCH TIME ON ANY ONE ITEM.

DO NOT START UNTIL YOU ARE TOLD

LOOKING FOR HIDDEN SHAPES

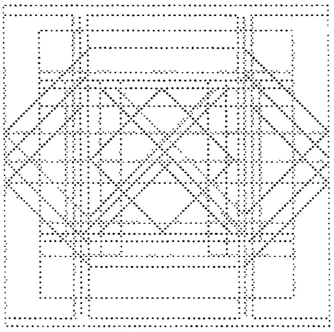
A simple geometrical figure can be 'hidden' by embedding it in a complex pattern of lines. For example, the simple L-shaped figure on the left has been hidden in the pattern of lines on the right. Can you pick it out?





Using a pen, trace round the outline of the L-shaped figure to mark its position.

The same L-shaped figure is also hidden within the more complex pattern below. It is the **same size**, the **same shape** and **faces in the same direction** as when it appears alone. Mark its position by tracing round its outline using a pen.



(To check your answers, open out the flap on the back cover of this booklet.)

More problems of this type appear on the following pages. In each case, you are required to find a simple shape 'hidden' within a complex pattern of lines, and then, using a pen, to record the shape's position by tracing its outine.

There are **TWO** patterns on each page. Below each pattern there is a **code letter** (**A**, or **B**, or **C** etc.) to identify which shape is hidden in that pattern.

Open out the flap on the back cover of this booklet, and you will see all the shapes you have to find, along with their corresponding code letters. Keep this page flap opened out until you have finished all the problems.

Note these points:

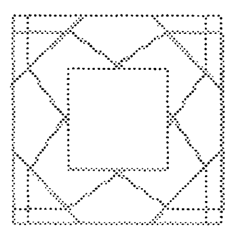
(1) You can refer to the page of simple shapes as often as necessary.

(2) When it appears within a complex pattern, the required shape is always
the same size,
has the same proportions,
and **faces in the same direction**
as when it appears alone.

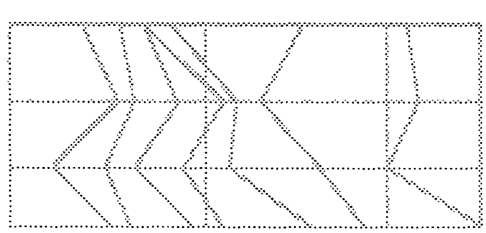
(3) Within each pattern, the shape you have to find appears only **once**. Trace the required shape **and only that shape** for each problem.

(4) Do the problems in order — don't skip one unless you are absolutely stuck.

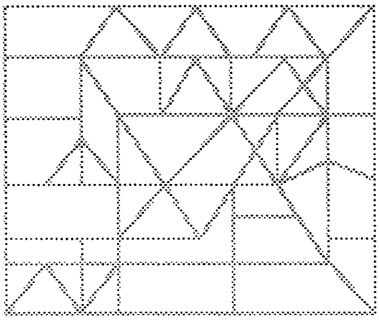
START NOW



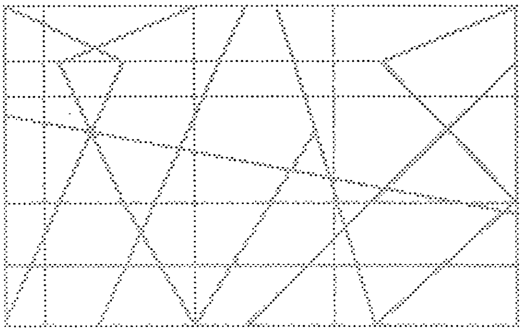
Find **SHAPE B**



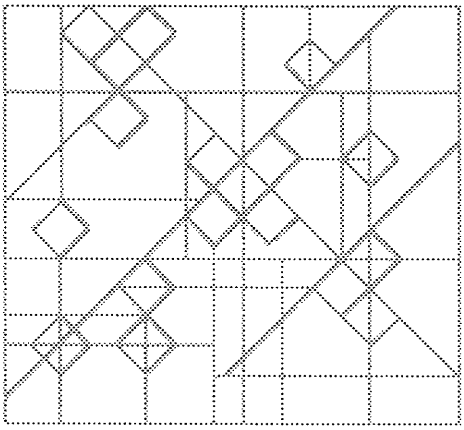
Find **SHAPE D**



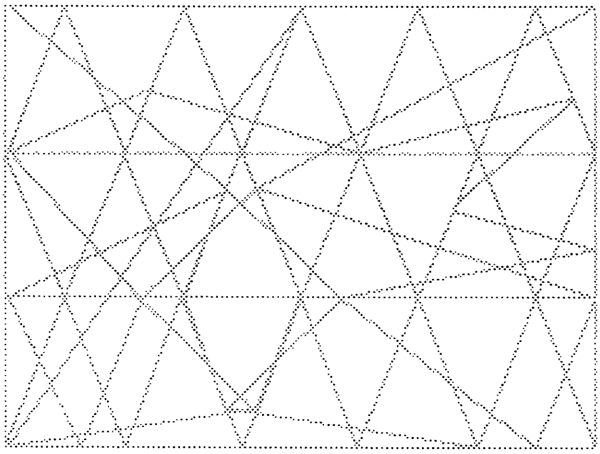
Find **SHAPE H**



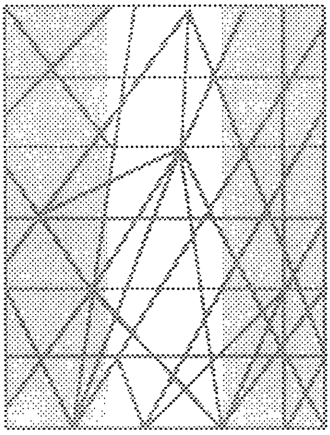
Find **SHAPE E**



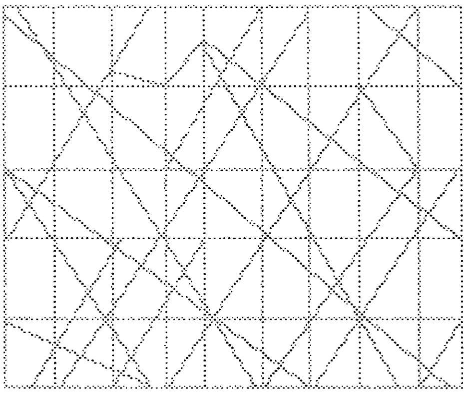
Find **SHAPE F**



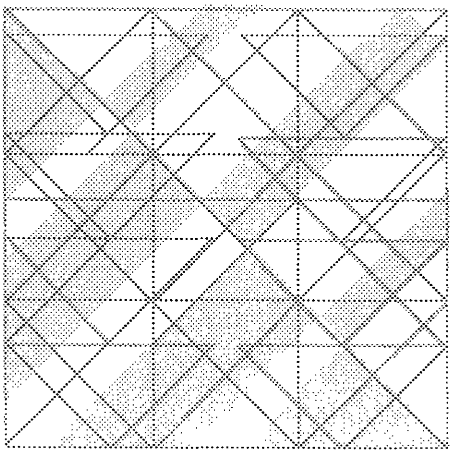
Find **SHAPE A**



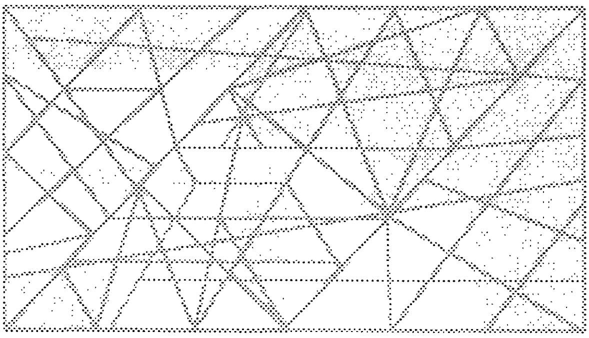
Find **SHAPE E**



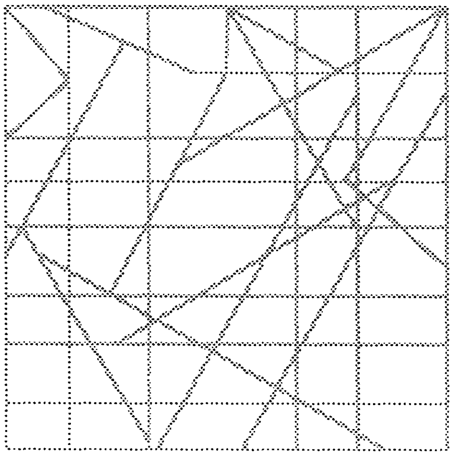
Find **SHAPE H**



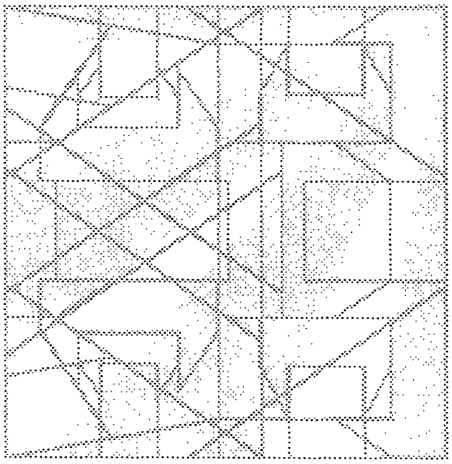
Find **SHAPE D**



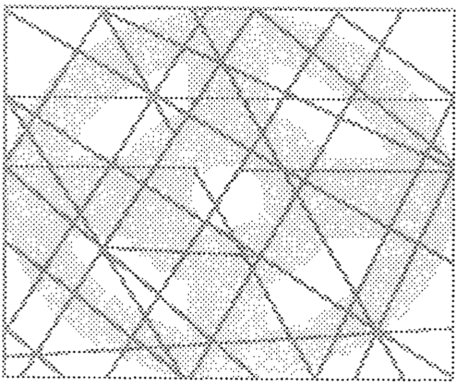
Find **SHAPE G**



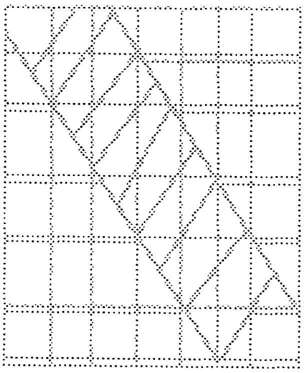
Find **SHAPE C**



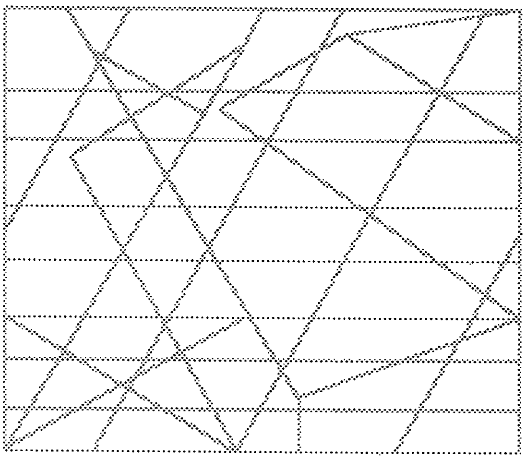
Find **SHAPE B**



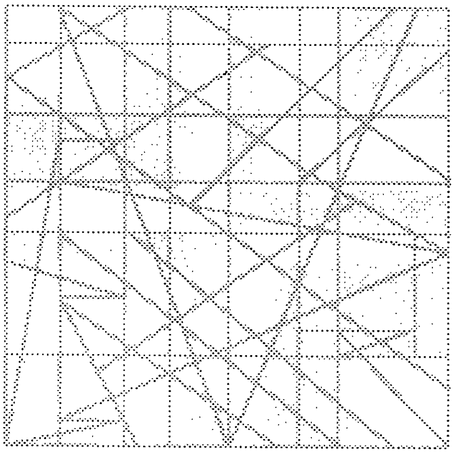
Find **SHAPE G**



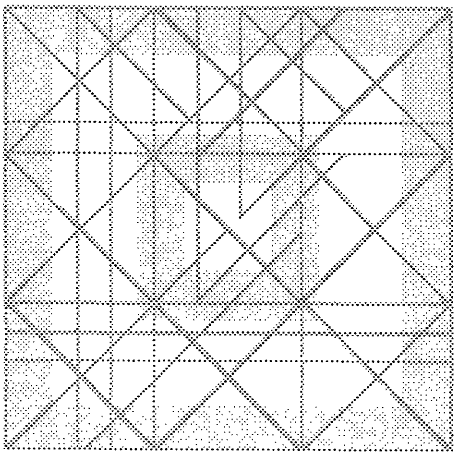
Find **SHAPE H**



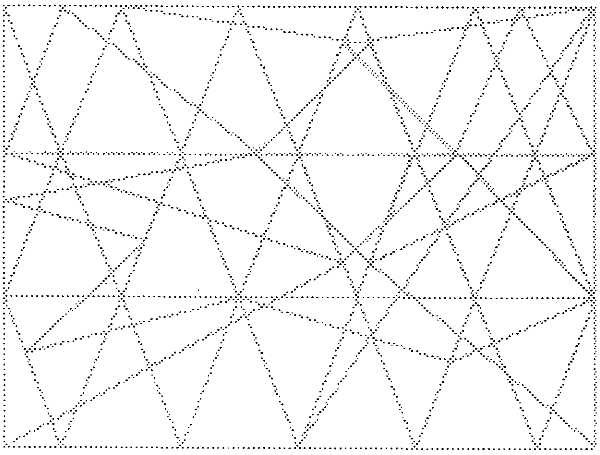
Find **SHAPE C**



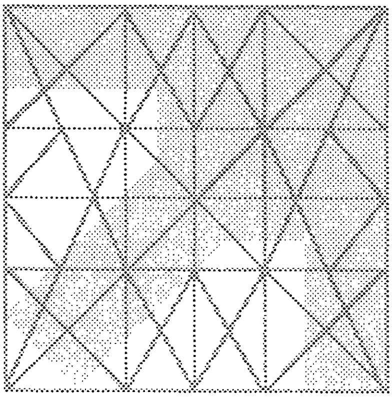
Find **SHAPE B**



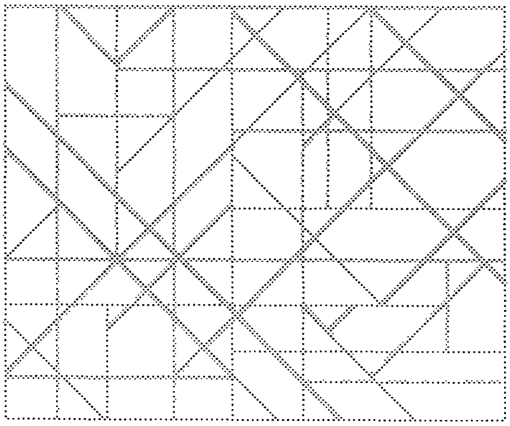
Find **SHAPE D**



Find **SHAPE A**



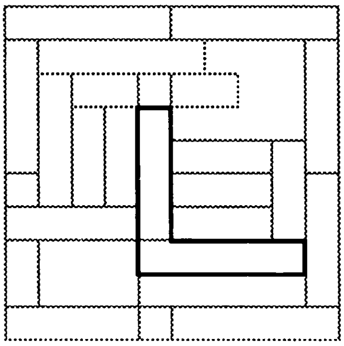
Find **SHAPE E**

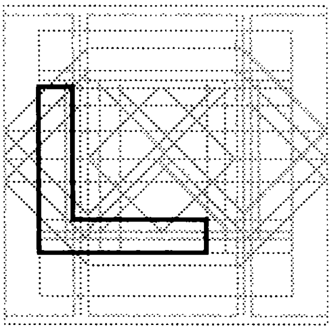


Find **SHAPE F**

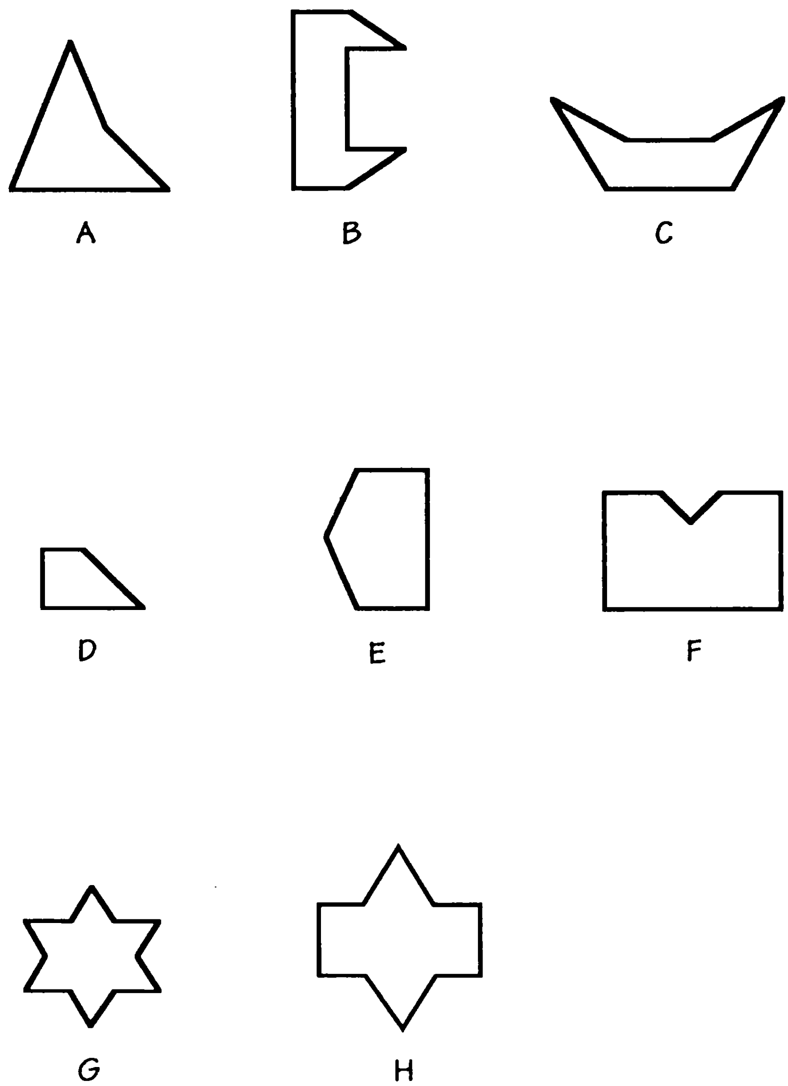
ANSWERS

When you have traced both L-shaped figures, the diagrams should look like this :

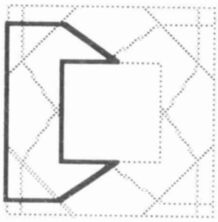




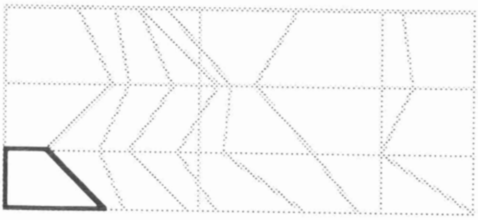
THE SHAPES YOU HAVE TO FIND



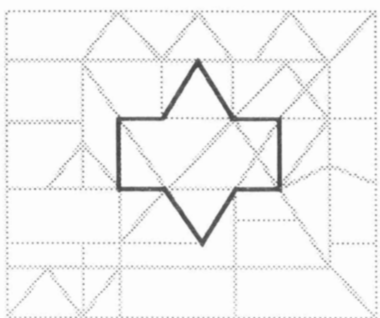
ANSWERS TO SHAPES



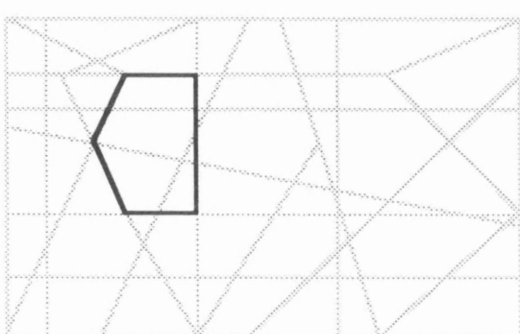
Find **SHAPE B**



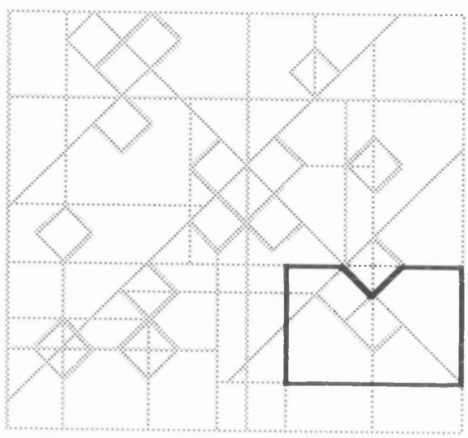
Find **SHAPE D**



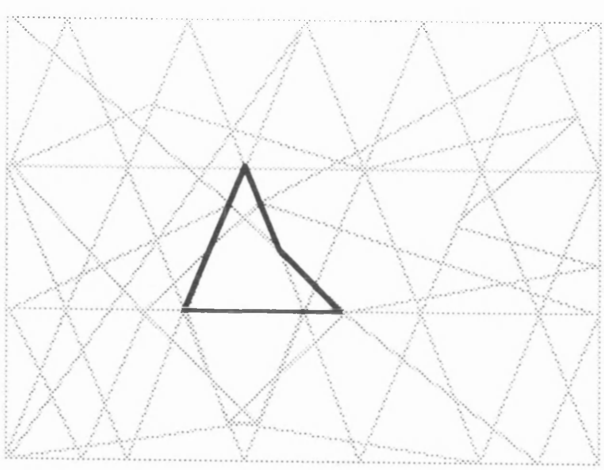
Find **SHAPE H**



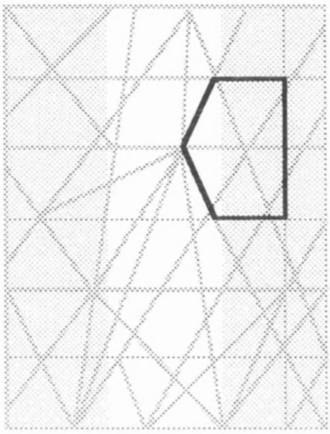
Find **SHAPE E**



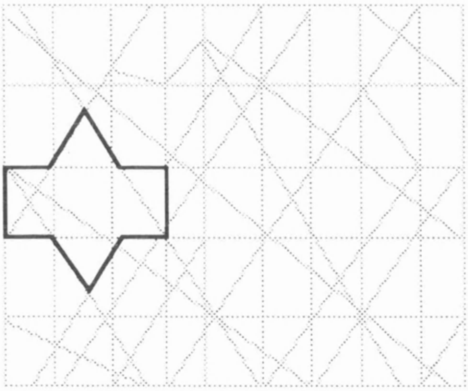
Find **SHAPE F**



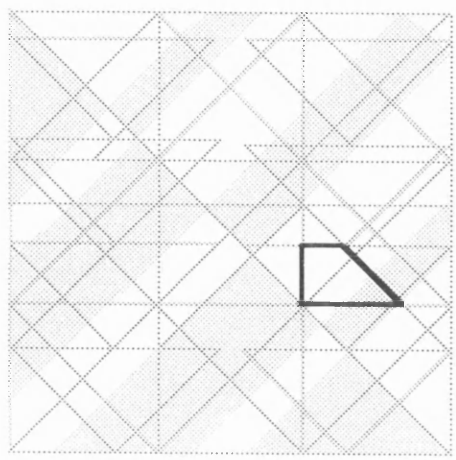
Find **SHAPE A**



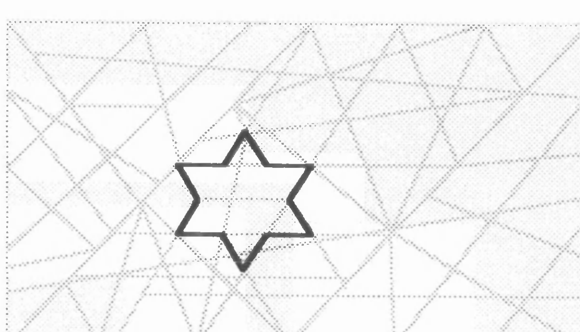
Find **SHAPE E**



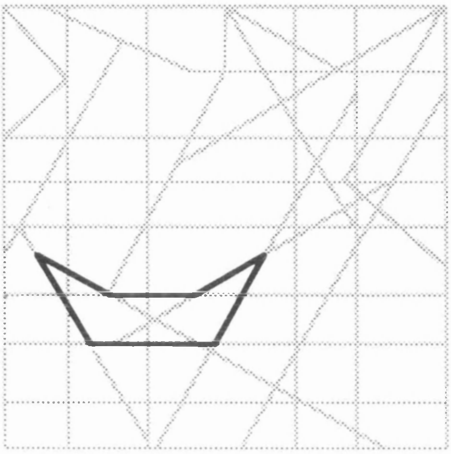
Find **SHAPE H**



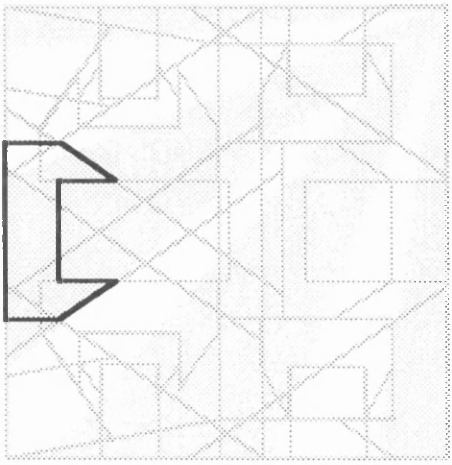
Find SHAPE D



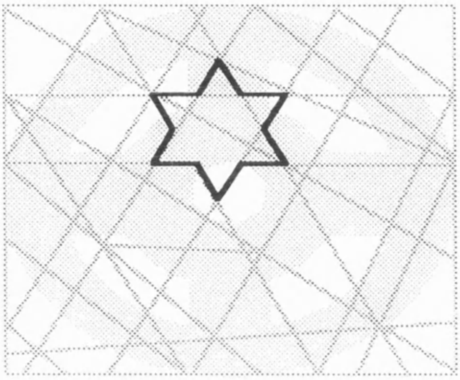
Find SHAPE G



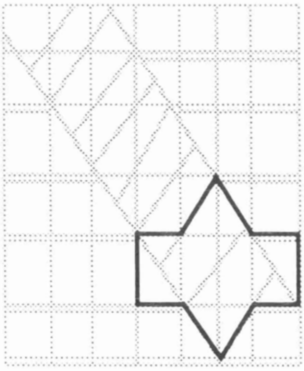
Find SHAPE C



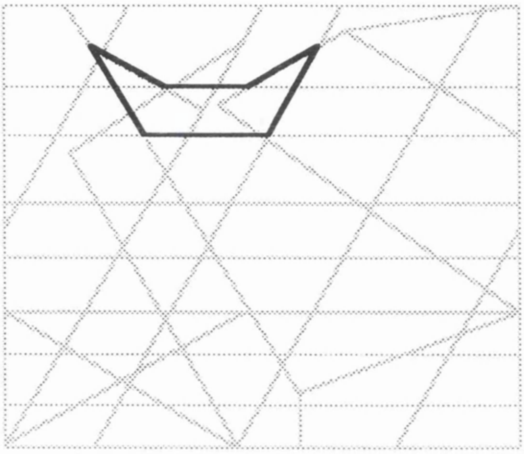
Find SHAPE B



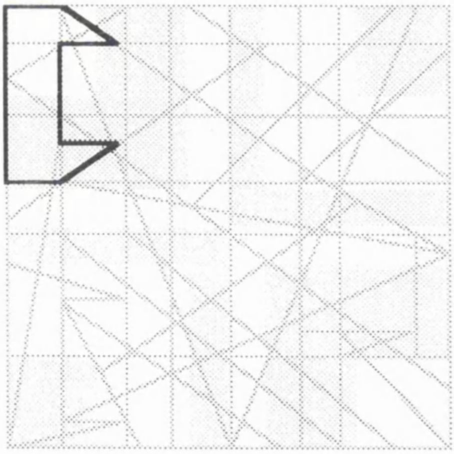
Find SHAPE G



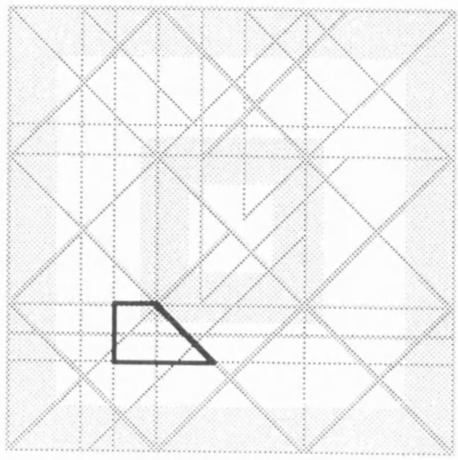
Find SHAPE H



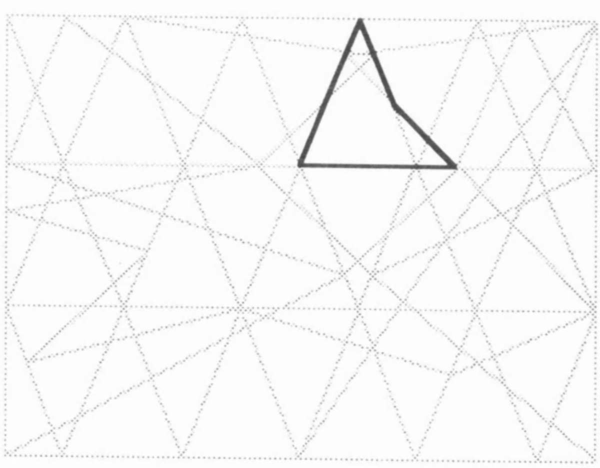
Find SHAPE C



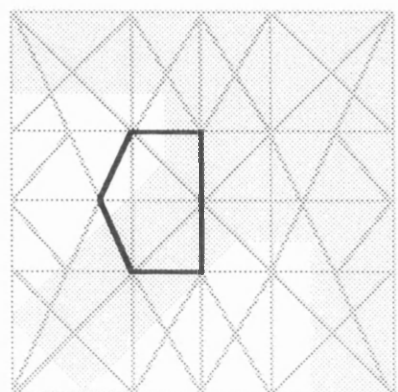
Find SHAPE B



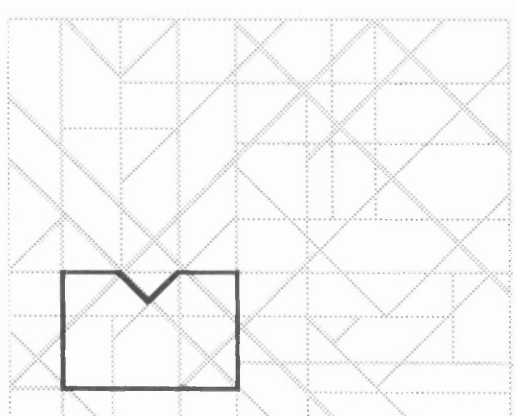
Find **SHAPE D**



Find **SHAPE A**



Find **SHAPE E**



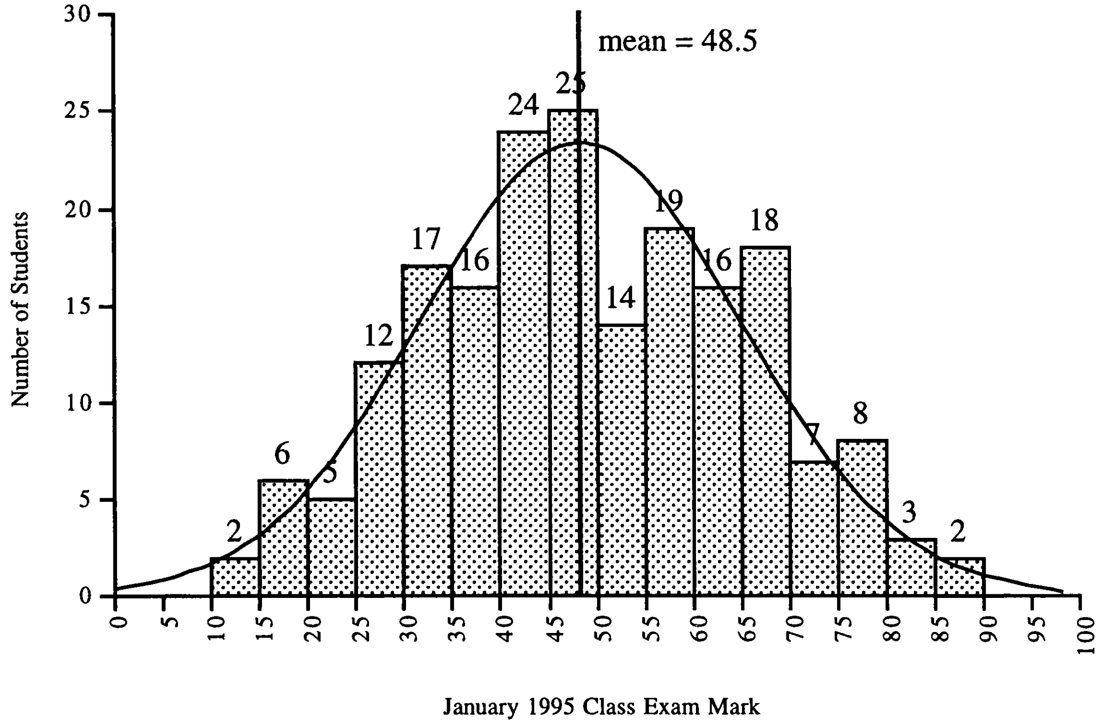
Find **SHAPE F**

Appendix J

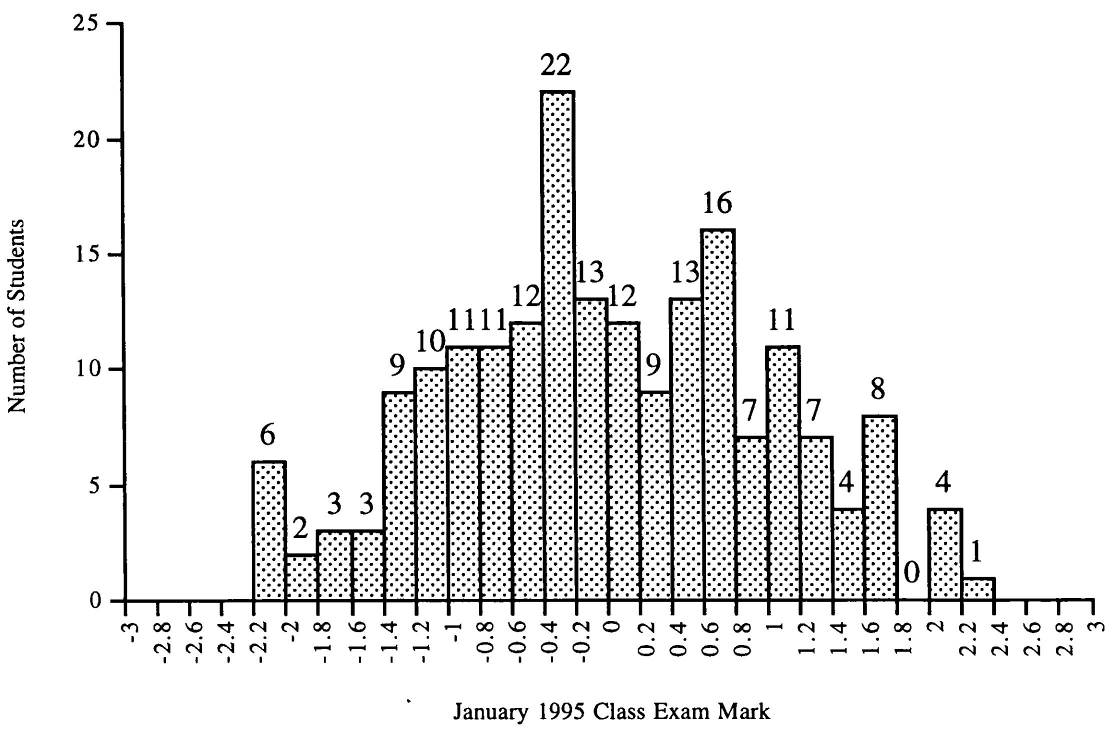
General Chemistry–1, 1994/95

January Exam Results

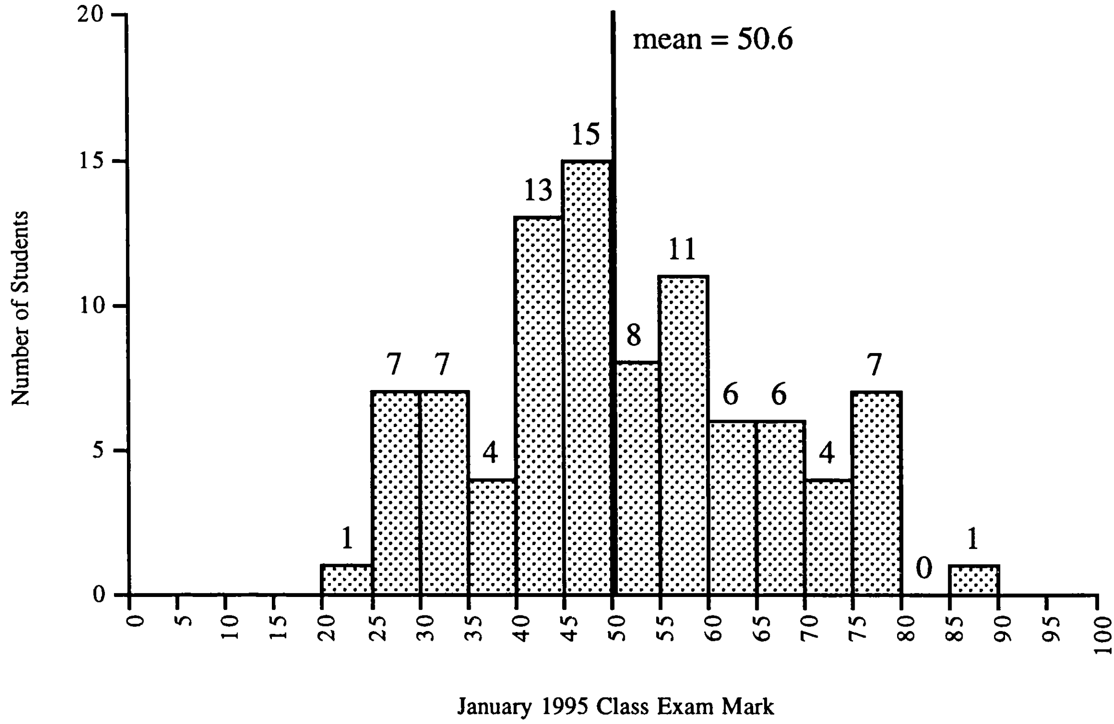
Graph J1 Distribution of General Chemistry–1 1994/95 January Class Exam Marks



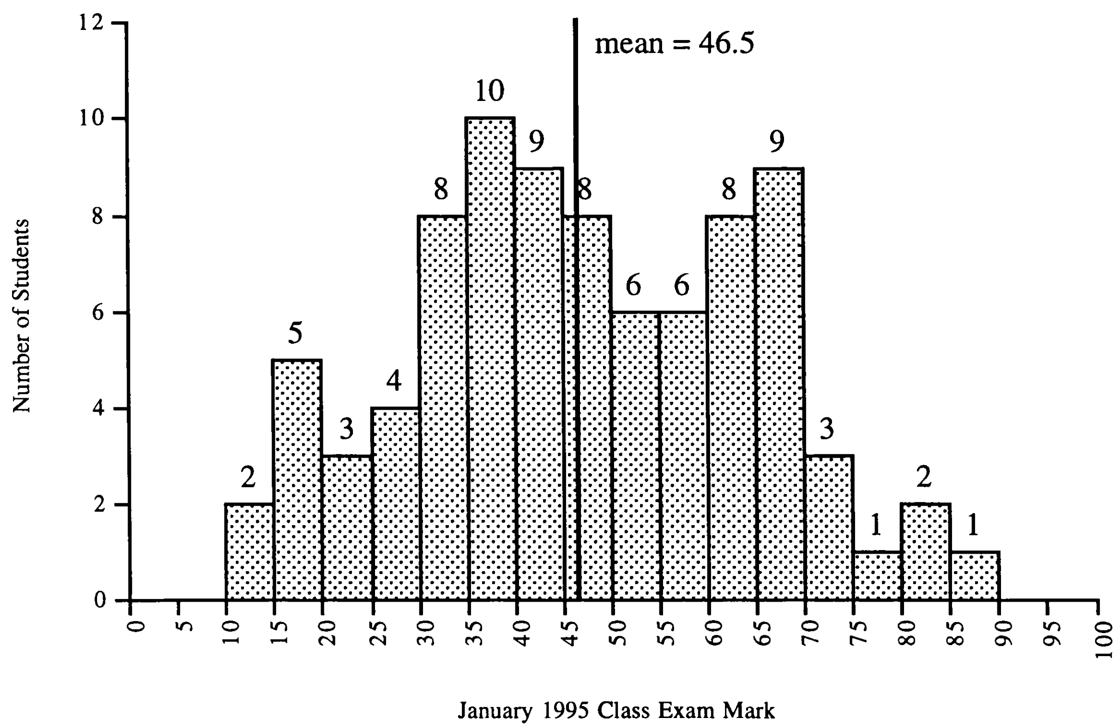
Graph J2 Distribution of General Chemistry–1 1994/95 January Class Exam Marks as Z-scores



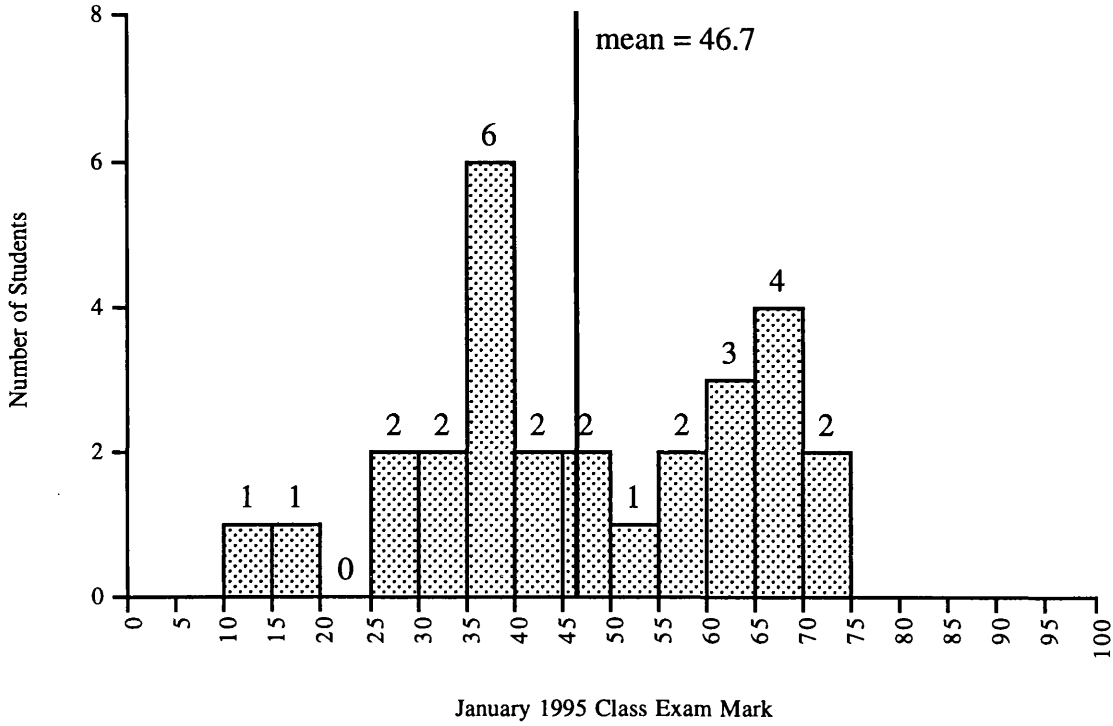
Graph J3 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Standard Entry (Chemistry) Qualifications



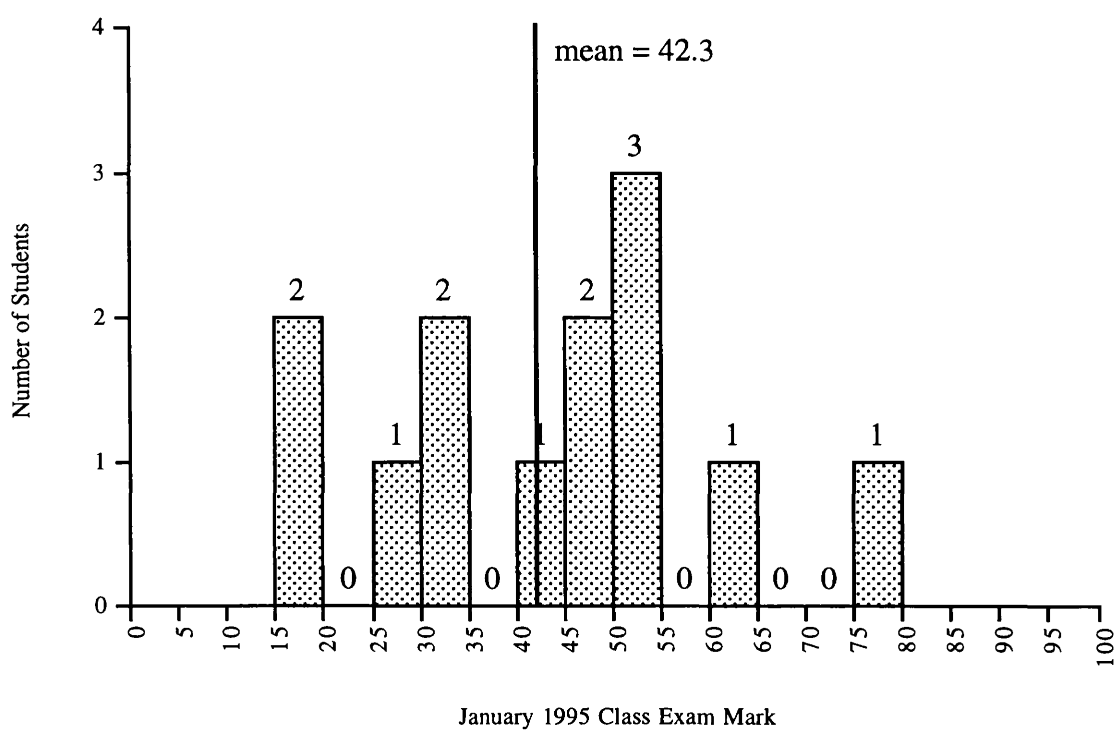
Graph J4 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Non-Standard Entry (Chemistry) Qualifications



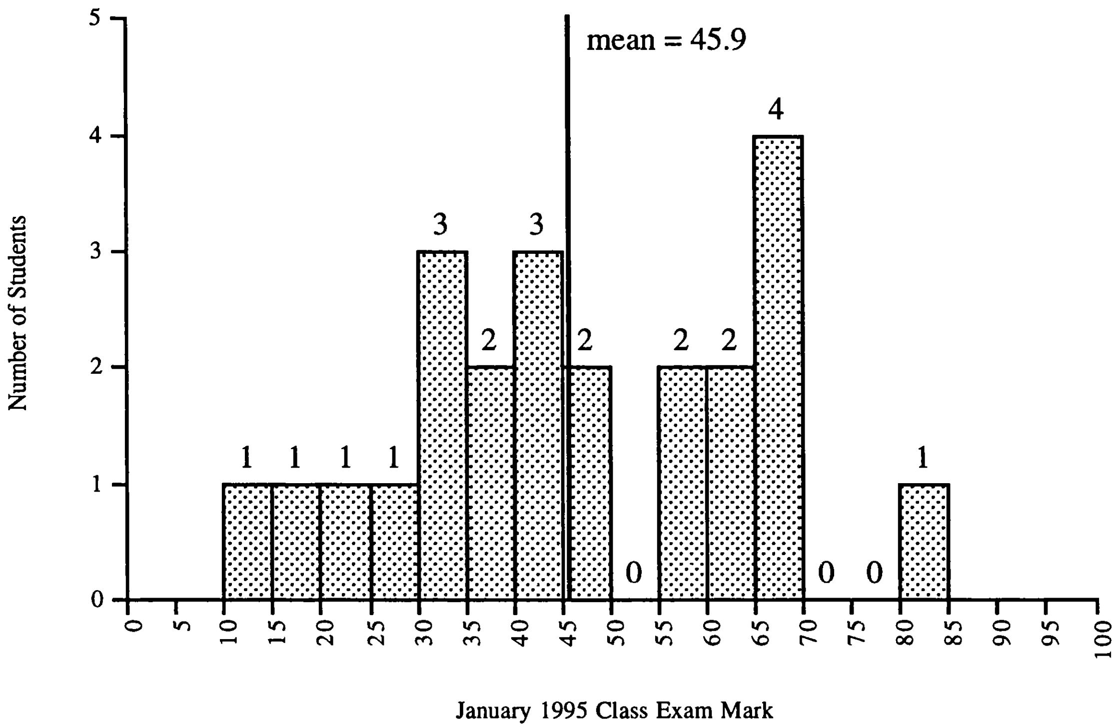
Graph J5 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Scottish Standard Grade Chemistry Qualifications



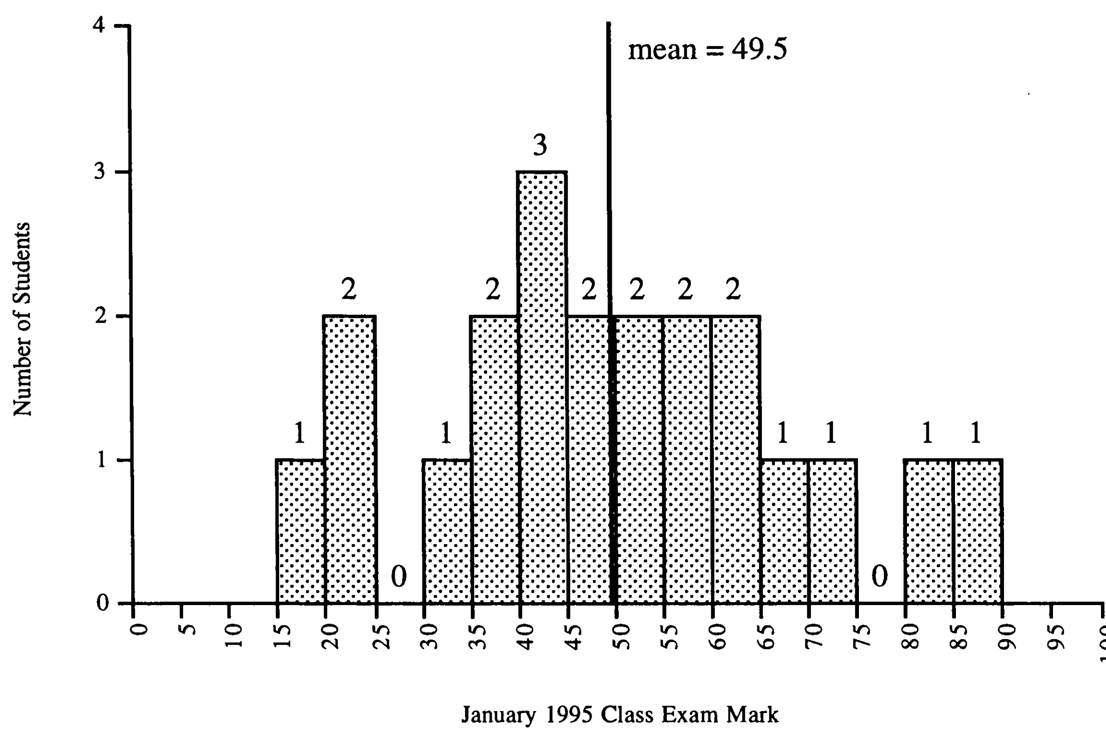
Graph J6 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Modular Chemistry Qualifications



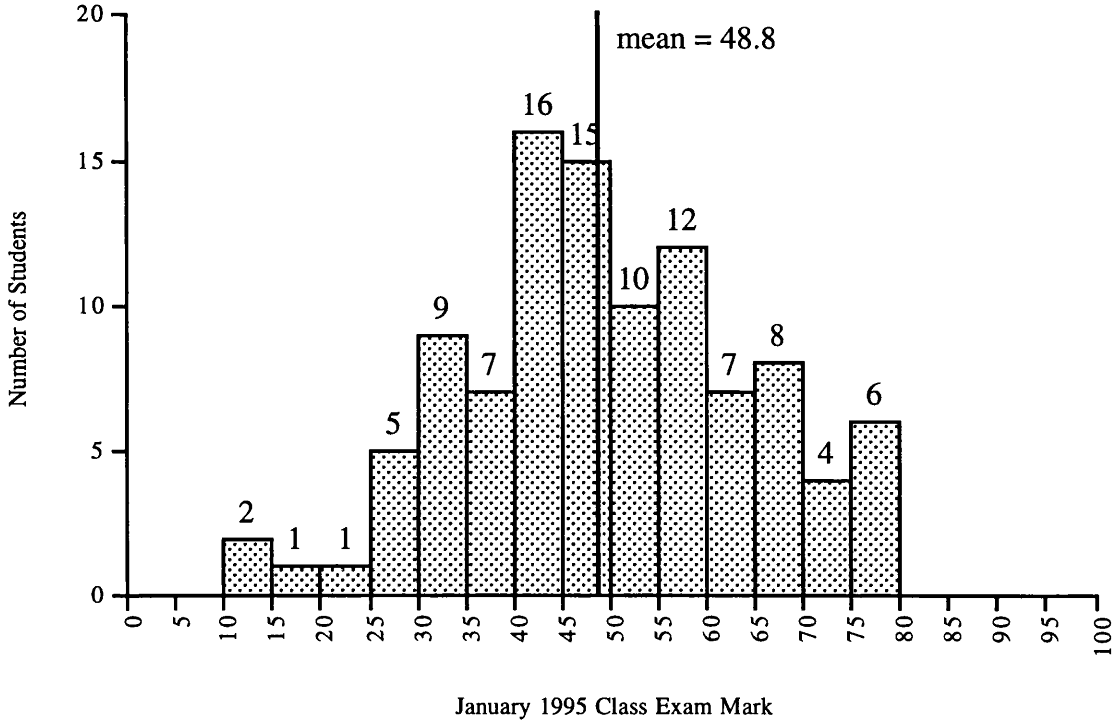
Graph J7 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with No Chemistry Qualifications



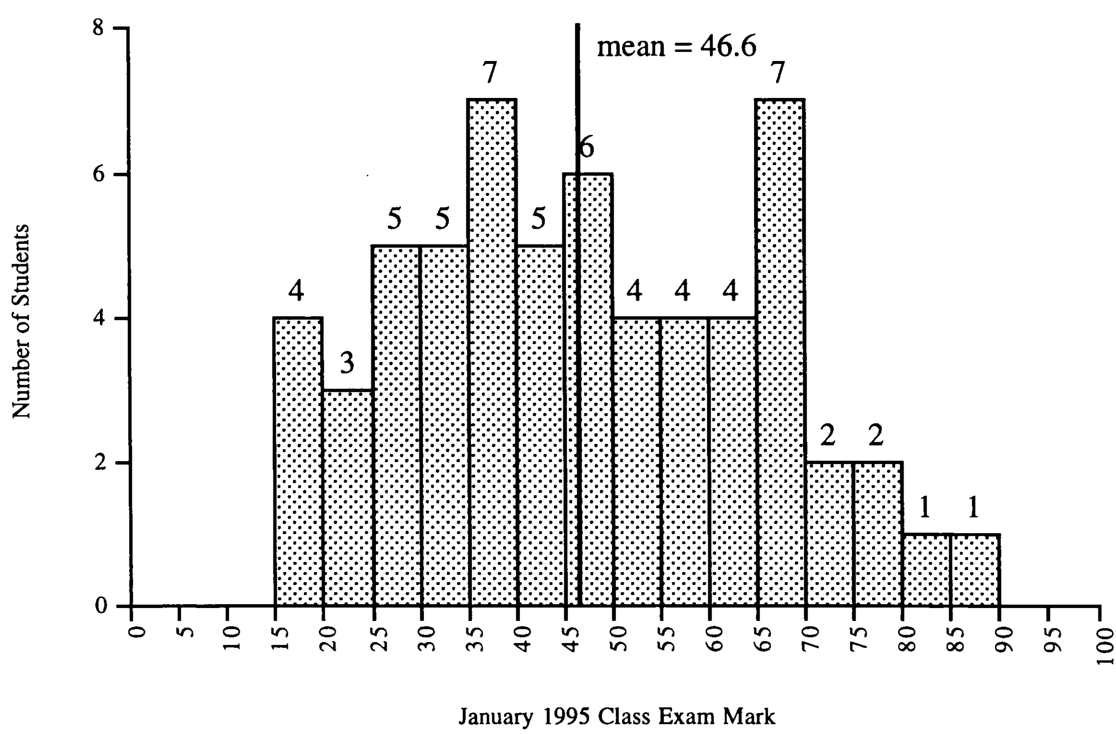
Graph J8 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Access / SWAP Chemistry Qualifications



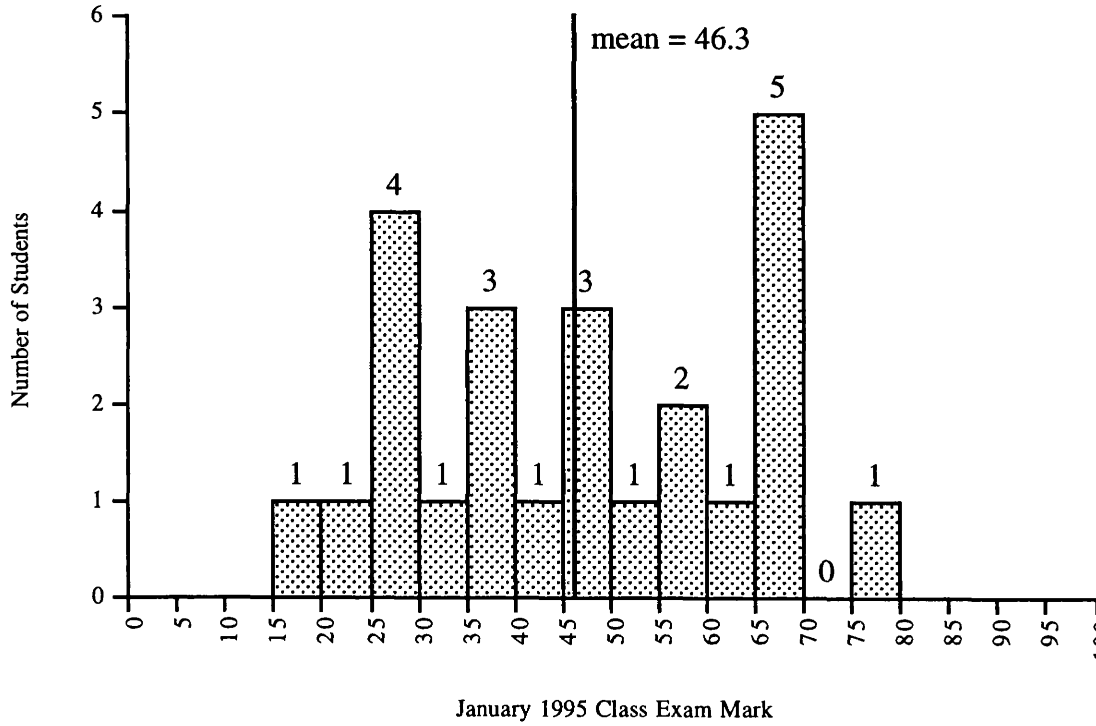
Graph J9 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Standard Entry (Mathematics) Qualifications



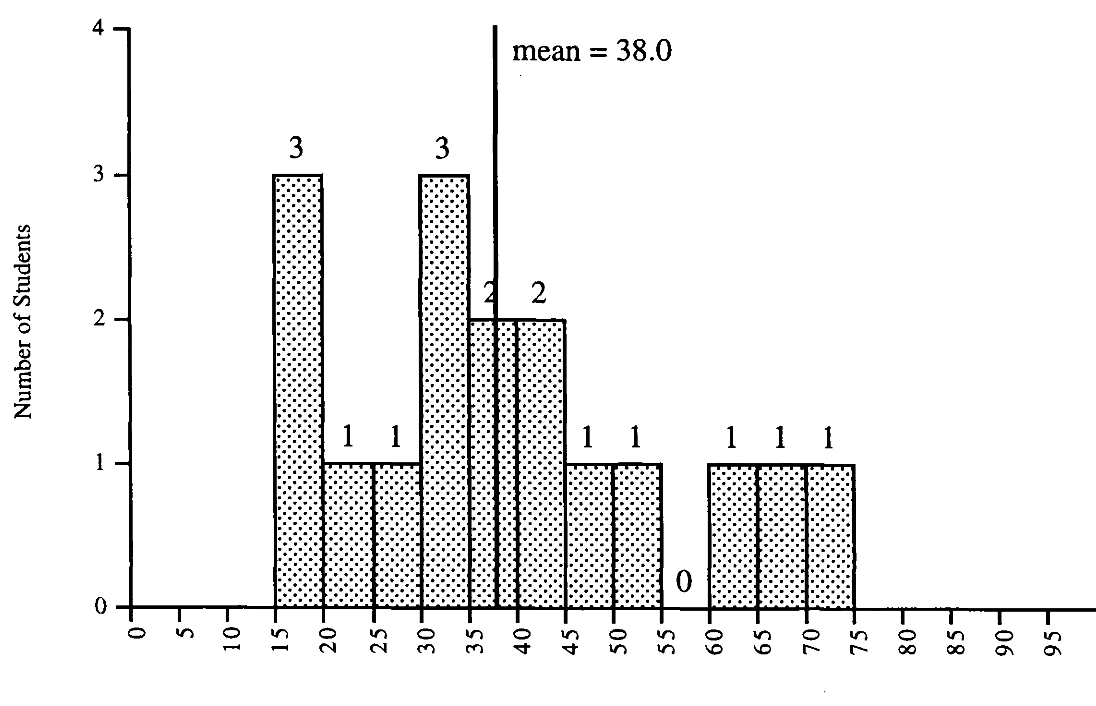
Graph J10 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Non-Standard Entry (Mathematics) Qualifications



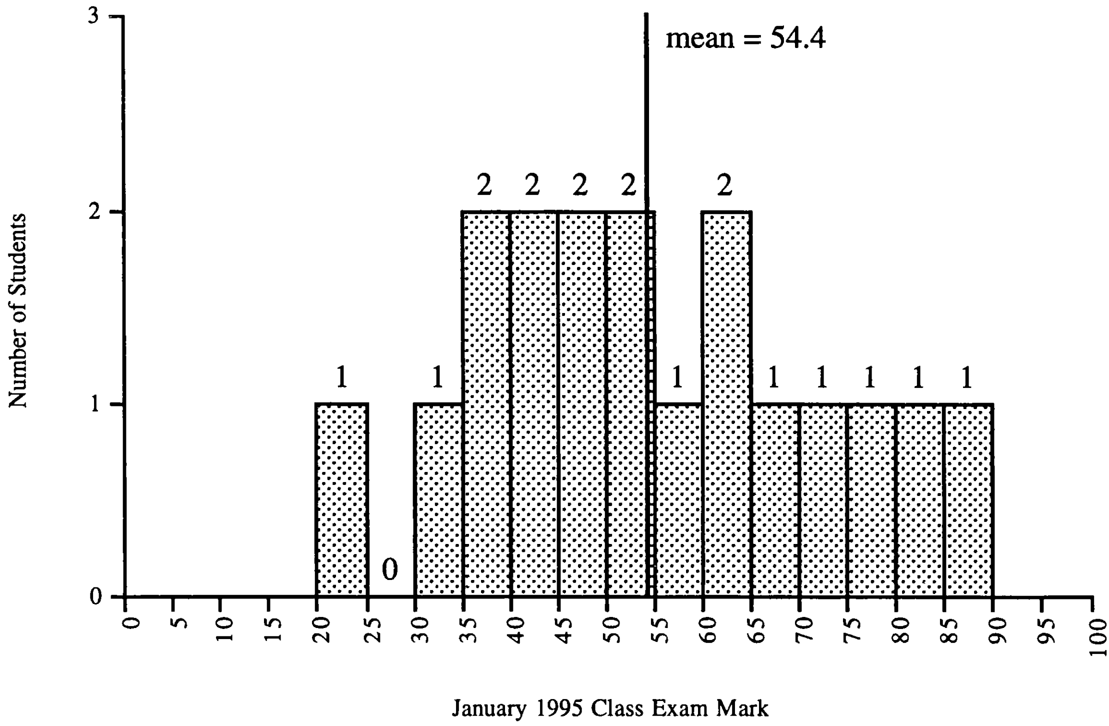
Graph J11 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Scottish Standard Grade Mathematics Qualifications



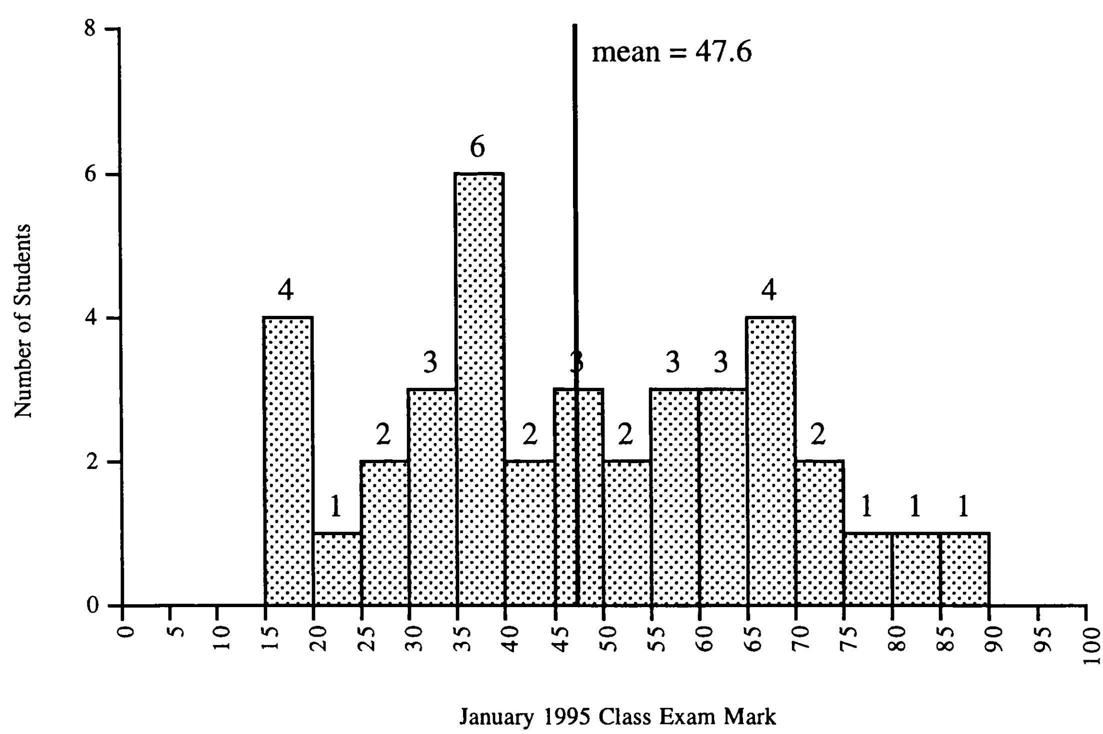
Graph J12 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Modular Mathematics Qualifications



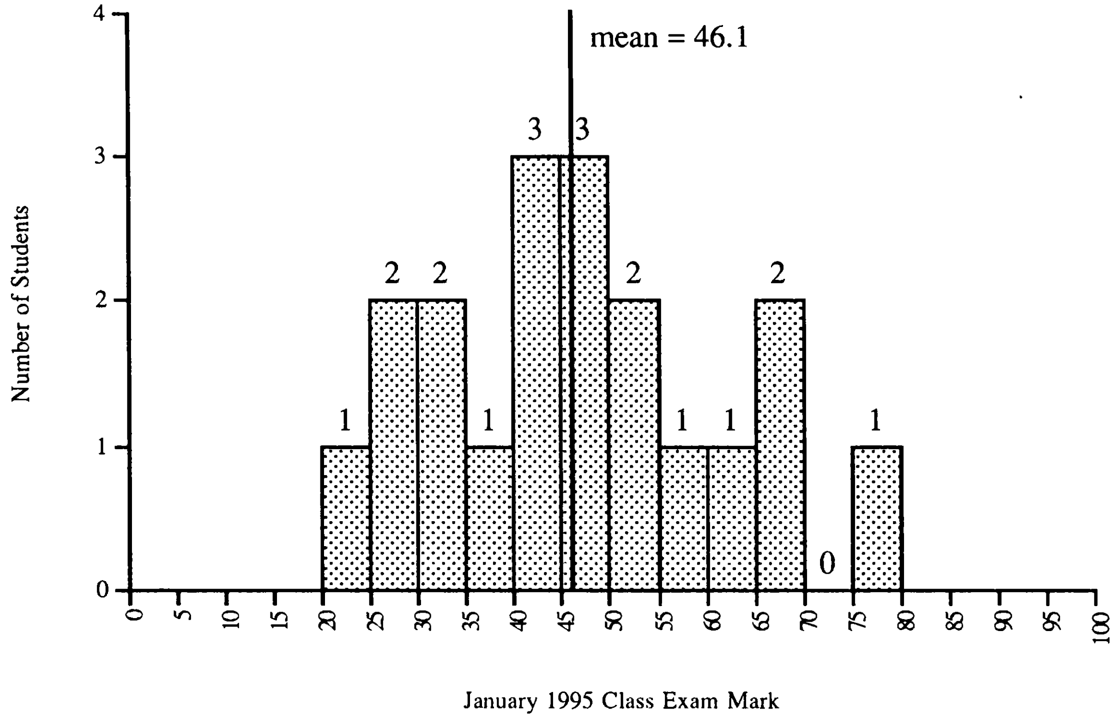
Graph J13 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Access / SWAP Mathematics Qualifications



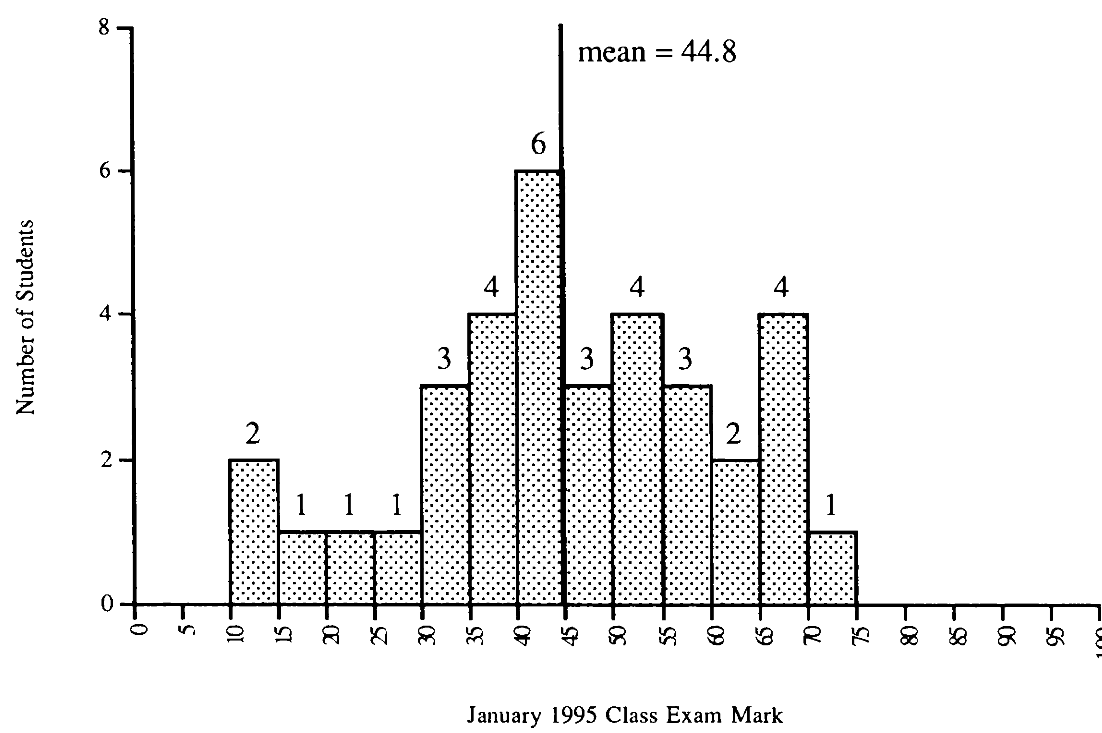
Graph J14 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Non-Standard Entry (Chemistry and Maths) Qualifications



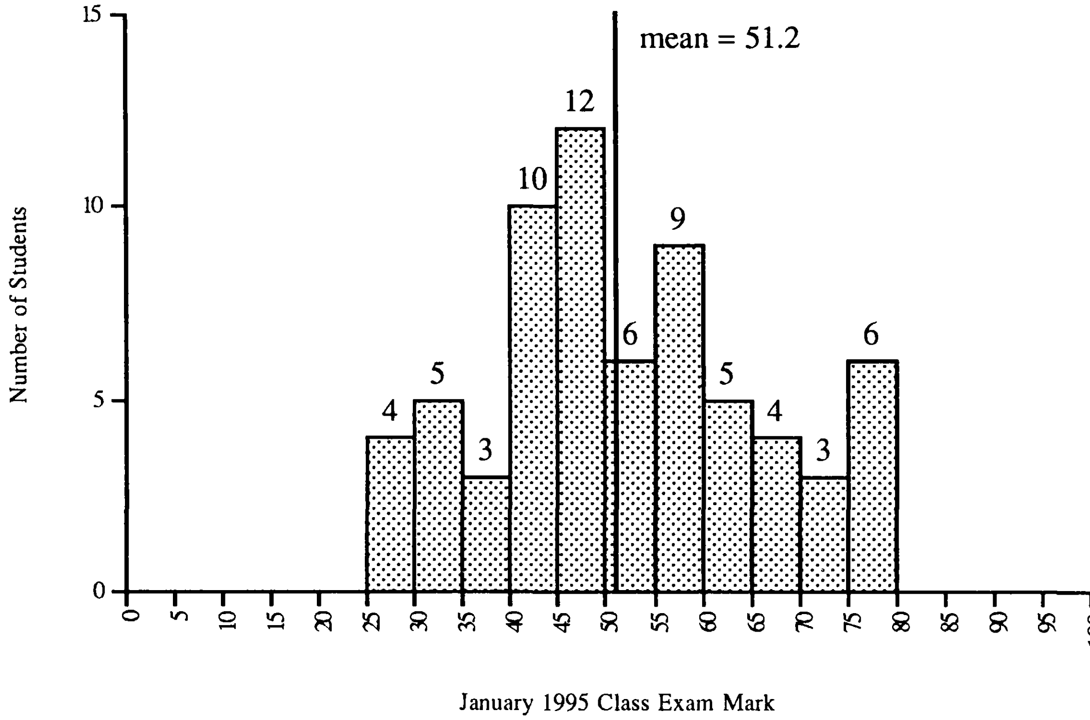
Graph J15 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Non-Standard Mathematics and Standard Chemistry Qualifications



Graph J16 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Standard Mathematics and Non-Standard Chemistry Qualifications

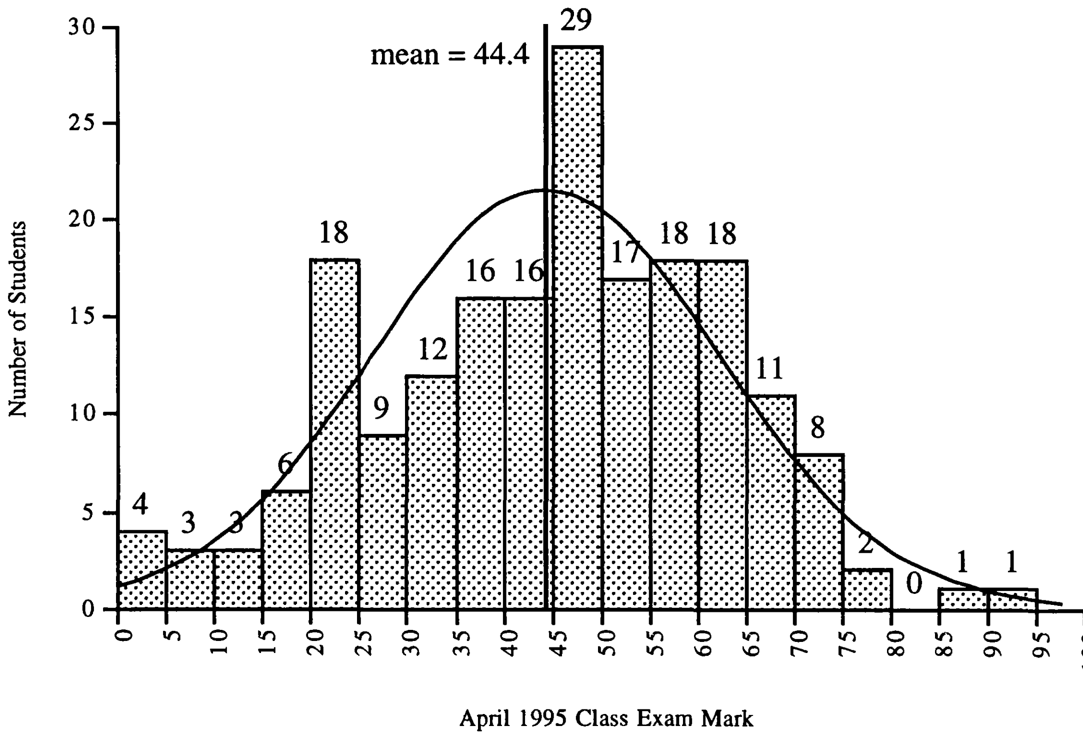


Graph J17 Distribution of General Chemistry–1 1994/95 January Class Exam Marks Students with Standard Entry (Maths and Chemistry) Qualifications

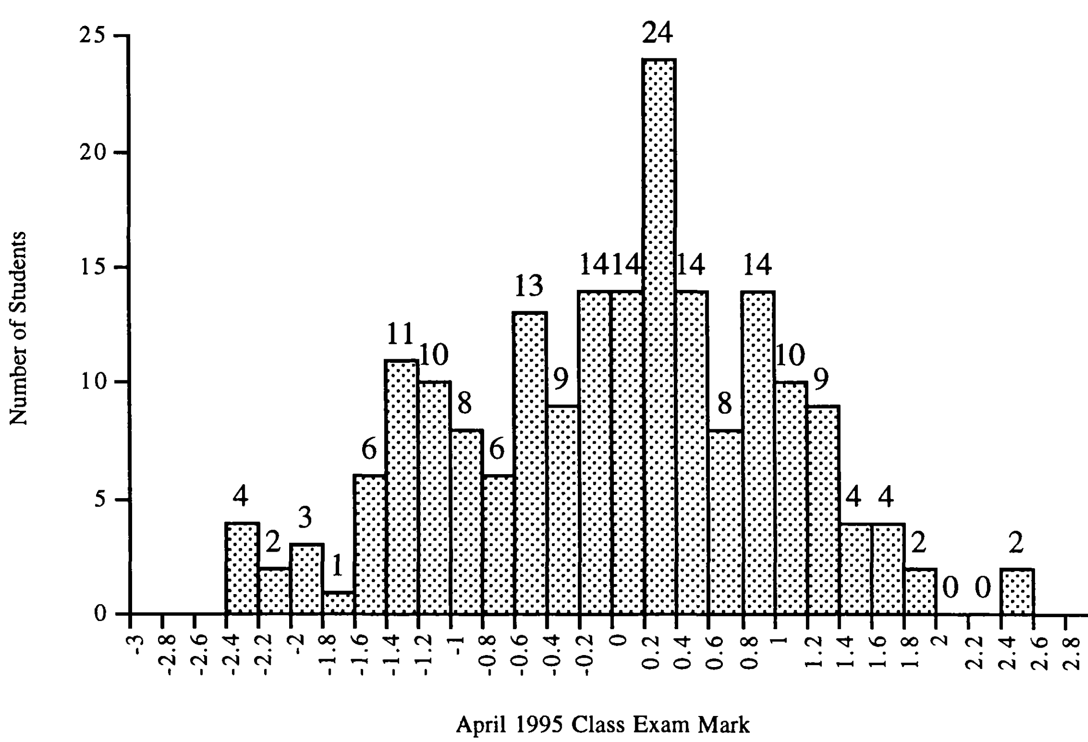


Appendix K
General Chemistry–1, 1994/95
April Exam Results

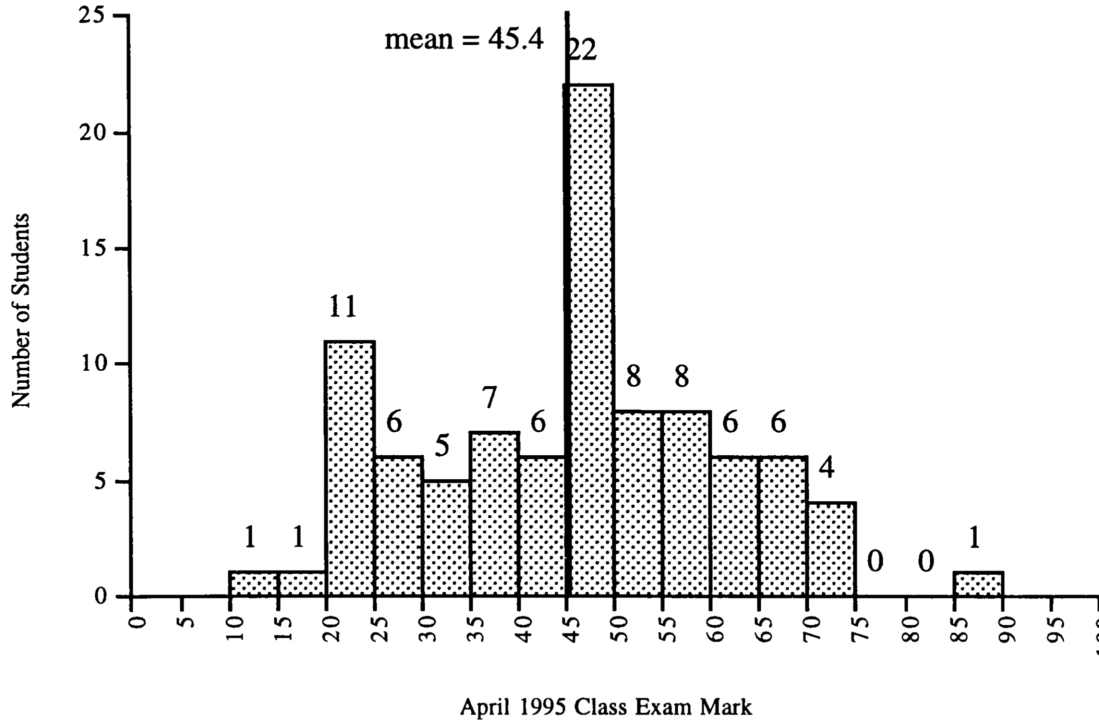
Graph K1 Distribution of General Chemistry–1 1994/95 April Class Exam Marks



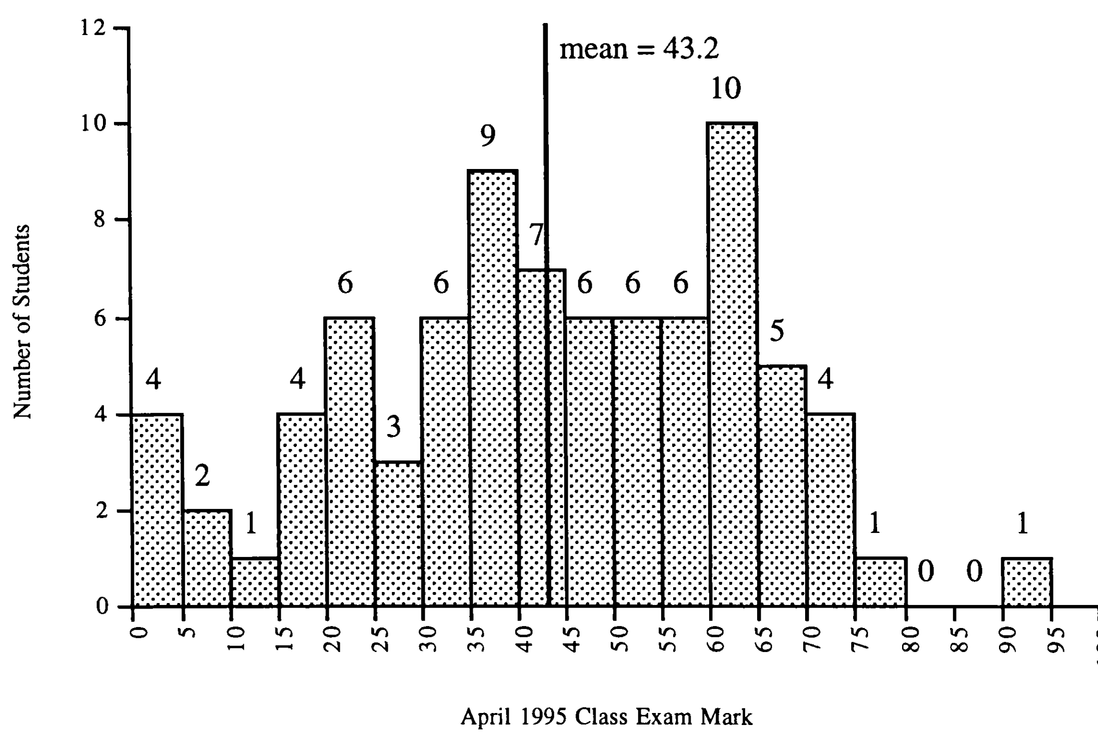
Graph K2 Distribution of General Chemistry–1 1994/95 AprilClass Exam Marks as Z-scores



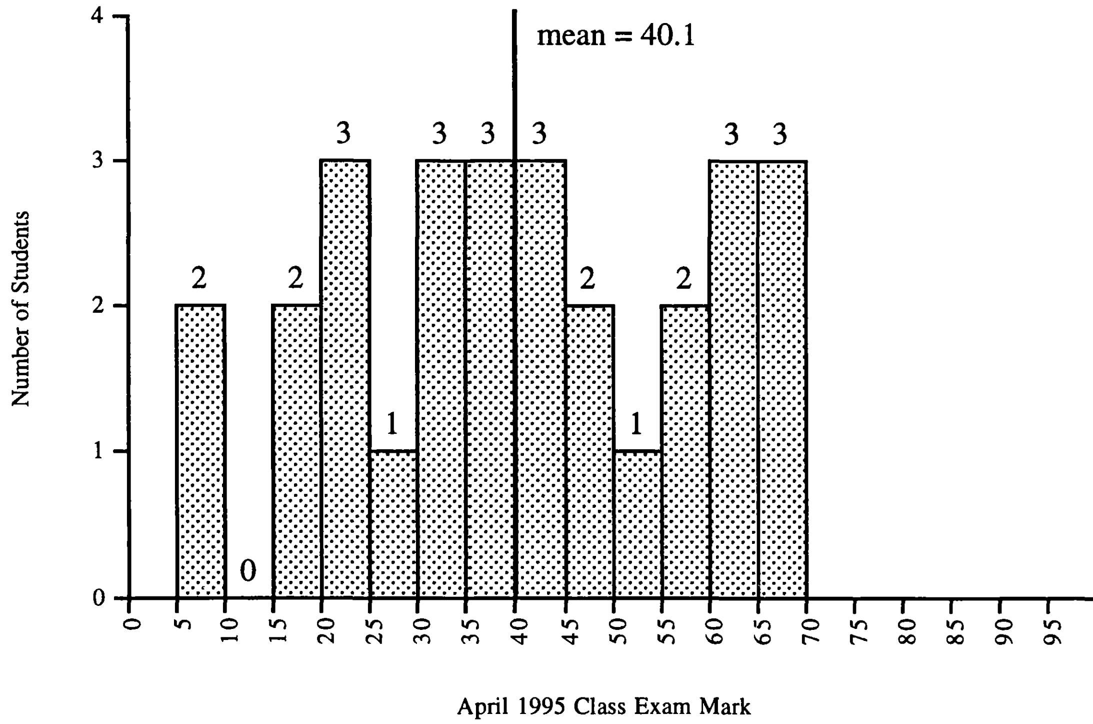
Graph K3 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Standard Entry (Chemistry) Qualifications



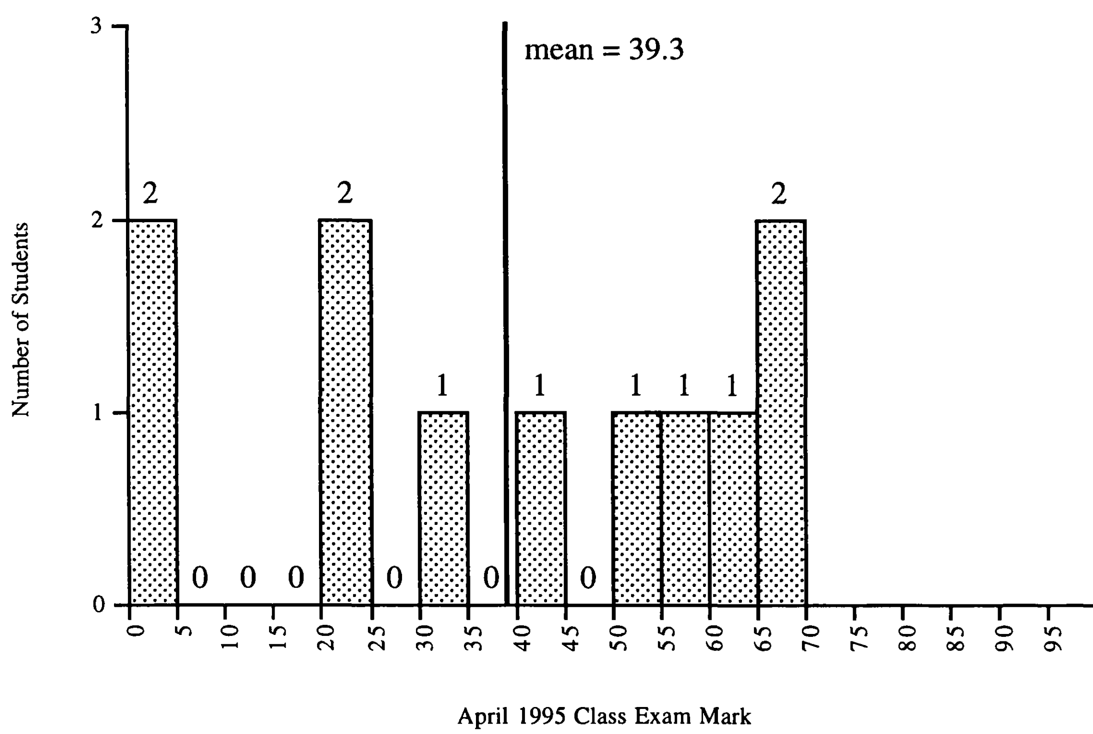
Graph K4 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Non-Standard Entry (Chemistry) Qualifications



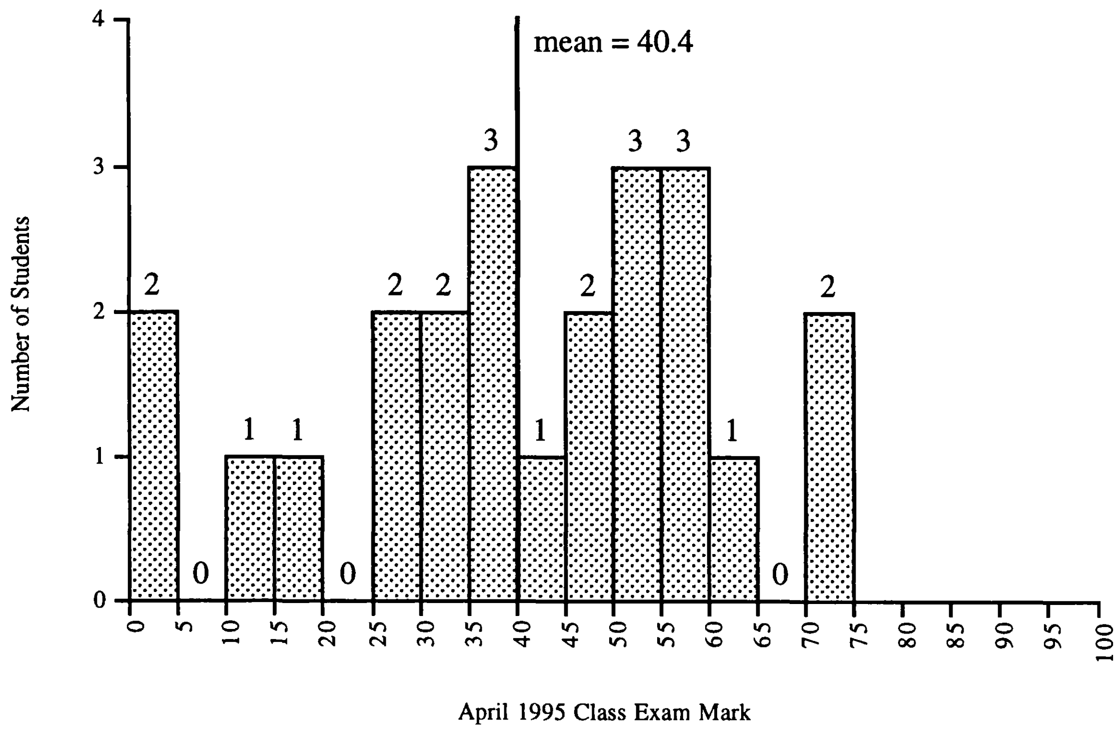
Graph K5 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Scottish Standard Grade Chemistry Qualifications



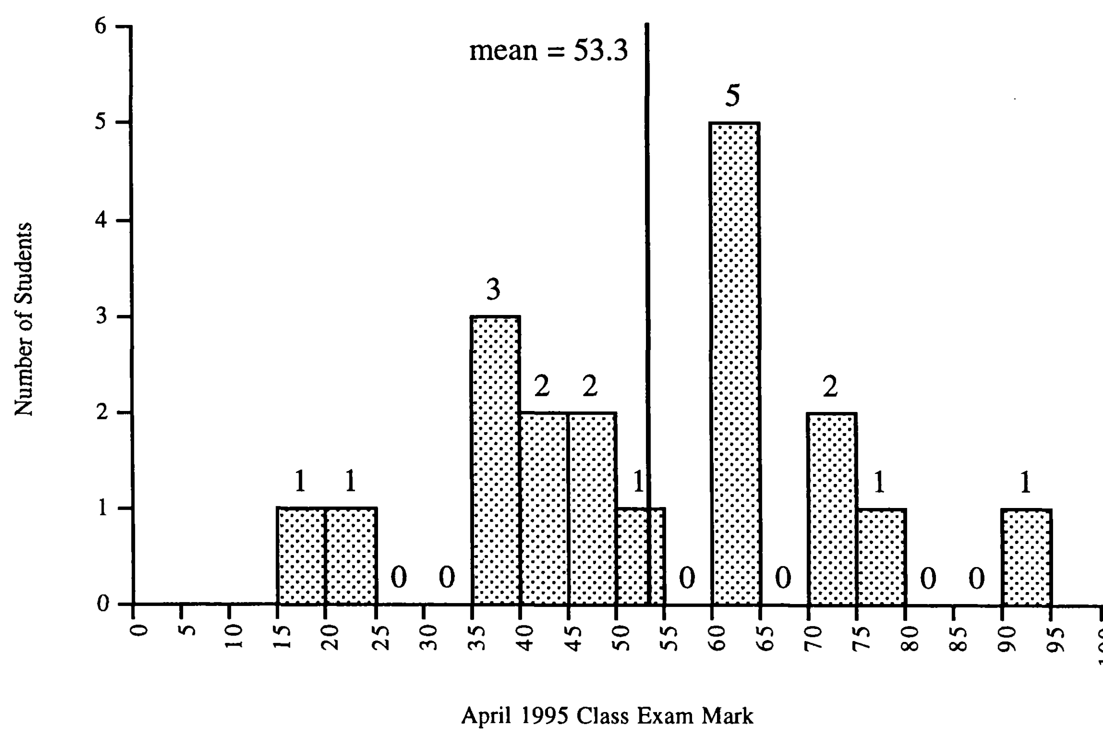
Graph K6 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Modular Chemistry Qualifications



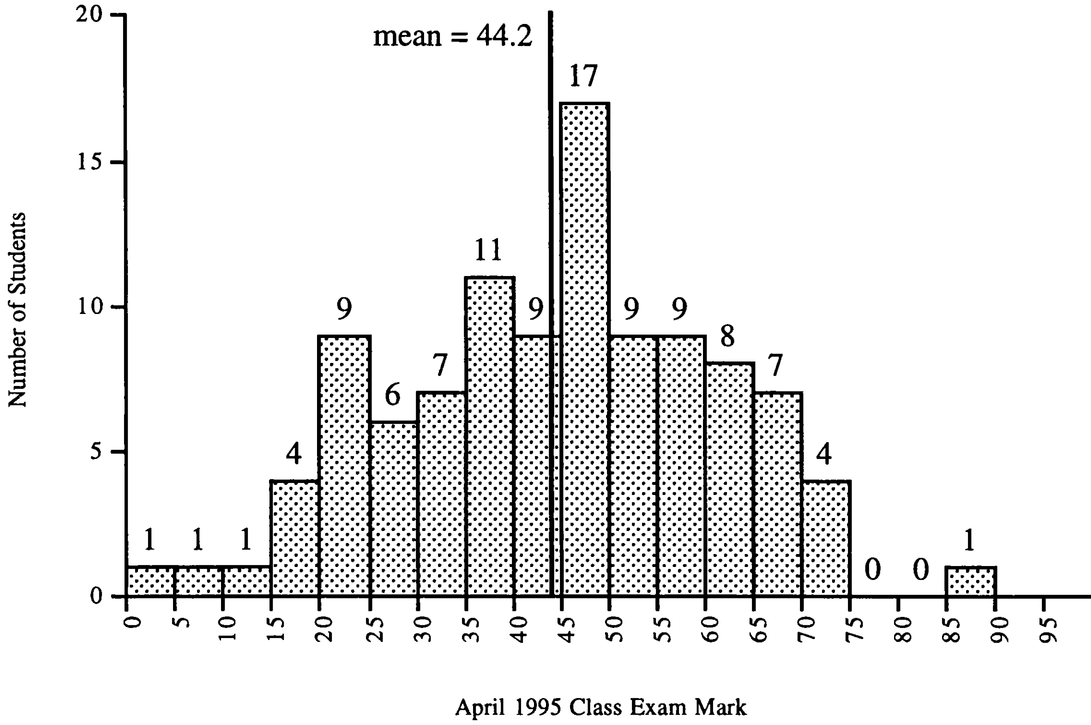
Graph K7 Distribution of General Chemistry–1 1994/95 April Class Exam Marks
Students with No Chemistry Qualifications



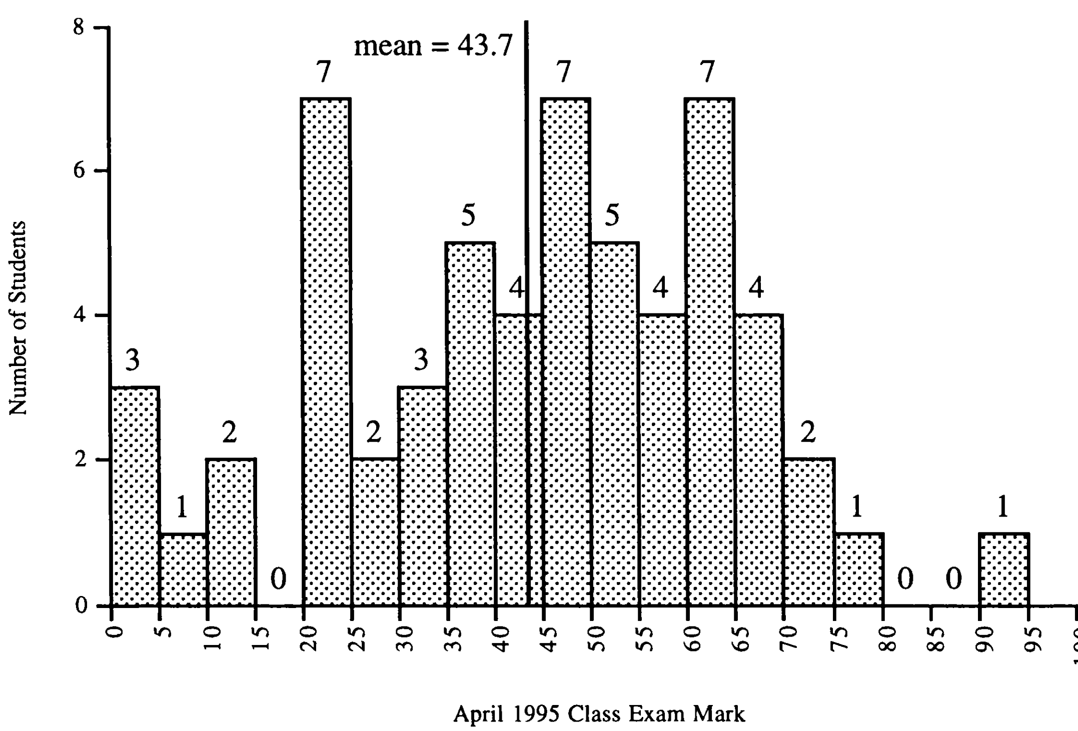
Graph K8 Distribution of General Chemistry–1 1994/95 April Class Exam Marks
Students with Access / SWAP Chemistry Qualifications



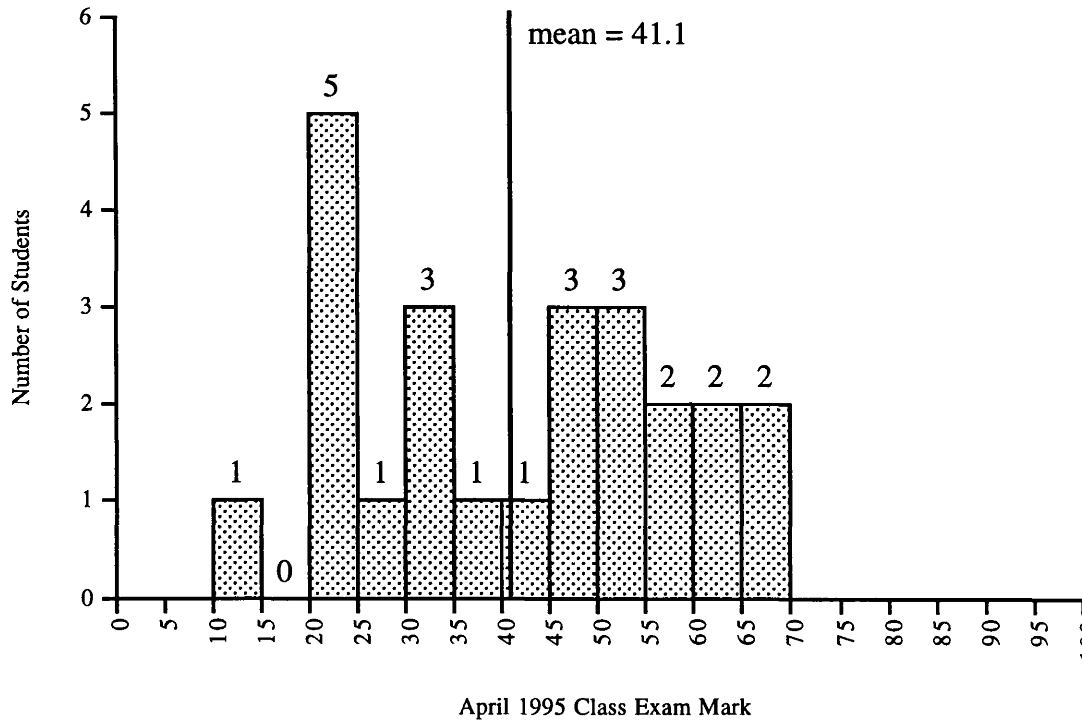
Graph K9 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Standard Entry (Mathematics) Qualifications



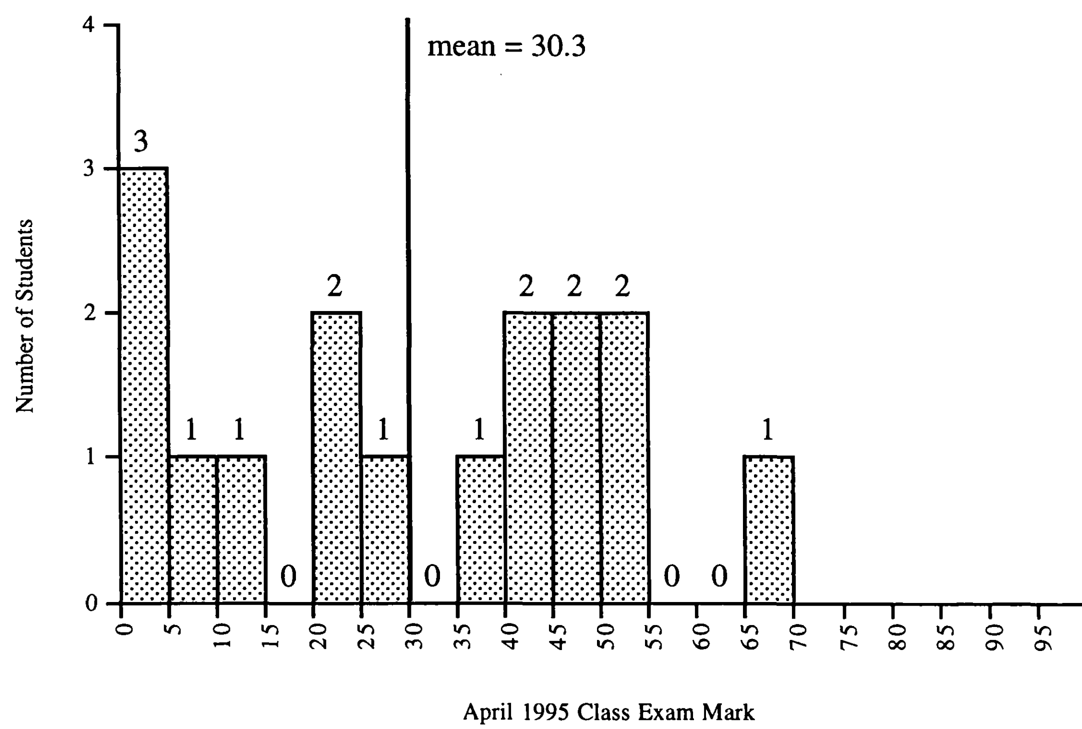
Graph K10 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Non-Standard Entry (Mathematics) Qualifications



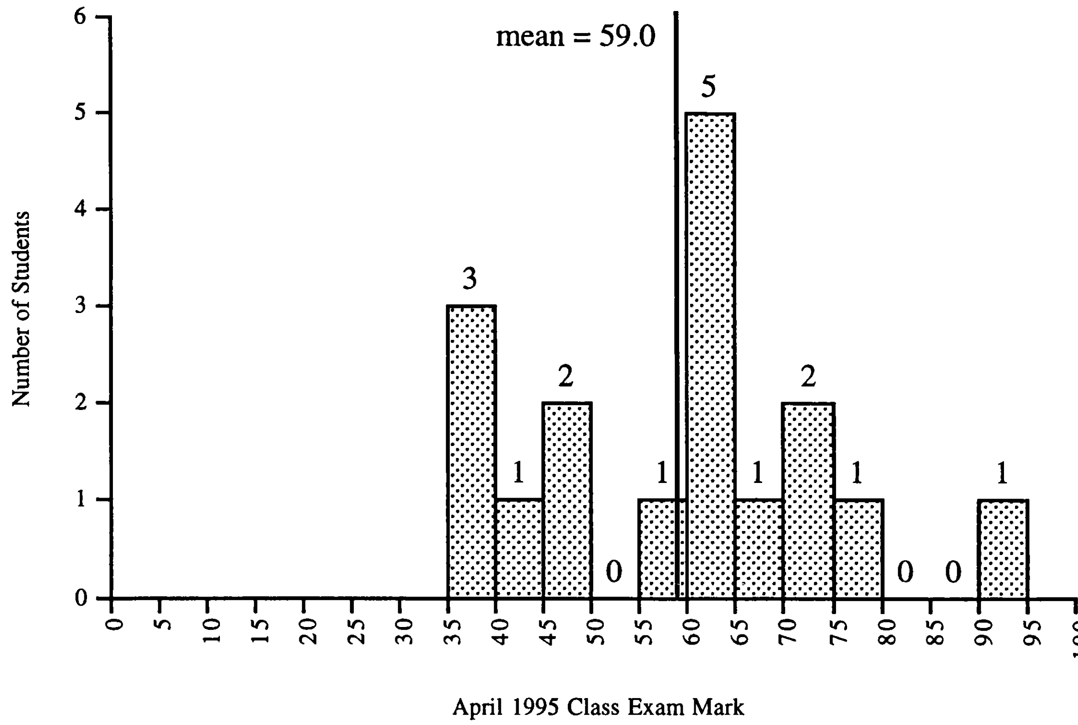
Graph K11 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Scottish Standard Grade Mathematics Qualifications



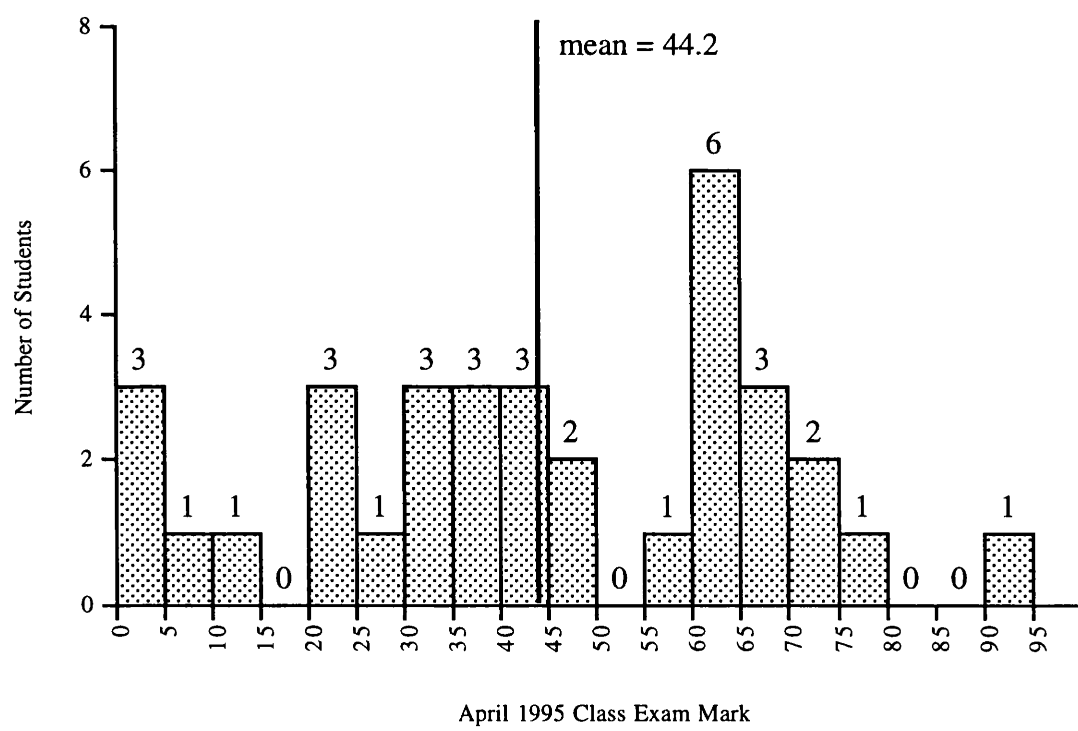
Graph K12 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Modular Mathematics Qualifications



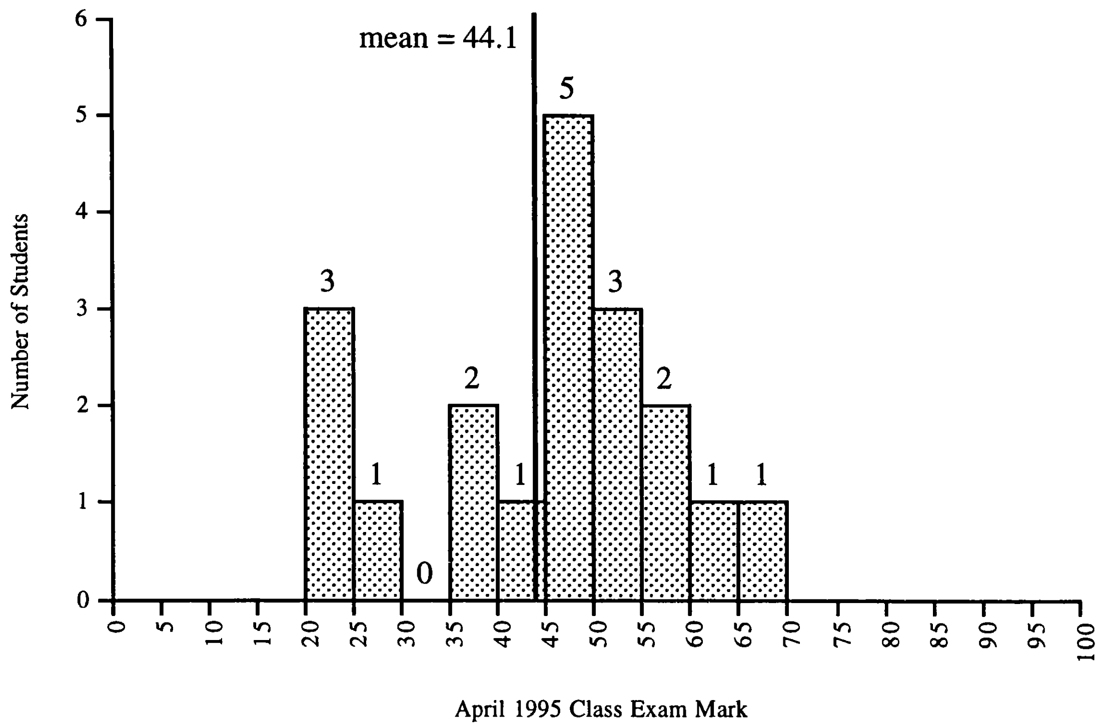
Graph K13 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Access / SWAP Mathematics Qualifications



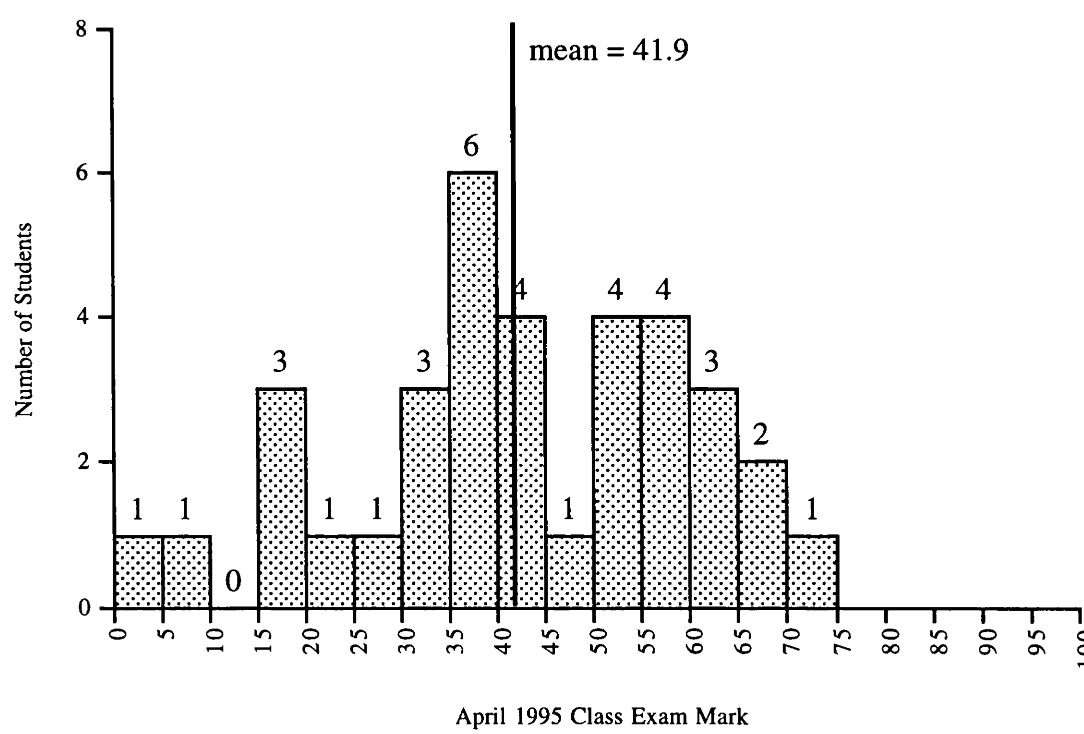
Graph K14 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Non-Standard Entry (Chemistry and Maths) Qualifications



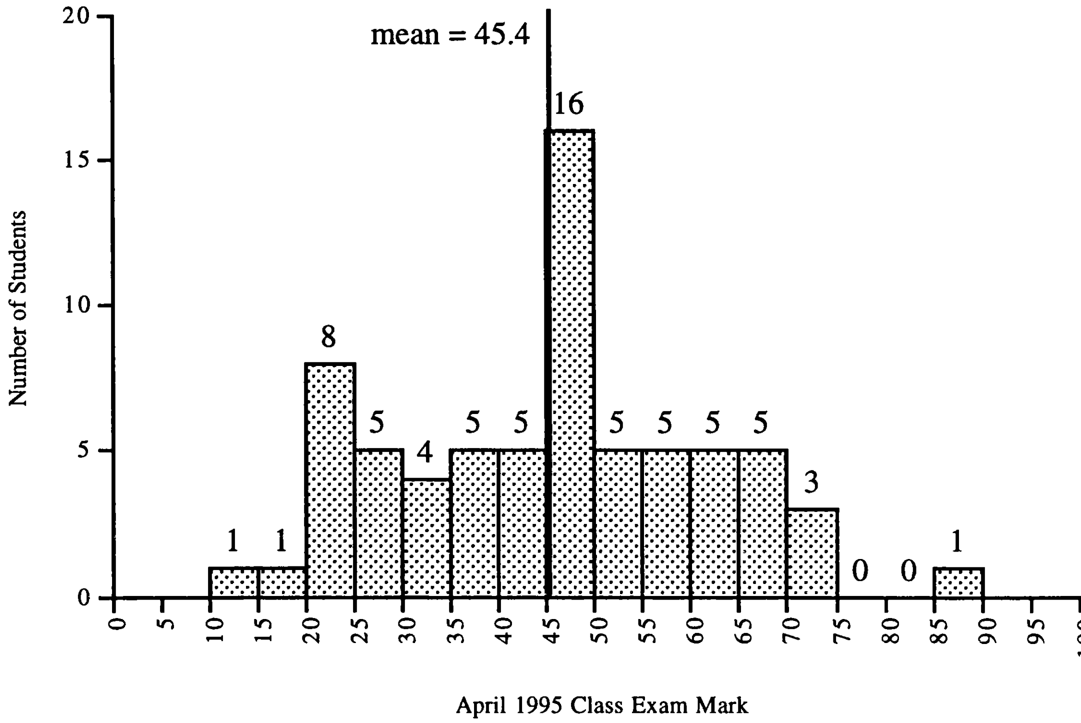
Graph K15 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Non-Standard Mathematics and Standard Chemistry Qualifications



Graph K16 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Standard Mathematics and Non-Standard Chemistry Qualifications



Graph K17 Distribution of General Chemistry–1 1994/95 April Class Exam Marks Students with Standard Entry (Maths and Chemistry) Qualifications

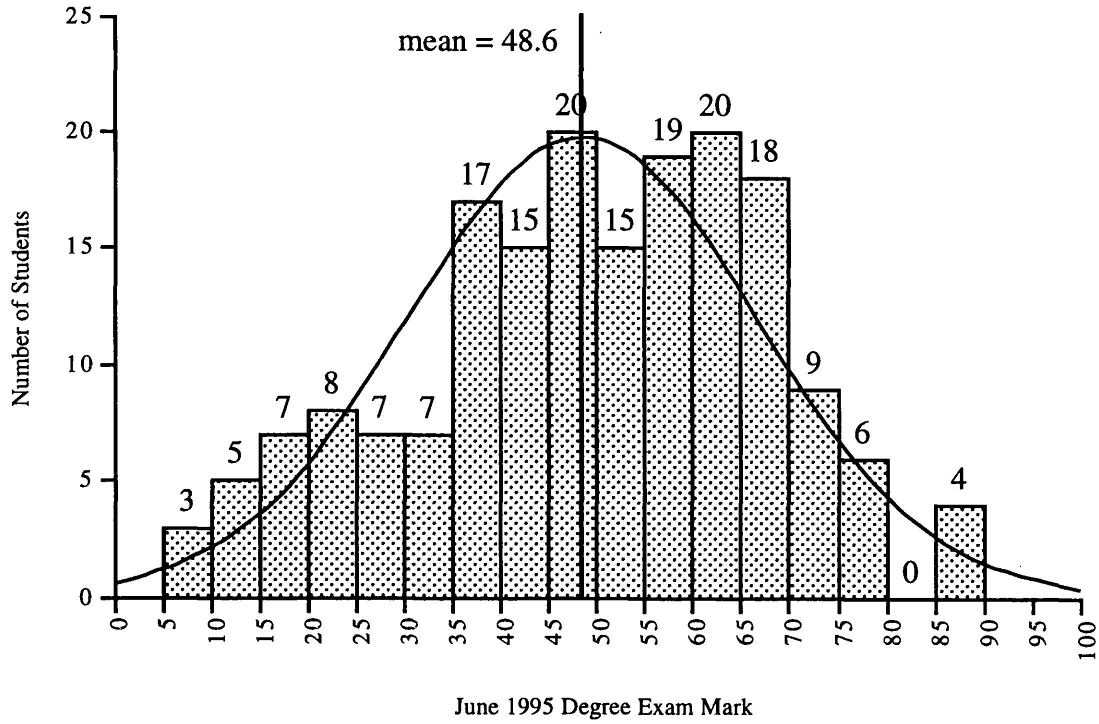


Appendix L

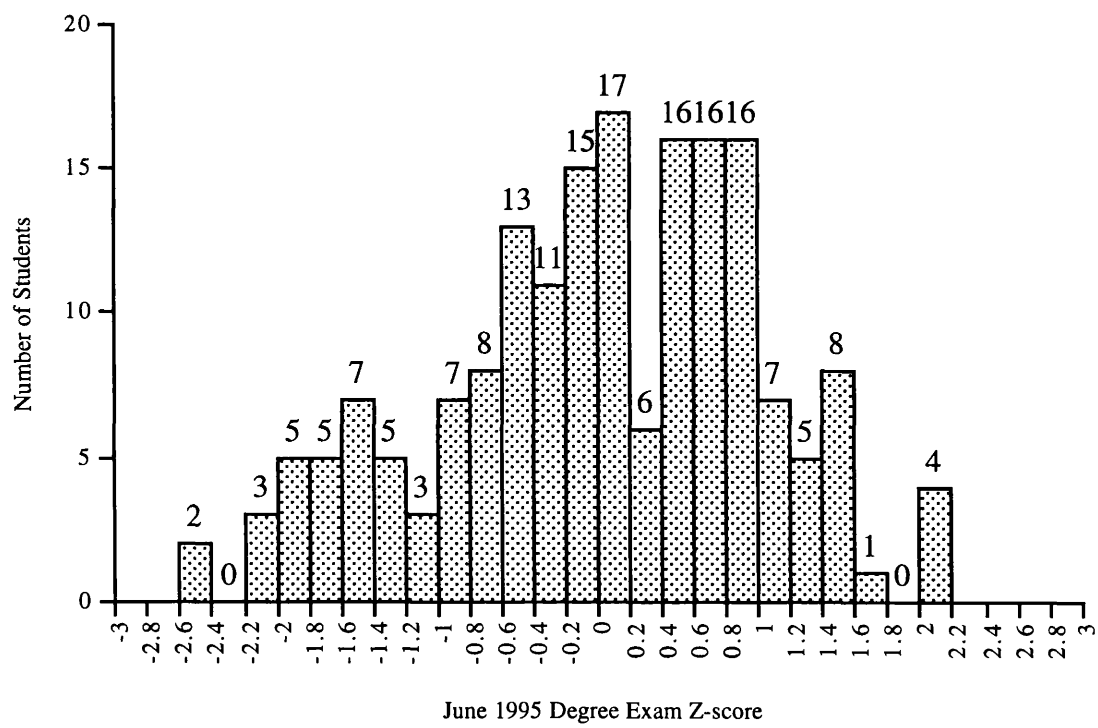
General Chemistry–1, 1994/95

June Exam Results

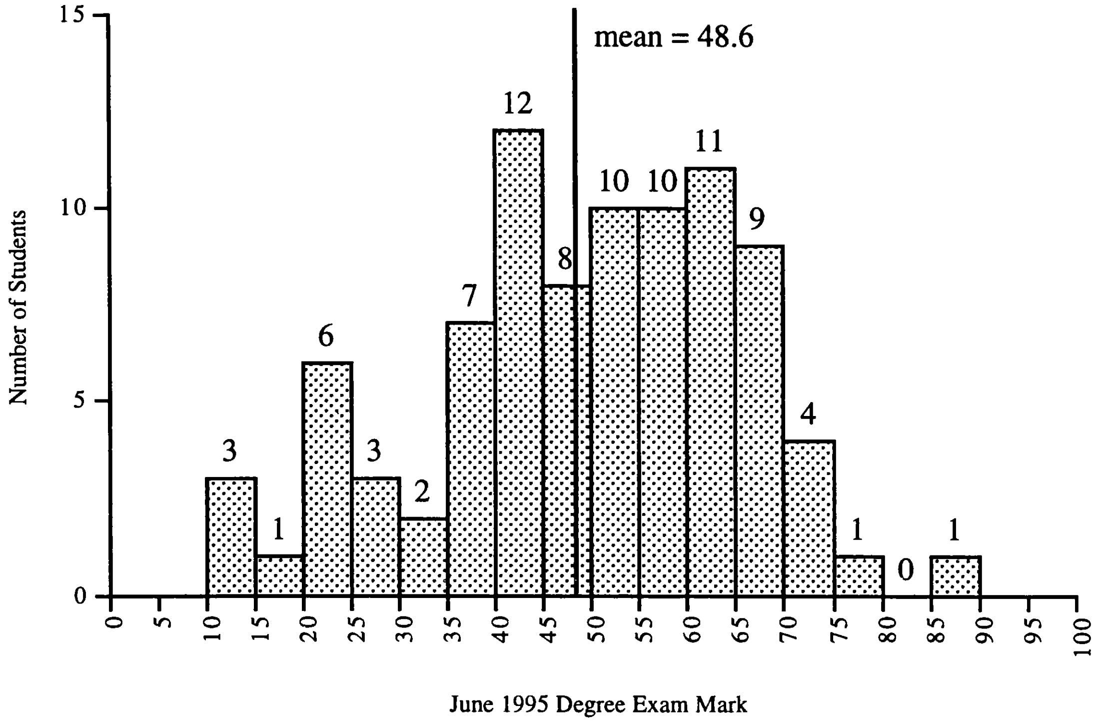
Graph L1 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks



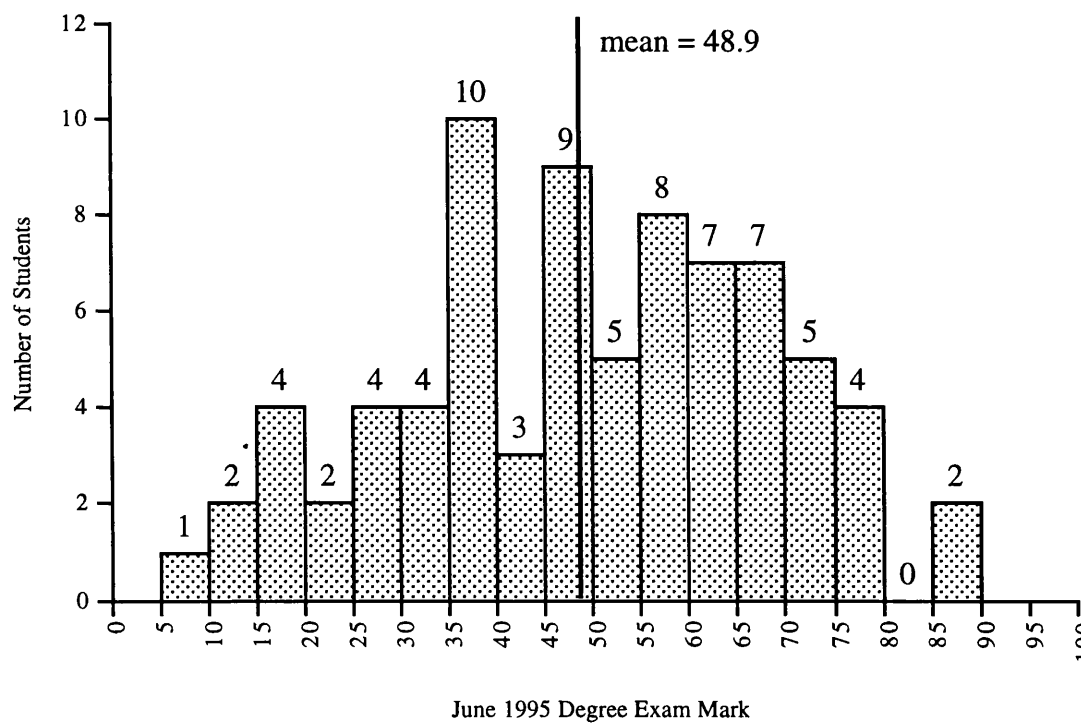
Graph L2 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks as Z-scores



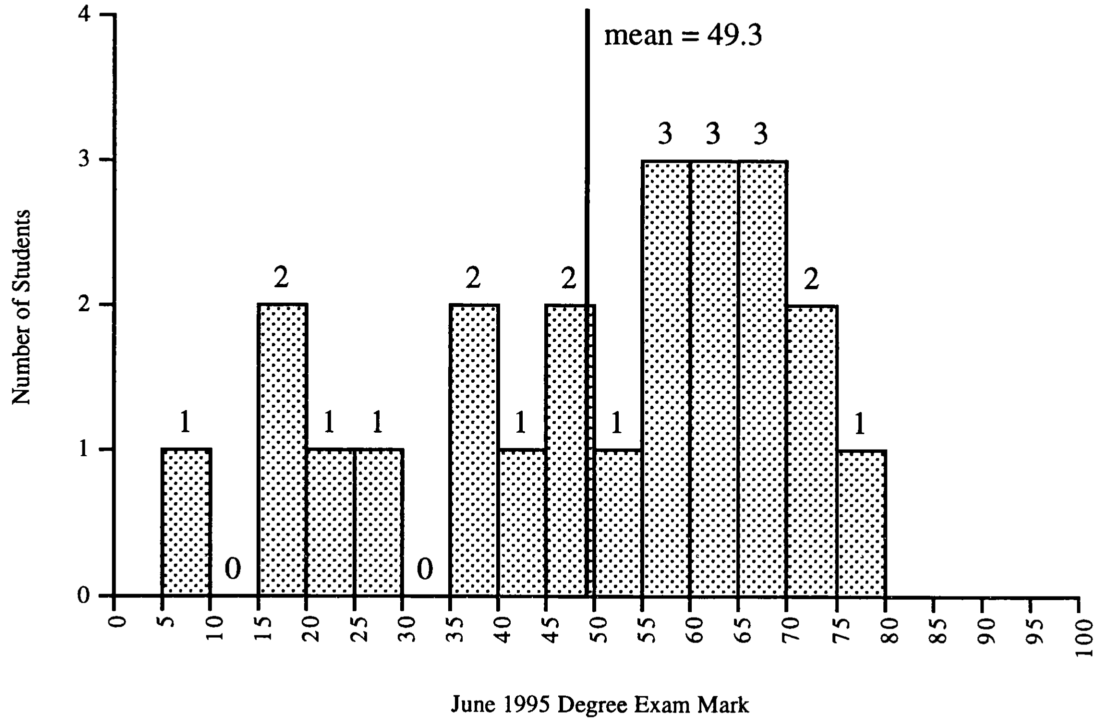
Graph L3 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Standard Entry (Chemistry) Qualifications



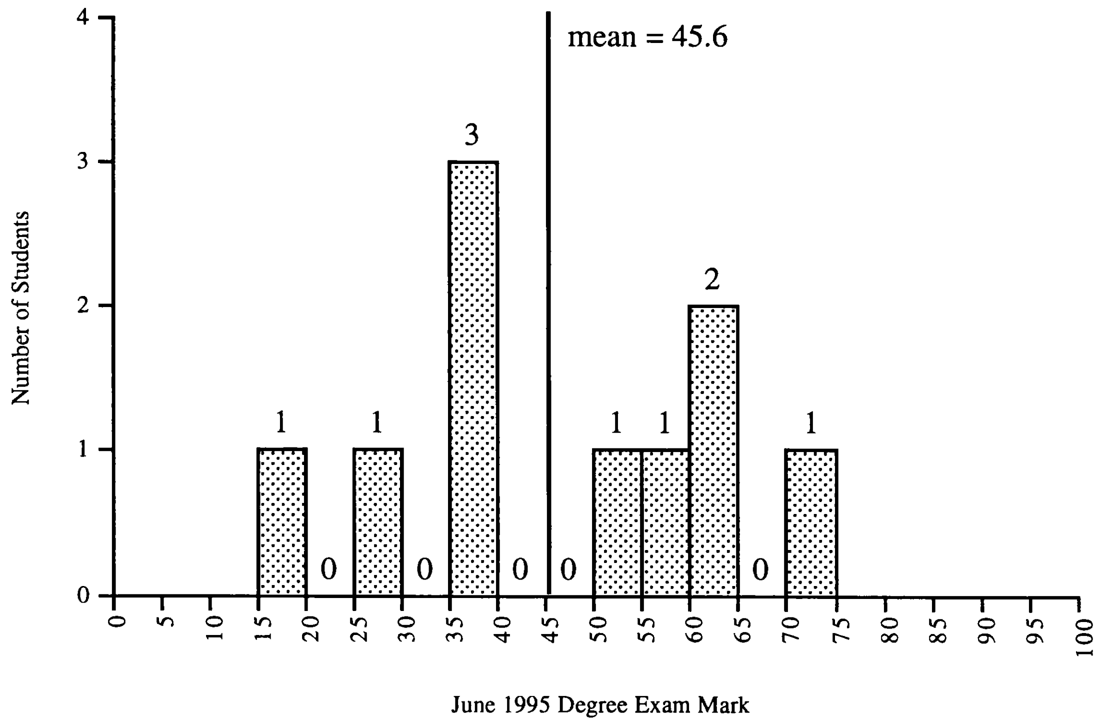
Graph L4 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Non-Standard Entry (Chemistry) Qualifications



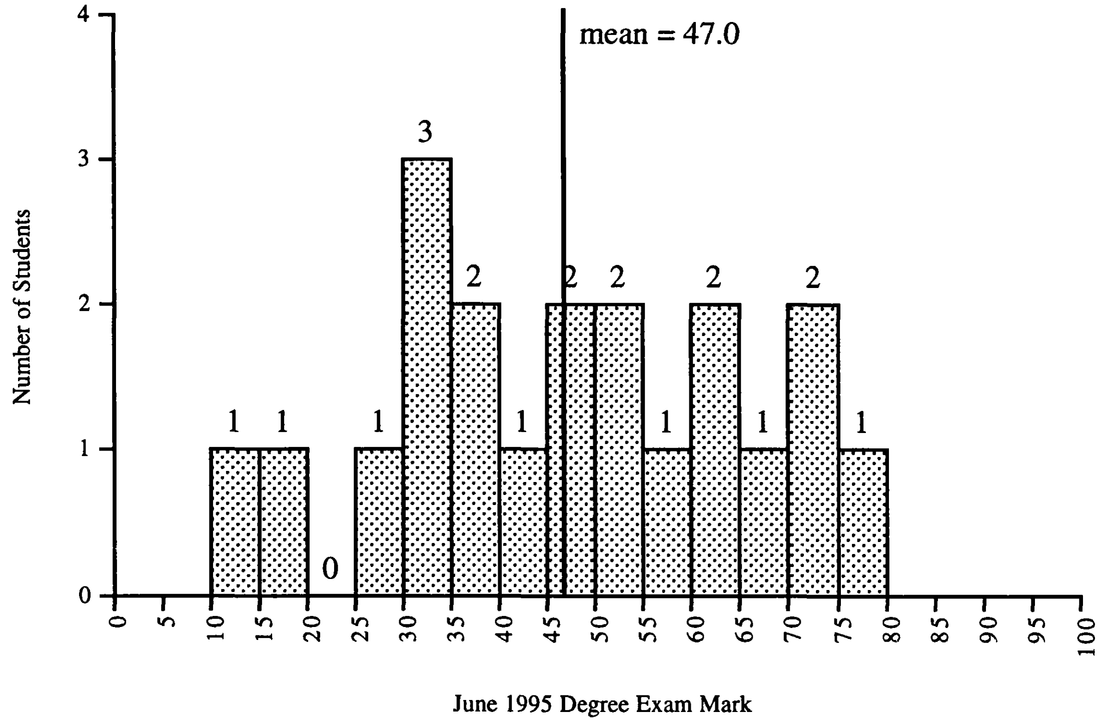
Graph L5 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Scottish Standard Grade Chemistry Qualifications



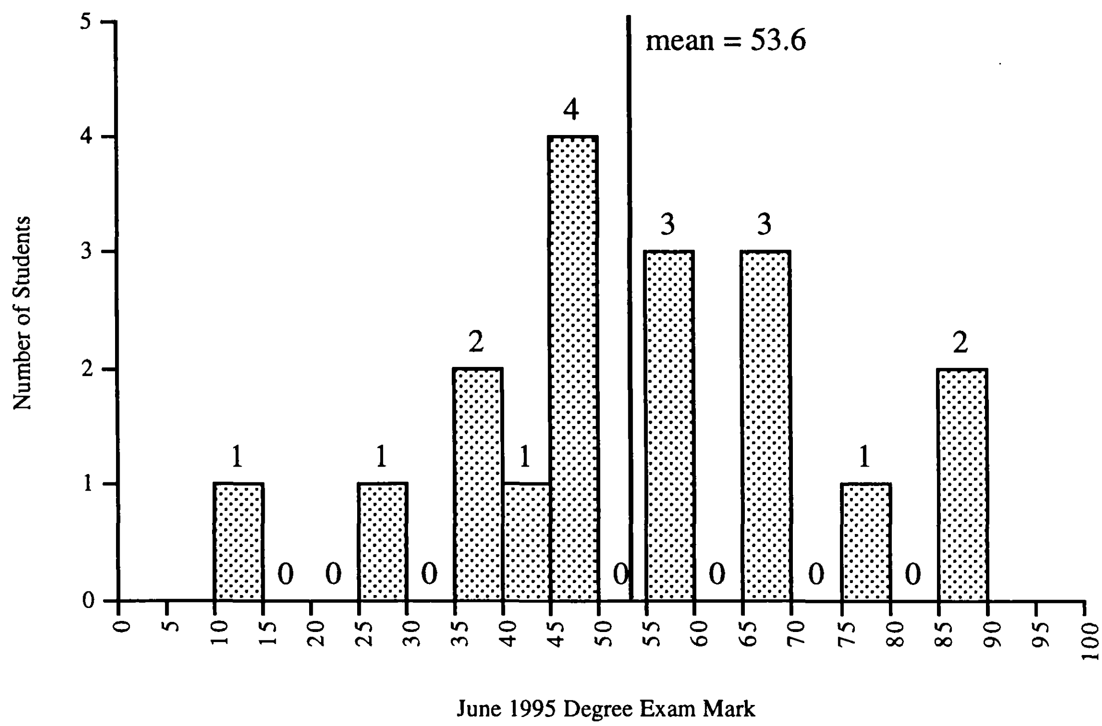
Graph L6 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Modular Chemistry Qualifications



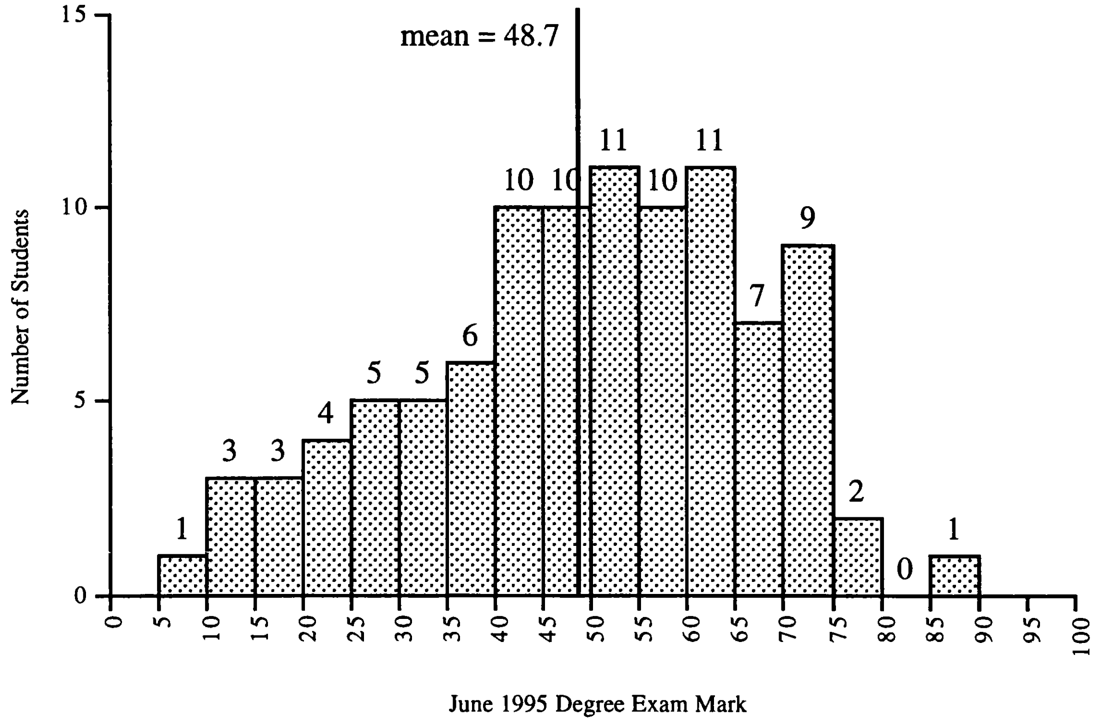
Graph L7 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with No Chemistry Qualifications



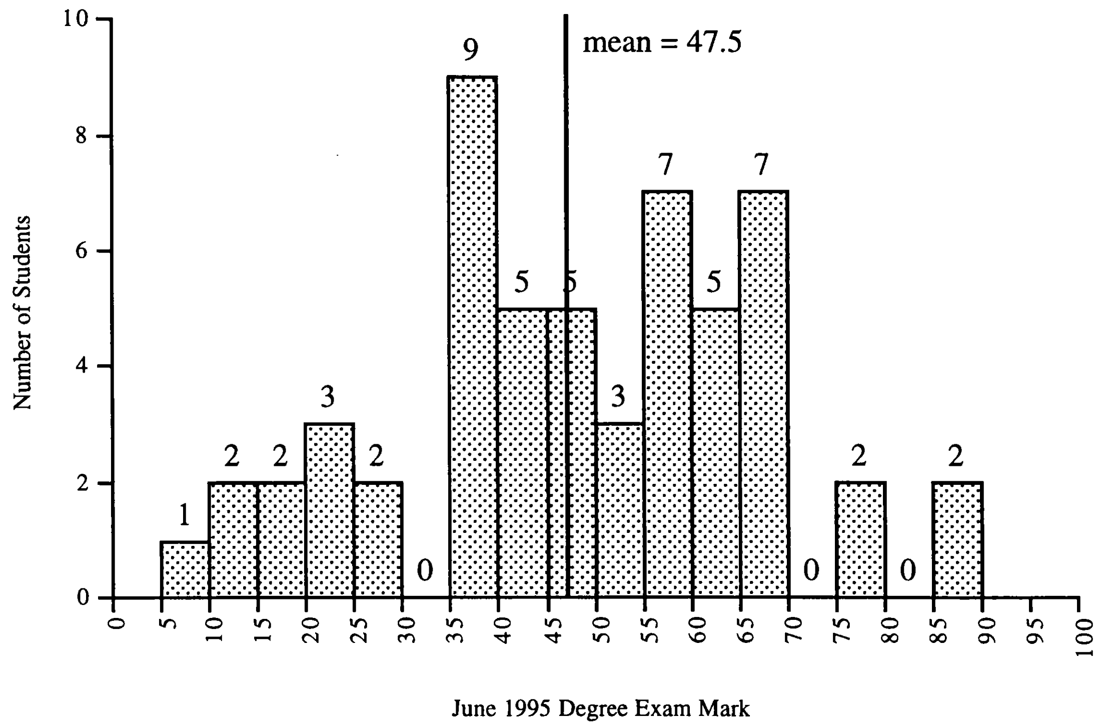
Graph L8 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Access / SWAP Chemistry Qualifications



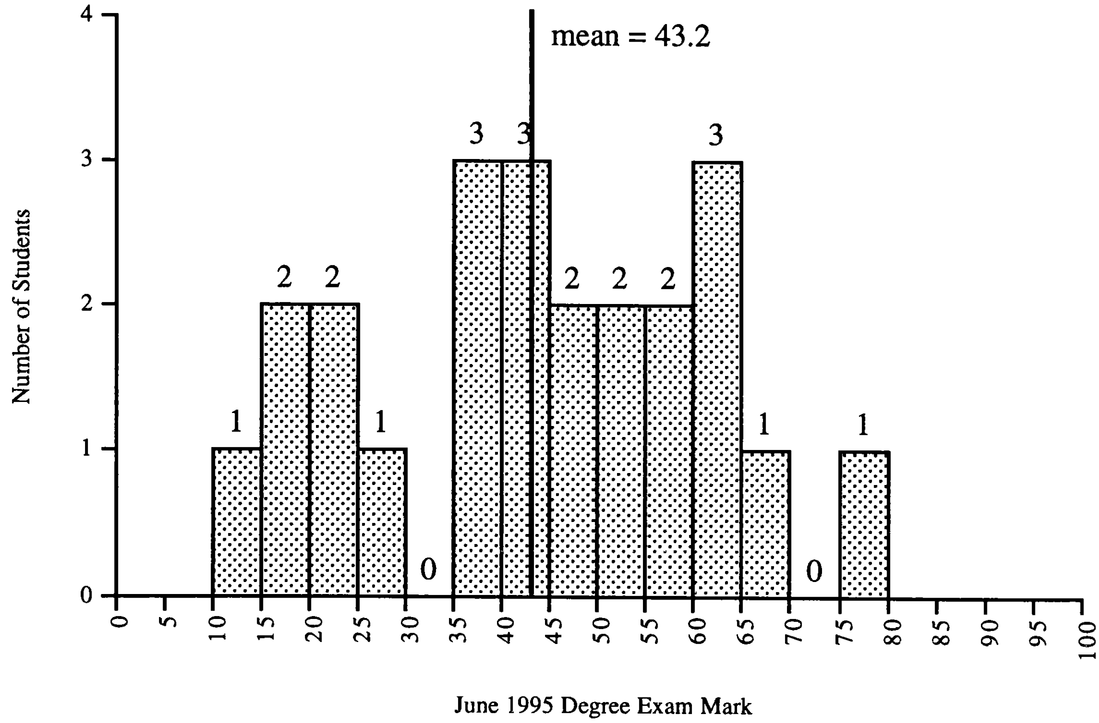
Graph L9 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Standard Entry (Mathematics) Qualifications



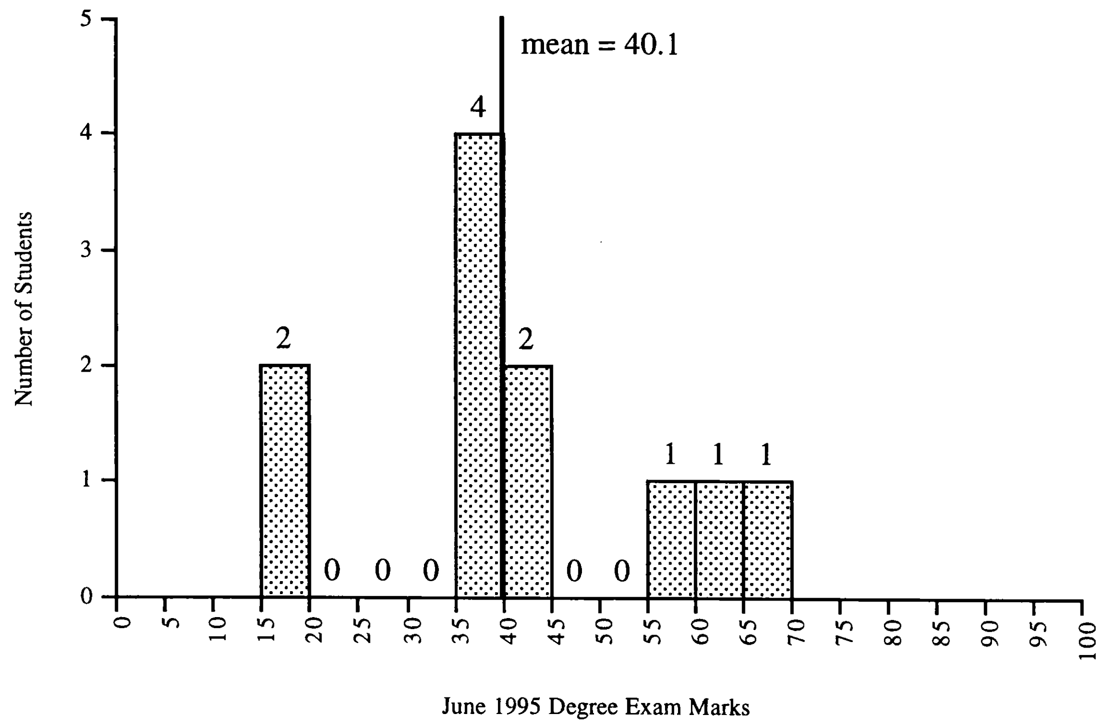
Graph L10 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Non-Standard Entry (Mathematics) Qualifications



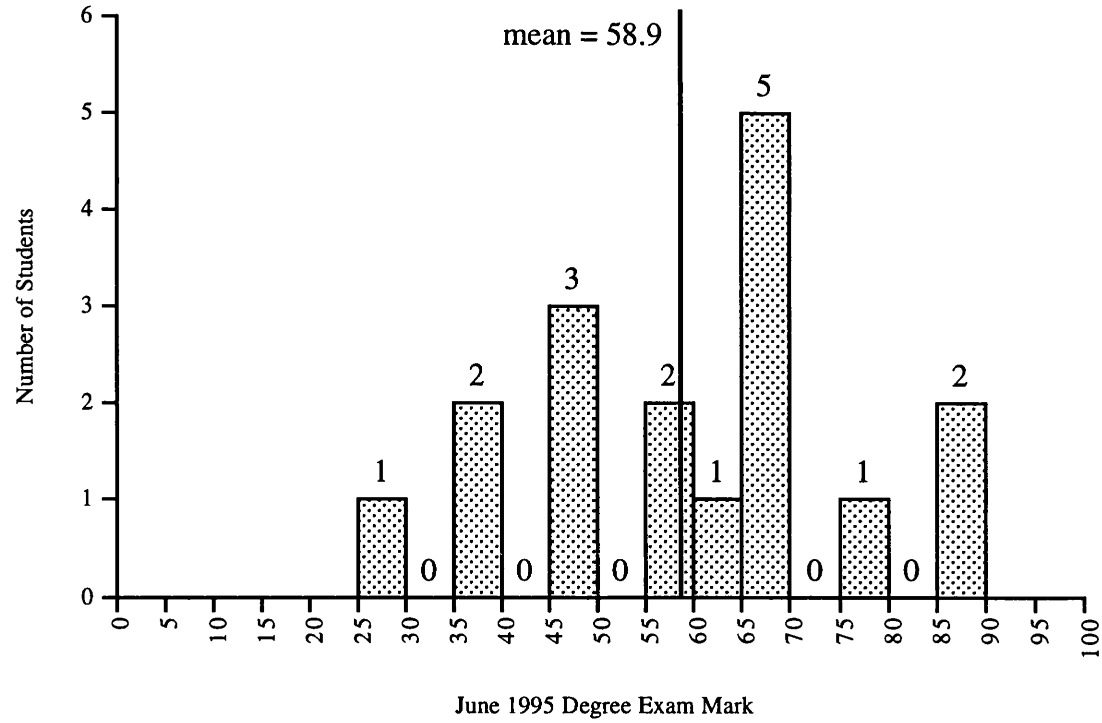
Graph L11 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Scottish Standard Grade Mathematics Qualifications



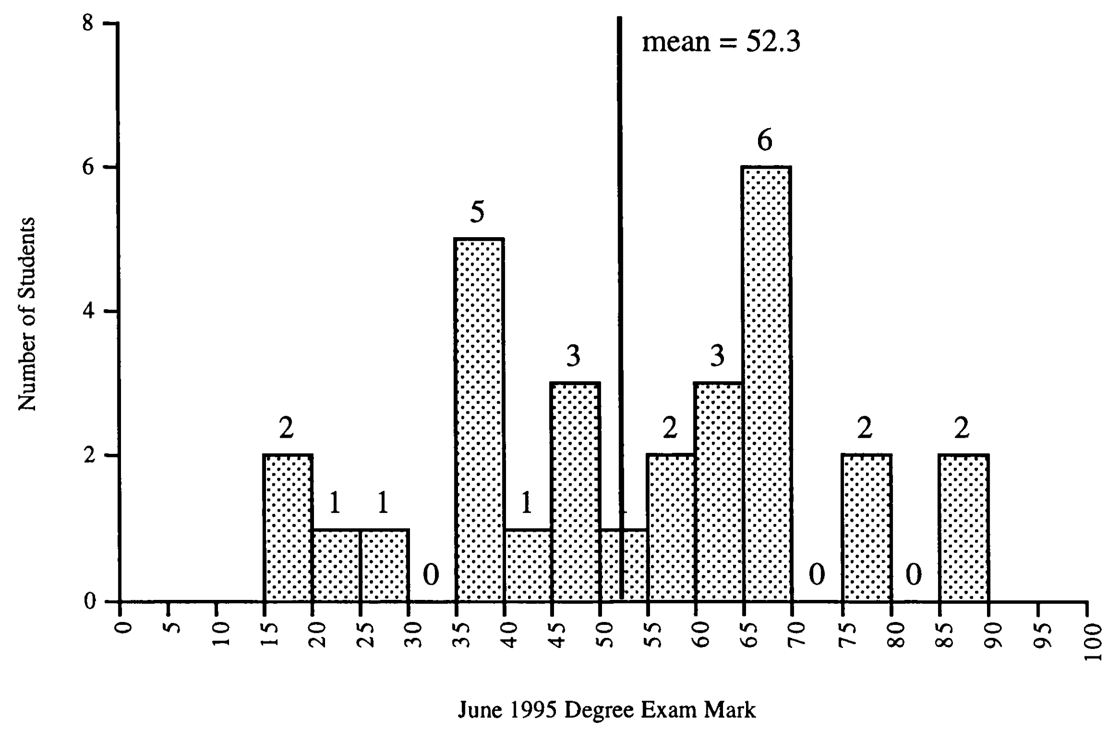
Graph L12 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Modular Mathematics Qualifications



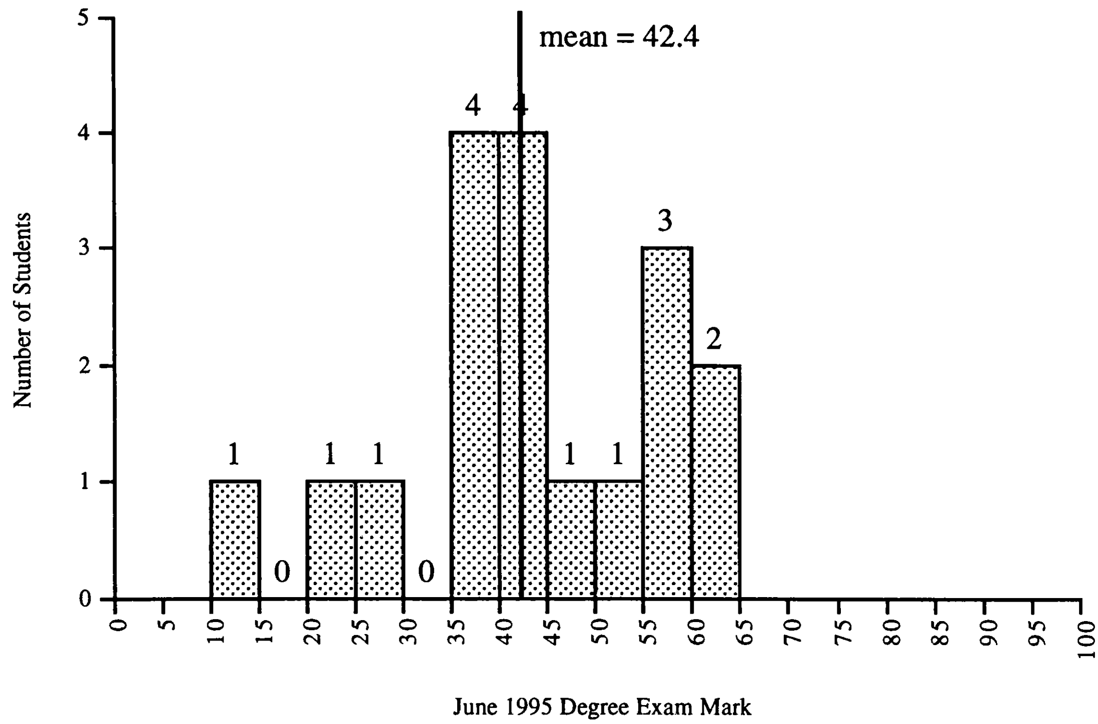
Graph L13 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Access / SWAP Mathematics Qualifications



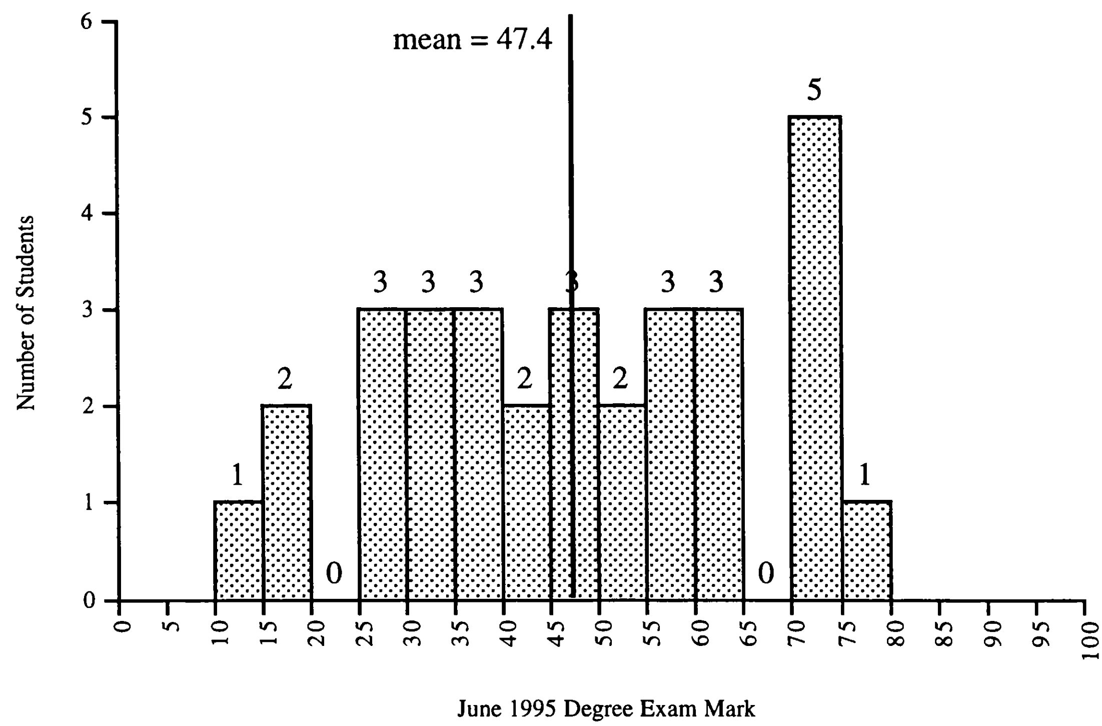
Graph L14 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Non-Standard Entry (Chemistry and Maths) Qualifications



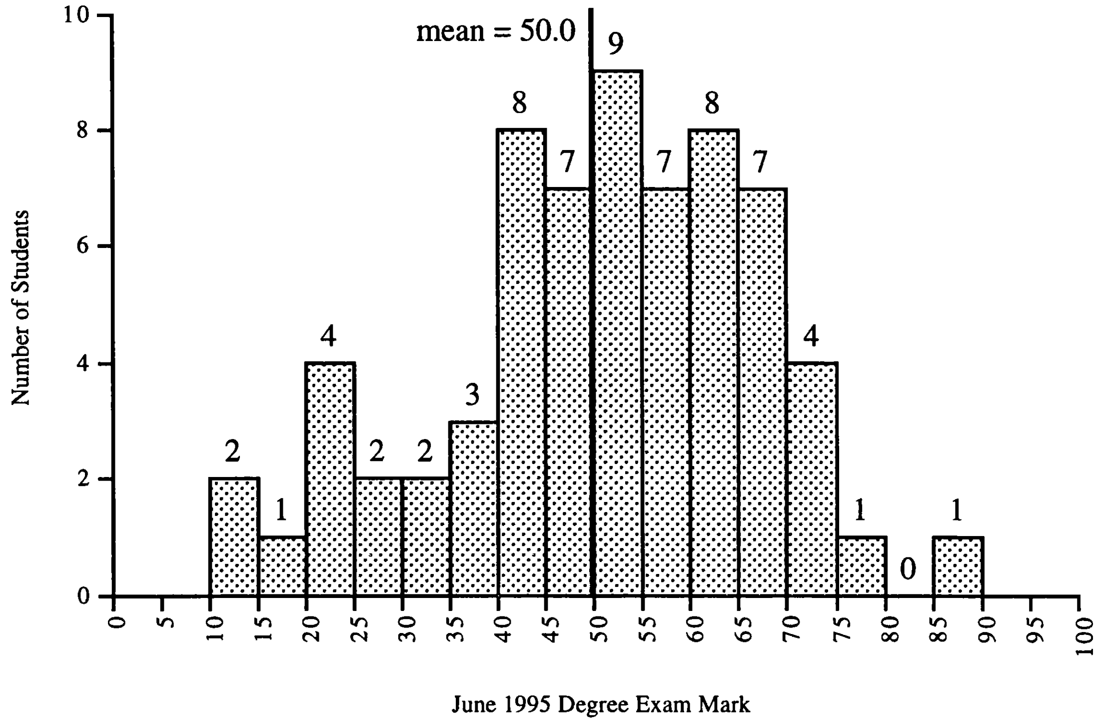
Graph L15 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Non-Standard Mathematics and Standard Chemistry Qualifications



Graph L16 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Standard Mathematics and Non-Standard Chemistry Qualifications

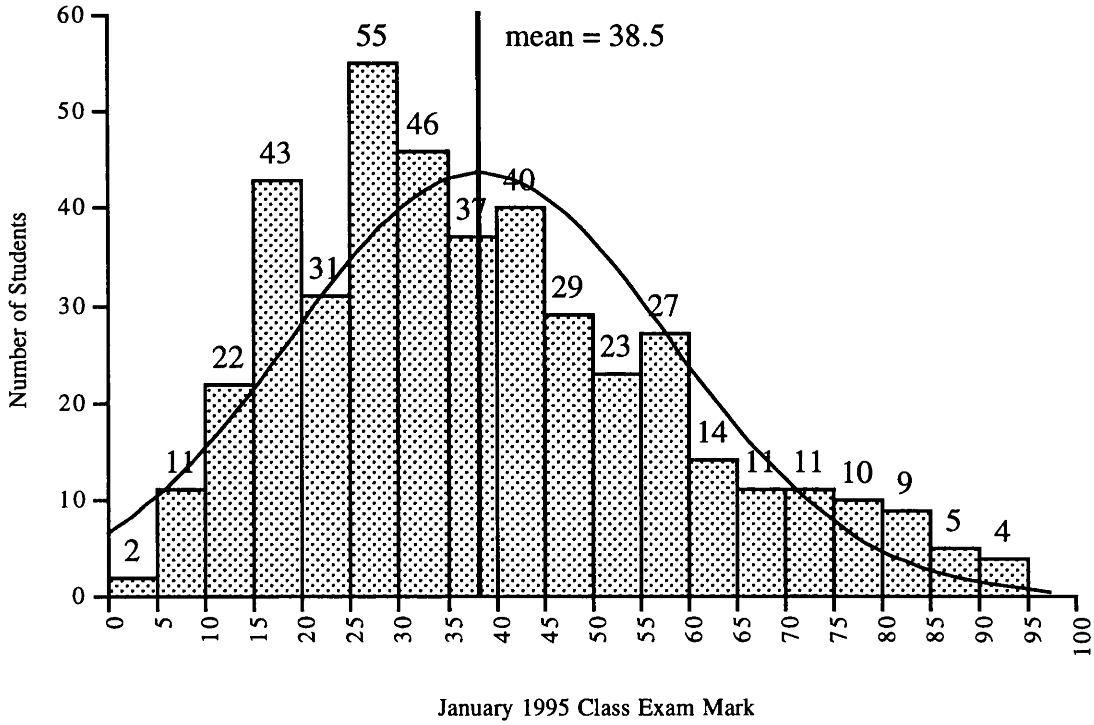


Graph L17 Distribution of General Chemistry–1 1994/95 June Degree Exam Marks Students with Standard Entry (Maths and Chemistry) Qualifications

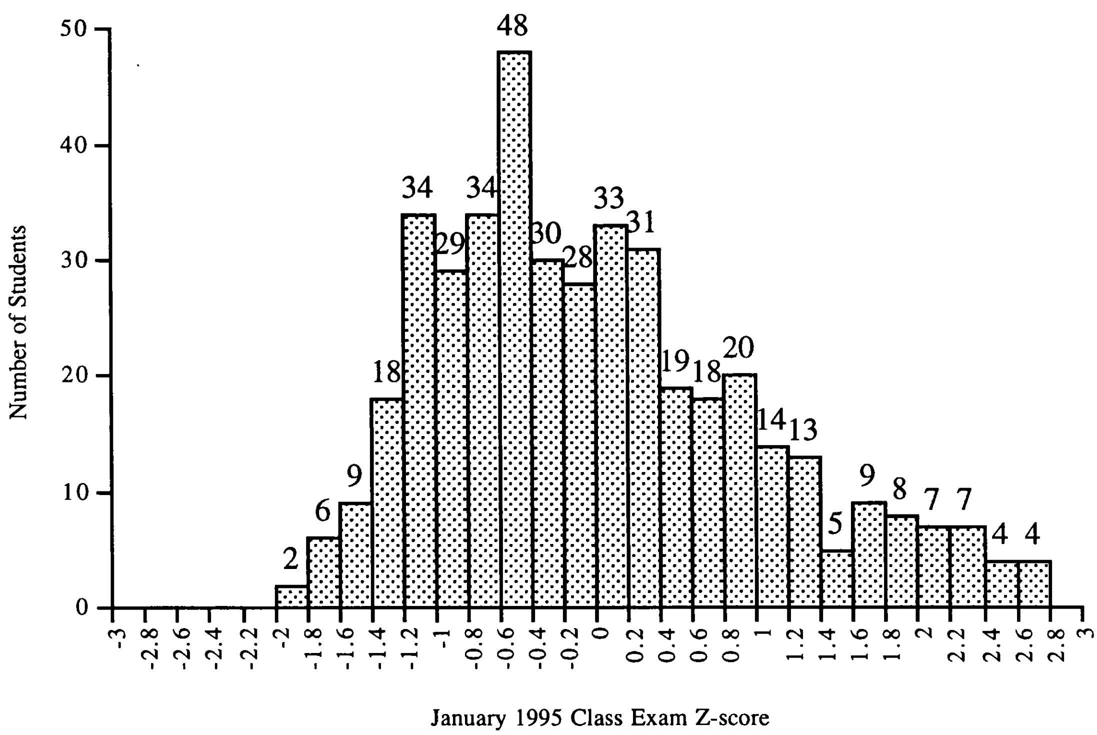


Appendix M
Chemistry–1, 1994/95
Exam Results

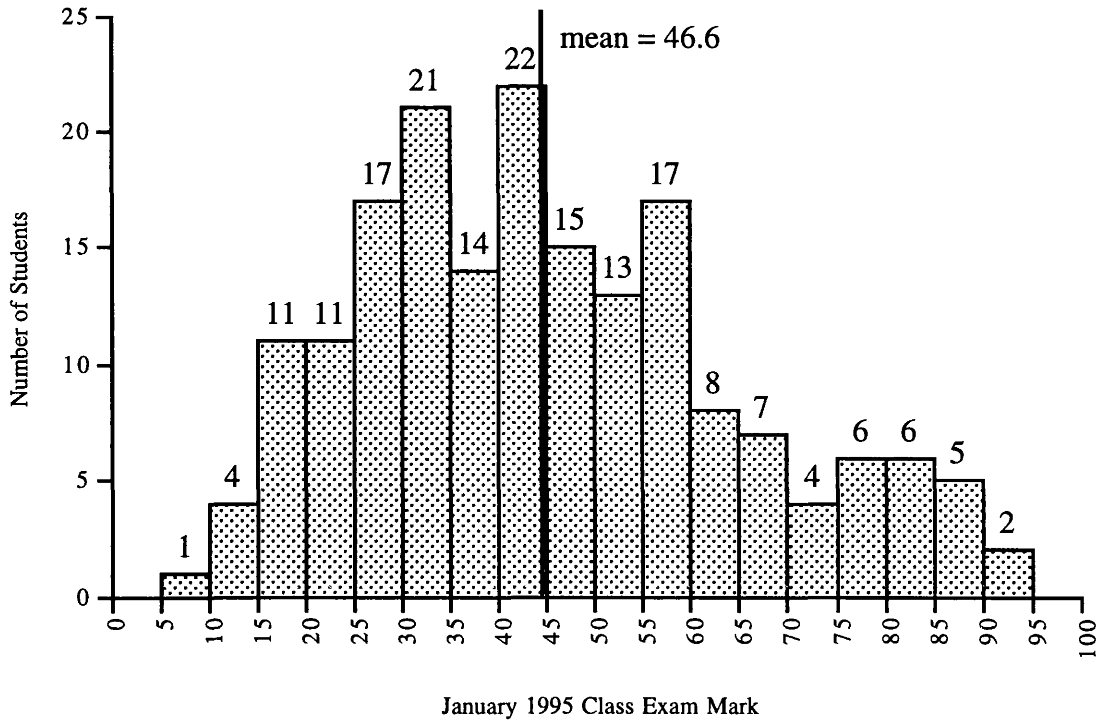
Graph M1 Distribution of Chemistry–1 1994/95 January Class Exam Marks



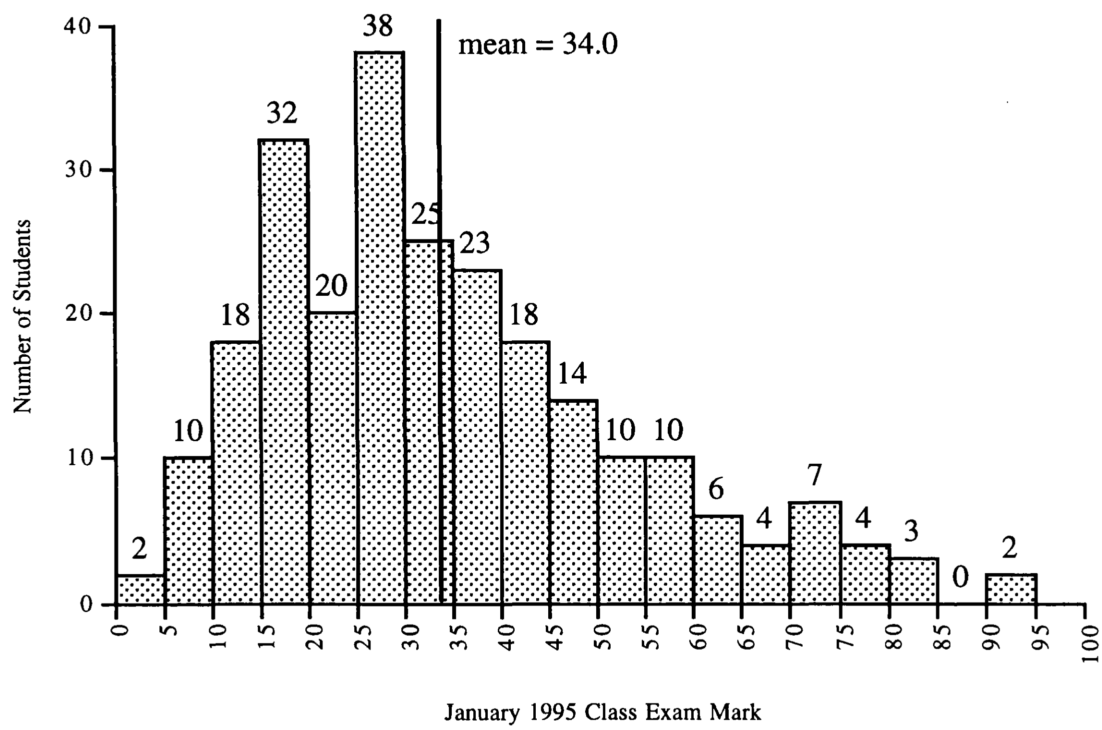
Graph M2 Distribution of Chemistry–1 1994/95 January Class Exam Marks as Z-scores



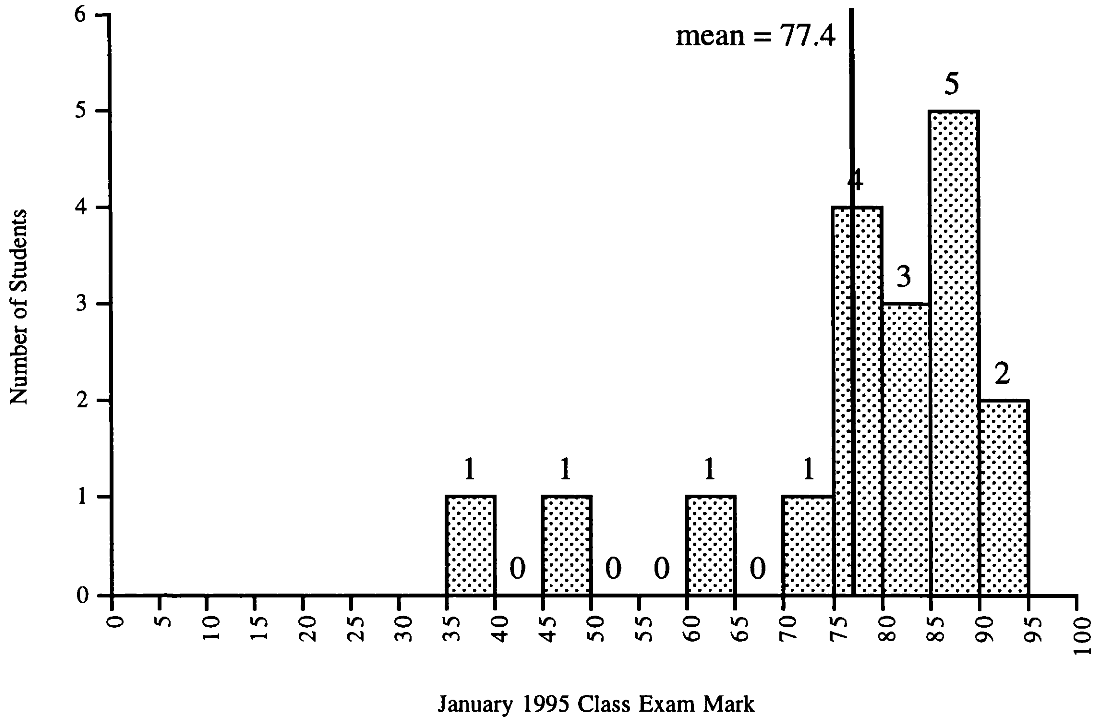
Graph M3 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry



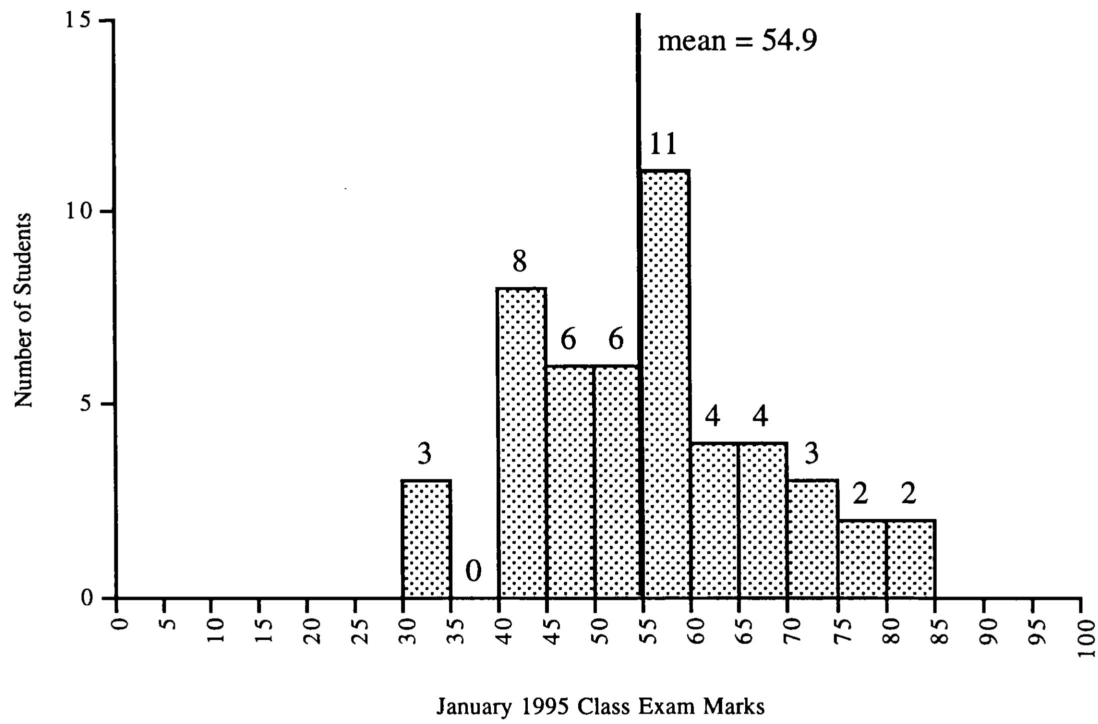
Graph M4 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Higher Grade Chemistry Qualifications



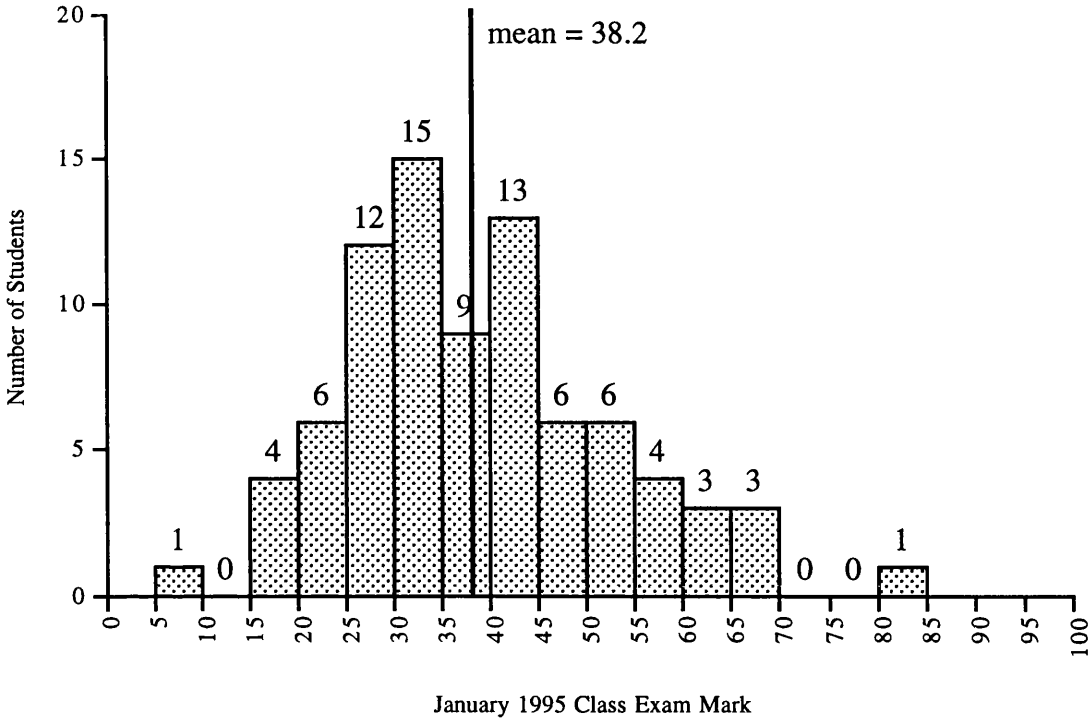
Graph M5 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade A



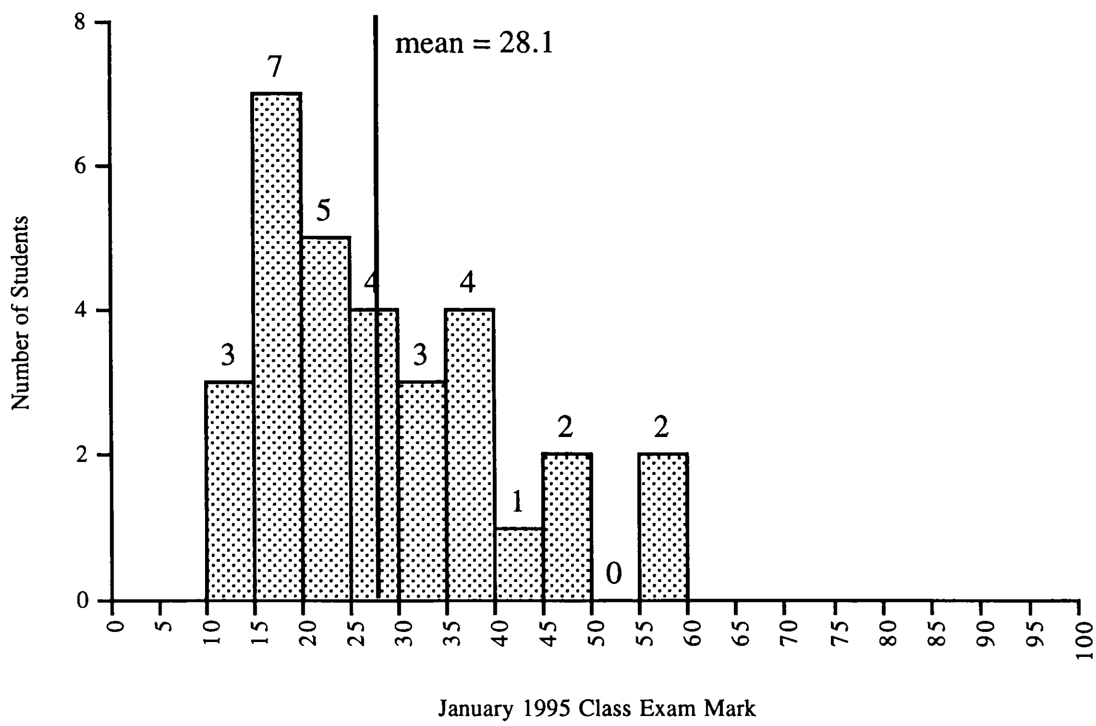
Graph M6 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade B



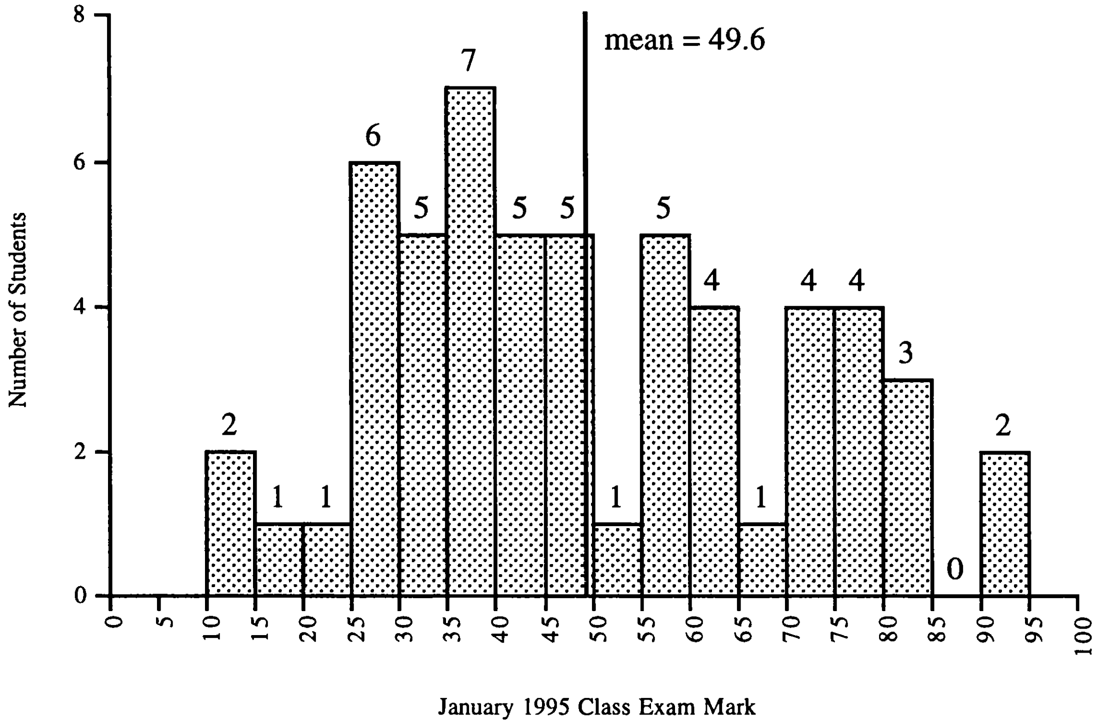
Graph M7 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade C



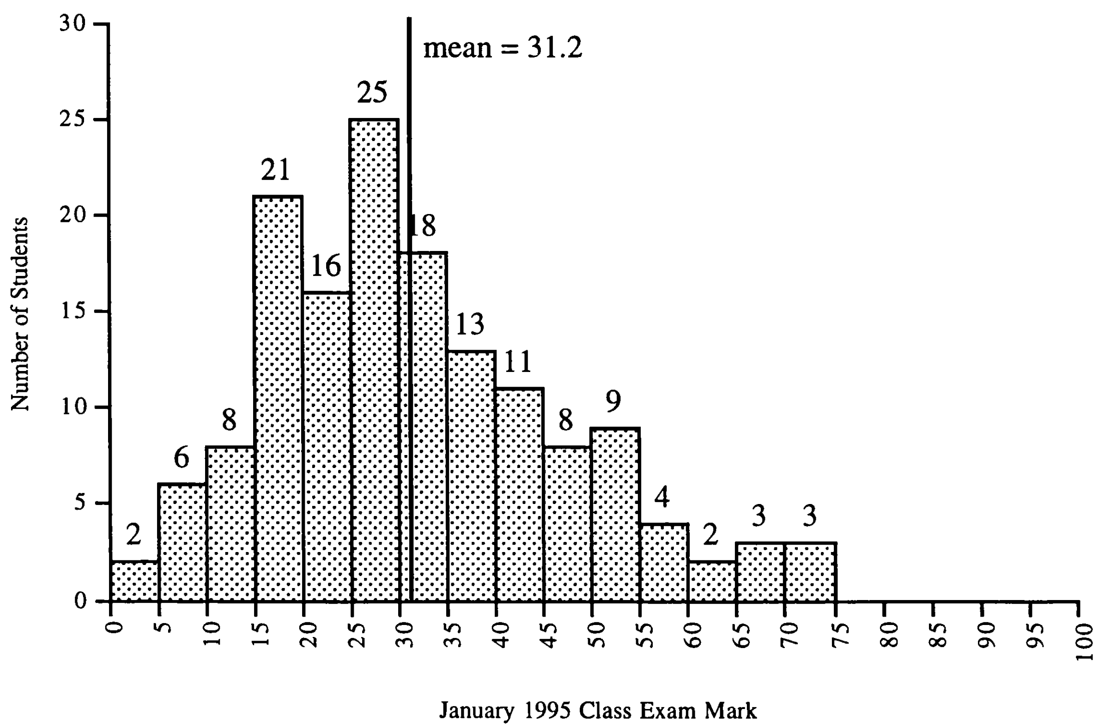
Graph M8 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade D



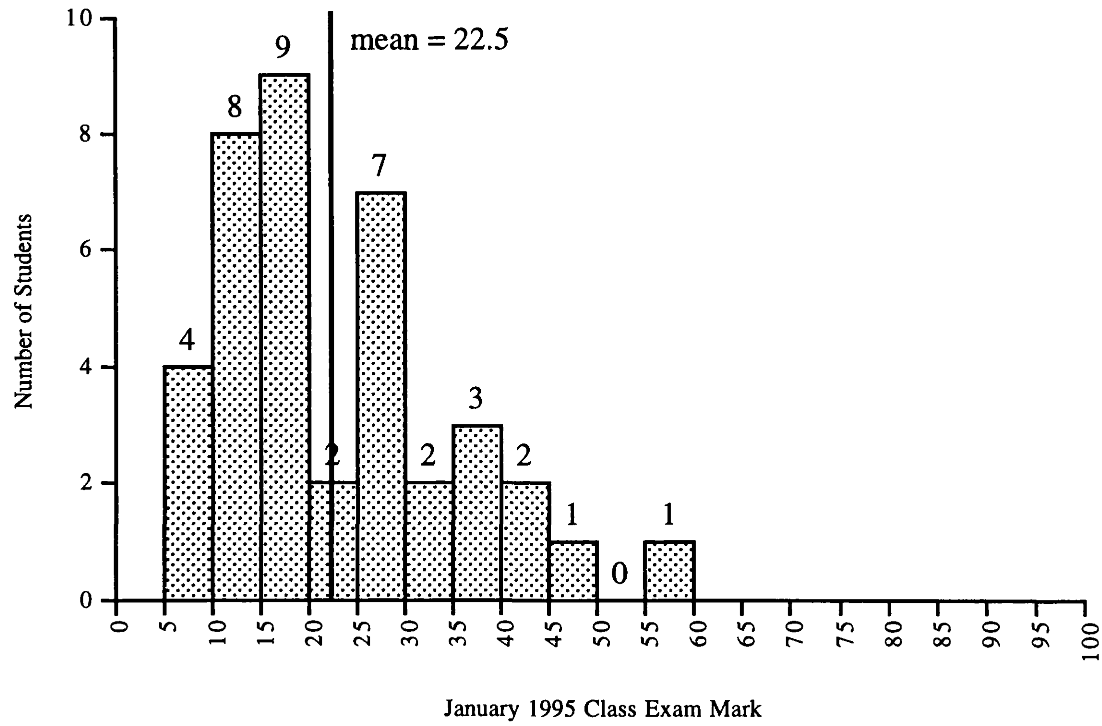
Graph M9 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Higher Grade Chemistry at Grade A



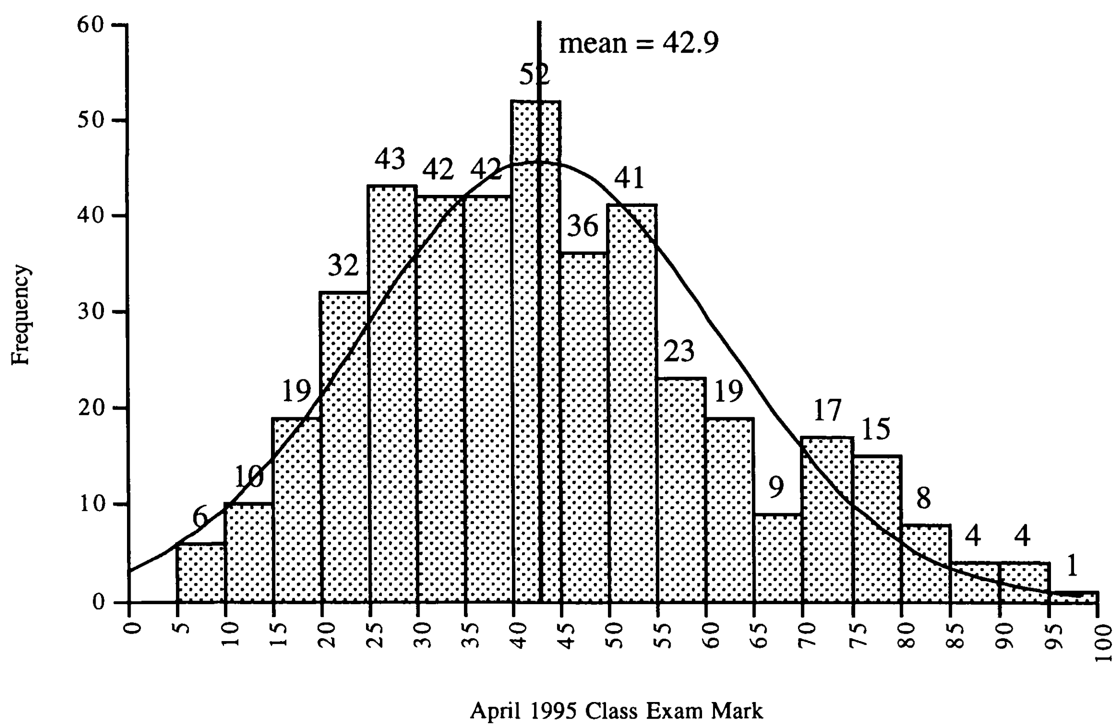
Graph M10 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Higher Grade Chemistry at Grade B



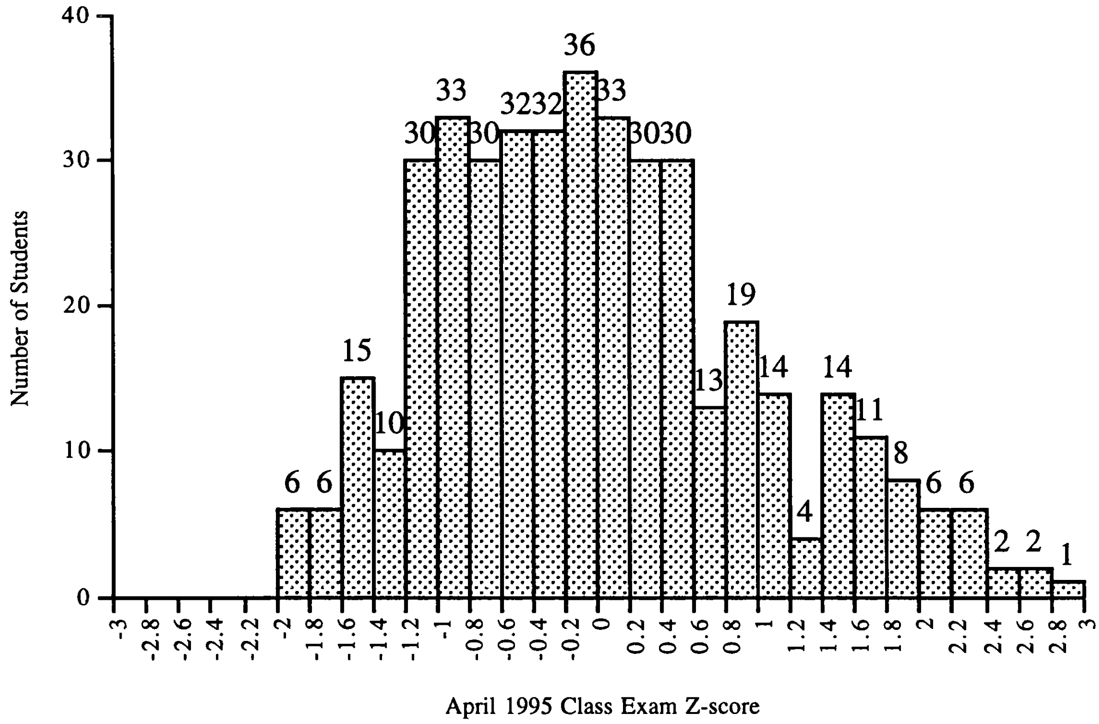
Graph M11 Distribution of Chemistry–1 1994/95 January Class Exam Marks Students with Higher Grade Chemistry at Grade C



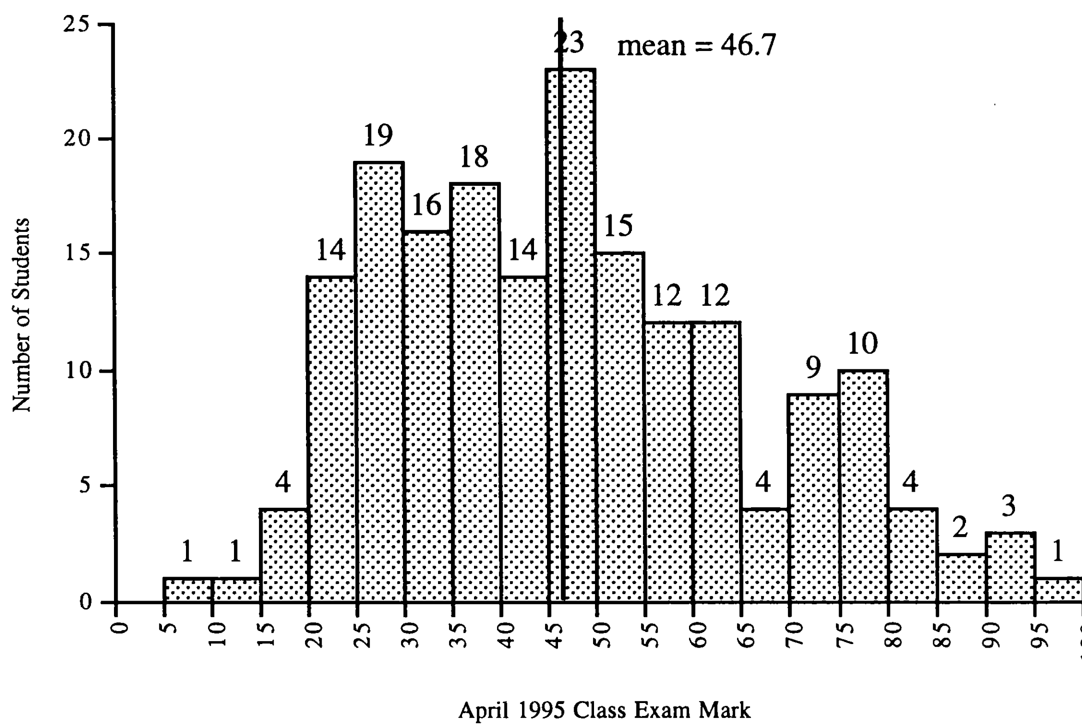
Graph M12 Distribution of Chemistry–1 1994/95 April Class Exam Marks



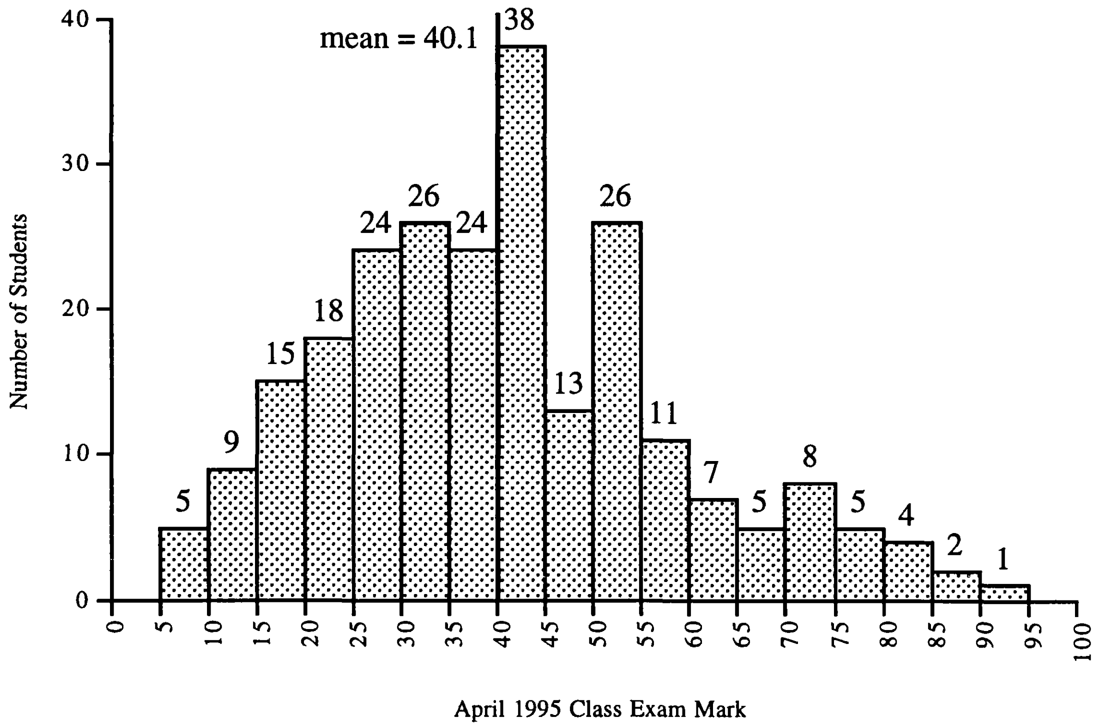
Graph M13 Distribution of Chemistry–1 1994/95 April Class Exam Marks as Z-scores



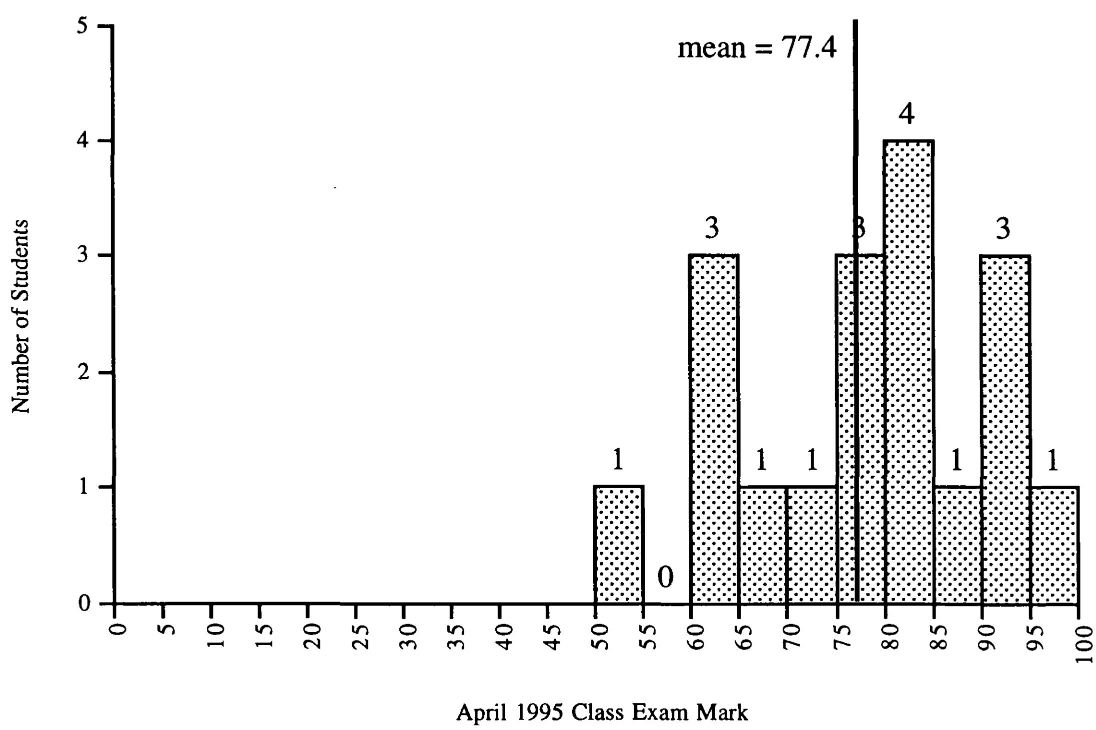
Graph M14 Distribution of Chemistry–1 1994/95 April Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry



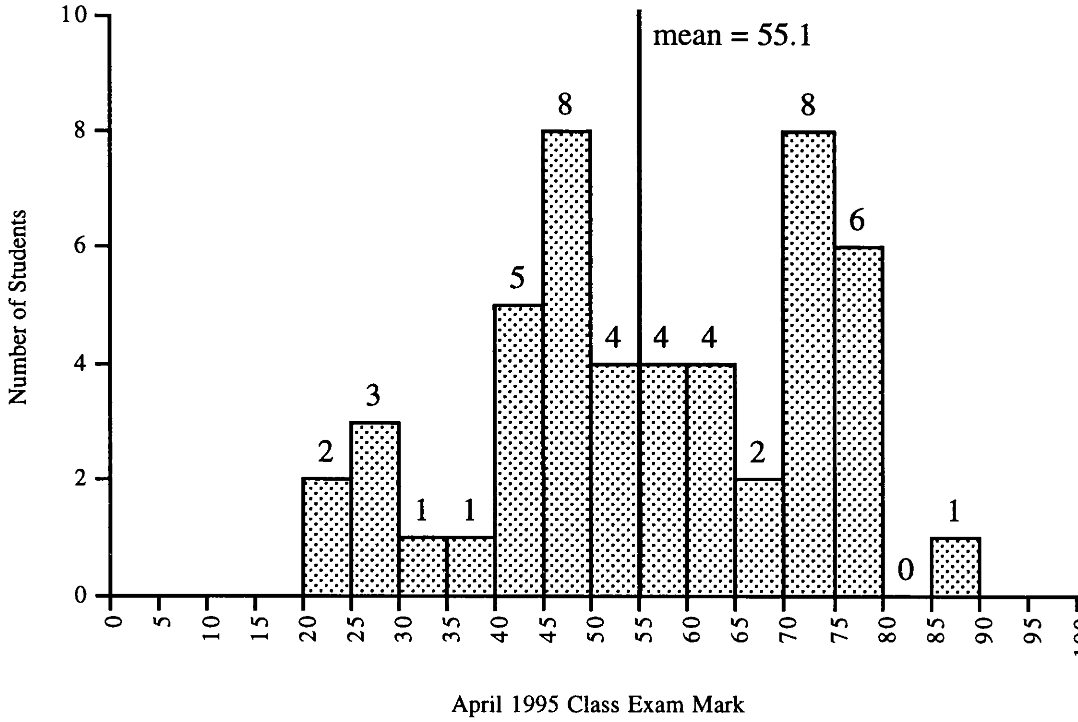
Graph M15 Distribution of Chemistry–1 1994/95 April Class Exam Marks
Students with Higher Grade Chemistry Qualifications



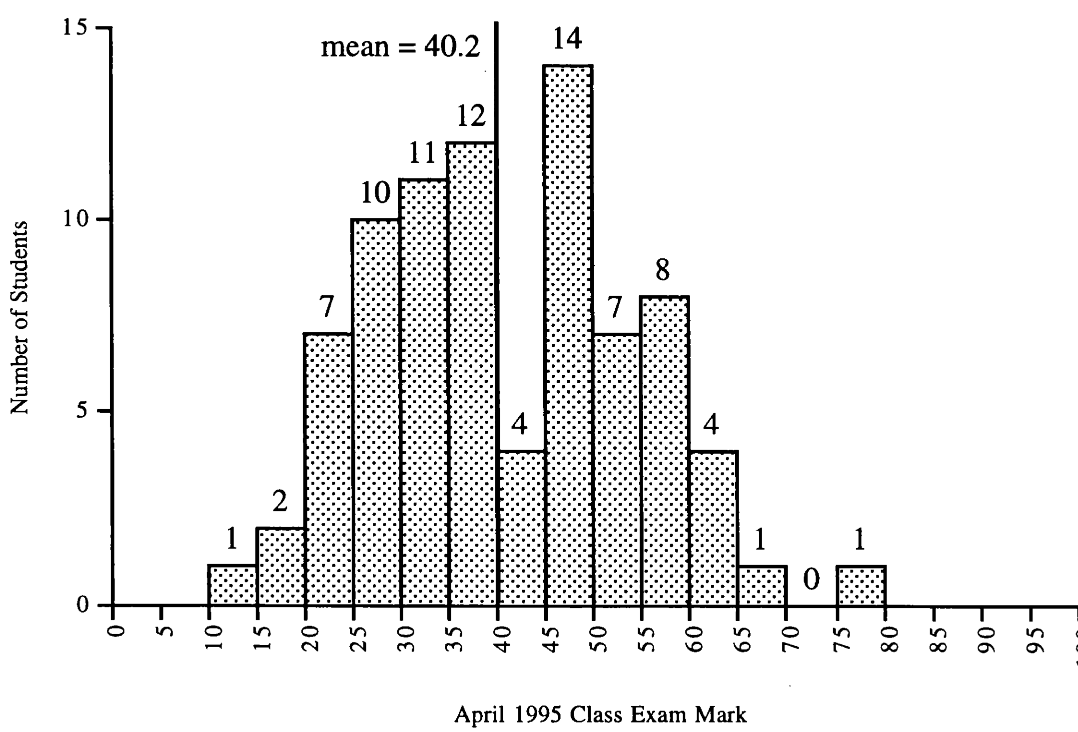
Graph M16 Distribution of Chemistry–1 1994/95 April Class Exam Marks
Students with Certificate of Sixth Year Studies in Chemistry at Grade A



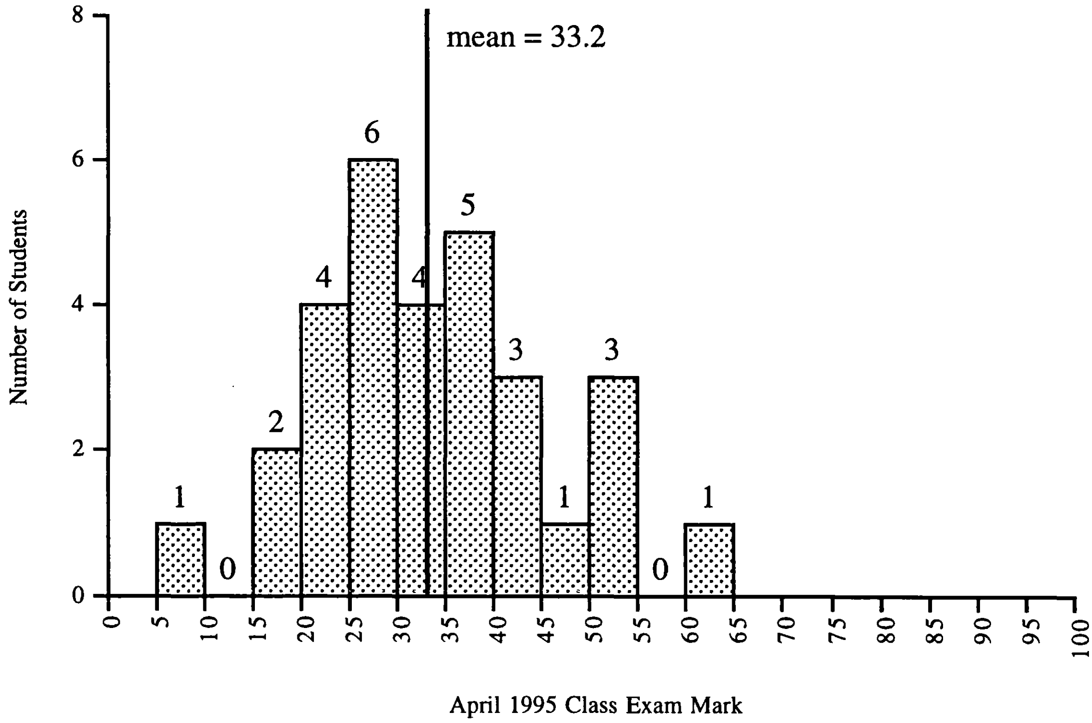
Graph M17 Distribution of Chemistry–1 1994/95 April Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade B



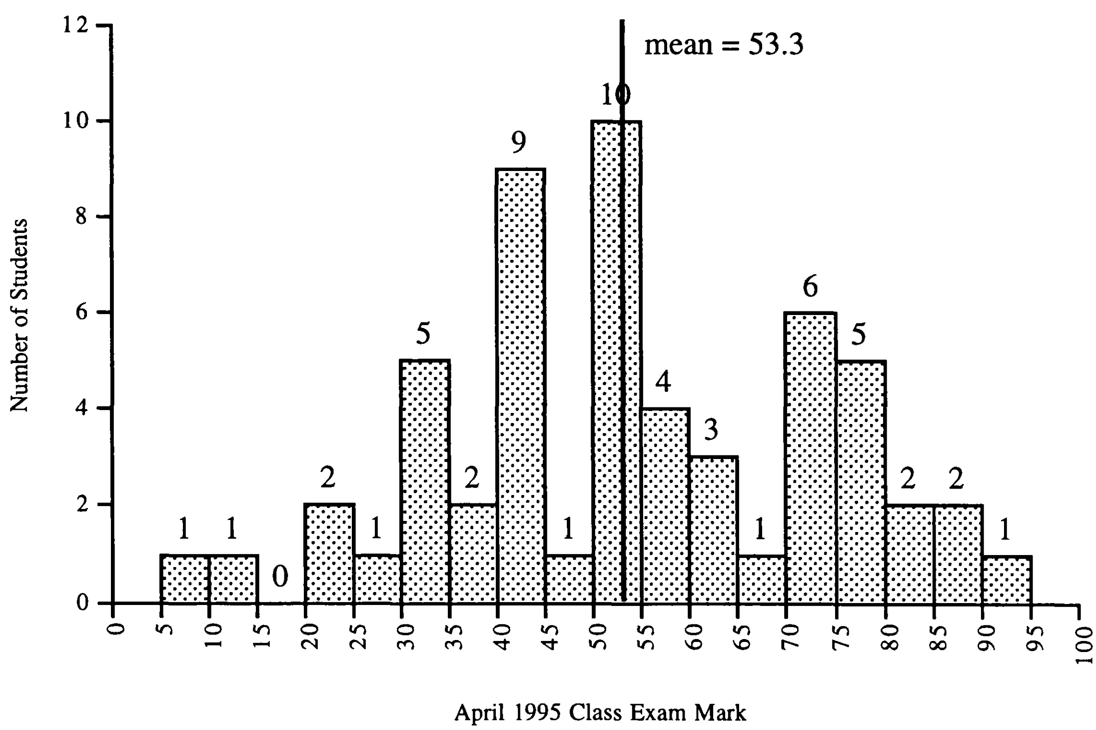
Graph M18 Distribution of Chemistry–1 1994/95 April Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade C



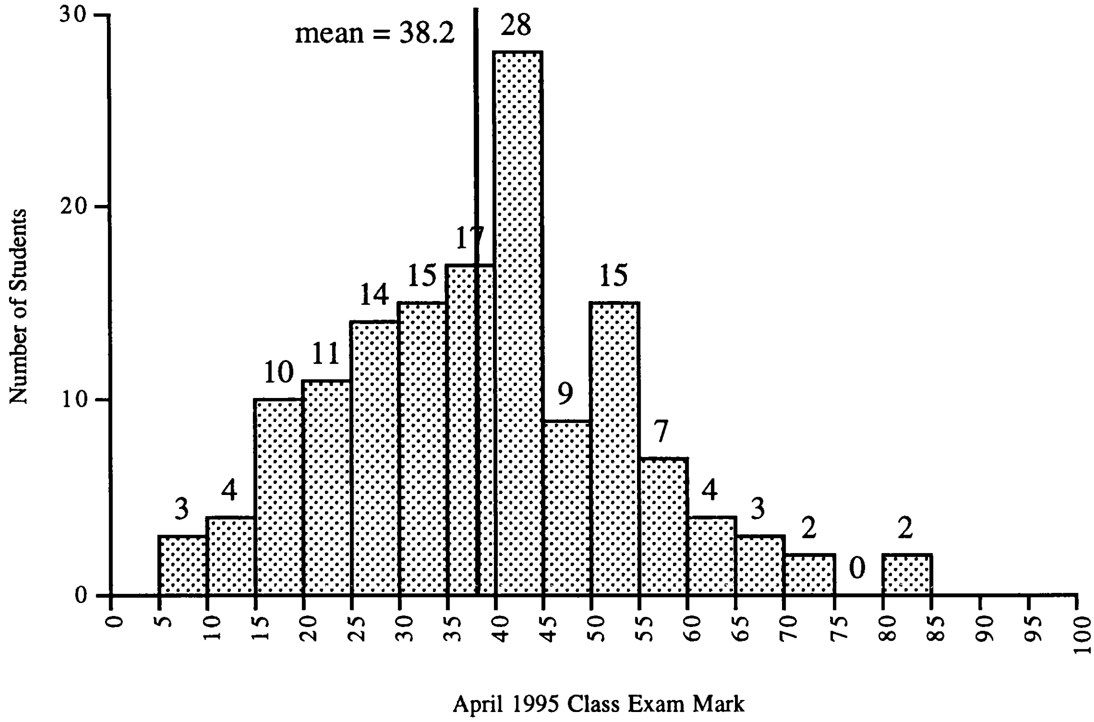
Graph M19 Distribution of Chemistry–1 1994/95 April Class Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade D



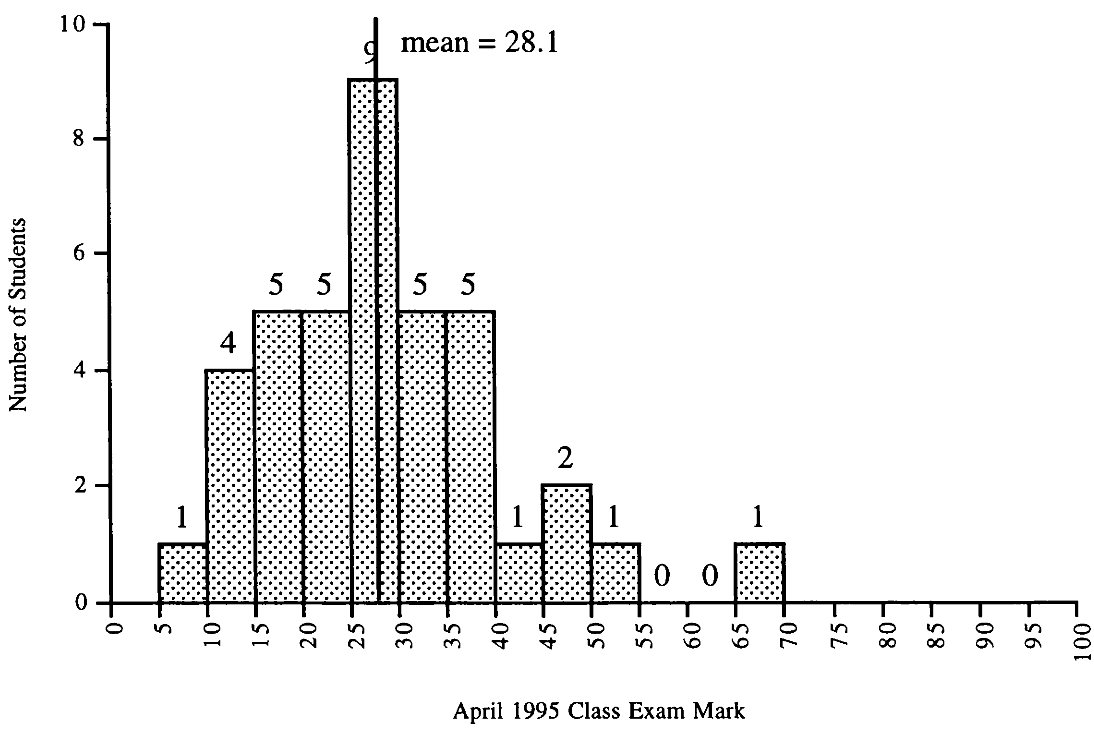
Graph M20 Distribution of Chemistry–1 1994/95 April Class Exam Marks Students with Higher Grade Chemistry at Grade A



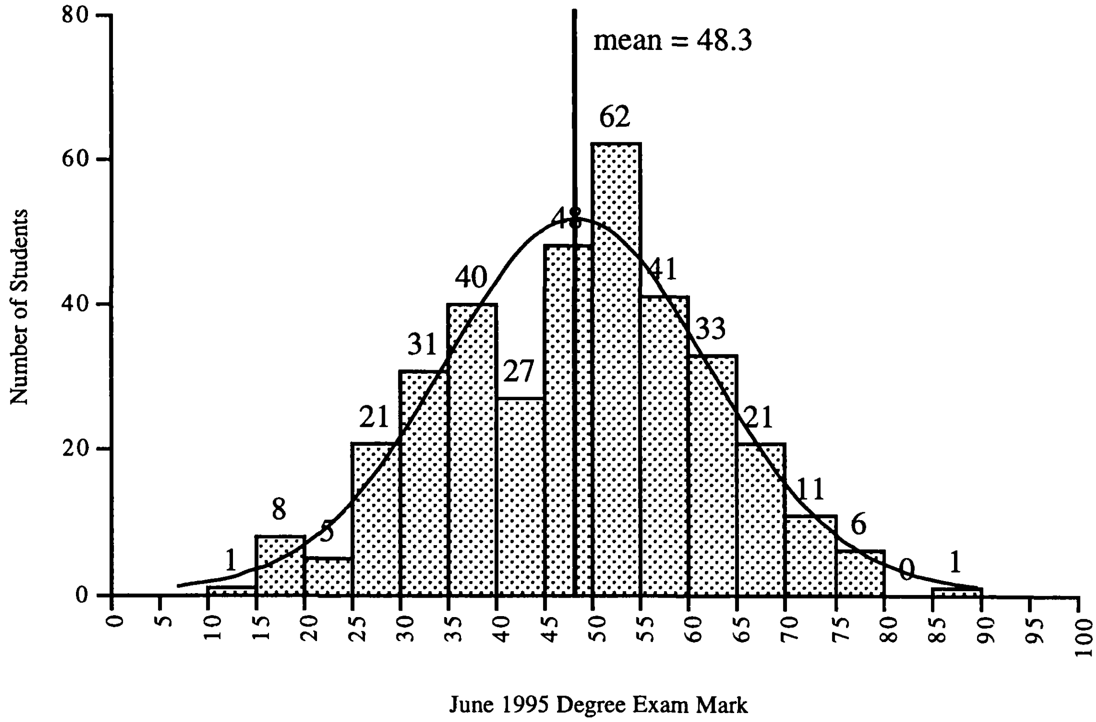
Graph M21 Distribution of Chemistry–1 1994/95 April Class Exam Marks
Students with Higher Grade Chemistry at Grade B



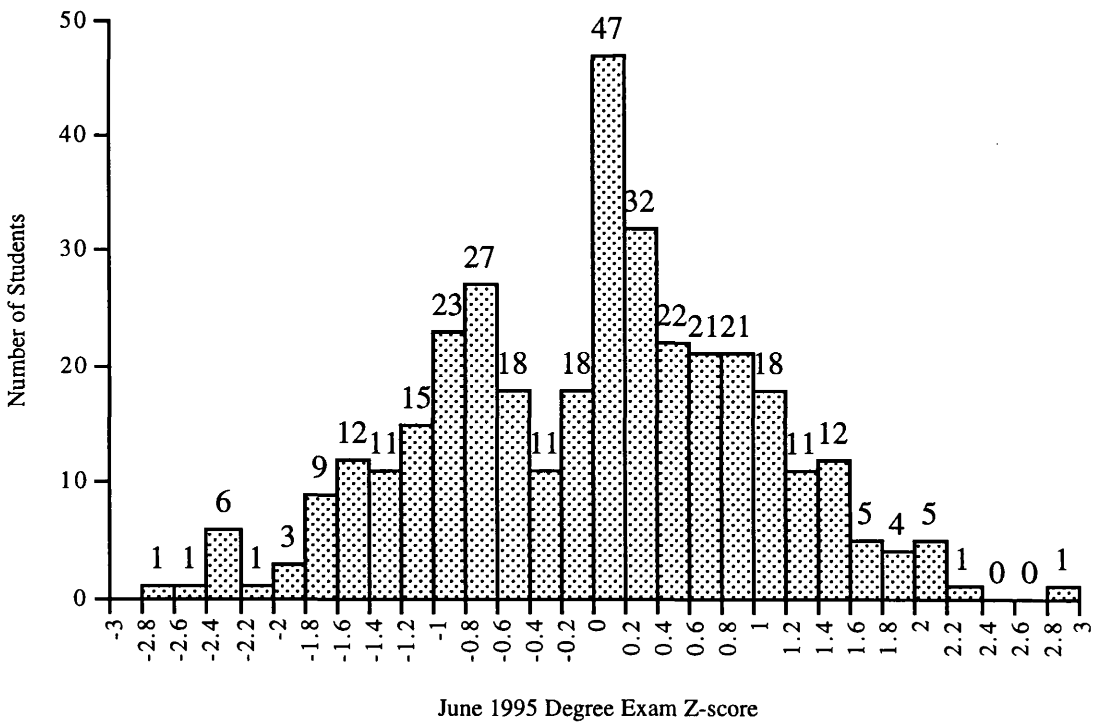
Graph M22 Distribution of Chemistry–1 1994/95 April Class Exam Marks
Students with Higher Grade Chemistry at Grade C



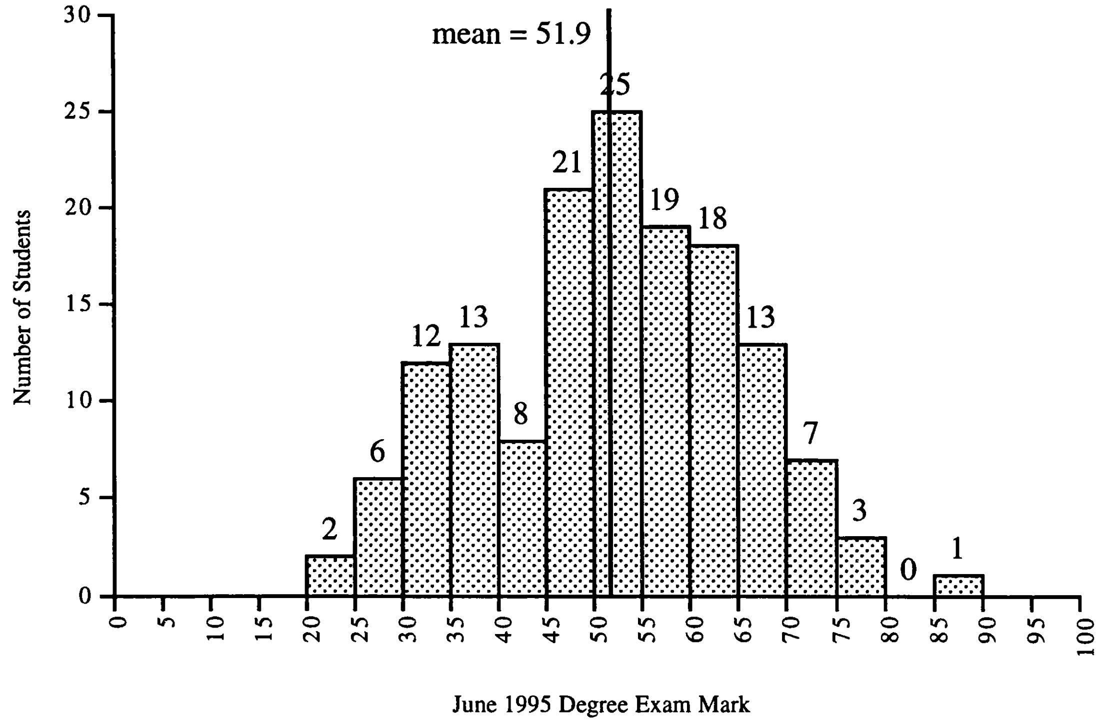
Graph M23 Distribution of Chemistry–1 1994/95 June Degree Exam Marks



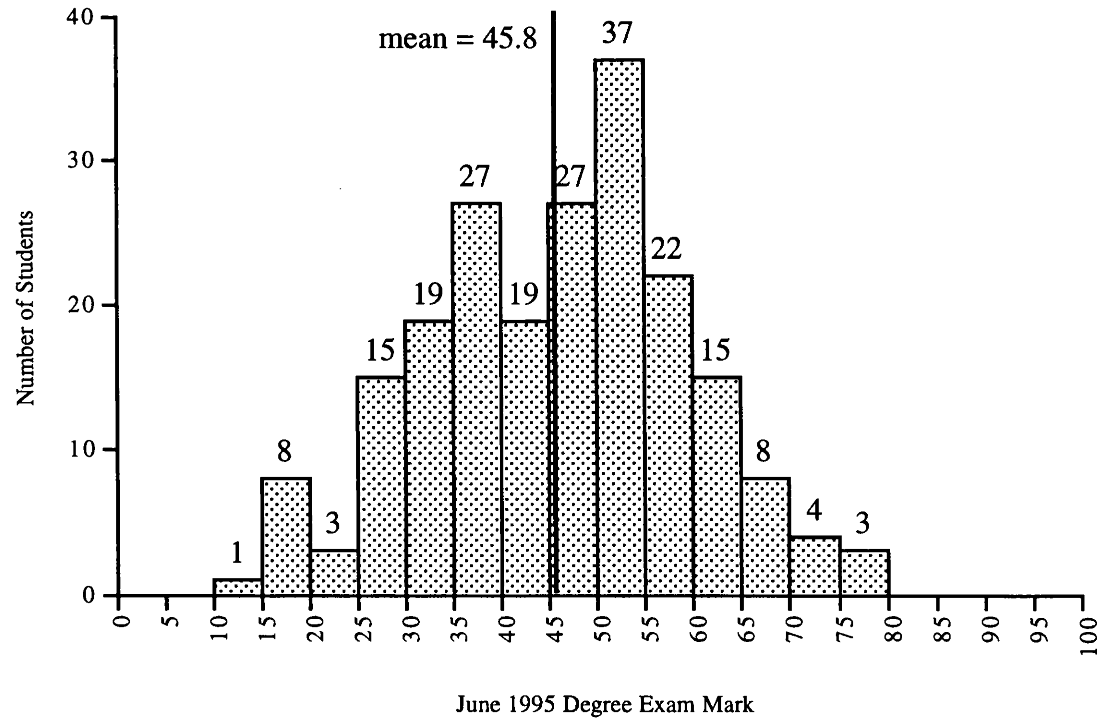
Graph M24 Distribution of Chemistry–1 1994/95 June Degree Exam Marks as Z-scores



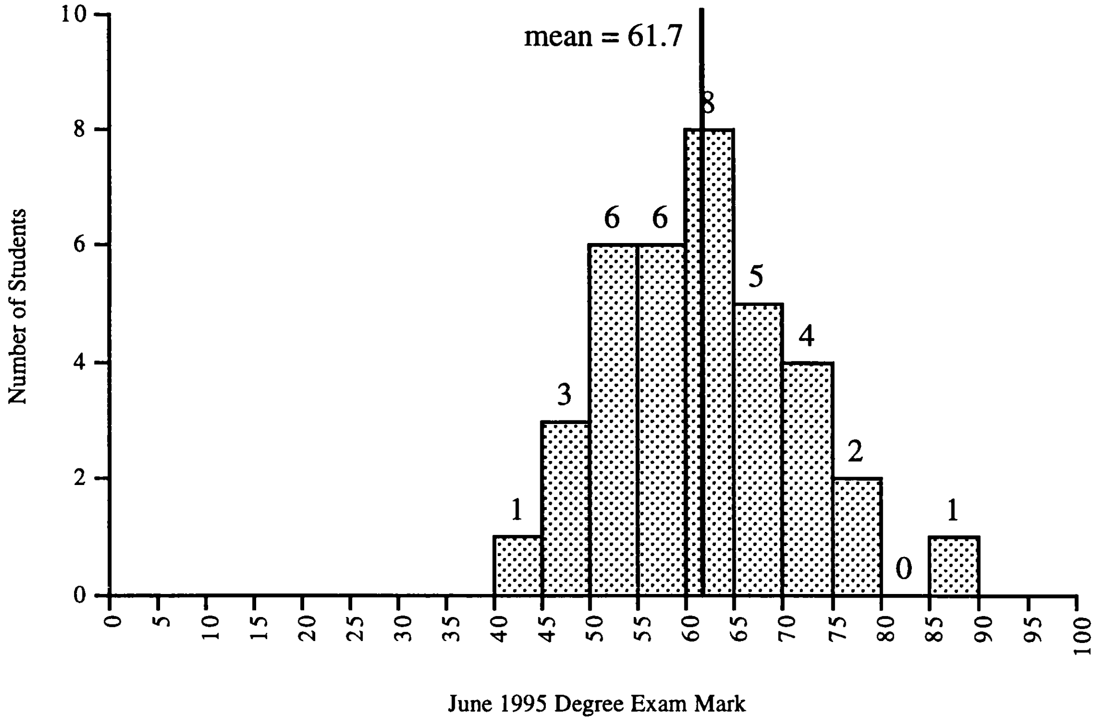
Graph M25 Distribution of Chemistry–1 1994/95 June Degree Exam Marks Students with Certificate of Sixth Year Studies in Chemistry



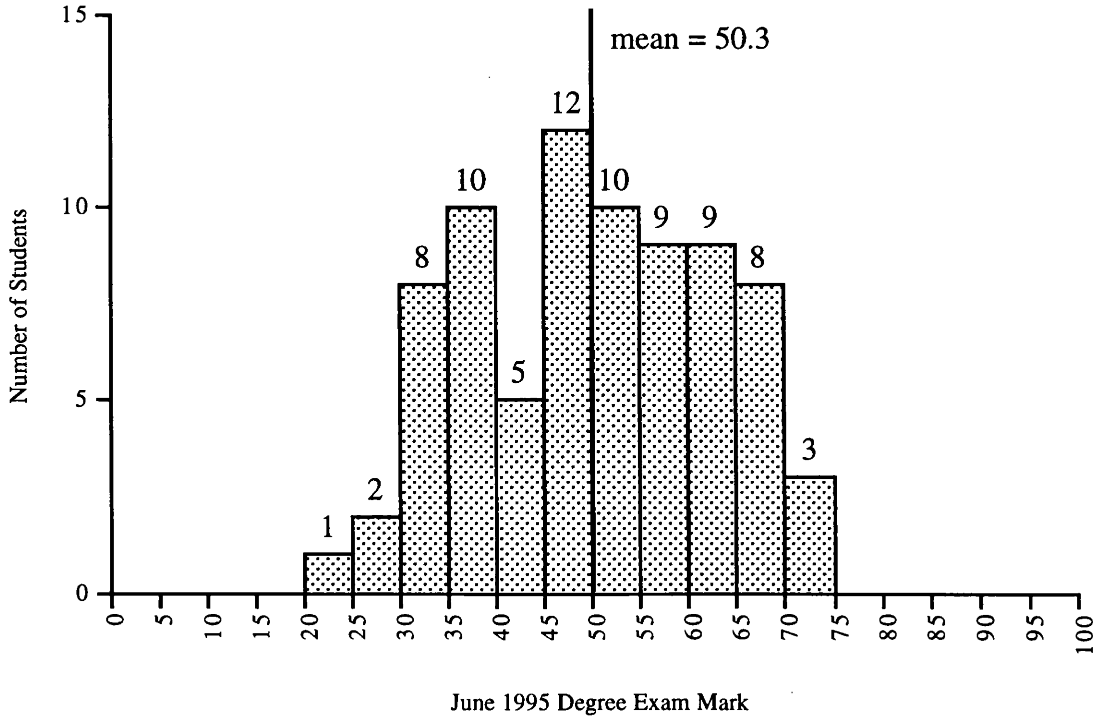
Graph M26 Distribution of Chemistry–1 1994/95 June Degree Exam Marks Students with Higher Grade Chemistry Qualifications



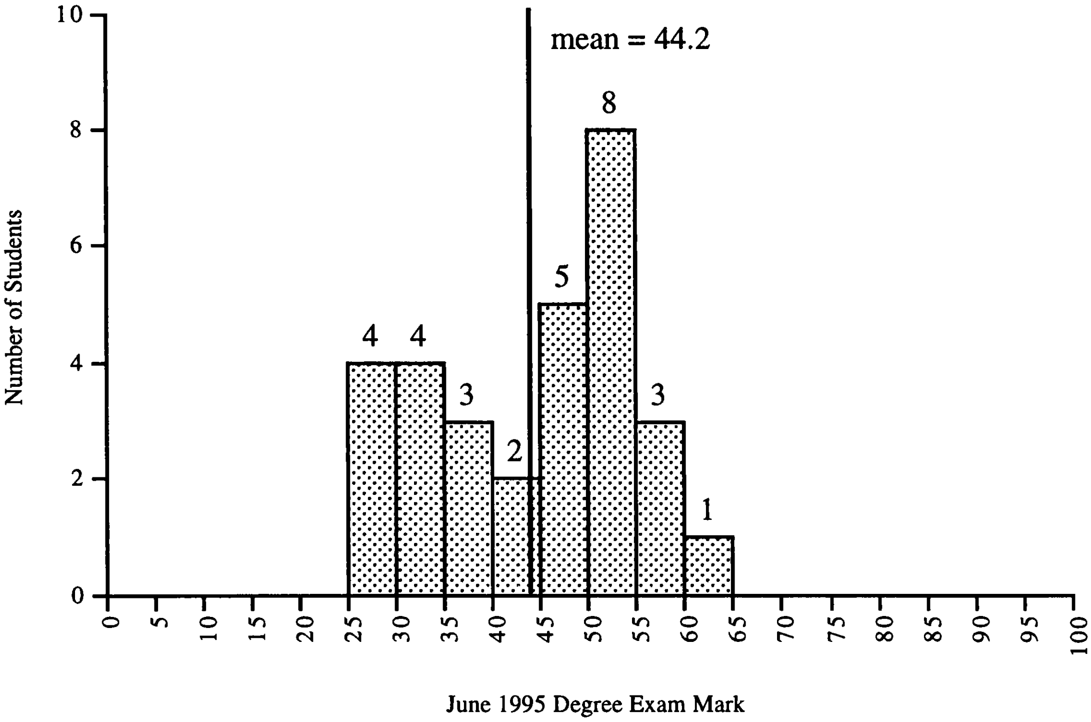
Graph M27 Distribution of Chemistry–1 1994/95 June Degree Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade B



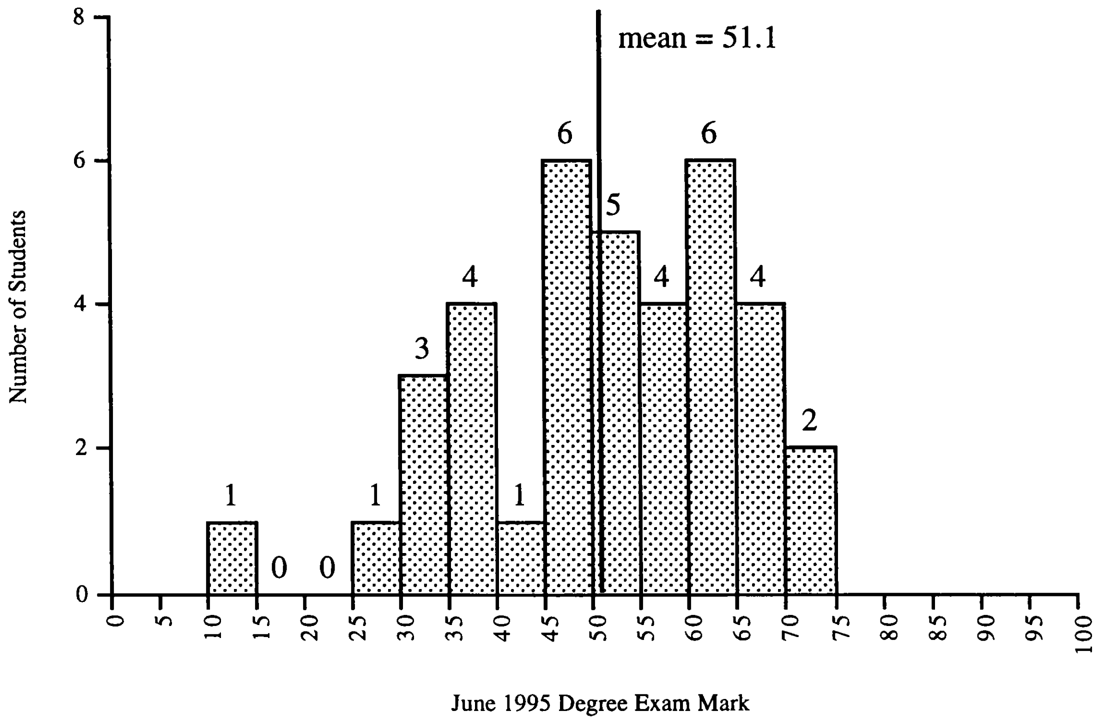
Graph M28 Distribution of Chemistry–1 1994/95 June Degree Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade C



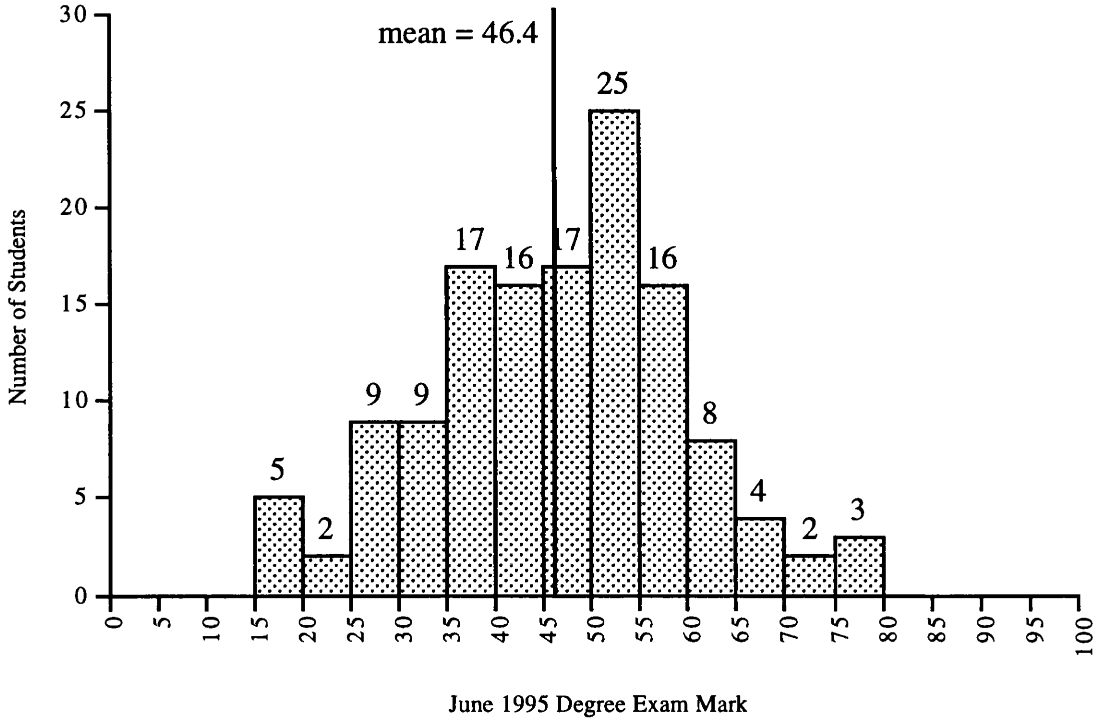
Graph M29 Distribution of Chemistry–1 1994/95 June Degree Exam Marks Students with Certificate of Sixth Year Studies in Chemistry at Grade D



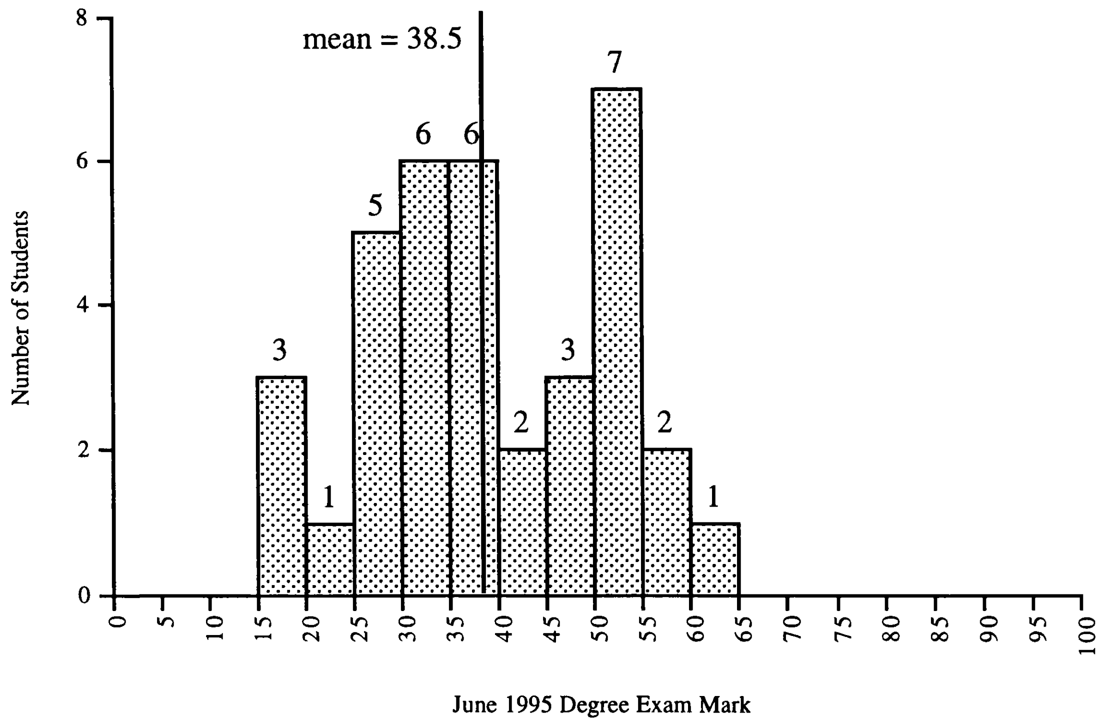
Graph M30 Distribution of Chemistry–1 1994/95 June Degree Exam Marks Students with Higher Grade Chemistry at Grade A



Graph M31 Distribution of Chemistry–1 1994/95 June Degree Exam Marks Students with Higher Grade Chemistry at Grade B



Graph M32 Distribution of Chemistry–1 1994/95 June Degree Exam Marks Students with Higher Grade Chemistry at Grade C

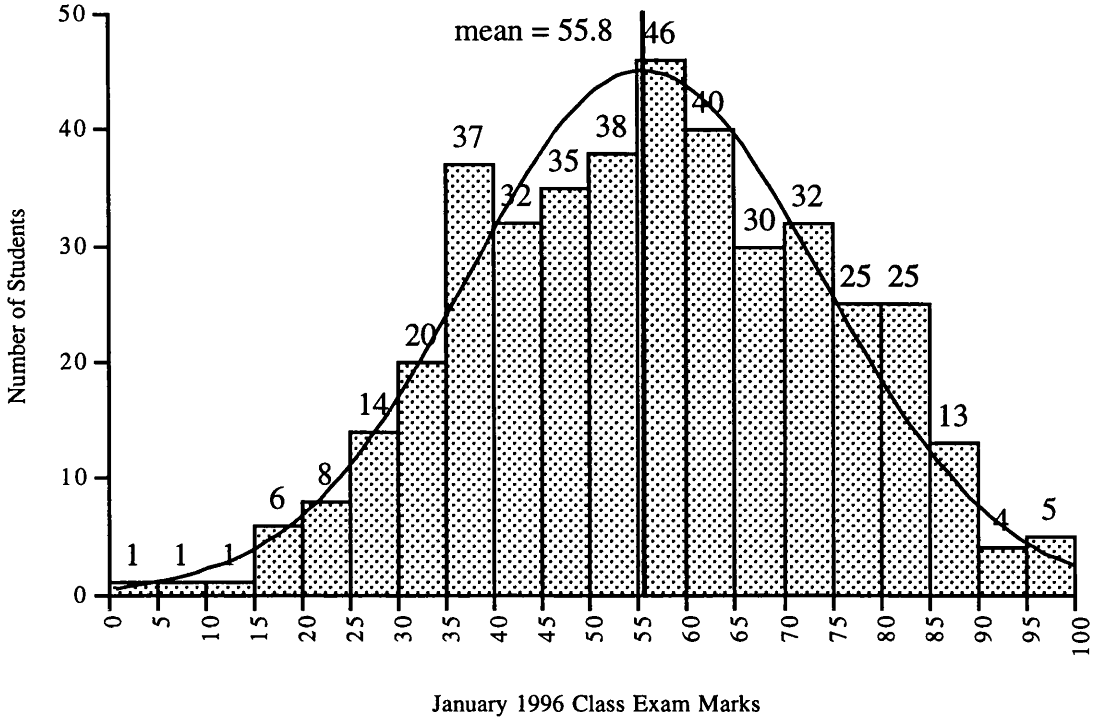


Appendix N

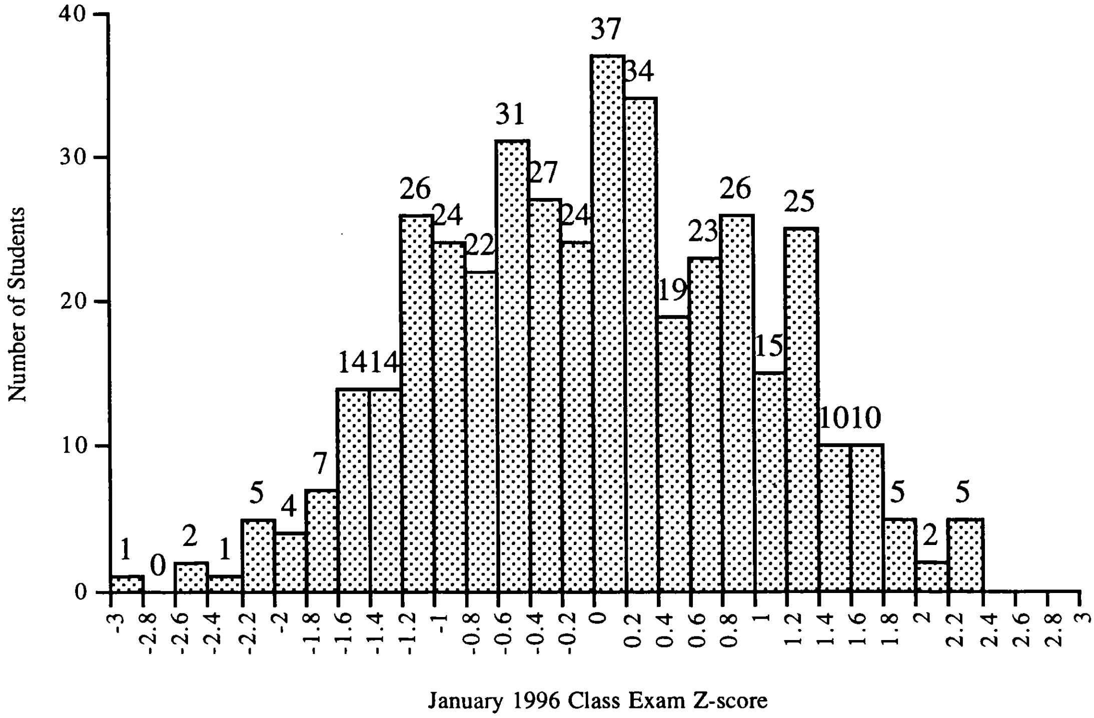
Chemistry-1, 1995-96

January Class Exam Results

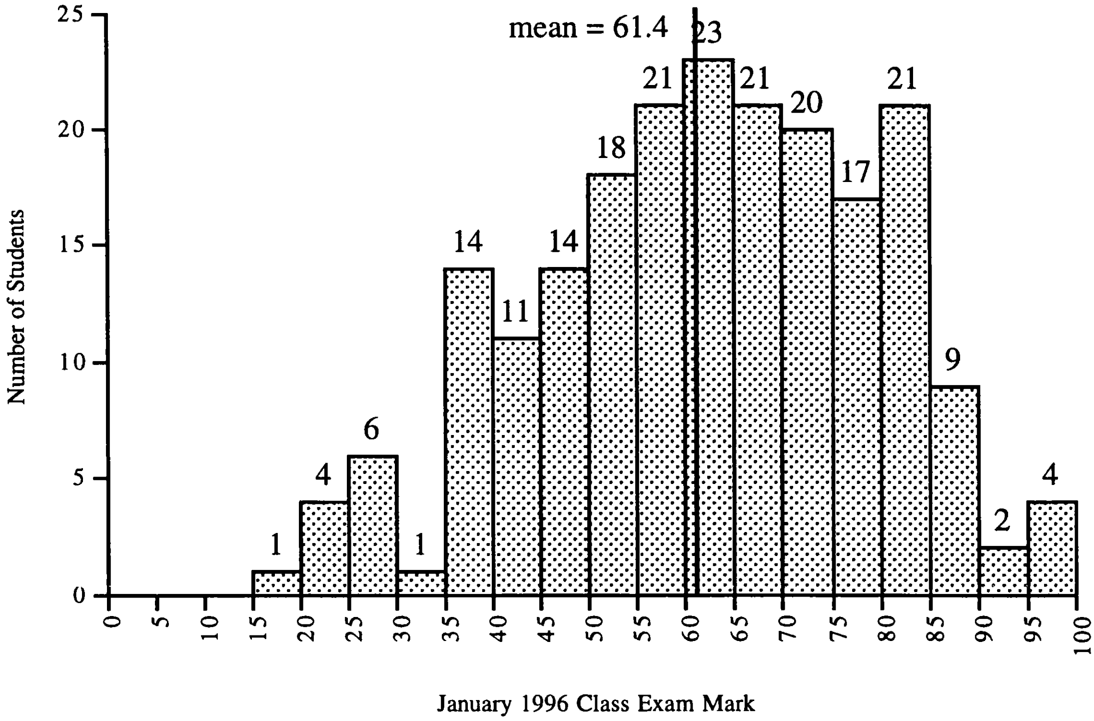
Graph N1 Distribution of Chemistry-1 1995/96 January Class Exam Marks



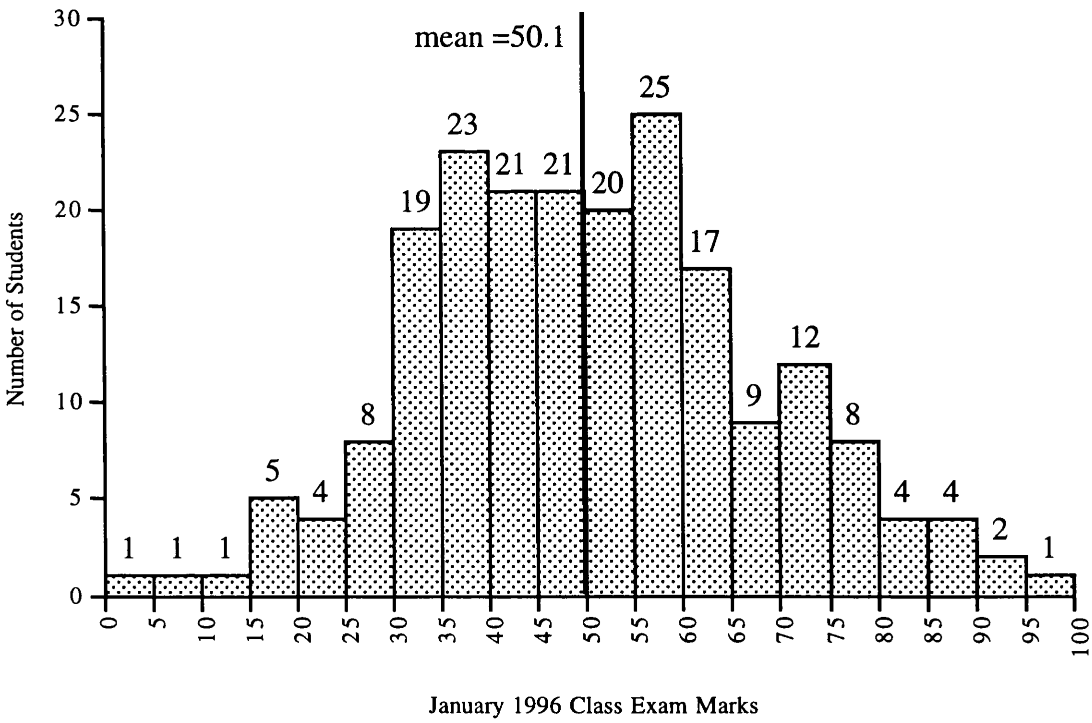
Graph N2 Distribution of Chemistry-1 1995/96 January Class Exam Marks as Z-scores



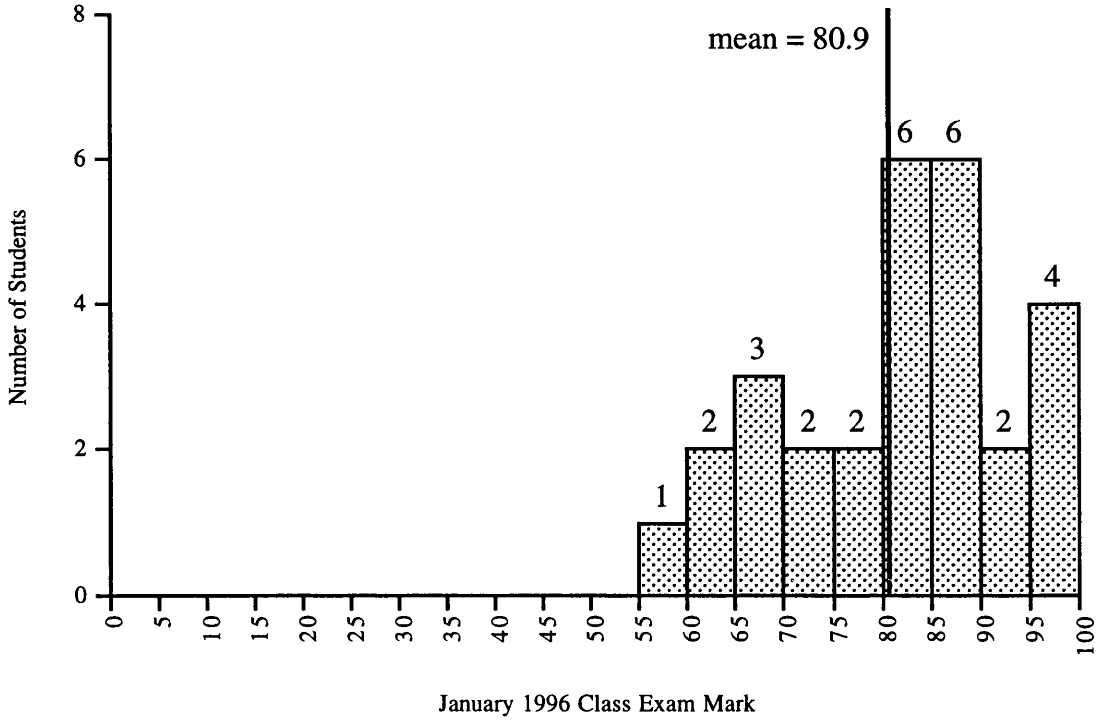
Graph N3 Distribution of Chemistry-1 1995/96 January Class Exam Marks Students with Certificate of Sixth Year Studies Chemistry



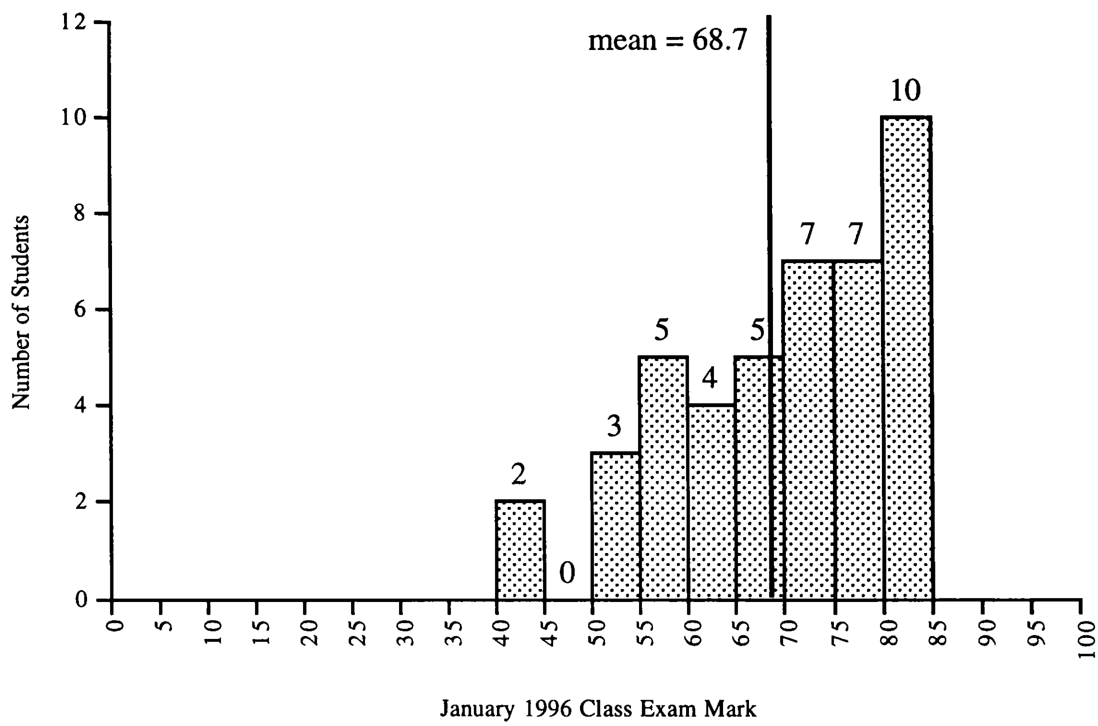
Graph N4 Distribution of Chemistry-1 1995/96 January Class Exam Marks Students with Higher Grade Chemistry



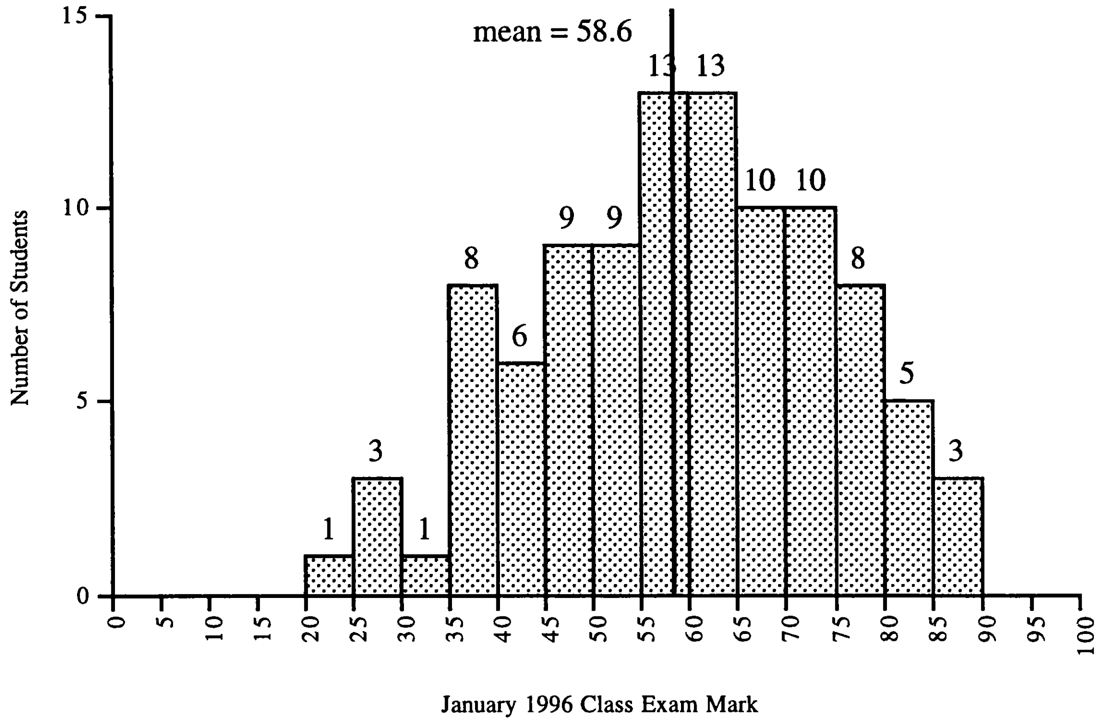
Graph N5 Distribution of Chemistry-1 1995/96 January Class Exam Marks Students with Certificate of Sixth Year Studies Chemistry at Grade A



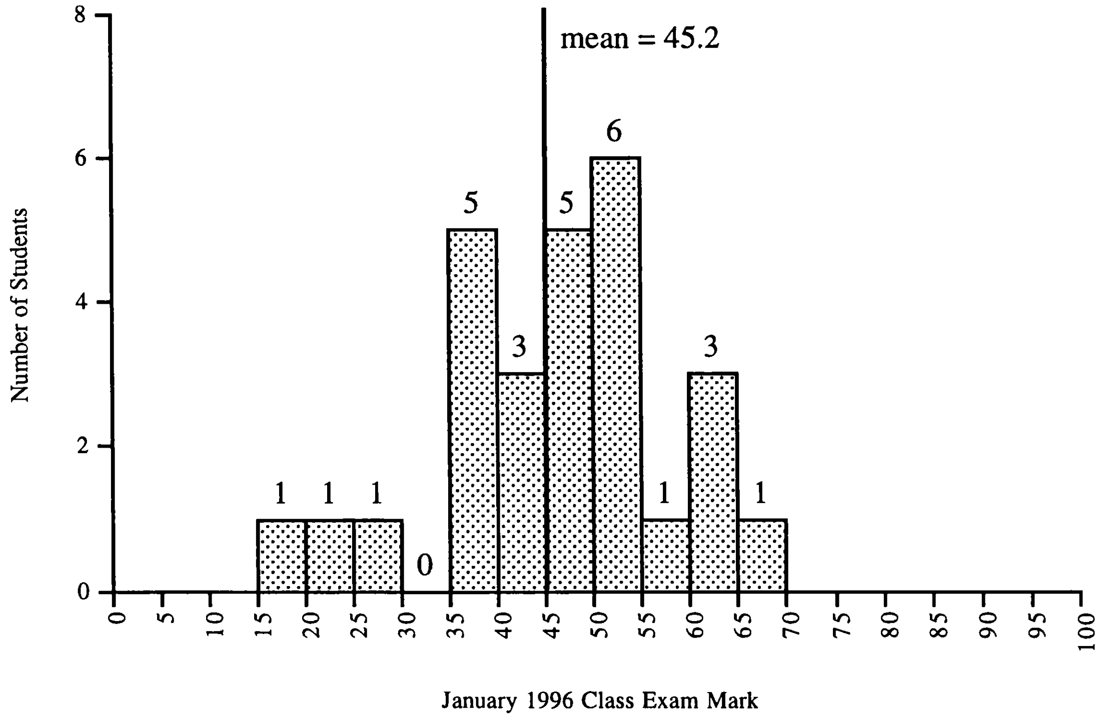
Graph N6 Distribution of Chemistry-1 1995/96 January Class Exam Marks Students with Certificate of Sixth Year Studies Chemistry at Grade B



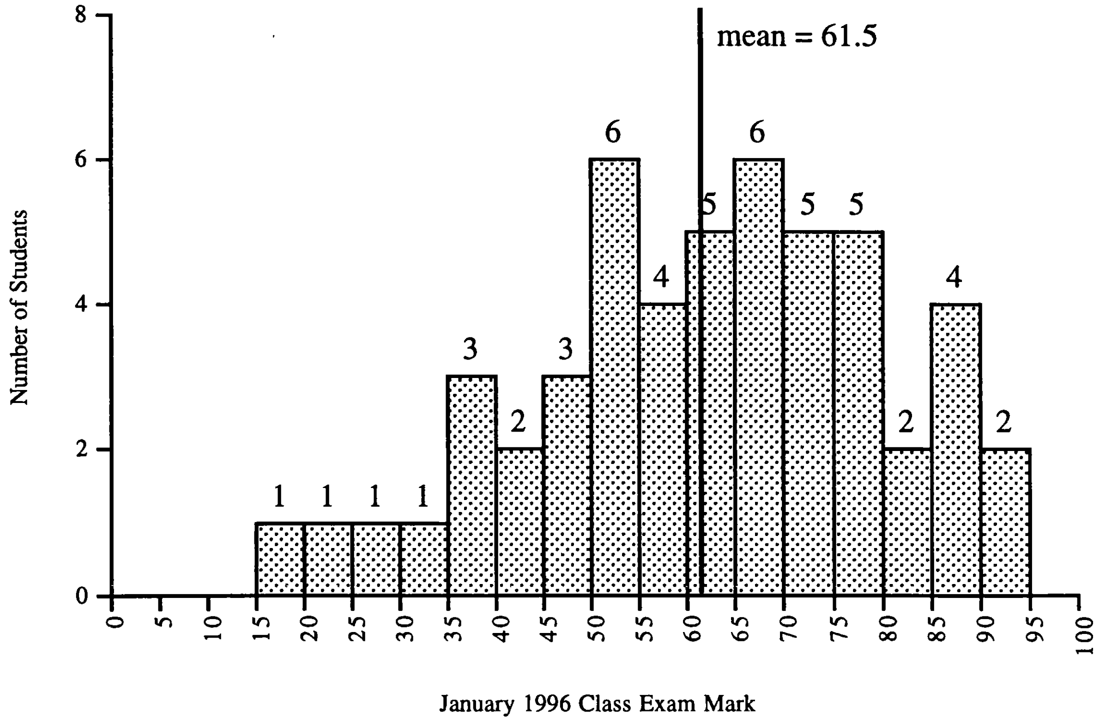
Graph N7 Distribution of Chemistry-1 1995/96 January Class Exam Marks Students with Certificate of Sixth Year Studies Chemistry at Grade C



Graph N8 Distribution of Chemistry-1 1995/96 January Class Exam Marks Students with Certificate of Sixth Year Studies Chemistry at Grade D



Graph N9 Distribution of Chemistry-1 1995/96 January Class Exam Marks Students with Higher Grade Chemistry at Grade A



Graph N10 Distribution of Chemistry-1 1995/96 January Class Exam Marks Students with Higher Grade Chemistry at Grade B