AN EXPERIMENT IN INDIVIDUALIZED INSTRUCTION AS AN APPROACH TO INTRODUCTORY CHEMISTRY

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AN EXPERIMENT IN INDIVIDUALIZED INSTRUCTION AS AN APPROACH TO INTRODUCTORY CHEMISTRY

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ABSTRACT

A comparison was made of the achievement of two groups of students, randomly enrolled in an introductory chemistry course at the Memorial University of Newfoundland. The control group was treated by a normal lecture presentation, while the members of the experimental group progressed at an individual rate in small or large groups as each individual desired. Each member of the experimental group was given a learning guide for each chapter.

Conclusions were drawn from the results of two criterion examinations, one taken after eight weeks and the other after twelve weeks. Analysis was by a series of regression equations, incorporating several covariates.

The effectiveness of individualized instruction cannot be determined from the results of any one experiment, but by an accumulation of evidence from many studies. However, the results of the present study suggested that the experimental treatment produced a marginally significant greater gain in achievement. It is not clear whether this might be claimed for the experimental group as a whole or simply for those without previous chemistry.

An attempt was also made to identify factors which might be used to predict the success of individual students differently in the individualized treatment compared to the

group treatment. General ability, albeit within a restricted range, and mathematical ability did not interact with treatment. It was suggested that there were indications that students with a tendency towards neuroticism were favored by the experimental treatment, although this did not reach statistical significance. The trait extraversion-introversion was found not to interact significantly with treatment.

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INTRODUCTION

A Rationale for Individualized Instruction

As Tyler has indicated, the notion that learning may be an essentially individualized phenomenon may be traced at least as far back as Plato.[1] Yet, while this may serve to remind us that there may be little, perhaps nothing, which is philosophically new under the educational sun, it offers little guide to the practice of individualized instruction today.

The need for education of the individual is perhaps greater now than ever before. In today's fast changing world education must equip each individual with a vastly greater ability to adapt. It must be directed towards maximum release of human potential and self direction. In short it must be a process of 'Becoming'.[2]

The concept of educating the individual has pervaded the writings of many prominent educationists and philosophers

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[1]Fred T. Tyler, Individualizing Instruction, The Sixty-First Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1962), p. 1.

[2]Gordon W. Allport, Becoming: Basic Considerations for a Psychology of Personality (New Haven: Yale University Press, 1967).

from quite different schools of thought. Rousseau based his tutorial method upon a belief in the development of the individual;[3] John Dewey saw the role of the teacher as guide to each individual student within his own social role;[4] Sartre and others pursued the existentialist view that the function of the teacher is to assist each student personally in his journey toward self realization. In his words

> Not only is man what he conceives himself to be, but he is also what he wills himself to be after his thrust toward existence. Man is nothing other than what he makes himself.[5]

Tyler has commented,

> Surely we must admit that pupils are variable--in readiness, in ability to learn, in any human attribute--recognizing, of course, that "the things we, as human beings, do not have in common are as nothing to the things we do have in common."[6]

It seems likely that each of the above was concerned with educating the individual in a different way. It may even be argued that we are concerned with educating each individual, even in a group setting. However, unless the members of the group are identical, which they cannot be, the identity of each individual must inevitably become clouded. It may be

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[3]Robert R. Rusk, "Rousseau", Doctrines of the Great Educators, (3rd Edition, New York: Macmillan, 1965), pp. 157-207.

[4]John Dewey, The Child and the Curriculum, (Chicago: University of Chicago Press, 1902).

[5]Jean P. Sartre, Existentialism, (New York: Philosophical Library, 1947), p. 18.

[6]Tyler, p. 2.

contended, therefore, that the education of the individual is catered for best within a setting designed to that specific end, the deliberate individualization of instruction.

The case is readily extended from the realm of the philosopher to that of the psychologist, and it is clear that the greatest thrust today comes from the latter quarter. Gagné has quoted Dewey

> The case is of Child. It is his present powers which are to assert themselves; his present capacities which are to be exercised; his present attitudes which are to be realized.[7]

and concluded that there was no reason to read into this statement any emphasis other than the intellectual one which seemed to have been intended.[8] Gagné has argued persuasively for individualization. Typical of his comments is,

> The mediation of learning is idiosyncratic . . . . If one is concerned about how to make learning efficient, the focus of emphasis must be the student. The design of efficient conditions for learning demands that learning be conceived as an individual matter . . . the site of learning is not in a group nor is it in a relationship between instructor and student. The site of learning is the individual's central nervous system. For this fundamental and unarguable reason learning is individual. Efficient learning is designed for the individual learner . . . modern studies of learning suggest the clear implication that some idiosyncratic processing of information is done by the learner. This provides

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[7]Dewey, p. 40.

[8]Robert M. Gagné, "Learning Research and Its Implication for Independent Learning," Perspectives in Individualized Instruction, ed. R. A. Weisgerber (Itasca, Illinois: F. E. Peacock Publishers Inc., 1971), p. 26.

> a fundamental process, and strongly suggests that individualized instruction represents the route of efficient learning.[9]

A second psychologist, Carroll, has suggested that because students appear to be normally distributed with respect to aptitude for a particular subject area, then it follows that the only way to break the normalized distribution of attainment scores is to provide differential learning treatments.[10] According to Carroll correlation between aptitude and achievement should then approach zero, and aptitude may be redefined in terms of time taken to attain mastery of a given task. Paradoxically, it may be inferred that individual differences are not eliminated, but manifested differently, even perhaps heightened as Ausubel has found,

> When pupils are allowed to learn at their own rate in sequentially organized subjects, initial individual differences in rate of achievement tend to increase rather than decrease over time.[11]

Hence it could be concluded that for many students the amount of material covered could be less. Despite this, the prospect of greater achievement by allowing individual progress only after mastery of necessary prerequisites is well in accord with Ausubel's theory of subsumption, and with

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[9]Robert M. Gagné, "Learning Theory, Educational Media and Individualized Instruction," Educational Broadcasting Review, 4:49-62, June, 1970.

[10]John B. Carroll, "A Model of School Learning," Teachers College Record, 64:723-733, May, 1963.

[11]D. P. Ausubel, The Psychology of Meaningful Verbal Learning. (New York: Grune and Stratton, 1963), p. 95.

Gagné's stress on a logical hierarchy.

Bloom has articulated Carrol's theory, and described the operation and results of a plan for mastery learning in a university psychology course.[12] A dramatic increase from twenty per cent to eighty per cent obtaining an A grade was observed, as well as a lowering of tension and greater mental health on the part of the students. Bloom attributed these affective results to the greater success obtained by the students. Sullivan has reported similarly favorable results elsewhere.[13] Keller, too, has given a most sensitive account of the philosophy and practicalities of such a treatment, but cautioned

> Such comparisons (i.e. of student attainment) raise many questions of interpretation, and their importance should not be overemphasized. The kind of change needed in education today is not one that will be evaluated in terms of the percentage of A's in grade distribution or of differences at the .01 (or .001) level of confidence. It is one that will produce a reinforcing state of affairs for everyone involved.[14]

The message of his paper is that he clearly believes that individualized study has a vital part to play in this.

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[12]Benjamin S. Bloom, "Learning for Mastery," Handbook on Formative and Summative Evaluation of Student Learning, ed. B. S. Bloom, J. T. Hastings, and G. F. Meadows (New York: McGraw Hill, 1971), pp. 43-57.

[13]Arthur M. Sullivan, "A Structured Individualized Approach to the Teaching of Introductory Psychology," Programmed Learning, 6:4:231-242, October, 1969.

[14]Fred S. Keller, "Goodbye Teacher . . . ." Journal of Applied Behavior Analysis, 1: 79-89, Spring, 1968.

The Keller plan has formed the model for similar studies elsewhere. It involved much freedom for the student, although all students completed the same units of work by the end of the course. The course was divided into small units, which the student could follow by any desired combination of written, visual, audio or lecture presented materials. The student could seek help from an undergraduate proctor, who also administered and scored tests as necessary. These could be repeated if necessary, but mastery of each unit was essential before progress to the next. The course could be completed at any time, after writing the final examination. One author noted that the plan is being used by more than a dozen disciplines in over 150 colleges and universities, but questioned,

> Is there any assurance that we have not merely substituted a narrow but sterile mastery of certain isolated thought techniques and problem-solving tricks for the broader perspective that leads to understanding and to the creative use of the knowledge thus acquired? As valuable as is the return to comprehensive reading of the textbook that this plan assures, is there a textbook or a study unit that can adequately replace the live, experienced teacher in giving meaning and vitality to the material learned? As willing as the undergraduate might be, what kinds of compromises are needed if student tutors are to decide when another has mastered a unit? In what way does this plan develop student talent or allow talented students to develop, other than as student tutors. Is the myth of mastery of the parts an improvement over the myth of comprehending and appreciating the whole?[15]

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[15]W. T. Lippincott, "Instructional Innovation: Questions and Myths," Journal of Chemical Education, 49:721, November, 1972.

The origins of individualized instruction, in the sense in which it is practiced today, may be seen in the Winnetka plan of sixty years ago.[16] Packages of written, largely self-instructional material, were developed in several subject areas, and it was observed that the better students progressed much more quickly while the others were not affected adversely. Today the development of non graded schools under plans such as those of Trump,[17] Goodlad,[18] and Brown,[19] involves extensive individualization within those schools. Yet individualized instruction is still of minor significance in schools in general.

It is even more surprising that the results of one study into the application of independent study at the college level indicated, despite assertions to the contrary, that it is almost unused.[20] The authors also could find little evidence of evaluation of independent study or that it is more effective than other practices. The corollary that

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[16]Carleton W. Washburne, Winnetka, (Englewood Cliffs: Prentice-Hall, 1963).

[17]J. Lloyd Trump and Dorsey Baynham, Guide to Better Schools, (Chicago: Rand McNally, 1966).

[18]John I. Goodlad, The Changing School Curriculum, (New York: Fund for Advancement of Science, 1966).

[19]B. Frank Brown, The Non Graded High School, (Englewood Cliffs, New Jersey: Prentice Hall, 1963).

[20]M. M. Thompson and P. L. Dressel, "A Survey of Independent Study Practices," Educational Record, 51:392-395, Fall, 1970.

independent study may be no less effective, is not sufficient to induce most teachers or institutions to adopt a practice which even its proponents recognize as difficult and time consuming, at least in its early stages.

Gagné, has commented

> Not only are there no results of experimental tests, there is not even any experience from which tentative conclusions can be drawn.[21]

To some extent this statement may be questioned. Certainly enough studies have accrued in recent years, so that tentative conclusions at least might be extracted. However, there is very little hard data upon which to base firm conclusions. Often evaluation is ex-post-facto when it need not have been; often it is soft when it could have been hard; and sometimes it is based upon unsound statistical practices. Gagné's comment could certainly be questioned by reference to the quite extensive research associated with programmed learning. However, such studies may lack transference. Keller has explained this most succintly

> The similarity of our learning paradigm to that provided in the field of programmed instruction is obvious. There is the same stress upon analysis of the task, the same concern with terminal performance, the same opportunity for individualized progression, and so on. But the sphere of action here is different. The principal steps of advance are not "frames" in a "set", but are more like the conventional home-work assignment or laboratory exercise.

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[21]Gagné,"Learning Research and Its Implications for Individualized Instruction," Perspectives in Individualized Instruction, p. 26.

> The 'response' is not simply the completion of a prepared statement through the insertion of a word or phrase. Rather, it may be thought of as the resultant of many such responses, better described as the understanding of a principle, a formula, or a concept, or the ability to use an experimental technique. Advance within the program depends on something more than the appearance of a confirming word or the presentation of a new frame; it involves a personal interaction between a student and his peers, or his betters, in what may be a lively verbal interchange, of interest and importance to each participant. The use of a programmed text, a teaching machine, or some sort of computer aid within such a course is entirely possible and may be quite desirable, but it is not to be equated with the course itself.[22]

It is clear that a well founded theoretical framework upon which to build the practice of individualized instruction does not exist. The focus of this problem may lie in a necessarily broad definition. Typically it is a plan which takes account of the vast differences in abilities, interests, backgrounds, and needs of any group of students. It is a plan which involves the teacher as a resource person, not a lecturer. Most of all it is a plan which allows each student to progress at his own rate using whatever learning materials are most appropriate, both to himself and the subject matter. It implies a substantial independent study component, although the two are not synonymous. The student may work individually or in small groups or occasionally in larger groups as he desires.

Consideration of the composition of introductory chemistry classes at Memorial University led to the suggestion

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[22]Keller, p. 23.

that such a plan for learning might be advantageous, and at the same time increase existing knowledge of the practice of individualized instruction.

The Problem

Students enrol initially in one of three introductory one semester chemistry courses:-

1. Students with a grade eleven average of less than eighty per cent, and either without grade eleven chemistry or with a mark of less than seventy per cent in it, enrol in the Foundation course (100 F).
2. Students with a grade eleven chemistry mark of more than seventy per cent, or with a grade eleven average in excess of eighty per cent regardless of previous chemistry, enrol in Chemistry 1000. Most of these students, and those taking Foundation, are first year students.
3. Students beyond first year, regardless of previous chemistry or average, normally enrol in Chemistry 1200. Some of these are likely to be repeating the course.

Clearly a class grouped in any of the above ways is likely to be quite heterogeneous in terms of ability and academic background. Additionally each class is likely to contain potential specialists in chemistry or other sciences, engineers, doctors, nurses, teachers, as well as others for whom chemistry is simply an elective. It is suggested that this heterogeneity of background, ability, and interest is too extreme to allow for an efficient interaction between instructor and students, and that learning, both cognitive and affective, may be severely impaired.

The present study was conceived in an attempt to provide a treatment which would allow the course to be individually paced by each student, to the benefit of all. Little attempt was made to provide alternative learning paths, although this might become the focus of attention in a subsequent study. The main gain was expected to be cognitive, although it was anticipated that greater success for the weaker students might itself promote affective gain.

It seems likely that the structure of a discipline, as well as the intellectual and psychological development of the students concerned, will be of major importance in the extraction of useful theoretical and empirical data. Hence, in the literature review which follows, specific reference will be made mainly to studies involving science education at the high school and early university levels. This is in accord with the present study which, although set in a university, is concerned with a course which is normally carried out at senior high school level.

CHAPTER II

RELATED LITERATURE

Individualized Instruction in Science

Introduction

The need for individualization in science has been discussed recently by two authors. McBurney commented that although the principle of individualization is widely accepted, its practice in the science area is limited.[1] The latter half of this statement at least, is irrefutable. McBurney correctly noted that most attempts at individualization involve the use of costly audio-tutorial and complex programmed instructional systems, and implied that this together with administrative difficulties may be the main inhibiting factor in the adoption of an individualized approach by science teachers. He suggested that such teachers could at least incorporate one important aspect of individualization, the use of independent student investigations, into their teaching. Lunetta and Dyrli raised the issue that much more is required of curriculum developers and psychologists in the development of effective approaches and

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[1]Wendell F. McBurney, "Individualized Instruction: A Case for the Independent Student Investigation in Science," School Science and Mathematics, 69:827-830, December, 1969.

materials. Classroom teachers suffer from a severe time limitation, and are generally probably ill-prepared to develop the necessary programs. Furthermore, continuity is lost and the program breaks down when those teachers who may have sufficient time, energy, knowledge, and support, leave.[2] Hence the scarcity of studies upon which to base conclusions and recommendations is not surprising. The review which follows therefore includes reference to studies not only in chemistry, but other sciences as well, in an attempt to apply the results of a greater volume of related evidence. It is recognized that there may be essential differences between chemistry and other sciences which render some comparisons difficult. However, it is believed that the usefulness of these comparisons outweighs any disadvantages. Each study will be examined against its own objectives, with particular regard to the quality of the study, the statistical methods applied, and the conclusions reached.

Studies in Biology

The greatest contribution to individualization of instruction in biology, and perhaps in any subject area, has been made by S. N. Postlethwaite at Purdue University.[3] An

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[2] V. N. Lunetta and O. E. Dyrli, "Individualized Instruction in the Science Curriculum," School Science and Mathematics, 71:121-128, February, 1971.

[3] S. N. Postlethwaite, J. Novak, and H. T. Murray Jr., The Audio-Tutorial Approach to Learning, (2nd ed., Minneapolis: Burgess Publishing Company, 1969).

audio-tutorial system of instruction for an introductory biology course was devised, and is still developing ten years later. Although Postlethwaite and his associates have recently experimented with 'mini-pacs', the procedure followed for most of the time has been to divide the student activities for each week into three kinds of session. Each week, at any time he chooses, the student attends a learning centre--a room containing booths equipped with tape players and assorted projectors, and also visual displays, simple demonstrations and experiments for the students to do. An instructor is on hand at all times. Directions for the week's work are presented by audio tape, which also includes appropriate background music.

> The student begins his study by picking up a mimeographed list of the behavioral objectives for the week's work. . . . When he activates the tape player the voice of the senior professor tutors the student through a great variety of learning activities. These activities may include the doing of an experiment, the collecting of data from the demonstration materials, reading short requirements from his text or appropriate journal articles, making observations through the microscope, filling in diagrams, charts, or appropriate blanks in his study guide or laboratory manual, viewing sections of films, and other kinds of learning activity suitable to the topic under consideration.[4]

The student may work independently or with other students, or may seek the help of the instructor. Toward the end of the week a general assembly session is held to cover activities

[4]Postlethwaite, p. 10.

best dealt with in a large group, such as lecturing and showing longer films. The final session of the week involves the student in a small group integrated quiz session in which he is quizzed orally and in writing, the questions applying very specifically to the objectives for the week. Other student activities include a small research project and a second larger project which the student must complete for an A grade. The system is clearly self paced only within the weekly independent study session. All students proceed at the same general pace and complete the course at the same time. The method is claimed to be much more successful in terms of student achievement than the course was previously, and in general students have been favorably impressed.

Only one of the biology studies might be said to involve complete individualization. The school concerned is situated near Purdue University and, although their program is very similar to that of Postlethwaite, it will be described as an illustration of what can be done in a school setting. Team teaching was carried out by three teachers operating in a suite of four rooms . . . two laboratories, a reading room and a thirty-six carrel tape room. The course was self paced and personalized, with no ability grouping. Students could choose to learn from audio tapes, written materials, or from another student, the latter getting partial credit towards an A or B grade. Attainment of a C grade was based entirely on a mastery criterion, the student being tested when he decided he was ready. The decision to aim for an A or B grade, and what he should do to attain it, depended mainly on the student. He could write a higher level examination or pursue a wide range of activities of cognitive or affective bias. A student who did not reach a C grade was given an incomplete, and required to repeat in a future year only those parts of the course on which he had failed to achieve criterion. At the end of the year the authors were intuitively very satisfied, although little formal analysis was done.[5] Unfortunately the lack of evaluative data precludes not only an objective overall evaluation but also an identification of areas of particular strength and weakness.

In two studies learners methods as well as objectives were institutionally selected. The account of one of these studies is somewhat trivial in its import. Set in a community college it described the need for a pleasantly appointed working area, and reported that the students were very enthusiastic. Tapes were used for introduction, direction, explanation, and summarization, but not for lectures, although attendance at lectures was optional.[6] No results

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[5]C. Smiley, K. Bush, and D. McGaw, "An AT Program in High School," The American Biology Teacher, 34:84-89, February, 1972.

[6]W. Ballou and T. Filteau, "Anyone Can Start an AT Biology Program," The American Biology Teacher, 33:480-483, November, 1971.

were reported. The title 'Anyone Can Start an AT Biology Program' is therefore misleading, the real question being whether anyone can run a successful program. The second study is of more significance. Richard and Sund described an attempt to compare a continuous progress approach in senior high school with a course built from individualized units plus enrichment materials. Thus both were self paced, the former for the course as a whole and the latter within each unit. Variability of enrichment materials enabled greater individualization in the latter approach. Neither approach yielded any significant difference in attainment on a BSCS examination, either between one another or with the BSCS national norms. Student response was moderately enthusiastic, but they felt they had to work harder than in other classes, and were generally not keen to see the approach adopted for their other subjects. The teachers decided to continue with the unit plus enrichment plan, and to drop the continuous progress approach. Their main reason for this decision was the difficulty of providing a continuous supply of live organisms, and maintaining an extensive supply of materials and equipment. At the same time they rejected their grouping of students into three levels of ability, partly because some of the slow students actually achieved higher on the standardized BSCS unit test than did some of those in the fast group.[7] This reasoning is difficult to follow. While it may be disappointing that the better students performed less well than expected, the relative improvement in the performance of the weaker students could lead one to hypothesize that the continuous progress plan was advantageous for them, especially as it appears that these 'weaker' students must have achieved at least to BSCS average. Truly a source of encouragement, not discouragement?

Most of the biology studies involved students in selecting their own methods of learning and most of these were quite well constructed methodologically, and were generally not solely or even predominantly concerned with cognitive gain. Fulton used the BSCS Blue Version, in Senior High School to compare group instruction with a self paced individualized approach. In the latter approach students progressed through verbal contracts agreed upon by student and teacher. Those who finished early were provided with additional excursion activities, these also being available to students in the group instructed class. Students were randomly selected for both groups, and performance on a number of tests was compared using a pre-test as covariate for the post-test. In all cases the results favoured the individualized group, some very significantly. A significant

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[7]P. Richard and R. B. Sund, "Individualized Instruction in Biology," The American Biology Teacher, 31:252-256, April, 1969.

difference was observed on the BSCS Comprehensive Final Examination, Facts About Science Test, Watson and Glaser Critical Thinking Appraisal, and Prouse Subject Preference Survey, with a particularly significant difference on the Test on Understanding Science. The individualized group not only rated their subject highly, but also rated the ability of the teacher to make the material understandable significantly more highly than did the control group. Fulton emphasized particularly the affective gain of his students, and the results certainly suggest a relationship between cognitive achievement and affective gain without, of course, delineating cause and effect.[8,9] The results of the study are so striking that they must serve as weighty evidence for the success of a self paced approach. Two questions may be placed against these results. The control group was treated in one year and the experimental group in the following year. It could be hypothesized that the results may be attributed to a gain in the teacher's understanding of the course, but the differences are so striking that such confounding seems

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[8]Harry F. Fulton, "A Comparative Study of Student Attitudes Toward Science and the Ability of the Teacher to Make Material Understandable in Individualized and Group Approach to BSCS Biology," School Science and Mathematics, 71: 198-202, March, 1971.

[9]Fulton, "Individualized versus Group Teaching of BSCS Biology," The American Biology Teacher, 33: 277-279, 291, May, 1971.

unlikely. Secondly, as in most such studies, there is the possibility that a particularly strong reactive effect may have caused confounding.

The success of the audio-tutorial approach to biology as developed by Postlethwaite has enabled researchers to use it to consider the next higher step in the developmental process. That is, rather than being concerned only with the success of the approach, he may investigate factors which enhance learning for particular groups of students, and he may also investigate the relative effectiveness of different teaching and learning strategies within the field of individualized instruction. Several such studies which relate to the first of these two factors will be considered later, specifically in connection with the effect of personality. One which relates to teaching strategy will be described here.

Hoffman and Druger used a Flander's type interaction analysis model, modified substantially to relate to individualized instruction, to investigate the relative effectiveness of direct (note taking) and non direct (question and answer) instruction. The vehicle was an audio-tutorial university introductory biology course. There was no confounding due to teacher interaction, as personal contact was made only for testing and general information. The study lasted six weeks, students signing up for as many two hour blocks of time as they felt they required at the beginning of each week. Students were selected randomly, and divided into an experimental and control group. All students were pre-tested on each of the final test instruments, and showed no significant differences on 't' tests. Final analysis was also based on a series of 't' tests.[10] A better method of analysis might have been to use the pre-test scores as covariates in an analysis of covariance on post-test scores, thus compensating for initial differences. If the statistical method used did introduce errors, they would be type II, for no significant difference was found between the two groups with regard to the learning or retention of facts, concepts, principles, the development of critical thinking abilities, or attitude to biology. There was a significant difference between the two strategies with regard to problem solving abilities, the indirect group performing better. However it might be questioned whether they had merely had more practice of solving the right kind of problems, by virtue of the method employed.

Finally, the results of one biology study tend to deny that independent study is advantageous. Programmed instruction, audio-tutorial instruction, and self pacing were ignored in order to concentrate on independent study as a means of maximizing the student's own learning. The

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[10]F. E. Hoffman and M. Druger, "Relative Effectiveness of Two Methods of Audio-Tutorial Instruction in Biology," Journal of Research in Science Teaching, 8:2: 149-156, 1971.

study was limited to high ability students enrolled in a ninth grade biology class, their mean grade-equivalent score on a science test being 12.3. Using a BSCS pre-test as covariate, no significant difference was observed between a conventional teacher directed class and a class which began about nine weeks of teacher directed study followed by independent study. However, both groups performed significantly better than a group which was allowed to proceed entirely by independent study, although the authors correctly noted that using the BSCS examination as criterion was probably inappropriate to the skills developed by the independent study group.[11] Thus the latter may have made more significant gains in areas not tested.

Studies in Physics

Interest in individualization of instruction appears to have been less widespread in physics than in chemistry or biology. The reason for this is not clear as it seems likely that the method might be potentially more advantageous in physics. While in biology there is the problem of providing continuous supply of live specimens, and in chemistry some experiments may be dangerous for the student to do in isolation, these problems do not exist in elementary physics

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[11]John B. Simmons and others, "Independent Study Methods and the Gifted Biology Student," The American Biology Teacher, 33: 416-418, October, 1971.

courses. Hence it may be suggested that the experimental part of the course at least is potentially easily individualized. Further, as one physics instructor has commented, the result of 'lock-step-learning' can prove disastrous in a subject like physics which has a pyramidal structure.[12] The lack of interest, therefore, is surprising. No studies have been located which involve 'hard' data, and the comments made will therefore be based on the subjective opinions of the teachers concerned. While this is unsatisfactory, it may be argued that if a teacher is satisfied enough to continue with a course that is likely to be difficult and time consuming for him to operate, then it is likely to be of some merit (albeit perhaps limited). The comments which follow should be seen in that light.

D'Amario and Rodano applied an audio-tutorial approach to the laboratory part of a junior college physics course. They also used video-taped sequences to demonstrate difficult experiments and to help with problem areas. They noted that students generally favored the method, and also commented on the vast expenditure of time needed on the part of the instructor to produce good materials.[13]

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[12]Carl Naegele, "A New Approach to Physics Instruction," The Physics Teacher, 7:45-47, January, 1969.

[13]J. J. D'Amario and S. J. Rodano, "Recorded Instruction for Physical Science," The Physics Teacher, 9:94-96, February, 1971.

Naegele has described the adoption of PSSC physics, with an extensive use of audio-tutorial methods. A branched activity guide provided for individual differences in ability, purpose, and interest. Two quite innovative features were (i) a requirement that the students should make a quick preview of each chapter and then be tested on it, which would seem to be in accordance with Ausubel's advance organizer technique, and (ii) students were asked to provide a problem card at the end of each chapter, with a novel problem on one side and the answer on the other.[14] Another attempt to individualize the PSSC course appears to have been born out of the teacher's dissatisfaction at being the middle man between the Committee and the students. Students were free to select the level of difficulty at which they worked and to choose to work alone or in small or large groups. Within limits they were also free to choose when to be tested, and the rate at which they progressed.[15] The latter really appears, though, to have been governed by a suggested schedule as all students were required to complete the course in the year. While this may have been realistic enough in the university school concerned, with selected gifted students and small classes, it does not seem realistic to expect

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[14]Naegele.

[15]J. W. Ashenfelter, "A Partially Learner-Paced Approach to Teaching PSSC Physics," The Physics Teacher, 7:93-98, January, 1969.

slower students in a normal school to complete the course in one year. Hence one problem noted by the teacher concerned, that the films and laboratory discussions were generally held at the right time only for students moving at an average pace, would be exacerbated in a normal school setting. Seventy five percent of the students favored the method, but no other evaluation was made. Moreover, any results of this study would not be generalizable.

A third high school study appears to have been better structured. It was based on the Harvard Project Physics course, which itself was partly designed to cater for individual interest by means of its optional readers. Students were provided with specific behavioral objectives, basic and advanced required assignments, tests to measure achievement of the objectives, lists of school resources related to each chapter, and a timetable providing deadlines for minimum satisfactory progress. Only occasionally was a teacher presentation made, and students generally worked as they wished. The grading system was arranged so that a good student was challenged to complete the whole course at a consistently high level while the poorer student could complete much less at a moderate level and still obtain a passing grade. Despite its many advantages the system proved to be progressively more unwieldy. Furthermore, parents and students expressed concern at the lack of teacher discourse and direction. Hence, the existing situation involves a compromise to a teacher controlled pace, and consisting of a teacher presentation at the beginning of each topic, followed by independent progress through the material, a teacher controlled problem session, and a test.[16] Again, no formal evaluation was made of the effectiveness of the approach.

The remaining two physics studies to be discussed both involve university courses. Green described an introductory physics course based very heavily on the philosophy and practice advocated by Keller. Thus the emphasis was on self pacing, mastery as a criterion for advancement, use of lectures only occasionally and optionally and then for motivation instead of transmission, written performance, and the use of undergraduate tutors within a test-grading context. Green noted that the grades being obtained as the course was developed were no different to those obtained by regular classes, but he expected them to improve with experience. He found, as did Keller in his psychology course, that the student proctors were much valued.[17] An interesting comment involved the student who goes much too slowly or who isn't able to work hard on the course,

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[16]John G. Payne, "Physics Just for Fun - An Individualized Course Using Harvard Project Physics," <u>The Physics Teacher</u>, 10:138-140, March, 1972.

[17]Ben A. Green Jr., "A Self Paced Course in Freshman Physics" (occasional paper number two, Educational Research Centre, Massachusetts Institute of Technology, 1969).

> He is so accustomed to working under the whip that his initiative is low. He needs the whip to keep him going, and he will complain if it is missing. We have a few like him now. It may be that because of him, there will always have to be highly disciplined, forced-pace courses made available if he is ever to graduate. But I question the wisdom of this course. For when this fellow graduates who will drive him then? Perhaps the best treatment for such a student is still the self paced course . . . So maybe the MIT freshman who can't get started should be allowed to stay put until he realizes that no one is going to push him - ever, and that he consequently won't get anywhere until he starts his own motor.[18]

Finally, a continuous progress course in atomic and nuclear physics has been described by Anderson. Students were provided with a learning guide indicating problems, additional problems, film loops, 16 mm film, and a laboratory exercise for each unit. Audio tapes were prepared on each problem exercise so that the student could consider the answers to the problems when he needed, and for however long he needed. Examinations were taken upon request and were generated from a computer bank. No final examination was taken, and each examination after the first contained not only material from the current unit but also a contribution from each previous unit, carefully weighted so that almost all units contributed equally to the final score. A criterion of seventy percent had to be achieved both on new material and old before progress was allowed to the next unit. After successful completion of four of the seven units the

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[18] Green, p. 4.

student could opt to take a pass on the course, or could continue for a higher grade.[19] It is not clear whether the course was prerequisite to others, and if so how the student would successfully cope with the content of a dependent future course.

Studies in Chemistry

The chemistry studies are perhaps the most varied in aims and methods. Again, some are almost trivial while others add substantially to the evidence for individualization.

In the opinion of this author it seems unlikely that relatively small adjustments in teaching style can lead to significant differences in attaiment. Hence it is not surprising that two such studies, which incidentally were both well controlled statistically, indicated no difference in attainment. The first of these applied the use of audio-tapes at three levels of difficulty for problem solving, the control group being presented with the same activities by class presentation.[20] The second involved the incorporation of an independent study session once a week and an independent

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[19]Owen T. Anderson, "Design of a Continuous Progress Course in Atomic and Nuclear Physics Including Laboratory" (paper read at a session of The American Association of Physics Teachers, February, 1969).

[20]C. J. Anderson, "The Development and Evaluation of Programmed Learning for High School Chemistry" (unpublished Doctor's dissertation, Arizona State University, 1971).

small group discussion once in two weeks for the experimental group.[21] The author concluded, weakly perhaps, that the results indicated that independent study might be useful because it did not worsen attainment at least.

While the provision of individualized instruction normally develops because of the teacher's personal dissatisfaction with large group methods, Gillespie and Humphreys at McMaster University appear to have moved in this direction incidentally, in their first year general chemistry course. In an attempt to help those students who missed classes or who did not assimilate some of the lecture material, each lecture was videotaped directly during class presentation, and was made available in a learning resource centre, also equipped with other audio-visual materials and staffed continuously by graduate student instructors. Some of the required content was approached solely by audio-tutorial presentation in the resource centre, in accordance with the premise that the formal lecture should not be expected to cover every detail the students are required to know.[22] This has developed to a trial group taught some concepts entirely by individualized

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[21]J. Davison, "A Comparison of Two Methods of Teaching High School Chemistry to Academically Able Sophomore Students" (unpublished Doctor's dissertation, Northwestern University, 1969).

[22]R. J. Gillespie and D. A. Humphreys, "The Application of a Learning System in Teaching Undergraduate Chemistry," Pure and Applied Chemistry, 22:2:111-115, 1970.

audio-tutorial materials, broken into short units with brief diagnostic tests.

Response was enthusiatic, but it was noted that the discussion facilities and informal contacts with the instructors were used as much as any of the self teaching programs.[23] This comment is interesting in view of the fact that it had previously been noted that the availability of a faculty member in his own office drew little response. Accordingly a discussion centre was established in the learning centre.

A major problem in the application of self pacing by the student is that the student, being human, generally tends to lag behind the pace of a teacher controlled class presentation. One answer to this is the application of the contract system, in which the student contracts with the teacher for a specific grade upon completion of a given unit of work at an agreed standard in an agreed time. Gilbert has described the application of this approach in a community college freshman chemistry course. The course is divided into modules. After attempting the first module the student is asked to contract for a grade of A, B, or C on the course. The contract can be revised at any time, upward and downward, the rate at which he achieves the contract being determined by the individual

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[23]D. A. Humphreys, "Individualized Audio-Visual Tutorial Methods in Undergraduate Education," Journal of Chemical Education, 48:277-278, April, 1971.

student. Gilbert noted that contracts were generally revised upward, with opportunity being provided for the student to raise grades for tests previously taken. Only the contracted grade was awarded, those not completing the course being required to complete it at the beginning of the next semester.[24] Thus, in accordance with Gilbert's belief that sequential lectures have minimal value when students are in varying stages of development, the student was not pressured to work at a level above his capabilities, or above his optimum rate. Nevertheless, because he had to justify his choice of contract to the teacher, the essential corollary existed that he would not work below his own optimum rate and level. The need for contracts or deadlines is corroborated by Krockover.[25] Noting that his students found the greatest source of pressure in an individualized class to be themselves, he commented,

> Students stated that they worked harder in an individualized chemistry class, but could have worked even harder since the course was easier to put off since it was individualized. Almost all students (95%) stated they could have gone further in the course.[26]

The course was based upon the CBA materials, and the author

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[24]Donald J. Gilbert, "An Ancient View on Teaching (chemistry) Revived," Journal of Chemical Education, 49:56-57, January, 1972.

[25]Gerald H. Krockover, "Individualizing Secondary School Chemistry Instruction," School Science and Mathematics 71:518-524, June, 1971.

[26]Krockover, p. 521.

suggested these to be particularly appropriate for individualization, citing particularly that the CBA laboratory investigations are meant to be designed and performed individually, that the textbook problems are graded as to level of difficulty, and that the course attempts to develop each student's critical thinking ability. A series of 't' tests showed the experimental and control groups to be equivalent on a number of intellective and biographic variables. Using an analysis of covariance design with a series of standardized measures to evaluate student outcomes, the author concluded that there was no significant difference between the groups with regard to understanding of science, understanding of chemistry, critical thinking ability, or preference for science, although they did rate their teacher significantly more highly. In this regard however it should be noted that the experimental group was treated in the second year of a two year sequence, and it could be argued that the teacher himself may have been more familiar with the CBA materials.

That individualized instruction can be implemented by the individual teacher in a typical school situation with little or no financial help, in ill-equipped conditions, is illustrated by two recent papers. Bibeau described the application of programmed materials as the vehicle for self pacing. Upon completion of each unit the student tested himself and marked and corrected his own answers from a master sheet, recorded his progress, and if appropriate asked for the next unit. The teacher checked the student's estimate of his own progress over longer time intervals, discussing any discrepencies between his estimate and the student's estimate of the quality of his work.[27] The second paper, by McKerlie, describes a more ambitious project with heavier media presentation. A small individual learning centre, with seating for twelve, was created by blocking off a corridor. The centre contained audio-cassettes and film strip previewers, the materials all being prepared by the individual teacher. Each student received a learning guide with the basic format including introduction, behavioral objectives, reference materials, time allotment, and a list of activities, all geared to the Chem Study materials. While it was up to the student to decide what, when, and how much he must do to complete each unit, overall deadlines were set to enable students to conform to externally imposed grading criteria.[28] Both Bibeau and McKerlie were clearly elated with their success, and both noted that most of their students liked the method. Neither carried out any formal

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[27]Robert W. Bibeau, "Programmed High School Chemistry --It's Working," Journal of Chemical Education, 47: 822-823, December, 1970.

[28]D. F. McKerlie, "An Audio-Tutorial Approach to Individualized Learning in High School Science" (paper presented at the Chemical Institute of Canada High School Chemistry Teachers Symposium, Halifax, Nova Scotia, June, 1971).

evaluation, with McKerlie appearing to decry the need for it, saying,

> Since both students and teachers are happy, a more formal quantitative evaluation has little meaning at this time.[29]

He may well be right in this opinion. Not only is happiness itself a laudible aim of education, but too early an evaluation of individualized study (as well as other areas of interest to educationists) may produce conclusions most notable for their tenuity. It is difficult to believe that methodological studies lasting only a few weeks can yield meaningful conclusions, although it is not clear what constitutes a realistic length of time in this respect. In this context it may be noted that teacher and students require time to adjust to a new method, and McKerlie's estimate that his students took three weeks to adjust may be too conservative and too general. A variation in such time both for individual students and for different studies may well be a confounding factor altogether ignored in such studies.

One study in which experimental design was heavily emphasized has been described by Altieri and Becht. Practical details resemble other studies already described. There is an emphasis on self pacing with recognition of the need for some pressure on the students, and hence the use of a contract system. The material, apparently mostly written, is divided

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[29]McKerlie, p. 3.

into basic units, followed by a number of alternative units, with no set textbook but with the Chem Study course as a basis. Although there is apparently great flexibility, examination of the materials themselves tends to belie this. In keeping with Chem Study philosophy, the course is heavily laboratory based. Interestingly, the students are provided with guide questions rather than behavioral objectives. Another innovation is the notion that not only need the students not take the same test questions, but that, in keeping with the concept of individualization, they should be allowed to select as many questions as they wish. To facilitate this an item bank of questions, coded according to Bloom's taxonomy, was developed, and stored for random retrieval from key sort cards.[30]

The difficulty of obtaining good experimental control in methodological studies may be illustrated by reference to this study. Noting that the results of most studies cannot technically be extended beyond the individual school concerned, the authors planned to extend the area of generalization by using a number of schools from a statewide population. However this removed the possibility of random selection of students, and hence necessitated the use

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[30]D. P. Altieri and P. A. Becht, "Individualized Chemistry for High School Students" (paper presented at 44th Annual Meeting of The National Association for Research in Science Teaching, March, 1971).

of a quasi-experimental non-equivalent pre-test post-test design. The use of ACS-NSTA examinations as a pre-test is then questionable in view of the different individuals and schools involved, especially if some students have no previous chemistry. The problems of control may be further illustrated by two quotations from the same page of their paper,

> Selection-maturation interaction is not controlled because the groups were not randomly selected and are not equivalent. An attempt to escape this problem was made by attempting to obtain experimental and control classes at the same school or in the same area as an attempt to obtain students from the same type of population.[31]

and,

> The effect of reactive arrangements on external validity should be limited because most of the schools participating in the program only have one class of Chemistry and the students should not be sensitive toward the experimentation.[32]

Unfortunately the researcher cannot have his proverbial cake and eat it! Moreover, the latter quotation itself is questionable. Further although the authors suggest that history and testing poses no threat to internal validity, the use of different schools quite widely separated would be expected to affect the former, while the particular kind of testing previously described might also be expected to produce differential and hence confounding effects. Becht

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[31]Altieri and Becht, p. 21.

[32]Altieri and Becht, p. 21.

has recently indicated that those students following the experimental treatment were found to perform better (at the .1 level of confidence) than the control students. Moreover, he also noted that the experimental students showed a more positive gain in attitude towards chemistry.[33]

Perhaps the best study operationally, if not methodologically, is that by DeRose.[34,35] Involving the use of CBA materials, the course was personalized around a basic core. Particularly noteworthy is the provision of an hierarchy of behavioral objectives, containing eighty six basic and eighty two optional objectives. Only the nine action verbs specified by the 'Science A Process Approach' curriculum project were used.[36] Further some of the sequences of the hierarchy were deliberately left open ended, so that inquiry should not be stultified. DeRose described how his approach developed over a period of four years,

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[33]Paul A. Becht, "Individualized Chemistry--A Program Designed to Personalize Instruction in Chemistry" Research Monograph Number 4 (Gainesville, Florida: P. K. Yonge Laboratory School), mimeographed, January, 1973.

[34]James V. DeRose, "New Directions for Chemical Education in High Schools," in The 1969 STAR Awards, (Washington: National Education Association Publications Inc., 1969).

[35]James V. DeRose, "Independent Study in High School Chemistry," Journal of Chemical Education, 47: 553-560, August, 1970.

[36]Science A Process Approach (published by Xerox for the American Association for the Advancement of Science, 1970).

during which time no teacher presentations were made and the students appeared to learn individually mainly from written materials. While it is not surprising that in the first year students were selected for the experimental group on the basis of ability, to ensure success, it is perhaps surprising that this practice continued in each succeeding year, although in the fourth year a random selection from the best was made. Thus any results could be a function of selection. In each year comparison was made both with an accelerated class from the next lower grade and also with the regular classes from the same grade as the experimental group. Each year, perhaps not surprisingly, the experimental group performed better in the end of year examinations. Lending support to the suggestion made previously in this review that both students and teachers take time to adjust to the approach it was found in each year that the experimental group showed greater gain by the end of the year than by the middle, and that the difference between the experimental group and the accelerated group was statistically significant in each year except the first. Further, in agreement with the comments of Gilbert and Krockover, it was apparent that the students needed an incentive to work at an optimum pace. Given a minimum schedule in the second year they simply worked spasmodically, increasing their effort as tests neared. Given the opportunity to move at their own pace in the third year, they (a new batch of students) generally moved at a slower pace and achieved lower than the group in the previous year. Accordingly the following year it was intended to provide an incentive to move more quickly by allowing students to begin a new science course immediately. DeRose, like McKerlie, Gilbert, and Bibeau sought to involve the students in learning how to learn, and provided them with an index, called a 'Know-You-Know' index, as a measure of this. This was simply the fraction of objectives attained successfully over the number attempted. Thus the student could follow his progress in demonstrating that 'he knew he knew'. Finally, like others, DeRose found the task of providing a large number of test items directly related to the objectives, and the provision of testing time and marking, to be quite formidable. It is impossible not to admire the work of DeRose. His practical wisdom and expertise as a guide for learning provide a model for all to follow. However it is disappointing that his research methodology is suspect. He did select only the best students and compared, nonparametrically, only with one group which was academically inferior and another which was younger and perhaps psychologically less ready for a course generally acknowledged to be difficult. It is really not surprising then that the experimental group, once accustomed to the method, generally did better, or that the gap widened with time.

Most of the chemistry studies described thus far, have been at the school level. This section of the review will be concluded by describing several studies at university level.

The Keller plan has been applied in the introductory general chemistry course at the University of Texas at Austin. That is, self pacing and strong student-instructor interaction were emphasized, and lectures were de-emphasized or even eliminated for the individual student if he so desired. The materials, comprising twelve units, were mainly written, with the textbook largely used in a supplementary fashion. Lectures were given for the first four units to ease the students into the course, but none were given after that. Each unit was tested by written examination and oral defence of the answers. Students had to satisfy the instructor on at least five out of six questions to be allowed to proceed to the next unit. Students were allowed to take the final examination any time after completing the twelve units. The results appear to be encouraging, grades and final examination performance being substantially greater than obtained by lecture presentation the previous two times.[37] However, if one includes the number of students who dropped the course the failure rate was much higher in the experimental group than in either of the others, although

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[37] John M. White, John S. Close, and Jerome W. McAllister, "Freshman Chemistry Without Lectures," Journal of Chemical Education, 49: 772-774, November, 1972.

it should also be noted that the proportion of A grades was substantially greater in the experimental group. While it is possible that nearly thirty percent of the students normally would, as in the experimental group, either drop the course or fail to complete much of it, no mention was made of this.

Day and Houk have described a similar first year course at Ohio University, although the student had more flexibility in choice of media. If he wished he could choose to follow the course entirely by lecture, or he could use any combination of this and audio-visual and programmed materials, available in a resource centre. This included a videotape of each lecture. A course office was staffed for twenty hours each week by third and fourth year students but, in contrast to the enthusiastic response noted by Wayne and Humphreys, these tutors were almost completely unused, as was the supplementary printed material provided. In contrast to this the students appeared to prize highly the list of behavioral objectives, and the specimen examination questions which were on display, indicating that a clear definition of what the instructor wanted was the prime consideration of the students. The final examination could be taken one week after the beginning of the course, and thereafter at three week intervals. The grade for the course depended only on the final examination, the last examination result being used for this purpose. Thus, unlike in most other programs, failure was not cumulative. The authors noted a fairly substantial gain over a control group in terms of grades obtained.[38] However, it should be noted that the experimental group had considerably more previous chemistry, and moreover that they had the opportunity to improve their grade by taking several final examinations. As the examinations more closely related to the objectives, and as these objectives themselves appeared to be quite low level in terms of Bloom's Taxonomy, the implication for the external validity of the study may conceivably be to more than eliminate the apparent gains made by the experimental group. The authors noted two particular difficulties, the problem of scheduling laboratories to fit a self paced approach and the need for a sequential course as an incentive to finish early.

A second year individualized inorganic chemistry course was produced at McGill university as part of a joint experiment to produce individualized courses in several subject areas. Although when the paper was written the experiment had just begun, it appears to offer more flexibility than the other programs described. Fourteen modules were prepared, which could be followed either from an audio-tutorial presentation or from written materials. All students were required to complete the first three modules

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[38]J. H. Day and C. C. Houk, "Student Paced Learning," Journal of Chemical Education, 47: 629-632, September, 1970.

as essential background followed by seven others in whatever order they chose, and finally any one of four optional modules. Thus the student could move gradually from a structured to a quite unstructured program, the major decisions in this process being made by the student himself. This is in contrast to almost all of the other studies described, in which the main decision made by the student was the pace at which he worked. Complete freedom is finally offered by allowing the student to pursue an independent project of his own choice.[39]

The application of computer assisted instruction has been ignored in this review. Clearly, in theory, use of computers has immense potential in individualization of instruction, particularly where enrollment is very high. However, it cannot be denied that preparation time and cost is prohibitively high for most institutions. In the interest of completeness, brief reference will be made to two papers which describe the application of computer assisted instruction in two separate courses at the University of Texas at Austin, one in general chemistry and the other elementary organic chemistry. In both application was made to modules emphasizing drill and repetition (for example by the random assignment of numbers to numerical problems), by a Socratic

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[39] Ian S. Butler and others, "A Summer Project on Modular Design," (paper presented at McGill Conference on University Teaching and Learning, Montreal, October, 1971).

type dialogue. Communication between student and computer was made by typewriter and the use of a light pen on a cathode ray tube. The student could thus be required to act upon visual images received from the computer program. The computer based modules were not meant to replace the existing course, but to supplement the regular presentation if the student desired. Students were guaranteed at least one hour of computer time every two weeks. In general the experimental group, who were all volunteers, scored significantly more highly in each of the two semesters of the trial in those parts of the final examination based on instruction by computer. The same pattern was observed for the organic course. The authors concluded that such use of computer assisted instruction was beneficial for those areas of the course in which the emphasis was on learning by the students rather than on the need for teaching by the instructor.[40,41] The authors noted the confounding effect of using volunteer groups. It might also be suggested that the fact that the experimental group spent more time in direct tutorial help outside the classroom than did the control group, could be even more confounding.

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[40]S. Castleberry and J. J. Lagowski, "Individualized Instruction Using Computer Techniques," Journal of Chemical Education, 47: 91-96, February, 1970.

[41]L. B. Rodewald, G. H. Culp, and J. J. Lagowski, "The Use of Computers in Organic Chemistry Instruction," Journal of Chemical Education, 47: 134-136, February, 1970.

Other Studies

With an important exception, it is not intended to extend this review beyond the areas already touched upon. This is not to deny that individualized instruction is practiced in other areas of science, but little is added to what has already been said. The exception to this lies in the realm of large scale curriculum projects, three of which appear to be of substantial importance to the practice of individualized instruction.

It has been argued that reasons for the lack of individualization, despite its more widespread conceptual acceptance, include difficulties of conception and implementation by the teacher. Thus only the ardent enthusiast will embark upon, and survive, the process of individualizing his instructional program. Further, when he leaves the program collapses. The Intermediate Science Curriculum Study produced a package of materials designed to alleviate these problems, for use at Junior High School level. The program was field tested on 200,000 students, and the authors claim that it enables pace and level and sequence of instruction to be varied to meet the needs of the student.[42] One study, based on the ISCS method and content, although not precisely on their materials, indicated no difference in

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[42]Probing the Natural World (Teachers Edition, Volumes 1 and 2), (Florida: Florida State University, 1970).

mean achievement, but found the experimental group to be significantly better with regard to knowledge of the methods and aims of science.[43] For a program that emphasizes process more than any other program at a comparable level, this is perhaps a good measure of success. The major importance of the program lies in its deliberate attempt to involve the normal classroom teacher in individualization, and does so by providing him not only with a suitable instructional program but with advice on all operational procedures, including storage and handling of equipment, adaptation of normal classrooms, and handling of students.

The major attempt to involve students and teachers in individualization of instruction on a large scale has been made by the Individually Prescribed Instruction project in mathematics, science and reading for children from kindergarten to grade six, emphasizing particularly self pacing, a greater involvement by the student in developing his own learning and self evaluation, and a congruence with individual learning styles. The program emphasizes something which is lacking in perhaps all of the studies described in this review. That is, a comprehensive formative and summative evaluation has been carried out. This involves affective and operational measures as well as cognitive.

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[43]Robert K. James, "A Comparison of Group and Individualized Instructional Techniques in Seventh Grade Science," Journal of Research in Science Teaching, 9:1:91-96, 1972.

Operationally, for example, observations are made of the precise actions of each student in class. The heart of the evaluation, however, lies in the program of achievement testing. Three kinds of tests have been provided, namely placement, diagnostic, and curriculum embedded tests. The tests are all criterion referenced, based directly on carefully specified behavioral objectives. The placement tests are broadly based, and provide correct initial placement of each student at the beginning of each year. To facilitate this the objectives within each unit, and overall, were sequenced into a learning hierarchy. Remediation could thus be assigned where necessary, and repetition of objectives already mastered could be avoided. Further refinement was effected by the application of diagnostic tests based on a relevant but narrower sequence of objectives, the tests again being directly criterion referenced. At this time the learning materials assigned to each individual would depend on these tests plus other standardized measures, such as a test of reading level. Thus each child should receive materials most appropriate to his needs. Curriculum embedded tests, again criterion referenced, are used to test each student on each objective, when he feels he has mastered it, and finally at the conclusion of each unit a post unit test is administered. At any time when the student misses an objective the teacher issues a prescription for appropriate action. Not only is the student continuously evaluated, but so is the system as a whole. Results from the tests described are useful in evaluating the objectives themselves, their place within the learning hierarchy, and the effectiveness of all instructional procedures. This has been discussed in detail by Lindvall and Cox, and their discussion emphasizes the need for a large scale attack on the problem.[44] It is possible that substantial progress in any area, including chemistry, will not occur other than by a large scale effort of this kind.

The heavy emphasis on teacher controlled prescription writing in IPI could be erroneous, but it seems likely that the age and development of the students concerned is the vital factor. There may be, therefore, no anomaly between this practice in IPI, the greater student control in ISCS, and at the college level complete control by the student over his own remediation. Such a development is consistent with the aim of helping the student learn how to learn, and to know what he knows, which has been discussed previously in this review.

One final curriculum project which is of importance does not, ironically, emphasize individualized instruction in the sense used in this thesis, but does emphasize the writing of behavioral objectives, the development and validation of a

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[44]C. M. Lindvall and R. C. Cox, Evaluation as a Tool in Curriculum Development: The IPI Evaluation Program, (Chicago: Rand McNally and Co., 1970).

learning hierarchy, and individual testing. This is the AAAS Science A Process Approach program,[45] the behavioral emphasis of which developed under the influence of Robert Gagné. Gagné has suggested that people learn in the form of a change in behavior, describable in terms of an observable human performance.[46] However, it is clear that a severe dichotomy exists between the proponents and opponents of behavioral objectives, often from polarized positions. The behaviorist wants clarity not vagueness, a direction for learning and appraisal, and a consequent basis for selection of appropriate experiences. His opponent argues that instruction is far too dynamic and complex to be specified in advance, and in behavioral terms. The literature is rich, but is well represented by the dialogue between Eisner and Hastings.[47,48,49] Despite such arguments those involved in individualized instruction seem to have no doubts. Many of the authors quoted in this review gave their students behavioral

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[45]Science A Process Approach (Published by Xerox for the American Associaiton for the Advancement of Science, 1970).

[46]Robert M. Gagné, The Conditions of Learning, (2nd ed.; London: Holt, Rinehart and Winston, 1970), p. 237.

[47]Elliott W. Eisner, "Educational Objectives Help or Hindrance," School Review, 73:3:250-260, 1967.

[48]J. Thomas Hastings, "Educational Objectives - Some Comments," School Review, 75:3:267-271.

[49]Elliott W. Eisner, "A Response to My Critics," School Review, 75:3:277-282.

objectives and found a most favorable reaction.

Summary

It was suggested in chapter one that the application of individualization of learning in the sciences is limited, and that the evidence which has accumulated is inadequate. It is contended that this review underlines these claims and justifies the need for the present study and others like it. Very little unequivocal evidence emerges from the studies presented. Mastery learning and criterion referenced testing are clearly fundamental to individualized instruction, and many of the studies emphasized these aspects. It follows logically that sufficient time must be allowed for development of mastery, and hence it is not surprising that in most studies self pacing was heavily emphasized, and often was synonymous with individualization. A few studies extended beyond this and emphasized individual treatment of the course, although perhaps never reaching personalization.

Self pacing, however, brings its own problems. Scheduling of laboratories, viewing of films, and testing are more difficult when handled on an individual or small group basis. Initially at least, the teacher often feels over-burdened with too many different questions from too many students at the same time. The student too, feels frustrated, and has difficulty in using his time efficiently. Nevertheless it is clear that eventually most of the students and most of the teachers preferred an individualized approach, despite difficulties of adjustment. Some patterns emerge, hopefully soon to be validated or denied empirically. These may be summarized.

1. The use of clear guidelines, generally in the form of behavioral objectives, is essential. The sequencing of these in a hierarchy is rare, but is potentially profitable.

2. Most students need a source of pressure to help them work. Several studies described the application of student contracts as one solution to this. Others simply specified deadlines but these often became translated as representing the required pace.

3. Criterion testing appears to be relatively rare. Yet it is implicit in the concept of individualized instruction. Many teachers suffer here because of an imposed norm referenced grading policy. The answer, little tried it appears, might be the use of criterion tests to monitor student progress within each unit and at the end of the course, with some norm referenced questions to distinguish between students at that time. Alternatively, and more in keeping with individualization, a student's progress might be represented only by those objectives successfully mastered. In either case the application of a self testing component seems desirable, both to simplify the teacher's role and to encourage the development of a good attitude toward learning by the student.

4. The use of student proctors or of students within the same class to aid instruction has often been recommended, although one author found they went unused. It is the opinion of this author that help from peers is potentially useful for all concerned only when the content to be treated is fairly restrictive.

5. The use of extensive audio visual aids does not seem essential, although it is likely that some students will learn better from different media.

6. In self paced courses there is a need for sequential courses to be immediately available, as an incentive for early finishing by those capable of it and to allow the slower student to proceed without interruption.

7. The evidence that individualization of instruction is successful in science education is almost non existent. Conversely, there is little hard data to reject its use. The majority of studies have used inadequate evaluation techniques for answers to these questions to be readily gained.

8. Finally, few attempts have been made to analyze the process of individualization, and how this may be optimized. Herein, perhaps, lies the main challenge for the future.

Personality and Individualized Study

Educators have long sought to identify factors which enable accurate prediction of academic success. Grade point average, marks in specific subjects, I.Q., verbal ability, teacher rating, and personality, amongst others, have all been used with varying degrees of claimed success. The picture is complicated, perhaps particularly in the area of personality testing. For example, the author of one study concluded that the same factors may contribute quite unequally to the prediction of marks in different subject areas,[50] which is perhaps a justification for investigating the effect of personality in the present study.

The most widely used personality measure has been the California Psychological Inventory (CPI) which contains 480 true-false items. Results are obtained on eighteen dimensions of personality.[51] Thorndike heavily criticized the CPI as too complex, suggesting that many of the scores highly overlap and that it will not provide a clear, efficient and simple personality description.[52] Despite this some workers have claimed that it is useful as a predictor of

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[50] Alice Pearl, "Personality and Attainment," (Unpublished Doctor's dissertation, Georgia, 1959).

[51] Harrison G. Gough, California Psychological Inventory Manual, (Palo Alto: Consulting Psychologists Press, 1957).

[52] Robert L. Thorndike, "Review of CPI," Fifth Mental Measurements Year Book, ed. O. K. Buros (New Jersey: Gryphon Press, 1959), p. 37.

academic achievement.[53,54]

An opposing view was taken as the result of a study on freshmen at the University of Alberta. The authors found none of a number of personality measures to be useful, the only significant contribution being made by grade point average.[55] However, in the context of the present study we are more concerned with the effect of personality on attainment in individualized instruction. Cronbach's comment,

> Pupils who are negativistic may blossom under discovery training, whereas pupils who are anxiously dependent may be paralyzed by demands for self reliance.[56]

may well be applied to individualized instruction. Two recent studies support some kind of differential effect. Bigelow and Egbert found that students who were successful in traditional study succeeded as well in independent study, and further that

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[53]Harrison G. Gough, "Academic Achievement in High School as Predicted from the California Psychological Inventory," Journal Educational Psychology, 55:3:174-180, 1964.

[54]David Rydback, "The California Psychological Inventory and Scholastic Achievement," Journal of Educational Research, 61:5:25, 1968.

[55]R. C. Conklin and D. G. Ogston, "Prediction of Academic Success for Freshmen at the University of Calgary," Alberta Journal of Educational Research, 14:185-192, September, 1968.

[56]Lee J. Cronbach, "The Logic of Experiments on Discovery," Learning By Discovery: A Critical Appraisal, ed. Lee S. Shulman and Evan R. Keislar, (Chicago: Rand McNally, 1966), p. 90.

> intellectual efficiency and responsibility were personality traits pertinent to independent study success, and that within the group of successful independent study students, those with higher social needs indices tended to be satisfied with completely autonomous study.[57]

In another study it was found that restraint was significantly related to success in an audio-tutorial course but not to success in the corresponding group presentation.[58] Thus, there is some encouragement for the use of personality as a predictor of achievement in individualized study. The Eysenck Personality Inventory and it's forerunner, the Maudsley Personality Inventory, appear to be particularly well suited to this task.

The Maudsley Personality Inventory consists of forty-eight yes-no questions, and measures the two dimensions extraversion and neuroticism.[59] In one study it was found that high scores on both factors were negatively related to academic performance, and it was further suggested that there

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[57]Gordon S. Bigelow and Robert L. Elbert, "Personality Factors and Independent Study," Journal of Educational Research, 62:37-39, September, 1968.

[58]M. Szabo and J. F. Feldhusen, "Success in an Independent Study Science Course at the College Level as Related to Intellective, Personality, and Biographical Variables," Journal of Research in Science Teaching, 8:3: 225-229, 1971.

[59]R. R. Knapp, Manual of the Maudsley Personality Inventory, (San Diego, California: Educational and Industrial Testing Service, 1962).

might be an optimum on the neuroticism scale.[60] Another study confirmed the negative correlation with extraversion but found neuroticism to be unrelated to academic attainment.[61] A third study confirmed the curvilinear nature of the relationship between neuroticism and attainment, indicating a medium score on the neuroticism scale to be most beneficial.[62]

The Eysenck Personality Inventory (EPI), was developed from the Maudsley Personality Inventory.[63] The similarity is sufficiently close to allow research on the Maudsley inventory to be transferred to EPI. As yet most interest in the latter has been shown in its clinical applications. However, some studies have linked the scales with attainment although the results are somewhat contradictory. Warburton claimed age to be a factor, with introverts doing better at university but worse at primary level, while Eysenck and Eysenck claimed the neurotic

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[60]R. D. Savage, "Personality Factors and Academic Performance," British Journal of Educational Psychology, 32:251-253, 1962.

[61]A. W. Bendig, "Extraversion, Neuroticism and Student Achievement in Introductory Psychology," Journal of Educational Research, 53:263-267, March 1960.

[62]Dennis Child, "The Relationship Between Introversion-Extraversion, Neuroticism and Performance in School Examinations," British Journal of Educational Psychology, 34:187-189, June, 1964.

[63]H. J. Eysenck and S. B. G. Eysenck, Manual for the Esyenck Personality Inventory, (San Diego, California: Educational and Industrial Testing Service, 1963).

introvert to be the successful student at tertiary level.[64] Kline and Gale, however, found no stable patterns over a five year period in a university study.[65] Amaria and Leith summarized a number of papers and noted that the kind of learning and learning environment, as well as age, appeared to be important variables when relating personality and achievement.[66] Lynn and Gordon have commented, with respect to the Maudsley and Eysenck scales, that introverts are superior to extraverts in tasks requiring sustained work or attention, and in tasks requiring accuracy. They also claimed that neuroticism is related to academic success through persistence.[67] This again suggests the application of EPI to prediction of attainment in individualized study seems possible. The test also has the advantages of speed and simplicity, and has been favorably reviewed. One reviewer has commented,

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[64]F. W. Warburton, "Personality Factors and Academic Success," (unpublished manuscript University of Manchester, 1968).

[65]P. Kline and A. Gale, "Extraversion, Neuroticism and Performance in a Psychology Examination," British Journal of Educational Psychology, 41:90-94, February, 1971.

[66]R. P. Amaria, L. A. Biran and G. O. M. Leith, "Individual versus Co-operative Learning," Educational Research, 11:95-103, February, 1969.

[67]R. Lynn and I. E. Gordon, "The Relation of Neuroticism and Extraversion to Intelligence and Educational Attainment," British Journal of Educational Psychology, 31:3:194-203, 1961.

> . . . for those who wish to measure the dimensions of neuroticism-stability and of extraversion-introversion, the EPI is probably the best instrument now available and certainly is backed by superior research.[68]

Another noted that the two traits measured by EPI have become known, under whatever name, as "the big two", and commented

> As measures of the two major factors of personality, the EPI scales are as good as any.[69]

A third reviewer was less kind, and particularly attacked the content of the manual and the validation of the scales.[70] However, for the purpose of the present experiment, the EPI seems particularly suited.

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[68]Victor B. Kline, "Review of EPI," Seventh Mental Measurements Year Book, ed. O. K. Buros, (New Jersey: Gryphon Press, 1972), pp. 162, 163.

[69]Richard I. Lanyon, Seventh Mental Measurements Yearbook, pp. 163, 164.

[70]A. W. Heim, Seventh Mental Measurements Yearbook, pp. 164-166.

CHAPTER III

DESIGN AND OPERATION

Development of Hypotheses

The need for individualization of instruction in general, and in particular in first year chemistry at Memorial University was established in chapter one. It was suggested that it is not possible to cater adequately for individuals in a group setting. In chapter two, a review of the relevant literature indicated that while there is some concrete evidence to support individualized instruction in science, this is limited. Moreover, it appears that it may be possible to use student characteristics to identify those who may benefit most from individualized instruction. The present study was conceived as an attempt to solve the first problem and to add to the existing body of knowledge on each of the others.

The Foundation course was chosen for study for several reasons. Normally a student registered in this course requires three semesters to complete the year's work, while those students exempted from the course take two. This may contribute to the unpopularity of the course. The possibility of enabling some Foundation students to complete the year's work in two semesters was intriguing. It also made sense to begin at the beginning. Against this was the problem that normally these students have a background which is either inadequate generally or in chemistry specifically. With few exceptions these students may be considered no more than average at best, and at worst not of the standard needed for work at a university. It may be noted that similar studies elsewhere have often concentrated on better students. However, it is certainly possible that a well structured course, emphasizing self pacing and allowing for individual remediation and guidance, may produce greater gains for poorer students. What constitutes this greater gain within the context of individualized instruction is debatable. Certainly there is merit in the suggestion that comparison of mean attainment is inadequate. Equally conceivable is the suggestion that some of the gains made when instruction is individualized are not, or should not be, immediately measurable. However, if claims are to be made for or against individualized instruction relative to group instruction, it does not seem unrealistic to compare the mean achievement of students enrolled in each kind of class. This is reflected in the major hypothesis.

> Hypothesis 1: Students allowed to pursue an introductory chemistry course by an individualized approach, will show greater achievement than students following the same course by a normal classroom presentation.

An attempt was made to identify variables which affect achievement differently in the individualized as opposed to the group treatment. This is reflected in the second hypothesis and its sub-hypotheses

Hypothesis 2: Variables can be identified which affect achievement differently in an individualized course relative to a group presented course.

In the context of this hypothesis the variables considered will be previous chemistry, general ability, mathematical ability, and the personality traits measured by the Eysenck Personality Inventory.

Previous chemistry was taken as completion of grade ten, which contains a substantial amount of the material covered in the Foundation course, which was used in this study. It seems likely that previous chemistry will affect achievement in the Foundation course, but it is not clear whether an interaction will occur with treatment. Hence the hypothesis will be stated in the null form.

Hypothesis 2A: There will be no interaction between previous chemistry and the individualized treatment relative to the group treatment.

The use of grade point average as a determinant of progress from one grade to the next is widespread, particularly where transfer to another institution such as a university is involved. In Newfoundland students enter university after successfully completing grade eleven. In this study the average grade eleven score in seven subjects was taken as a measure of general ability, although it is recognized that extraneous influences will interfere to some extent. Again the direction of any interaction is not clear, and the hypothesis will be stated in the null form.

Hypothesis 2B: There will be no significant interaction between general ability and the individualized treatment relative to the group treatment.

The Foundation course does not feature any refined mathematics, but does require simple computational skills and an ease with concepts such as ratio and proportion. It seems possible that mathematical ability may interact with treatment, a conclusion which was reported from an audio-tutorial biology course.[1] However again the hypothesis will be stated in the null form.

Hypothesis 2C: There will be no significant interaction between mathematical ability and the individualized treatment relative to the group treatment.

As was indicated in chapter two there is some evidence to suggest that individualized study interacts with the personality dimensions of the Eysenck Personality Inventory. Hence the remaining two hypotheses will be stated positively.

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[1]David Sherrill and Marvin Druger, "Relationships among Student Variables in an Audio Tutorial Biology Course," Journal of Research in Science Teaching, 8:2:191-194, 1971.

Hypothesis 2D: Introverts will achieve relatively more highly if given the individualized treatment and extraverts will achieve relatively more highly if given the group treatment.

Hypothesis 2E: Neurotic students will achieve relatively more highly if given the individualized treatment and stable students will achieve relatively more highly if given the group treatment.

Population and Sample

Strictly the population from which a sample was drawn should be defined as Foundation chemistry students at Memorial University. It is not possible to generalize to other first year chemistry students at Memorial, for reasons indicated previously in this chapter. However it seems likely that there are many other similarly average students enrolled in similar introductory chemistry courses elsewhere. Hence the population may be defined as being restricted to students such as those described earlier.

In choosing the sample a good degree of randomization was achieved during the registration of the approximately two hundred Foundation chemistry students. Every n^{th} student was placed in the experimental group and every $n+1^{th}$ student in the control group. Only very occasionally did this procedure break down due to particular timetabling problems.

Significance of the Study

The significance of the study is fourfold. It may provide an answer to the problem of catering for individuals with a wide range of interests and abilities, in an introductory chemistry course. It may add to the growing body of information and concrete evidence needed to guide efforts in individualization of instruction. It may help indicate not only whether individualized instruction can work for average students, but also whether certain student characteristics are related to the degree of success. Finally, a version of Chem Study is currently being tried in Newfoundland schools, and seems likely to become the major course of study soon.[2] The development of materials involved in this study may hence be subject to a much wider use.

Materials

At the time of the experiment, as now, first year chemistry at Memorial was based heavily on the most recent version of Chem Study.[3] The Foundation course refers to the first six chapters of the text and, with some modifications, to the appropriate laboratory work. The text is not well

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[2]Paul R. O'Connor and others, Chemistry: Experiments and Principles, (Boston, Mass.: Copp Clark, 1968).

[3]Robert W. Parry and others, Chemistry: Experimental Foundations, (Englewood Cliffs, New Jersey: Prentice Hall, 1970).

suited to individualized study, and the decision was made to provide a major learning guide to accompany the text. In accordance with the conclusions reached in chapter two, the first task was to identify and write the behavioral objectives implicit in the course. As DeRose had noted this was a very time consuming operation, but perhaps very worthwhile. The exhortation of Mager to state objectives in terms of what the learner should do to show his mastery and to

a. Identify and name the over-all behavior act.
b. Define the important conditions under which the behavior is to occur (givens or restrictions or both).
c. Define the criterion of acceptable performance.[4]

was followed. Mager's emphasis on action verbs was accommodated by using mainly the verbs recommended in the AAAS Science A Process Approach materials.[5] Having established and written the objectives of the existing course an attempt was made to sequence them into a logical learning hierarchy. This was difficult as the book itself was not arranged completely hierarchically. Hence, as a substitute, a learning flow chart was produced for each chapter, mainly but not always following the order of the book. The material of several chapters was rearranged in the suggested treatment given to the students. Thus a needed sense of direction,

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[4]Robert F. Mager, Preparing Instructional Objectives, (Palo Alto, California: Fearon Publishers, 1962), p. 53.

[5]Science A Process Approach (published by Xerox for the American Association for Advancement of Science, 1970).

normally provided by the teacher, was provided as a help to the student in structuring his conception of the learning path. Upon this base a learning guide for each chapter was prepared, and included suggestions for reading the text and other materials, suggestions for using films, film loops, film strips and programmed materials, and suggested exercises, as well as the objectives and the learning flow chart. The audio-visual materials were located in a resource room, which was open to all students. No audio-visual materials were prepared especially for the experiment. A sample from the written learning guides is presented in the Appendix.

Operation

No attempt was made to hide the experimental nature of the experimental group. The control group were also told they were part of an experiment, and this was emphasized periodically during the course. Hence an attempt was made to control for a possible Hawthorne effect although, as will be argued later, it is possible that the nature of this particular experiment had a negative effect in the sense implied here. Consideration was given to the possibility of providing the control group with the learning guides given to the experimental group, and hence to eliminate reactive effects due to the materials themselves. This was not done, partly because the materials were only meant to be equivalent to the normal teacher presentation, and further because the instructions contained might have been confusing when taken conjointly with the teacher presentation.

Both the experimental and control class met at appropriate times in the normal classroom set aside for the 100F course. Adjacent to this room was the resource room and another room into which small groups could be taken as required. The resource room was quite small, and contained seating space for about a dozen students, as well as books, periodicals, projectors etc. This room was open to all first year students, and operated from nine to five daily. A graduate student was available as tutor at all times. The students were required to report to the classroom at each regular meeting time for their time section, and were then allowed to work alone or in small groups of their own choice, to move into the resource room, or to seek the assistance of the instructor individually or in groups. The instructor (the author) guaranteed to be available in his office at stated times, and was also available at most other times. The result of this was a doubling of contact time with the students. However some never came while others were regular visitors. Similarly, some students in the experimental group almost boycotted the resource room, and the group as a whole used the room little more than anyone else.

Although each student was required to report to class regularly, he was free to proceed as he wished. He could ignore any or all of the suggestions in the learning guide, and was free to take a chapter test at any time. For each chapter at least three different tests were available, each based specifically on the behavioral objectives. Each objective was normally tested twice. Tests were usually corrected immediately by the instructor, and a guarantee was given that corrected exercises and comments on both exercises and tests would be available in the resource room by 9 a.m. the day after receipt. Initially, for about four weeks, no marks were awarded, but the student was told which objectives he had missed and what he should do about it. Thus an attempt was being made to set each student against his own standards, not in competition with others. This did not succeed, because students were concerned about a mark and erroneously converted to raw scores, and was eventually abandoned in favour of giving a mark on a ten point scale for each test. Prescriptions were still given, but extensive remedial work was difficult to impose because nobody wanted to risk taking more than one semester for a Foundation course. That is, the option to decrease the normal pace was not taken to any real extent. Conversely, by the fourth week it was clear that a group of nine students was proceeding at a faster rate than that needed to complete the course in the normal time. Two students, both of whom had almost gained exemption from the course and subsequently gained an A grade, were proceeding at a rate which would have allowed them to complete the course in little more than half the normal time. Approximately half the students were completing tests and remedial work almost exactly according to the schedule given them to indicate a normal rate of progress. About six to eight students, two of whom had taken some chemistry previously, had difficulty maintaining a normal rate. While they made periodic spurts to take the tests on schedule, the remedial work which was necessary for all of them repeatedly placed them about a week behind. Five of these students took an alternative version of the mid-semester examination one week late. The multiple choice section of the examination, worth half the marks, was identical. The other section, mainly problems, was equivalent to that given in the main examination. By departmental policy students do not keep their examination papers. There was no evidence that the students had knowledge of the content of the examination, and their performance was low. Four of the six who wrote late failed, and one barely passed. The sixth student, who was not in the slow group but wished to write the examination late, obtained a B grade. He continued to perform at this level throughout his first year chemistry courses. No one wished to write the mid-semester examination early. The reasons for this may be varied. The two fastest moving students had already decided that they no longer wished to complete the course early, but preferred to improve their grade. They also reasoned that they had one other Foundation course which would keep them at Memorial for the third semester. Hence little would be gained by completing chemistry early. Most of the others in the fast group preferred to use the time gained in chemistry to study for other mid-semester examinations. These were held at about the mid way point in the semester, contrary to the chemistry examination which was held the day before the mid semester break. This break, paradoxically, was two weeks beyond the mid point in the semester. It is clear, therefore, that differential pacing was more evident before the mid semester break, and was minimal after that time. All students, experimental and control, took the final examination on the same day.

Two other instruments were used. The B version of the Eysenck Personality Inventory was given to both the experimental and control group in a normal class session several weeks after the beginning of the semester. This should have been given at the beginning but was not available at that time. Secondly, as part of a faculty wide course and instructor evaluation, a questionnaire was administered to all students about two weeks before the end of the course. A small additional section, devised by the author and dealing with the experimental course in particular, was given to the experimental section at the same time.

Instruments Used

Grade Eleven Scores

As has been previously indicated grade eleven average was used as a measure of general ability and a grade eleven mathematics score as a measure of mathematical ability. Although this is only accepted practice, it was also dictated by the results of an earlier study carried out by the author. In that study the students concerned were also Foundation students, taking a different but very similar course to the students in the present study. The sample was not randomly selected, but there is no reason to believe the students were unrepresentative except inasmuch that those with previous chemistry were eliminated from the study. As indicated in Table 1 a correlation matrix was developed involving the Foundation chemistry final examination score, scores on a scholastic aptitude test (SACU),[6] grade eleven average, and grade eleven mathematics. The scholastic aptitude test was given to all students on entry to the university. Grade eleven average was found to correlate most highly with the chemistry score (.56), which is in agreement with two of the recent studies elsewhere. Correlation in these, however, were only .41 and .34 respectively.[7,8] The verbal parts of

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[6]The SACU Guidance Manual 1970 Test Administration (obtained from SACU, 151 Slater Street, Ottawa 4).

[7]Nicholas A. Sieveking and Jeffrey C. Savitsky, "Evaluation of an Achievement Test, Prediction of Grades, and Composition of Discussion Groups in College Chemistry," Journal of Research in Science Teaching, 6:4:374-376, 1969.

[8]R. C. Conklin and D. G. Ogston, "Prediction of Academic Success for Freshmen at the University of Calgary," Alberta Jōurnal of Education Research, 14:185-192, September, 1968.

the SACU instrument, although correlating well with one another, correlated poorly with chemistry achievement (.04, .17 respectively). The numerical scores of the SACU instrument showed correlations (.38, .44) which were similar to that of the grade eleven mathematics score with chemistry achievement (.38). Hence the use of grade eleven average as an indicator of general ability and grade eleven mathematics as an indicator of mathematical ability seemed potentially most useful for the present study. The mathematics was narrowed further to the grade eleven algebra score in the present study, as it was observed that the correlation of the geometry score with chemistry achievement was almost zero.

TABLE I

CORRELATION MATRIX OF CHEMISTRY 100F EXAM SCORE; SCHOLASTIC APTITUDE TEST: 1 (VERBAL), 2 (NUMERICAL), 3 (NUMERICAL), 4 (VERBAL); GRADE 11 MATH SCORE; GRADE 11 AVERAGE.

N = 38

Test			(a)	(b)	(c)	(d)	(e)	(f)	(g)
Chemistry 100F Exam Score		(a)	1.0	.04	.38**	.44**	.17*	.38**	.56**
	Verbal	(b)		1.0	.27*	.40**	.65**	.20	.10
Scholastic	Numerical	(c)			1.0	.64**	.45**	.63**	.44**
Aptitude	Numerical	(d)				1.0	.62**	.41**	.39*
	Verbal	(e)					1.0	.30*	.33*
Grade 11 Math Score		(f)						1.0	.43*
Grade 11 Average		(g)							1.0

*significant at .05 level.
**significant at .01 level.

The Eysenck Personality Inventory

As has been previously indicated this inventory measures two dimensions, extraversion - introversion and neuroticism - stability, the scales being developed after a vast amount of factor analytic work.[9] The authors have provided data which is compatible with their hypothesis that these two factors are orthogonal (Table II). The authors claim that the inventory is superior to the Maudsley Inventory, from which it was developed, in five ways.

1. Two parallel forms are provided, enabling retesting.

2. Rewording enables low intelligence students to understand the questions.

3. The marginal correlation of extraversion and neuroticism shown on MPI is eliminated.

4. A Lie Scale is incorporated to eliminate desirability response.

5. Retest reliability is higher.

The reliability data given in the manual are satisfactory (Tables III, IV) but the application of MPI validity studies as well as the nature of those studies has been criticized, as has the validity of the Lie Scale. In the present study it may be noted that no attrition occurred on the basis of the Lie Scale.

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[9]H. J. Eysenck and S. B. G. Eysenck, Manual for the Eysenck Personality Inventory, (San Diego, California: Educational and Industrial Testing Service, 1963).

TABLE II

CORRELATIONS BETWEEN EYSENCK E AND N SCALES
(A and B subscripts relate to forms A and B respectively)

	Normals	Neurotics	Psychotics
E vs N	-.040	-.091	-.090
E_A vs N_A	-.002	-.040	-.047
E_B vs N_B	-.089	-.157	-.217

TABLE III

TEST--RETEST RELIABILITIES FOR EPI SCALES

Group	Sample Size	E_A	E_B	E	N_A	N_B	N
X	92	.82	.85	.88	.84	.81	.84
Y	27	.97	.80	.94	.88	.91	.92

TABLE IV

FORM A VERSUS FORM B AND SPLIT HALF RELIABILITY
COEFFICIENT FOR EPI SCALES

	Normals	Neurotics	Psychotics
E_A vs E_B	.747	.750	.751
E	.855	.857	.851
N_A vs N_B	.800	.873	.906
N	.889	.932	.951

1655 normals, 210 neurotics, 90 psychotics.

Criterion Examinations

Two criterion examinations were used, a mid-semester and a final examination. The mid-semester examination was of one hour duration and contained thirteen multiple choice questions, worth half the total mark, the remainder being mostly short problems. The final examination was two hours long and contained sixteen multiple choice questions and five longer questions. The multiple choice questions were worth one-third of the marks. There was no choice on either paper. The usual departmental procedure for first year examinations was followed. That is, each examination was approved, first by an examination committee and then by each person teaching the course, for content and construct validity. No statistical data was taken for the second half of either examination, but a Kuder Richardson formula 20 for reliability coefficient was calculated for the multiple choice sections. For the mid-semester examination it was 0.65 and for the final examination 0.69. In both mid-semester and final examination one section B question appeared to be less satisfactory than the others, but did not perform badly enough to necessitate elimination. The final examination was board marked, each instructor marking one question each. The multiple choice section was marked by an instructional assistant. The mid-semester examination was marked by the individual instructor, following a closely scheduled marking scheme. Even the questions in the second section were very objective, and there was little room.

for variation in standard. Nevertheless the papers submitted by students in the experimental and control groups were carefully scrutinized after marking. No discrepancies were observed.

Student Questionnaire

A small questionnaire was prepared to determine student response to the experimental treatment. This was given toward the end of the semester. The questionnaire was not validated, and the results will be used for qualitative comparisons and comments only.

Experimental and Statistical Design

Experimental Design and Limitations

In the format adopted by Campbell and Stanley the chosen design may be represented by

R	X	O
R		O

i.e. their Design 6, a post-test-only control group design.[10] Equivalence of groups is assured by randomization, and the use of several covariates in the regression equation used in statistical analysis of the results also helps remove fear of confounding by initial bias. The use of a pre-test was

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[10] D. T. Campbell and J. C. Stanley, Experimental and Quasi-Experimental Designs for Research, (Chicago: Rand McNally and Co., 1966), pp. 25, 26.

inappropriate because many students had no previous knowledge of the subject. The main threat to internal validity lies in the use of a different teacher and consequently in the specific events occurring throughout the course. However, this is perhaps less important in an experiment in which each student is more responsible for his own learning. There may well have been as many treatments as students in the individualized class, plus one. It is also possible that either or both teachers are normally particularly successful or particularly unsuccessful. However care was taken to match the teachers on background, qualifications and success, as much as possible. Nevertheless a possible source of confounding clearly exists. Maturation, instrumentation, statistical regression, differential selection, selection-maturation interaction and other interactions are considered controlled for by the experimental and statistical design. The chapter tests might be considered to have a differential effect, but again this might be more severe within the experimental group by the nature of individualization than between groups. It is not believed that significant confounding occurred from this source. Finally, in studies involving individualization mortality is often appreciable. This was not a major problem in this study. Three students in the control group were eliminated from statistical analysis on the assumption that they were atypical. One of these was repeating the course, another was clearly misplaced and had a particularly high grade eleven average, while the third failed all subjects at the end of the semester. One of the experimental group was eliminated also for the last reason. Two left the course because of complete course changes, which they claimed were independent of chemistry. A fourth was eliminated because his grade eleven marks were not available.

In terms of external validity it could be argued that findings are strictly limited to the immediate population, that is Foundation students at Memorial University. However, as has been suggested previously, it is reasonable to generalize findings to average students enrolled in a typical introductory chemistry course either at senior high school or early college level.

Statistical Design

With the development of high speed computers, the use of multiple linear regression as a tool for statistical analyses, hitherto done by analysis of variance or covariance, has increased rapidly. It has been well documented, and reference will be made here only to modification for the present study, for which it forms the basis. Hypotheses were tested by determining an F ratio of the squared multiple correlations of appropriate regression models where F was defined by the equation

$$F = \frac{(R_1^2 - R_2^2) / (df_1 - df_2)}{(1 - R_1^2) / (N - df_1)}$$

in which subscripts 1, 2 refer to the full and restricted models respectively.

The models were generated by applying the methods of Flathman[11] and Hunka,[12] but as the method was not identical with either it will be described here. Consider the present experiment in which the attainment of an experimental and a control chemistry class is to be compared. In each class some of the students have previous chemistry. The four cells which develop can be illustrated,

	With Chemistry	Without Chemistry
Experimental	X_1	X_2
Control	X_3	X_4

Suppose we wish to test the null hypotheses,

I. There is no interaction between method and previous chemistry.

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[11] Dave Flathman, "Hypothesis Testing with Multiple Regression," (Edmonton Educational Research Services, University of Alberta), mimeographed, November, 1968.

[12] S. Hunka, "How to Build Your Own Models for Statistical Analysis," (Edmonton: Educational Research Services, University of Alberta), mimeographed, July, 1966.

II. There is no difference between the experimental and control group.

III. There is no difference between those with previous chemistry and those without.

The full regression equation for the total sample of students is

$$Y = A_0U + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4$$

where

$\hat{Y}$ is the predicted score

X_1 = 1 for those in the experimental group with chemistry, 0 otherwise

X_2 = 1 for those in the control group with chemistry, 0 otherwise

X_3 = 1 for those in the control group with chemistry, 0 otherwise

X_4 = 1 for those in the control group without chemistry, 0 otherwise

A is a constant, U the unit vector, and E the error term. Successive terms A_iX_i may be added for any number of covariates. Suppose in this instance two such terms exist. The regression equation (the full model) therefore becomes

$$\hat{Y} = A_0U + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + A_5X_5 + A_6X_6 \quad \text{(Model 1)}$$

This may be rewritten:

$$\hat{Y} = A_0U + A_1X_1$$
$$+ A_2X_2$$
$$+ A_3X_3 - A_1X_3 + A_1X_3$$
$$+ A_4X_4 - A_2X_4 + A_2X_4$$
$$+ A_5X_5 + A_6X_6$$

Collecting terms.

$$\hat{Y} = A_0U + A_1(X_1 + X_3) + A_2(X_2 + X_4) + X_3(A_3 - A_1)$$
$$+ X_4(A_4 - A_2) + A_5X_5 + A_6X_6$$

If $X_1 + X_3 = V_1$ and $X_2 + X_4 = V_2$

$$\hat{Y} = A_0U + A_1V_1 + A_2V_2 + (A_3 - A_1) X_3 + (A_4 - A_2) X_4$$
$$+ A_5X_5 + A_6X_6$$

The hypothesis of no interaction can be illustrated diagramatically,

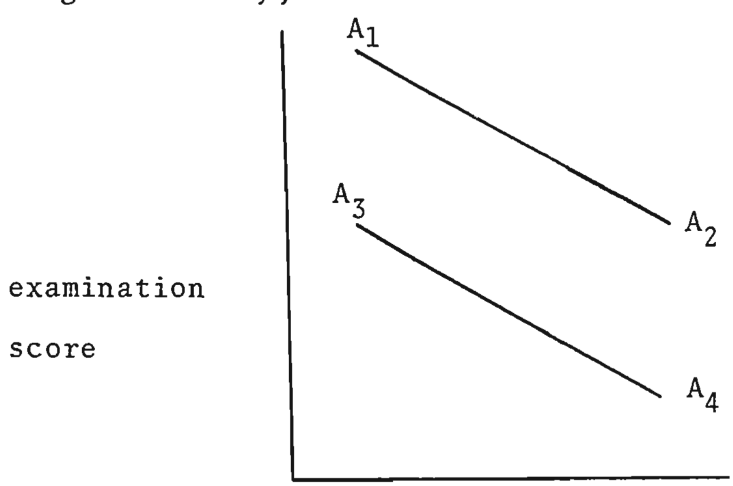

Diagram 1.

because the A values are essentially the mean scores for the corresponding cells.

$A_3 - A_1 = A_4 - A_2$, and

$\hat{Y} = A_0U + A_1U_1 + A_2V_2 + B_2W_2 + A_5X_5 + A_6X_6$

where $W_2 = X_3 + X_4$

As Flathman has indicated, the equation may be made more symmetrical by including a term in W_1. Since $W_1 + W_2 = U$, the vector W_1 is linearly dependent on vectors already in the model. Thus neither the predicted scores nor R^2 is changed by this addition.

The equation therefore becomes

$$\hat{Y} = A_0U + A_1V_1 + A_2V_2 + B_1W_1 + B_2W_2 + A_5X_5 + A_6X_6 \qquad \text{(model 2)}$$

model 2 thus incorporates the null hypothesis of no interaction, and this hypothesis may be tested by comparing model 1 with model 2.

Similarly, models may be constructed to test the main effects which generated hypotheses 2 and 3.

If there is no difference between the experimental and control groups, $B_1 = B_2 = B$, say

$$\therefore \quad \hat{Y} \quad A_0U + A_1V_1 + A_2V_2 + B\,(W_1 + W_2) + A_5X_5 + A_6X_6$$

$$\text{or } \hat{Y} = A_0U + A_1V_1 + A_2V_2 + BU + A_5X_5 + A_6X_6$$

$$= (A_0 + B)U + A_1V_1 + A_2V_2 + A_5X_5 + A_6X_6$$

$$= B_0U + A_1V_1 + A_2V_2 + A_5X_5 + A_6X_6 \qquad \text{(model 3)}$$

Now model 2 becomes the full model, and is compared with model 3 to test the effect of treatment.

Model 4 may be developed similarly and compared with model 2 to test the second main effect of previous chemistry. Neither of these main effects may be tested for in this way if interaction is significant.

Models similar to these were developed to test each of the hypotheses generated in chapter III. The computer program MULR05, which is available at Memorial University, is designed to enable hypothesis testing from models of the kind generated above. It was used throughout the present study.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

Introduction

Each hypothesis was tested by comparison of appropriate regression models, constructed by the procedure described in chapter three, by determining the significance of the appropriate F ratios. Analysis, therefore, was essentially equivalent to a series of two way analyses of covariance. Mid-semester examination score, final examination score, and a weighted combination of these scores were used successively as criterion variable. The weighted combination chosen was that used normally in compiling students marks in first year chemistry courses at Memorial. That is, the mid semester examination contributed fifteen and the final examination fifty marks to the total percentage. In this study, the total out of sixty five was scaled to a percentage, for comparability. Membership in the experimental or control group was used as one main variable in each analysis, with previous chemistry (defined as at least grade ten), grade eleven average, grade eleven algebra, EPI extraversion-introversion score, and EPI neuroticism-stability score, used successively as the other. It was thus possible to identify any interaction between treatment and each of these variables, as well as the main effects in each case. Grade eleven average, grade eleven algebra, and previous chemistry were used as covariates whenever they were not involved as main variables. Because neither personality score correlated significantly with any of the criterion variables, they were not used as covariates. If subsequent analysis had indicated a curvilinear relationship, the appropriate variable would have been included trichotomously as a covariate.

Means, standard deviations, and intercorrelations for the relevant continuous variables are given in tables V, VI.

TABLE V

MEANS AND STANDARD DEVIATIONS
N = 60

Variable	Mean	Standard Deviation
Grade XI Average	68.2	4.4
Grade XI Algebra	68.5	9.4
Mid Semester	64.2	16.9
Final Examination	53.8	15.0
Examinations Weighted and Combined	56.3	14.6
Extraversion	14.5	3.5
Neuroticism	13.5	4.6

TABLE VI

INTERCORRELATIONS AMONG ALL CONTINUOUS VARIABLES FOR COMBINED GROUPS

N = 60

Grade XI Average	1.00	.51**	.43**	.37**	.41**	-.04	.01
Grade XI Algebra		1.00	.39**	.34**	.37**	-.09	.04
Mid Semester			1.00	.70**	.82**	-.13	-.12
Final Examination				1.00	.98**	-.09	-.13
Examinations weighted and combined					1.00	-.11	0.14
Extraversion						1.00	-.02
Neuroticism							1.00

**significant at .01 level.

*significant at .05 level.

It can be seen from Table VI that both the mid semester and final examination, as well as the weighted combination of these scores, correlate significantly (at the .05 level) with grade eleven average and also with grade eleven algebra. Hence these variables would be expected to exert a significant influence in a regression equation developed to predict performance on the separate or combined criterion variables. On the contrary, both personality variables correlated poorly with each of the criterion variables and hence, unless a curvilinear relationship exists, would be expected to contribute little to the regression equation. It may be noted that the actual numerical values of these correlations were similar to those in a number of the studies described in chapter two, but the smaller sample size mitigates against a significant effect. The almost zero correlation of the two personality variables with one another supports Eysenck's contention that the scales are orthogonal. The correlation between grade eleven average and grade eleven algebra mark (.51) is high enough to suggest that little might be gained in the value of R^2 by including the latter as a covariate in the regression equations. However, it was found that the actual increase was sufficient to warrant inclusion. Finally, the fairly high correlation (.70) between scores on mid-semester and final examination suggests good reliability between these examinations.

Hypothesis one was effectively tested simultaneously with each sub hypothesis of hypothesis two. In each case four regression models were developed and from these three F ratios were developed to determine the significance of interaction and of each main effect. This was repeated using final examination and combined score as criterion variables. An identical procedure, using appropriate covariates in each case, was applied to further test the main hypothesis and each sub hypothesis of hypothesis two.

The Effects of Treatment and Previous Chemistry

Treatment and previous chemistry were used as dichotomous main variables in developing regression equations. Grade eleven average and grade eleven algebra score were used as continuous covariates. Scores on the mid-semester examination, and final examination, and the weighted combination of these, were used successively as criterion. The equations were used in the manner previously described, and the results of this analysis are shown in Tables VII, VIII, and IX.

Table VII indicates that the mean performance of the experimental group was better than that of the control group on each examination, and hence also when the examination scores were combined. However, large within group variances minimized the effect of the apparently large mean differences, and these differences were consequently statistically insignificant. The second main effect, the effect of previous chemistry, was significant at the .01 level in the mid semester and marginally insignificant in the final examination. Consequently a marginally significant interaction in the final examination, was observed which is illustrated in Figure 1.

The reasons for this are somewhat hypothetical. While the final examination marks are lower than the mid semester marks for each cell, the difference is much more marked for the experimental group with previous chemistry. Whereas in the mid semester examination both experimental and control group contributed almost equally to the difference

TABLE VII

MEANS AND STANDARD DEVIATIONS
(Grouped by treatment and previous chemistry)

Group	Mid-semester	Final	Examinations Combined
Experimental	69.1	56.0	59.2
	(14.9)	(14.0)	(13.6)
With chemistry	74.1	57.0	61.1
	(12.0)	(13.1)	(12.4)
Without chemistry	64.5	55.1	57.3
	(15.8)	(14.8)	(14.4)
Control	59.5	51.7	53.5
	(17.4)	(15.5)	(15.0)
With chemistry	66.7	59.3	61.2
	(12.1)	(13.2)	(11.9)
Without chemistry	55.0	46.9	48.7
	(18.7)	(14.9)	(14.7)
Combined Groups	64.5	53.9	56.5
	(16.0)	(14.8)	(14.2)
With chemistry	70.7	58.1	61.1
	(12.6)	(13.1)	(12.2)
Without chemistry	59.2	50.5	52.5
	(18.1)	(14.8)	(15.2)

With chemistry defined as having taken at least grade ten. Examinations combined score arrived at by weighting Final examination to Mid semester in a ratio of 50:15.

TABLE VIII

R^2 FOR EACH MODEL

(treatment and previous chemistry)

Model	Restriction	R^2
1	none	.355
2	no interaction	.348
3	no difference by treatment	.317
4	no difference by previous chemistry	.267
5	none	.270
6	no interaction	.219
7	no difference by treatment	.216
8	no difference by previous chemistry	.173
9	none	.321
10	no interaction	.281
11	no difference by treatment	.272
12	no difference by previous chemistry	.218

Models 1 - 4 mid semester examination.

Models 5 - 8 final examination.

Models 9 -12 examinations combined.

TABLE IX

F TESTS

(effect of treatment and previous chemistry)

Testing	Models	df	F	Probability
Mid Semester				
Interaction	1:2	1/54	0.633	-
Effect of treatment	2:3	1/55	2.629	.111
Effect of previous chemistry	2:4	1/55	6.781	.011
Final				
Interaction	5:6	1/54	3.780	.057
Effect of treatment	6:7	1/55	0.197	-
Effect of previous chemistry	6:8	1/55	3.282	.075
Examinations combined				
Interaction	9:10	1/54	3.258	.077
Effect of treatment	10:11	1/55	0.645	-
Effect of previous chemistry	10:12	1/55	4.796	.032

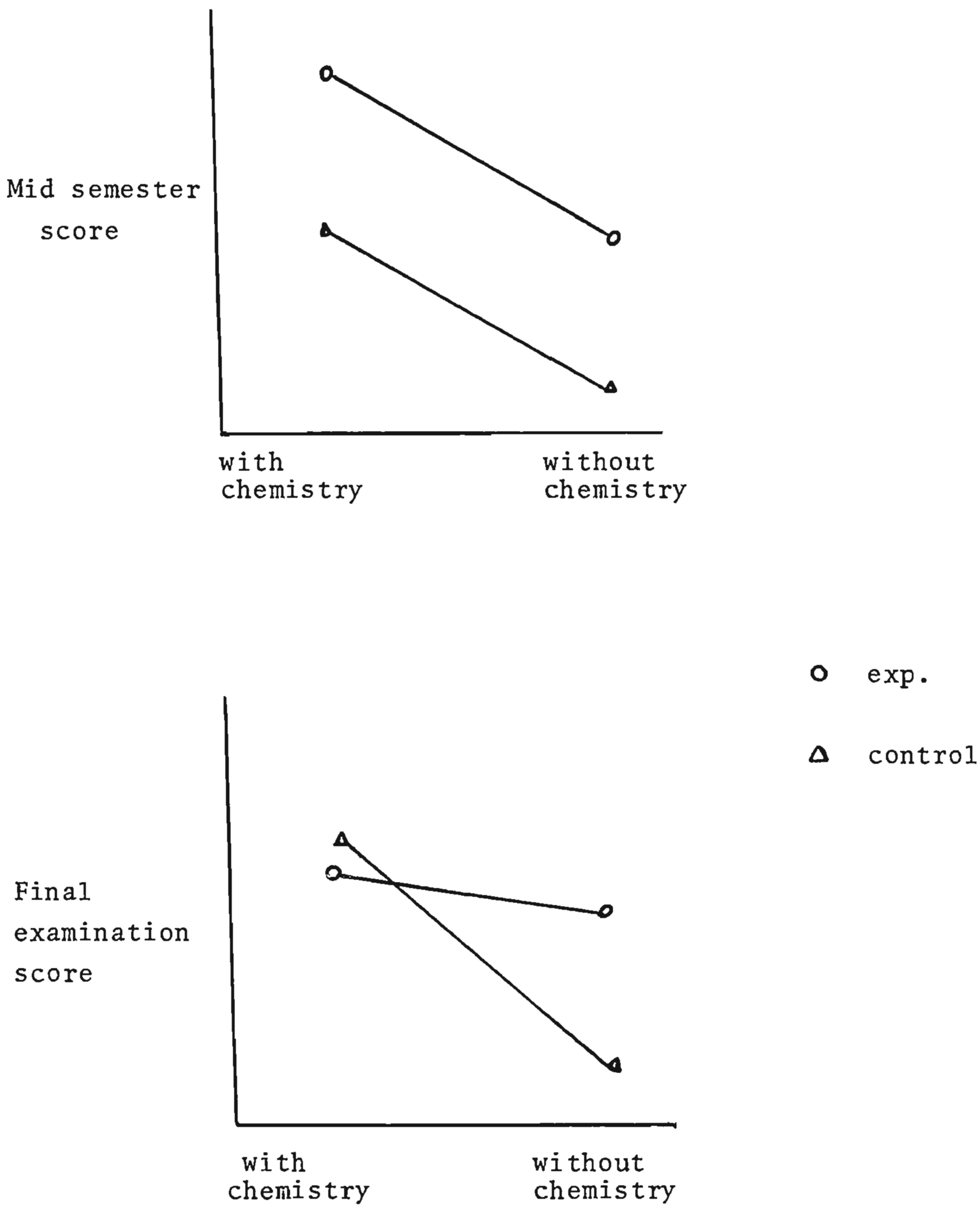

Figure 1

Interaction between treatment and previous chemistry between those with and without previous chemistry, in the final examination this difference can be attributed entirely to control group students without chemistry. The difference between experimental and control group students without previous chemistry was maintained with little change, suggesting that for these students the result might be only marginally insignificant. Conversely, the results could suggest that the experimental treatment was not beneficial to those students with previous chemistry. However, it was noted in chapter three that self pacing effectively ceased at the mid semester break. The author noted some disillusionment on the part of the fastest group of nine students, most of whom had previous chemistry. It is entirely possible that this was the cause of the relatively large change in attainment for those students.

The Effects of Treatment and General Ability

The effect of treatment was again tested, this time using grade eleven averaged trichotomized equally as the other main effect. Previous chemistry, categorically, and grade eleven algebra, continuously, were used as covariates. Means and standard deviations are given in Table X, R^2 for each model in Tables XI, and F ratios and probabilities in Table XII.

The data given in Table X, indicates that the experimental group performed better than the control group on each examination, and, hence on the combined score. However, while this effect was significant at the .05 level on the mid semester examination, it was quite insignificant on the final examination and overall. Again it might be suggested that this difference could have been caused by the particularly large drop suffered by the experimental students with previous chemistry, but it must be reiterated that this is hypothetical. The second main effect, general ability, was also significant at the .05 level in the mid semester and insignificant in the final examination. The cause of this change is not clear. It may be simply that the already low R^2 values became so low for the final examination that no significance can be attached to the results from that examination. In each case interaction was insignificant. Hence it cannot be claimed that either an individualized or a large group treatment is particularly beneficial for high, medium or low ability students within the ability range of the sample. It must be remembered, however, that the ability range itself was restricted to medium to low for the university population by the method of selection for the course.

TABLE X

MEANS AND STANDARD DEVIATIONS
(Grouped by treatment and general ability)

Group	Mid-semester	Final	Combined
Experimental			
High ability	75.3	61.1	64.5
	(11.8)	(13.8)	(12.6)
Medium ability	73.4	59.3	62.7
	(9.5)	(8.4)	(8.0)
Low ability	57.3	46.4	49.1
	(15.8)	(14.0)	(13.8)
Control			
High ability	64.7	53.9	56.4
	(18.6)	(17.3)	(16.4)
Medium ability	61.2	53.6	55.3
	(16.6)	(13.9)	(13.6)
Low ability	52.9	47.5	48.8
	(15.2)	(14.8)	(14.1)
Groups combined			
High ability	70.5	57.9	60.9
	(16.0)	(15.9)	(15.0)
Medium ability	66.4	56.0	58.5
	(15.3)	(12.2)	(12.0)
Low ability	55.0	47.0	48.9
	(15.6)	(14.4)	(14.0)

High - top one third of sample in grade eleven average.
Medium - middle one third of sample in grade eleven average.
Low - bottom one third of sample in grade eleven average.

TABLE XI

R^2 FOR EACH MODEL

(treatment and general ability)

Model	Restriction	R^2
1	none	.365
2	no interaction	.352
3	no difference by treatment	.301
4	no difference by general ability	.272
5	none	.228
6	no interaction	.206
7	no difference by treatment	.196
8	no difference by general ability	.158
9	none	.291
10	no interaction	.269
11	no difference by treatment	.249
12	no difference by general ability	.209

Models 1 - 4 mid semester examination.

Models 5 - 8 final examination.

Models 9 -12 examinations combined.

TABLE XII

F TESTS

(effect of treatment and general ability)

Testing	Models	df	F	Probability
Mid Semester				
Interaction	1:2	2/51	0.541	-
Effect of treatment	2:3	1/53	4.14	.047
Effect of general ability	2:4	2/53	3.25	.047
Final				
Interaction	5:6	2/51	0.746	-
Effect of treatment	6:7	1/53	0.648	-
Effect of general ability	6:8	2/53	1.58	.215
Examinations combined				
Interaction	9:10	2/51	0.788	-
Effect of treatment	10:11	1/53	1.43	.236
Effect of general ability	10:12	2/53	2.19	.122

The Effects of Treatment and Mathematical Ability

As has been previously indicated grade eleven algebra score was considered a relevant indicator of mathematical ability. The sample was trichotomized according to this score. This was used as one main variable and presence in experimental or control group the other. Previous chemistry, categorically, and grade eleven average score were used as covariates. The results are shown in Tables XIII, XIV, XV.

Table XIII suggests that mathematical ability was more important for the experimental group. However the insignificant interactions shown in Table XV deny this. Again, Table XIII suggests the likelihood of a significant difference for each main effect, but Table XV indicates that at best these effects can be said to approach marginal significance (both at the .12 level), and warrant further research. The low value for each R^2 in Table XIV is disappointing, and mitigates against meaningful interpretation.

TABLE XIII

MEANS AND STANDARD DEVIATIONS

(grouped by treatment and mathematical ability)

Group	Mid-semester	Final	Combined
Experimental			
High math ability	76.9	60.3	64.3
	(7.9)	(13.2)	(11.4)
Medium math ability	73.3	60.8	63.8
	(11.7)	(8.8)	(9.2)
Low math ability	54.1	43.9	46.4
	(14.4)	(14.1)	(13.0)
Control			
High math ability	65.9	57.6	59.6
	(18.3)	(14.1)	(13.6)
Medium math ability	59.9	54.1	55.6
	(15.4)	(8.2)	(8.9)
Low math ability	54.4	45.3	47.3
	(16.8)	(18.5)	(17.4)
Groups combined			
High math ability	71.4	58.9	61.9
	(15.1)	(13.7)	(12.8)
Medium math ability	67.2	57.8	60.1
	(15.0)	(9.2)	(10.0)
Low math ability	54.3	44.8	47.0
	(15.9)	(16.9)	(15.8)

High - top one third of sample, grade eleven algebra.
Medium - middle one third of sample, grade eleven algebra.
Low - bottom one third of sample, grade eleven algebra.

TABLE XIV

R^2 FOR EACH MODEL

(treatment and mathematical ability)

Model	Restriction	R^2
1	none	.394
2	no interaction	.363
3	no difference by treatment	.333
4	no difference by math ability	.333
5	none	.279
6	no interaction	.267
7	no difference by treatment	.265
8	no difference by math ability	.206
9	none	.340
10	no interaction	.323
11	no difference by treatment	.316
12	no difference by math ability	.265

Models 1 - 4 mid semester examination.

Models 5 - 8 final examination.

Models 9 -12 examinations combined.

TABLE XV

F TESTS

(effect of treatment and mathematical ability)

Testing	Models	df	F	Probability
Mid Semester				
Interaction	1:2	2/51	1.299	.281
Effect of treatment	2:3	1/53	2.481	.121
Effect of math ability	2:4	2/53	1.261	.292
Final				
Interaction	5:6	2/51	0.438	-
Effect of treatment	6:7	1/53	0.117	-
Effect of math ability	6:8	2/53	2.193	.121
Examinations combined				
Interaction	9:10	2/51	0.655	-
Effect of treatment	10:11	1/53	0.511	-
Effect of math ability	10:12	2/53	2.255	.115

The Effect of the Personality Trait Extraversion-Introversion

In testing both the effect of extraversion-introversion and neuroticism-stability it was impossible to obtain reasonably equal cell sizes for analysis. Hence, two random selections were taken, with an N of 42 in each case. The personality score was trichotomized to provide six cells of seven students each. Grade eleven average, grade eleven algebra score, and previous chemistry were used as covariates. The results for both random selections are shown in Tables XVI, XVII, XVIII.

Introverts appeared to be most successful, in agreement with the findings quoted in several of the papers discussed in the literature review. Secondly the experimental and control groups differed most for those with medium scores on the extraversion-introversion scale, suggesting a possible interaction. However, neither interaction nor either of the main effects was statistically significant. The observation that introverts performed better appeared to be marginally significant in one determination but was so insignificant in the other that it must be discounted. This was substantiated by taking a third random selection, although no data is presented for this. Further it was clear that nothing was added by analysis of the combined examination scores, and these were hence omitted.

TABLE XVI

MEANS AND STANDARD DEVIATIONS
(grouped by treatment and extraversion-introversion)

Group	Mid-semester		Final	
	(1)	(2)	(1)	(2)
Experimental	70.3	67.2	56.8	53.8
	(15.3)	(13.6)	(12.6)	(14.8)
High (extravert)	62.9	64.7	51.0	53.3
(≥ 17)	(19.0)	(16.4)	(14.5)	(16.5)
Medium	72.6	73.9	55.4	53.9
(14 - 16)	(6.2)	(9.8)	(6.4)	(10.1)
Low (introvert)	75.4	65.8	61.9	53.9
(< 14)	(14.4)	(14.2)	(14.3)	(16.9)
Control	61.2	59.3	53.6	52.3
	(15.5)	(18.4)	(12.6)	(14.5)
High (extravert)	56.6	56.6	51.4	51.4
(≥ 17)	(14.9)	(14.9)	(12.8)	(12.8)
Medium	59.6	51.3	49.3	42.9
(14 - 16)	(16.5)	(18.1)	(12.6)	(13.1)
Low (introvert)	67.9	70.2	61.4	62.6
(< 14)	(15.6)	(16.4)	(12.0)	(10.1)
Combined groups	65.8	63.3	55.2	53.1
	(15.4)	(16.0)	(12.6)	(14.5)
High (extravert)	59.7	60.6	51.2	52.4
	(17.4)	(15.3)	(13.7)	(14.6)
Medium	66.1	62.6	52.4	48.4
	(14.1)	(13.4)	(10.5)	(11.4)
Low (introvert)	71.6	68.0	61.6	58.3
	(15.5)	(15.4)	(13.2)	(12.8)

TABLE XVII

R^2 FOR EACH MODEL

(treatment and extraversion-introversion)

Model	Restriction	R^2 (1)	R^2 (2)
1	none	.502	.405
2	no interaction	.490	.356
3	no difference by treatment	.471	.323
4	no difference by extraversion-introversion	.399	.331
5	none	.494	.258
6	no interaction	.482	.216
7	no difference by treatment	.481	.216
8	no difference by extraversion-introversion	.430	.185

Models 1 - 4 mid semester examination.

Models 5 - 8 final examination.

TABLE XVIII

F TESTS

(effect of treatment and extraversion-introversion)

Testing	Models	df	F (1)	F (2)	Probability (1)	Probability (2)
Mid Semester						
Interaction	1:2	2/32	0.389	1.308	-	.284
Effect of treatment	2:3	1/34	1.249	1.738	.271	.196
Effect of extraversion-introversion	2:4	2/34	3.019	0.656	.062	-
Final						
Interaction	5:6	2/32	0.370	0.905	-	-
Effect of treatment	6:7	1/34	0.074	0.016	-	-
Effect of extraversion-introversion	6:8	2/34	1.722	0.689	.193	-

The Effect of the Personality Trait Neuroticism-Stability

Neuroticism-stability was investigated in a similar fashion to extraversion-introversion. The score was again trichotomized to provide equal cells containing seven students, after randomly selecting twenty-one students from each group. Two such selections were made. Grade eleven average, grade eleven algebra score, and previous chemistry were again used as covariates. The results for both selections are presented in Tables XIX, XX, XXI. Again analysis of the combined scores was considered superfluous.

It may be noted that the tendency towards a marginally significant difference in favour of the experimental group in the mid semester examination which has been observed previously occurs again, and further that this again becomes quite non significant in the final examination. In both mid semester and final examination the effect of the personality trait neuroticism-stability is clearly non-significant. However, three of the four interaction terms suggest a tendency towards some interaction (.09, .12, .15) between this trait and presence in control or experimental group. Further, although there is no consistent appreciable difference between those in experimental and control group with medium and low neuroticism scores, there is an appreciable difference for those with high neuroticism scores. In this latter group those receiving the individualized treatment appear to benefit much more than those in the control group.

TABLE XIX

MEANS AND STANDARD DEVIATIONS
(grouped by treatment, neuroticism-stability)

Group	Mid semester		Final	
	(1)	(2)	(1)	(2)
Experimental	70.8	68.8	55.3	56.9
	(15.6)	(11.2)	(14.3)	(14.3)
High (neurotic)	74.8	75.3	60.3	58.1
(≥ 16)	(14.8)	(10.0)	(11.7)	(13.7)
Medium	73.6	68.6	57.6	64.4
(11 - 15)	(12.4)	(8.2)	(13.7)	(9.6)
Low (stable)	62.3	62.3	48.1	48.1
(< 11)	(18.2)	(18.2)	(14.3)	(14.3)
Control	58.9	61.0	55.9	52.4
	(15.8)	(16.8)	(15.7)	(13.6)
High (neurotic)	45.9	57.9	44.1	45.3
(≥ 16)	(14.7)	(13.3)	(15.4)	(8.2)
Medium	68.3	62.7	62.7	51.3
(11 - 15)	(11.2)	(22.7)	(13.2)	(15.7)
Low (stable)	62.4	62.4	60.7	60.7
(< 11)	(11.7)	(11.7)	(11.0)	(11.0)
Groups combined	65.4	65.0	55.6	54.7
	(15.6)	(13.8)	(15.0)	(13.9)
High (neurotic)	60.3	66.7	52.2	51.7
	(14.7)	(11.7)	(13.6)	(10.2)
Medium	70.9	65.7	60.1	57.9
	(11.9)	(16.5)	(13.4)	(11.9)
Low (stable)	65.4	62.4	54.4	54.4
	(14.8)	(14.5)	(12.9)	(12.9)

TABLE XX

R^2 FOR EACH MODEL

(treatment, neuroticism-stability)

Model	Restriction	R^2 (1)	R^2 (2)
1	none	.509	.376
2	no interaction	.433	.361
3	no difference by treatment	.340	.312
4	no difference by neuroticism-stability	.407	.337
5	none	.328	.412
6	no interaction	.233	.339
7	no difference by treatment	.232	.320
8	no difference by neuroticism-stability	.216	.328

Models 1 - 4 mid semester examination.

Models 5 - 8 final examination.

TABLE XXI

F TESTS

(effect of treatment and neuroticism-stability)

Testing	Models	df	F		Probability	
Mid-semester			(1)	(2)	(1)	(2)
Interaction	1:2	2/32	2.485	0.372	.099	-
Effect of treatment	2:3	1/34	5.552	2.661	.024	.111
Effect of neuroticism-stability	2:4	2/34	0.789	0.662	-	-
Final						
Interaction	5:6	2.32	2.257	1.996	.121	.152
Effect of treatment	6:7	1/34	0.076	0.951	-	-
Effect of neuroticism-stability	6:8	2/34	0.381	0.265	-	-

Too much significance cannot be attached to this effect but it does suggest the desirability of further research.

Student Attitude to the Treatment

Response to individualized courses in science has been varied, but is generally claimed to be at least moderately enthusiastic. To elicit some attitudinal response to the treatment used in the present study, a brief questionnaire was given to the students. This was completed in normal class time toward the end of the course. The questionnaire was not validated in any way, and the results should be considered in terms of the general impression conveyed only. The results are detailed in appendix A and will be summarized here.

Almost half the students said they would have preferred a lecture course, despite the fact that almost all of them felt that their achievement was at least as high as it would have been in a regular class. Meetings with the instructor were rated highly, but it appeared that other students were consulted more often than the instructor when help was needed. Most students claimed that they did not use the resource room more than occasionally, although most of those who used it claimed that the material contained there was useful, at least. The learning guides, on the other hand, were rated highly, with only one student claiming that they were not helpful. Finally, response to the question 'would you do another course this way?' was no more than mildly positive.

In general student reaction to the experimental treatment could perhaps be considered apathetic. The results of this questionnaire must be treated with caution, but it seems clear that any cognitive gains made by the experimental group relative to the control group are not due to significant differences in affective gain. On the contrary, evidence from another questionnaire administered by the administration indicated that the control group rated both the course and their teacher appreciably more highly than did the experimental group. This may coincide with the suggestion made earlier that the nature of the previous education received by these students mitigates against ready acceptance of a treatment involving substantial self direction. Hence, it is reiterated that it is quite possible that this exerted a negative influence on the student achievement, perhaps tending to nullify benefit from the nature of the experimental treatment.

CHAPTER V

IN CONCLUSION

SUMMARY

It seems likely that educationists will always disagree, to some extent at least, about how to optimize learning for their students. The present study was concerned with one aspect of such disagreement. It was designed to add to existing evidence regarding the effectiveness of individualization of instruction as a means of optimizing learning. Further, it was hoped to identify factors which might aid in selection of students for such an approach. The meaning of individualized instruction is not precise. In theory each learner should be involved in selecting his own objectives as well as progressing at a rate optimum to himself. Ideally there should be as many distinct programs as individuals. In practice, the majority of programs appear to involve self pacing as a major component, with minor deviations of content. There are good reasons for this, in the science area at least. Many science curricula are necessarily sequential. This is true of Chem Study, which develops mainly through an integration of conceptual themes. The present study not only applied the Chem Study materials, but the content of the particular course was a necessary prerequisite to succeeding courses. Thus it is not surprising that the self pacing aspect of individualized study was emphasized in the present study. Nevertheless, the individual was free to work individually or in small groups, as he wished, and emphasis in treatment to some extent and in remediation to a larger extent, were apparent.

The sample consisted of two groups of about thirty students each, one of which was exposed to an individualized treatment with almost no formal lectures. The other group was treated by a normal group presentation, involving three lectures and an optional tutorial per week. Both groups knew they were part of an experiment.

Each member of the experimental group was given a learning guide consisting of behavioral objectives, a learning flow chart, and suggested readings and exercises. Each student could opt to be tested on a unit of work when he required, within a suggested schedule.

Criterion tests were a mid semester examination of one hour duration and a final examination of two hours duration. Both examinations contained a free response and an objective part. Analysis was by means of a series of regression equations, incorporating appropriate covariates.

CONCLUSIONS

Hypothesis one, that the provision of an individualized course will produce significantly greater achievement, must be rejected, but with some reservation. The level of significance varied depending on which variables or covariates were used. In several cases the difference, in favour of the experimental group, was significant at the .05 level for the mid semester examination. It was never significant for the final examination or for the combined score. This suggests that even marginal significance should be rejected. However, the combination of marginal significance for the intact groups in the mid semester examination, and an interaction (at the .05 level) in the final examination in favour of those without previous chemistry in the experimental group, suggests that for this kind of student the removal of the constraints of a group presentation may be beneficial. Whether or not it is beneficial for those with previous chemistry depends on the interpretation placed upon the relatively large decrease in attainment suffered by these students in the experimental group from mid semester to final examination. If, as has been previously suggested, the decrease in attainment for these students was caused by an adverse change of attitude, it can be argued that at least a marginally significant gain could be attributed to the experimental treatment.

Hypothesis 2A was concerned with the possibility that previous chemistry might affect achievement differently in an individualized class than when a group presentation was made. Taken at face value the results of the final examination indicated that such an interaction did exist; that students without previous chemistry were helped significantly by the individualized treatment; and that the null hypothesis should be rejected. As has been indicated, such a conclusion depends on interpretation of what happened, between the mid semester and final examination, to those students with previous chemistry in the experimental group. Further generalization is therefore difficult.

Hypothesis 2B suggested that general ability would not interact with treatment. The data gave no hint of interaction, and hence for the immediate population the null hypothesis must be retained. However this population represents a narrow spread of ability, by nature of selection for the course. Hence it is not possible to refute the possibility of a differential effect in general. It may also be noted that general ability might be said to have contributed a marginally significant effect on achievement for the sample as a whole, at least in the mid semester examination.

Hypothesis 2C suggested that mathematical ability would not interact with treatment. Again there was no suggestion that the null hypothesis should not be retained. Further, in this case the range of grade eleven scores was not severely restricted. It is thus possible to generalize more liberally the finding that mathematical ability did not interact with treatment. The effect of mathematical ability on the sample as a whole was to exert a marginally significant influence on achievement.

Hypothesis 2D, that introverts would achieve more in the individualized class and extraverts in the group presentated class, was not substantiated. In no case was a significant interaction observed. Despite this it was noted that in each of the four analyses carried out the greatest difference between experimental and control group was shown by those with medium scores on the extraversion-introversion scale, always favoring the individualized group. It should also be noted that the designation introvert-extravert has no absolute significance for the students in this sample. Three divisions were made arbitrarily. Thus extraverts were those with a score of seventeen or more on the Eysenck scale, while introverts were those with a score of less than fourteen.

Hypothesis 2E related to a possible differential effect caused by the degree of neuroticism of the student. While the effect of this trait clearly was insignificant for the sample as a whole, and the interaction was also insignificant, it did appear that those students with high neuroticism scores fared considerably better in the experimental group. It must be conceded however, that this can be held only to suggest that further research might be profitable. Again the actual divisions are arbitrary, those with a score greater than fifteen being considered neurotic and those less than eleven stable. In practice the divisions made on both personality scales agree favorably with the norms for American college students published in the Eysenck manual, and hence these findings may be considered quite generalizable.

IMPLICATIONS

In chapter one it was noted that substantial cognitive and affective gains have been observed for students enrolled in individualized introductory psychology courses. In chapter two it became apparent that such spectacular gains have not generally been observed for students enrolled in similar courses in the pure sciences. In the area of chemistry the studies by De Rose, Day and Houk, and Becht might be said to provide quantitative support, but in each case the evidence was not equivocal. The present study offers further support of this kind. At least for those students without previous chemistry, the results of the present study suggested that individualized instruction in introductory chemistry is potentially profitable. There is no reason to suppose that such a conclusion cannot be generalized to other sciences, although it must be stressed that the level of significance was marginal. Further, it must be recognized that individualized instruction, like any other form of instruction, will not be equally beneficial to all. The present study, therefore, sought to identify factors which might be used to predict success in such a treatment.

The intellective factors, general ability and mathematical ability, appeared not to interact with treatment. The effects of the personality traits, extraversion-introversion and neuroticism-stability were not definitive, but there were indications that identification of these traits could be useful as determinants of success in individualized study. Thus, it appears possible that those with relatively high neuroticism scores, and those who are not particularly extraverted or introverted, may benefit most from an individualized treatment. However, this implies a direction for further research rather than providing strong evidence for the use of these measures.

In terms of operational details the present study generally offers support to the suggestions from other studies which were quoted in chapter two. These students too favored the provision of fairly precise objectives. The weaker students tended to fall below an optimum rate unless provided with deadlines. The better students, conversely, were more concerned that a sequential course should be available. Hence both groups needed an extrinsic source of motivation. For each kind of student mastery learning, although apparently acceptable as a concept, was not well received in practice.

LIMITATIONS

The limitations of the present study may be viewed in terms of external and internal validity. Thus several factors exist which limit the extent to which any findings may be generalized. Other factors, more hypothetically, may have adversely affected the effectiveness of the experimental treatment. In the opinion of the author four such factors mitigated against a more significant gain for the experimental group. There is no reason to suppose that these would not have exerted a similar influence in studies elsewhere.

Firstly, the conditions under which the study was performed were not ideal. At the time of the study, although to a lesser extent now, apart from a small resource room in the chemistry department there was nowhere for the students to work. Hence they were required to attend the regular classroom at the normal time for their section. This was not conducive to a good working atmosphere for individual study. Such an atmosphere seems essential.

Secondly, the students clearly felt tied to a semesterized system and to norm referenced evaluation. The average student was not prepared to risk failing to complete the course in one semester, even if this meant risking failing the course itself--which happened in several cases. Thus extensive remedial work was difficult to impose and mastery learning was impossible.

Thirdly, it is clear that a substantial change in teacher role was necessary, and it seems likely that experience is needed to produce a better teacher performance. In this respect it is of interest that the teacher was not rated well by the students, but was rated very highly by many of the same students in the subsequent group presented course.

Fourthly, and in the author's opinion most importantly, the change in role expected of the students themselves may have been too great. The educational climate in Newfoundland is undergoing rapid change. It seems likely, however, that these students had come through a fact centred, teacher oriented system. What study skills they had developed were not attuned to a method requiring a substantial element of self direction.

Just as a typist would take time to change to a new style, so it is possible that by the end of one semester these students had still not adapted. It is also possible that adaptation would be more rapid if several subject areas were treated in a similar fashion. Thus it may be suggested that, instead of a Hawthorne effect aiding the experimental group, their performance may have been inhibited thereby minimizing the effect of the experimental treatment.

Several other limitations are apparent. The use of a different teacher was clearly undesirable. However, as has been previously discussed, this may not be too serious a limitation in this study. Secondly, the squared multiple correlations of the regression models were all low. In no case was more than fifty per cent of the variance accounted for. This is not uncommon but it does restrict meaningful interpretation of results. Thirdly, it is clear that the findings of this study cannot strictly be generalized beyond Foundation students at Memorial University. However, it may be reasonably hoped that the materials produced and the lessons learned may have some generalizability to other Chem Study students, both at Memorial and in the schools of Newfoundland as it develops there.

FOR FURTHER RESEARCH

It seems certain that individualized instruction is successful for some students, in the hands of some teachers, particularly for some components of the curriculum. The problem for the future, therefore, appears to be the identification of which kinds of students and teachers and which parts of the curriculum, and how to optimize learning within such a framework. It is suggested that further research is needed to delineate the influence of each of the following

1. What factors contribute to the success of individual students in an individualized course? In particular it seems likely that identification of the effect of particular personality traits of students and teachers will be

important.

2. There is some evidence that students differ in their reactions to different media. It seems clear that research designed to elicit more precise information on this aspect of learning will continue.

3. The relative effectiveness of inquiry and expository modes of teaching and learning is of current interest to educators. It seems likely to this author that the success of emphases on such strategies will vary according to the nature of the specific instructional matter, the structure of the discipline, and the personality of the students involved. More importantly in the present context it seems possible that the results of such strategies may be different in an individualized setting.

4. Several references have already been made to the desirability of well formulated objectives in individualized learning. The arrangement of these objectives within a structured validated hierarchy seems potentially more profitable in individualized learning even than it may be in group learning. It seems likely that this will become a focus for future interest.

5. Related to four is the realization that the majority of individualized programs, in the sciences at least, have tended to emphasize differential pacing rather than flexibility of learning. It seems likely that more emphasis will be placed on flexible patterns. The results of this

for subsequent learning will need to be monitored carefully.

6. Related to five are the long term affective results of learning science in an individualized system, as well as the effect of different learning strategies on this.

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APPENDICES

APPENDIX A

QUESTIONNAIRE

Student Attitudes to the Experimental Treatment

1. How much time per week do you spend on this course outside of normal class time? Try to give an average not a maximum or minimum. — 5.8 hours average

2. Would you have preferred to have a regular lecture course? Yes or No — 45% Yes

3. Would you have preferred not to have to attend the classroom at all? Yes or No — 10% Yes

4. If the answer to 3 is Yes, would you have worked at regular class time? Yes or No — -

5. If the answer to 4 is Yes, where would you have worked? ________ — -

6. How often did you consult your instructor, outside of class time?
   - (a) whenever you needed help. — a. 22.6%
   - (b) on most occasions when you needed help. — b. 16.1%
   - (c) sometimes when you needed help. — c. 19.3%
   - (d) occasionally when you needed help. — d. 32.2%
   - (e) never. — e. 9.8%

7. How do you rate such meetings?
   - (a) very useful — a. 34%
   - (b) quite useful — b. 38%
   - (c) useful — c. 24%
   - (d) not very useful — d. 4%
   - (e) useless — e. 0%

8. How often did you consult other students?

(a)	whenever you needed help.	a.	19.3%
(b)	on most occasions when you needed help.	b.	19.3%
(c)	sometimes when you needed help.	c.	38.6%
(d)	occasionally when you needed help.	d.	16.1%
(e)	never.	e.	6.7%

9. Did you use the resource room?

(a)	very often	a.	6.7%
(b)	often	b.	10.1%
(c)	occasionally	c.	56.5%
(d)	once or twice	d.	20.0%
(e)	never	e.	6.7%

10. If you used the resource room, was the material

(a)	very useful	a.	10.3%
(b)	quite useful	b.	34.5%
(c)	useful	c.	34.5%
(d)	not very useful	d.	20.7%
(e)	useless	e.	0%

11. How would you rate the learning guides?

(a)	very helpful	a.	27.6%
(b)	quite helpful	b.	31.1%
(c)	helpful	c.	38%
(d)	not very helpful	d.	3.3%
(e)	not at all helpful	e.	0%

12. This course was based on giving you the opportunity to progress at your own rate, so that you would not do new work until you were ready. How do you rate this idea?

(a)	very important	a.	43.7%
(b)	quite important	b.	40.0%
(c)	important	c.	6.3%
(d)	not very important	d.	9.4%
(e)	unimportant	e.	0%

13. When small group sessions were held did you find them

(a) very useful	a.	36.8%
(b) quite useful	b.	30.0%
(c) useful	c.	23.4%
(d) not very useful	d.	9.8%
(e) useless	e.	0%

14. How do you think your achievement in this course compares with what you would have achieved in a regular class?

(a) much higher	a.	20%
(b) higher	b.	23.5%
(c) the same	c.	46.5%
(d) lower	d.	10%
(e) much lower	e.	0%

15. Your personal contact with your instructor in this course as compared with others was

(a) more than any others	a.	7.1%
(b) more than most	b.	32.2%
(c) average	c.	53.5%
(d) less than most	d.	3.6%
(e) less than any others	e.	3.6%

16. Would you do another course this way?

(a) most definitely	a.	9.4%
(b) yes	b.	25%
(c) possibly	c.	50%
(d) no	d.	12.5%
(e) definitely not	e.	3.1%

APPENDIX B

Criterion Examination

I. Mid Semester (1 hour)

SECTION A

Answer all questions

1. Each member of a group of students weighed a beaker empty and then containing a solid. The average value obtained for the weight of the solid was 2.84 ± 0.04 grams. The molecular weight of the solid was 143.4 grams/mole. Which of the following best represents the number of moles of solid in the beaker?

   A. 1.98×10^{-2} mole
   B. 1.980×10^{-2} mole
   C. 2.0×10^{-2} mole
   D. 1.9805×10^{-2} mole
   E. 2×10^{-2} mole

Questions 2 - 4 relate to the following situation:

Assume that a bunsen burner is burning pure gaseous methane, CH_4, with sufficient oxygen to form the products carbon dioxide gas (CO_2) and water, according to the following equation.

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O + \text{heat}$$

2. When 8.0 g of methane, CH_4, burn, how many moles of water will be produced?

   A. 0.5 mole
   B. 1.0 mole
   C. 2.0 moles
   D. 18 moles
   F. 36 moles

3. When 8.0 g of methane, CH_4, burn, the number of grams of carbon dioxide, CO_2, produced is:

   A. 0.50 g
   B. 11 g
   C. 14 g
   D. 22 g
   E. 28 g

4. How many liters of oxygen gas are required to burn 1.5 liters of methane gas, CH_4, according to the equation given above? Both gases are measured at room conditions of temperature and pressure.

A. 1.5 liters
B. 3.0 liters
C. 22.4 liters
D. 32.0 liters
E. 44.8 liters

Questions 5 and 6 related to the following experiment:

Two syringes of equal volume are evacuated, then one is filled with gas A and the other with gas B at the same temperature and pressure. The weight of gas B is found to be 0.80 g, while the weight of gas A is found to be 1.40 g.

5. What is the weight of one molecule of B as compared to one molecule of A? B is

A. 0.25 times as heavy as A
B. 0.40 times as heavy as A
C. 0.57 times as heavy as A
D. 0.80 times as heavy as A
E. 1.8 times as heavy as A

6. If the molecular weight of gas A is 28.0 g, which of the following is the calculated value for the molecular weight of gas B?

A. 49.0 g
B. 8.0 g
C. 24.5 g
D. 16.0 g
E. 32.0 g

7. The volume of a gas collected at 27°C. and 745 mm of mercury was found to be 550 ml. What would be the volume at STP?

A. $550 \times \frac{300}{273} \times \frac{745}{760}$ ml
B. $550 \times \frac{273}{300} \times \frac{745}{760}$ ml
C. $550 \times \frac{300}{273} \times \frac{760}{745}$ ml
D. $550 \times \frac{273}{300} \times \frac{760}{745}$ ml
E. 550 ml

8. One liter of the gas at standard temperature and pressure is found to weigh 5.4 g. The formula for this gas could be

A. SO_2
B. SO_3
C. CCl_2F_2
D. SF_6
E. CCl_4

9. How many atoms of calcium are present in a 3.0-gram sample of solid calcium?

A. 3
B. $\frac{3}{40}$
C. 6.02×10^{23}
D. $3 \times 6.02 \times 10^{23}$
E. $\frac{3}{40} \times 6.02 \times 10^{23}$

10. 0.10 moles of magnesium (Mg) was completely converted to magnesium oxide (MgO). Which of the following, if any, represents the weight of magnesium oxide formed?

A. 40 g
B. 4.0 g
C. 1.6 g
D. 0.10 g
E. None of these

11. For a mixture of the gases NO, N_2, NO_2. Which one of the following statements relating to this system is INCORRECT?

A. The average kinetic energy of NO molecules is the same as that of the N_2 molecules at the same temperature.
B. The average velocity of the NO molecules is the same as that of the N_2 molecules at the same temperature.
C. The temperature of each gas is proportional to the average kinetic energy of its molecules.
D. The partial pressure exerted by each gas is proportional to the number of its molecules.
E. The molecules undergo frequent collisions with each other and with the sides of the container.

12. A small piece of calcium carbonate, $CaCO_3$, reacted with hydrochloric acid producing carbon dioxide gas, CO_2. At 26°C and 756 mm pressure the volume of wet CO_2 collected was 30.0 ml. The vapor pressure of water at 26°C is 25.2 mm.

The fraction of the total pressure caused by the carbon dioxide is

A. $\frac{25.2}{30}$ B. $\frac{25.2}{756}$ C. $\frac{731}{756}$ D. $\frac{30.0}{756}$ E. $\frac{30.0}{25.2}$

13. Hydrogen and chlorine react according to the equation

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

The equation indicates all of the following <u>except</u>

A. The amounts of hydrogen and chlorine that are used up per unit of time.

B. Mass is conserved as hydrogen reacts with chlorine.

C. Atoms are conserved as hydrogen reacts with chlorine.

D. A new chemical compound is formed in the reaction.

E. The physical state of the reactants.

SECTION B

Answer all questions

1. Name the following:

   (a) $AgNO_3$ ____________________

   (b) $NaCl$ ____________________

   (c) CuO ____________________

   (d) $PbCl_2$ ____________________

   (e) HNO_3 ____________________

   (f) NO_2 ____________________

2. Balance the equations:

   (a) ____ Fe + ____ Cl_2 → ____ $FeCl_3$

   (b) ____ C_4H_{10} + ____ O_2 → CO_2 + ____ H_2O

   (c) ____ $Pb(NO_3)_2$ → ____ PbO + ____ NO_2 + ____ O_2

3. Iron reacts with hydrogen chloride according to the equation

$$Fe(s) + 2\ HCl(g) \rightarrow FeCl_2(s) + H_2(g)$$

   If 2.8 g iron reacted

   (a) what weight of $FeCl_2$ would be formed?

   (b) what volume of hydrogen would be collected at 546°K and 2 atm. pressure?

4. Hydrogen and bromine react accordingly to the equation

$$H_2(g) + Br_2(g) \rightarrow 2\ HBr(g)$$

If 30 ml hydrogen and 10 ml bromine were reacted until no further change took place, how much gas would be present at the end, and what would be its composition, assuming no change of temperature and pressure?

5. Calculate the empirical formula of a compound which contained 7.8 g potassium combined with 3.2 g oxygen.

II. Final Examination (2 hours)

SECTION A

Answer all questions.

1. 100 ml of nitric oxide gas (NO) combine with 50 ml of oxygen to form 100 ml of a single gaseous compound. Which of the following equations fits these facts?

   A. $2NO + O_2 \rightarrow 2NO_2$

   B. $2NO + O_2 \rightarrow N_2O_4$

   C. $2NO + 2O_2 \rightarrow 2NO_3$

   D. $NO + O_2 \rightarrow NO_2$

   E. $NO + O \rightarrow NO_2$

2. On analysis a certain compound was found to contain iodine and oxygen in the ratio 254 g of iodine to 80 g of oxygen. The atomic weight of iodine is 127 and that of oxygen is 16. Which of the following is the formula of the compound?

   A. IO B. I_2O C. I_5O_2 D. I_2O_5 E. I_3O

3. A certain element forms a gaseous compound with hydrogen (formula XH_4 where X represents one atom of the element). At STP 44.8 litres of the compound weigh 64 g. Which of the following is the atomic weight of X?

   A. 7 B. 28 C. 32 D. 60 E. 64

4. An atom of bromine weighs more than an atom of hydrogen. Which of the following contains the greatest number of molecules?

   A. 1 g of methyl bromide, CH_3Br

   B. 1 g of methylene dibromide, CH_2Br_2

   C. 1 g of bromoform, $CHBr_3$

   D. 1 g of carbon tetrabromide, CBr_4

   E. All contain the same number of molecules

5. Two particles possessing equal numbers of positive charges repel each other with a force F. If the distance between the particles is halved, the force will be

   A. ¼F B. ½F C. F D. 2F E. 4F

6. 100 ml of neon gas were measured at 0°C (273°K) and 1 atm pressure. What temperature and pressure will be necessary to double the kinetic energy of the molecules, <u>without changing the volume of the gas</u>?

   A. 136½°K and 2 atm
   B. 273°K and 2 atm
   C. 546°K and ½ atm
   D. 546°K and 1 atm
   E. 546°K and 2 atm

7. What is the best description of what happens when a gas is compressed?

   A. The molecules of the gas are made smaller and flattened out.
   B. The molecules of the gas are merely forced closer together.
   C. The pressure decreases.
   D. The volume increases.
   E. Both A and B are correct.

Questions 8 and 9 refer to the following system: Two identical bottles, A and B, which have the same volume, are kept at the same constant temperature. Bottle A is evacuated, filled with 10 grams of neon, and sealed. Bottle B is evacuated, filled with 10 grams of argon, and sealed. (Atomic weights: Ne = 20; Ar = 40.)

8. In bottle A the number of molecules

   A. equals the number of molecules in bottle B.
   B. is twice the number in bottle B.
   C. is one-half the number in bottle B.
   D. varies from one moment to the next, although it is constant on the average.
   E. is 1.5×10^{23}.

9. If these two bottles are joined mouth-to-mouth to form a single large container, the pressure in the system (at the same temperature) will be

   A. greater than originally in B, but less than originally in A.
   B. greater than originally in A, but less than originally in B.
   C. less than the original pressure in either A or B.
   D. equal to the original pressure in A.
   E. equal to the original pressure in B.

10. If XF_2 is the correct formula for a metallic fluoride, the formula for the oxide of X is

    A. X_2O B. XO C. X_2O_3 D. XO_2 E. XO_4

11. Statements A to D below are all true. Which of them, if any, is a suitable explanation for the observation 'Molten sodium chloride conducts electricity well, whereas molten sugar does not conduct at all.'

    A. Sodium chloride has a lower molecular weight than sugar.
    B. Sodium chloride has a higher boiling point than sugar.
    C. Sodium chloride contains ions, while sugar does not.
    D. Sodium chloride has a higher heat of vaporization than sugar.
    E. None of these is the correct explanation.

12. In order to make up one liter of 5.00 M NaCl solution, the amount of solid NaCl the student should weigh out is

    A. 0.40 ± 0.02 g
    B. 11.69 ± 0.02 g
    C. 58.45 ± 0.02 g
    D. 292.25 ± 0.02 g
    E. 584.50 ± 0.02 g

13. Once the proper amount of NaCl is weighed to prepare the solution referred to in question 12, which one of the following procedures would be best?

    A. Place the NaCl in a beaker and add exactly 1 liter of water from a volumetric flask.

    B. Place the NaCl in the beaker and add exactly 1000 ml of water from a one-liter graduated cylinder.

    C. Place the NaCl in a volumetric flask, mix it with somewhat less than 1 liter of water, and then dilute it to the one-liter mark.

    D. Using the beaker and balance, weigh out exactly 1000 g of water and add the NaCl to it.

    E. Dissolve the NaCl in somewhat more than 1 liter of water in a beaker, mix thoroughly, and then fill the volumetric flask to the line with the solution.

14. If one liter of gas E at STP weighs 3.16 grams, the molecular weight of E is

    A. 36 B. 45 C. 71 D. 86 E. 19×10^{23}

15. An atom containing 12 protons and 12 electrons lost 2 electrons. The ion formed would have a charge of

    A. -2 B. +2 C. $+2^2$ D. +12 E. +22

16. In an electrolysis the same quantity of electricity liberated twice as many moles of element X as of magnesium, at the same electrode. If the magnesium ion can be represented as Mg^{2+} how would you represent the ion of X?

    A. X+

    B. 2X+

    C. X^{2+}

    D. X^{4+}

    E. X^{4-}

SECTION B

Answer all questions.

1. Sodium hydrogen carbonate decomposes when heated, according to the equation

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

(a) What weight of sodium carbonate would be produced if 0.1 moles of sodium hydrogen carbonate was completely decomposed?

(b) How many moles of carbon dioxide would have been given off in the same experiment?

(c) What volume would this carbon dioxide occupy at STP?

(d) How many molecules would this volume of gas contain?

2. In this question you will need to use the following data:

Several 10 ml portions of a 0.2 M solution of a substance NaX were put into tubes. Each was mixed with a different volume of a solution of silver nitrate containing 34 g/liter. The height of each precipitate formed was measured. The results are set out below.

Volume of 0.2M NaX	Volume of $AgNO_3$ solution (34 g/l)	Height of Precipitate
10 ml	6 ml	2.8 cm
10 ml	7 ml	3.3 cm
10 ml	8 ml	3.8 cm
10 ml	9 ml	4.2 cm
10 ml	10 ml	4.7 cm
10 ml	11 ml	4.7 cm
10 ml	12 ml	4.7 cm

(a) What is the weight of 1 mole of $AgNO_3$?

(b) What is the molarity of the $AgNO_3$ solution?

(c) What volume of the $AgNO_3$ solution was necessary to react completely with 10 ml NaX?

(d) How many moles of $AgNO_3$ is this?

(e) How many moles NaX were contained in 10 ml solution?

(f) From this data write the equation for the reaction.

3. Water has a molar heat of vaporization of 9.7 kcal per mole.

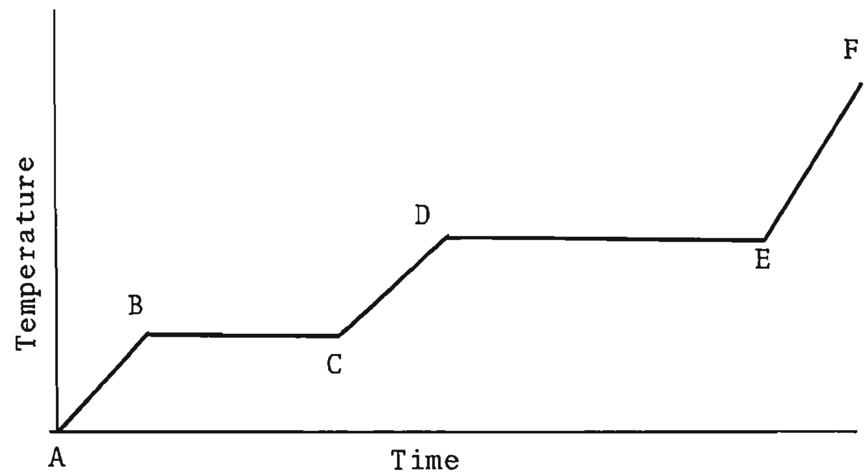
(a) Explain briefly what this means.

(b) Calculate the heat required to raise the temperature of 25 g of liquid water from 0°C to 100°C.

(c) If this same amount of heat vaporized 26 g benzene (molecular weight 78), calculate the molar heat of vaporization of benzene.

(d) From these values which liquid has the greater boiling point? Explain your answer.

4. Consider the following diagram, which represents the behavior of a substance being heated. B represents the melting point of the solid.



Answer the following questions, in terms of kinetic molecular theory.

(a) Explain why the temperature remains the same from B to C?

(b) Explain what is happening at point D.

(c) What would happen to the temperature represented by D if the same experiment was repeated with the same substance, now containing impurity? Explain your answer.

5. (a) The two spheres of a simple electrometer were charged by connecting to the opposite poles of a battery. State and explain what you would expect to happen to the distance between the spheres, and what, if anything, would happen if a metal wire was allowed to touch both spheres simultaneously.

(b) Balance the ionic equations:

(1) ____ $Fe(OH)_3(s)$ → ____ $Fe^{3+}(aq)$ + ____ $OH^-(aq)$

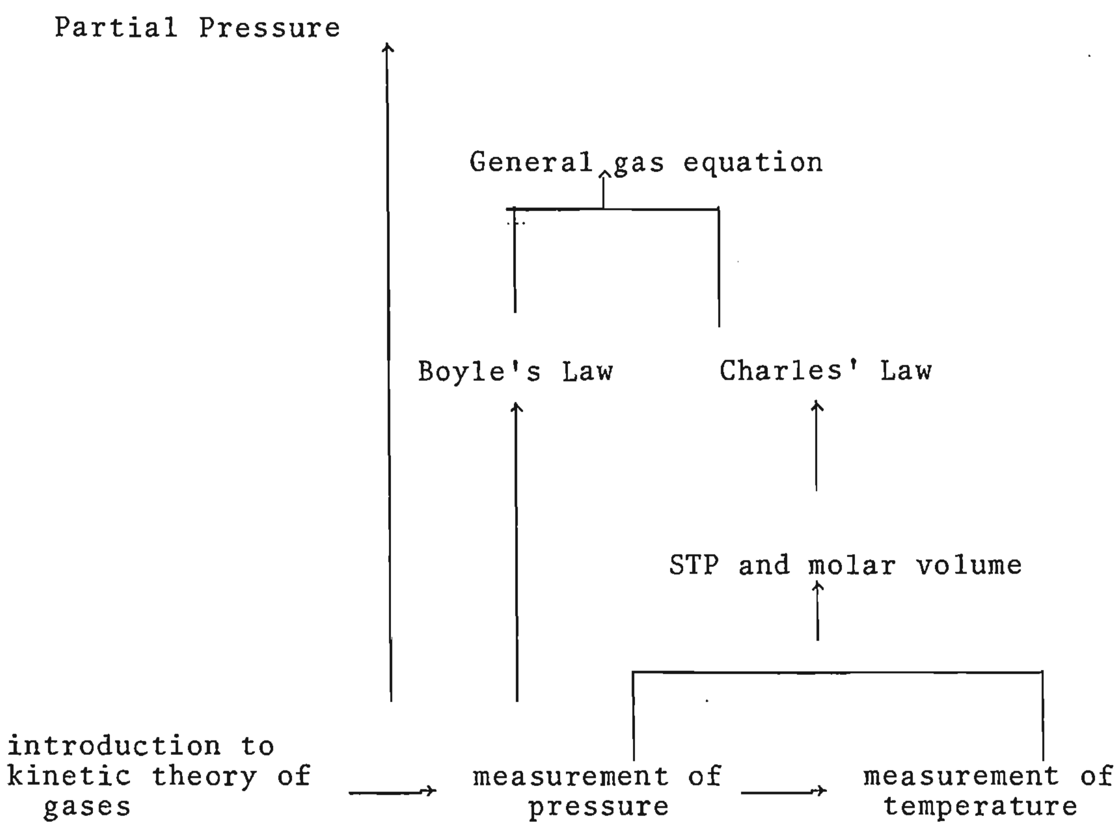
(2) ____ $Al(s)$ + ____ $Cu^{2+}(aq)$ → _____ $Cu(s)$ + $Al^{3+}(aq)$

(c) Give the net ionic equation for the reaction between silver nitrate ($AgNO_3$) and potassium chromate (K_2CrO_4) if the only insoluble product was silver chromate.

APPENDIX C

A SAMPLE LEARNING GUIDE

Learning Guide for Chapter 4



CHAPTER 4

OBJECTIVES

By the end of this chapter you should be able to:

1. Calculate the pressure of a gas, given suitable barometric or manometric data.

2. Convert temperatures on either the Centigrade or Kelvin scales, to the other.

3. Apply Boyle's Law, Charles' Law, the general gas equation, and the definition of molar volume, as appropriate to the solution of typical gas calculations involving the relationships between concentration, volume, temperature, and pressure, including when conditions are quoted as STP.

3. Calculate the partial pressure of each gas in a mixture, given the mass, molar or volume concentrations of the constituents, and given the total pressure or sufficient data to calculate it.

5. Calculate any one of the partial pressure of an individual gas in a mixture, the total pressure, and the combined pressure of every other gas, given the values of the other two variables.

6. Specify the changes occurring on the molecular level in a gas, when one of the variables pressure, volume, temperature, mass of gas present, is considered the dependent variable and one or more of the others is changed.

CHAPTER 4

THE KINETIC THEORY OF GASES

You are probably familiar with some general properties of gases.

1. They are compressible and expandable.

2. They diffuse into one another readily (as one example consider how a smelly gas soon seems to fill a room).

3. They will spread throughout the entire volume of a container, and hence will assume the shape of the container.

To these we might add:

4. The volume occupied by a substance in the gas phase is much greater than the volume occupied by the same mass of the substance when it is a liquid or a solid.

5. The pressure exerted by a fixed mass of gas in a constant volume at a constant temperature, does not vary with time.

All of the above are observed general properties of gases. On the basis of these properties the kinetic theory of gases was proposed. The following statements are included in that theory.

A. The gas molecules are far apart in comparison to their size. (Read section 4-1.1 and answer exercises 4-1 and 4-2).

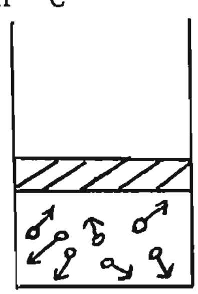
B. The gas molecules are in constant motion in random directions. (Hence, in conjunction with A, diffusion may be explained).

C. Collisions between molecules are elastic, i.e. any energy lost by one molecule on collision is gained by the other. Thus, after collision one of the molecules will move more slowly and the other more quickly. If we consider all of the molecules present, the average velocity remains the same. Refer back to section 1-5.2 (pages 11-13) and you will see how this relates to constant gas pressure.

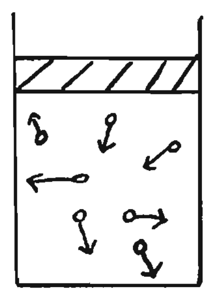
I hope this gives you a clear mental model of a gas. You will find it very useful in future discussions.

Next you should extend your knowledge of gas pressure by reading section 4-2.1. By this stage you may have carried out gas pressure measurements in the laboratory. If not, see me for a demonstration. It is important that you approach this experimentally. When you understand this section do exercise 4-4 and 4-5.

Read sections 4-2.2 and 4-2.3 and then sections 4-3.3 and 4-3.4. Some of the main ideas with which we are concerned here are that the temperature of a gas is a measure of the average kinetic energy of its molecules; that gas volume varies with temperature; and more particularly that the volume of a fixed mass of gas, at a constant pressure is directly proportional to the <u>absolute</u> temperature of the gas (Charles' Law), stated mathematically, $V \propto T$ or $V = kt$ or $\frac{V}{t} = k$. You should be able to convert 0°C to 0°K (or 0°A), using the relationship °K = °C + 273°
Let's emphasize that Charles' Law does NOT APPLY to changes in °C



V = 1 liter at 300°K
(i.e. 27°C)



V = 2 liter at 600°K
(i.e. 327°C)

You can see that the volume has doubled, when the absolute temperature has doubled. The temperature, measured in °C. has increased more than 10 times, but the volume has only doubled. Be clear about this, and you will avoid a common mistake. You might like to ponder about what happens to the gas molecules as they are cooler more and more. We will return to this in the next chapter.

Now look at the following worked example.

example: A fixed mass of gas occupied 250 ml. at 27°C
What would it occupy, if pressure does not change, at -73°C

solution: There are several ways of setting out your answer to this problem.

example: (1) $\frac{V}{T} = k$ i.e. $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ where V_1, T_1 are the original volume and temperature, and V_2, T_2 are the final values. Remember temperatures are in °K, and you must do this conversion first,

$V_1 = 250$ ml $\qquad$ $V_2 = ?$

$T_1 = 300$°K $\qquad$ $T_2 = 200$°K

$$\frac{250}{300} = \frac{V_2}{300} \qquad \text{or} \qquad V_2 = \frac{200 \times 250 \text{ ml}}{300}$$

$$= \frac{2}{3} \times 250 \text{ ml}$$

$$= 166\frac{2}{3} \text{ ml}$$

or, you may (as I would) look at it rationally.

Apply the statement of Charles' Law, this way. If the temperature doubled, so would the volume. If the temperature decreased to ¼ of its original value, so would the volume. In the present example the temperature changes in the proportion 200/300. So does the volume. Hence, final volume is 250 x 200/300 ml.

Do it whichever way you wish, but remember that even simple formulas can be forgotten or confused.

Now try a few yourself.

1. A sample of hydrogen occupies 200 ml. at 27°C. What would it occupy at -23°C. (Answer 166 2/3 ml)

2. A mass of oxygen gas occupies 100 ml. at a temperature of -73°C. At what temperature (in °C) will this same mass occupy 150 ml., the pressure remaining constant. (Answer 27°C)

If you got them right, carry on. If not, see me.

Now you are able to perform calculations involving direct application of Charles' Law. What if both pressure and temperature are allowed to alter? No problem, you just apply the two laws consecutively, e.g. calculate the final volume when 380 ml. of a gas at 27°C and 750 torr is heated to 127°C and the pressure changed to 760 torr.

Method 1: step 1. consider the pressure fixed. When temperature increases proportionately.

$\therefore$ volume becomes $380 \times \frac{400}{300}$ ml.

step 2. consider temperature fixed at new value, when pressure increases volume decreases.

$\therefore$ final volume is $380 \times \frac{400}{300} \times \frac{750}{760}$ ml.

Method 2: Combine Boyle's Law and Charles' Law

$$\frac{PV}{T} = k \quad \text{or} \quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{or} \quad V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$$

Substitute the figures,

$$V_2 = \frac{750 \times 380 \times 400}{300 \times 760}$$

$$V_2 = 500 \text{ ml.}$$

Method 2 looks easier but I would prefer you to use method 1 because it is more general and because my experience suggests that students get tangled up when trying to remember formulae. Now try the following exercise.

In each case calculate the final volume. You may consider that the mass does not change.

	initial volume	initial conditions	final conditions
(a)	546 ml.	0°C and 760 mm	14°C and 861 mm
(b)	400 ml.	STP	91°C and 836 mm
(c)	220 ml.	99°C and 744 mm	STP

(answers (a) 506.7 ml; (b) 485 ml; (c) 136.5 ml

If successful on all three, carry on. If not, see me.

Some examples of gas law calculations.

Next read section 4-4.1, but read it for understanding not repetition. You will not be asked to reproduce this. Out of it you gct the general gas equation PV = nRT. You may find it useful in certain calculations. In fact, by fixing n and R (R is a constant anyway), in the last worked example we used this equation in the form

$$\frac{PV}{T} = k$$

Now, in many gas law calculations you can use the general gas equation. Again, I suggest you use the formula only where you have to, and generally work by applying the principles you have learned.

What do you need to know?

1. How to apply Boyle's Law. $(V \alpha \frac{1}{p})$
2. How to apply Charles' Law. $(V \alpha T)$
3. The meaning of molar volume (one mole of a gas at 0°C and 760 tons (1 atm) occupies 22.4ℓ. If you do need to apply the formula, be careful of the units used. The table on page 84 illustrates this.

No let's consider alternative solutions to some of the worked examples on pages 84-86 of your text.

Example 1. In order to solve this we need to determine the molecular weight of the gas. The questions gives the weight of 1 liter as STP. If we can determine the weight of 22.4 liters at STP we will have the weight of one mole. Hence the solution,

1ℓ of gas at 0°C. and 1 atm weight 0.715 g.

22.4ℓ of gas at 0°C. and 1 atm weight 22.4 x 0.715

i.e. 16.0 g

$\therefore$ molecular weight is 16.0.

To determine which gas is present the procedure shown in the book is satisfactory. Note that experimental error must be taken into account.

Example 2 Again this formula PV = nRT can be used, because the only unknown quantity is P.

alternatively,

1 mole in 22.4ℓ at 0°C exerts a pressure of 1 atm.

2 moles in 22.4ℓ at 0°C exerts a pressure of 1 atm.

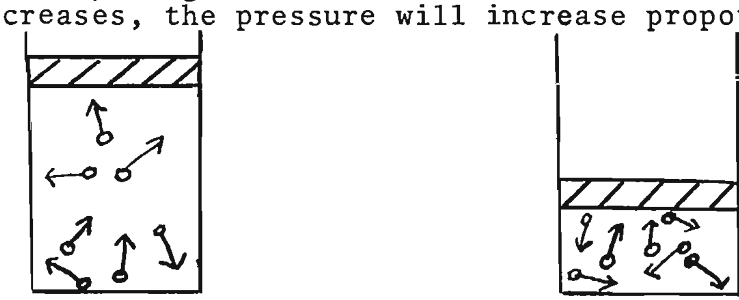
2 moles in 10ℓ at 0°C exerts a pressure of $2 \times \frac{22.4}{10}$ atm.

= 4.48 atm.

Do you understand the two steps?

(a) more moles means more molecules, which proportionately increases the pressure.

(b) if everything else remains the same but the volume decreases, the pressure will increase proportionately.



Let's leave examples 3, 4 for now and look at example 5.

Example 5 Again PV = nRT can be used, V being the only unknown.

alternatively,

1 mole exerting a pressure of atm. at 273°K occupies 22.4ℓ

3 moles exerting a pressure of 1 atm. at 273°K occupies 3 x 22.4ℓ

3 moles exerting a pressure of 120 atm. at 273°K occupies $3 \times 22.4 \times \frac{1}{120}$ ℓ

3 moles exerting a pressure of 1 atm. at 323°K occupies $\frac{3 \times 22.4}{120} \times \frac{323}{273}$

i.e. 0.66ℓ

In each of the above examples it would be possible to compress the reasoning into one statement. You may do this if you wish, although I prefer to set them out as shown. If you understand the steps shown in each of the above examples you need have no fear of any typical gas calculations. Perhaps it may also be noted that if you use the formula you must either know or be given the gas constant R.

Now try the following exercises.

Exercise 1 Calculate the number of moles present in a gas confined to 22.4ℓ at 27°C and 380 mm. of mercury.
(Answer 0.456 moles)

Exercise 2 Calculate the molecular weight of a gas which weighs 0.8 g and occupies a volume of 2 liters at 0.25 atm and 27°C.
(Answer 39.5)

In the next two exercises, equations will be combined with gas laws.

Exercise 3 Heating limestone ($CaCO_3$) produces oxide and carbon dioxide.

(a) write the equation.

(b) calculate how many liters of carbon dioxide are produced at STP from 200 g of $CaCO_3$. (hint--calculate the number of moles first.)

(c) calculate the volume which the gas would occupy at 27°C and 2 atm.

(Answers) (b) 44.8ℓ, (c) 24.6ℓ

Exercise 4 What weight of $KClO_3$ is needed to produce 0.50ℓ of O_2 at 27°C and 0.9 atm. The equation is

$$2\ KClO_3 \rightarrow 2\ KCl + 3\ O_2$$

(Answer 1.50 g)

If you did not fully understand what we have done in this chapter, you may have had some difficulty with some of these. If so, don't worry--come and see me (not necessarily before you progress to the next step). If you got them all right you're in great shape! Let's proceed to our final topic in this chapter.

Partial Pressures

Read section 4-3.1 (pp. 77-79). Basically, what this section is getting at is that in a mixture the gas molecules behave independently, each exerting its own influence on the total pressure. The contribution of each is called the partial pressure, and clearly the sum of the partial pressures equals the total pressure. The partial pressure may be though of in two ways.

e.g. (a) if 2/3 of the molecules of a gas mixture, at a total pressure of 2 atm, is gas A the partial pressure of A is 2/3 x 2 atm.
i.e. 4/3 atm.

(b) if 40 ml. of A is mixed with 20 ml. B under the same conditions (say 27°C and 2 atm) the proportion of A molecules is 40/60
i.e. 2/3 of the total (remember Avagadvo?) and the partial pressure of A is still 2/3 x 2 atm.
i.e. 4/3 atm.

One application of this lies in determining the pressure due to the gas molecules when the gas is collected wet by displacement of water, a common way of collecting gases. The gas collected contains water vapour molecules as well as molecules of the gas being collected. The pressure due to the water molecules depends on the temperature, and can be found in prepared tables.

Thus Total pressure = Pressure due to gas + Pressure due to water vapour

Refer to examples 3 and 4 on pages 85, 86 of your text, then do exercises 4-9 (p. 79) and the following example . . . .
A sample of nitrogen gas was collected over water at 22°C, and the observed pressure was 727 torr. If the aqueous vapour pressure at that temperature is 20 torr, calculate the pressure due to the gas.

Finally you should try questions 2,4,7,8,9,10,15,16,17, 20,21,25.